Horizon 2020 Societal challenge 5
Climate action, environment, resource
Efficiency and raw materials

D5.5: OUTCOME OF TASK 5.2 SUPPORTING DECISION MAKING IN 12 CASE STUDIES

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DOCUMENT HISTORY

VERSION	INITIALS/NAME	DATE	COMMENTS-DESCRIPTION OF ACTIONS

1	VERSION 1.0	6 APRIL 2020	VERSION WITH CASE STUDIES UK, GREECE, LATVIA, SWEDEN AND AZERBAIJAN INCLUDED
2	VERSION 2.0	11 APRIL 2020	VERSION UPDATED, WITH CASE STUDIES SARDINIA, ANDALUSIA, NETHERLANDS, FRANCE-GERMANY, GERMANY-CZECH REPUBLIC-SLOVAKIA INCLUDED
3	VERSION 3.0	14 APRIL 2020	UPDATED WITH THE GLOBAL CASE STUDY
4	VERSION 4.0	29 APRIL 2020	FINAL DRAFT WITH THE 12 CASE STUDIES
5	DELIVERABLE D5.5	30 APRIL 2020	FINAL VERSION FOR UPLOAD IN PARTICIPANT PORTAL
6	DELIVERABLE D5.5	19 MAY 2020	UPDATE LIST OF AUTHORS
7	DELIVERABLE D5.5 REVISION	21 NOVEMBER 2020	REVISION WITH COMMENTS FROM REVIEW

ADDRESSING REVISION COMMENTS	
COMMENT	RESPONSE
THE SHORT SUMMARY SHOULD BE THE EXECUTIVE SUMMARY, AND A SHORT SUMMARY SHOULD BE ADDED	CHANGES ARE IMPLEMENTED.
EDITORIAL CHANGES NEEDED: TABLE PAGE 58 HAS GRAPHICAL BUGS	TABLE IS CHANGED.
SECTION 3.4.3.2 IS EMPTY. TO BE COMPLETED OR REMOVED.	SECTION 3.4.3.2 IS REMOVED.

Table of Contents

List of figures

List of tables

Executive summary

Tools and methodologies (i.e. conceptual model, steps to System Dynamics Modelling (SDM), and the flow of work from the SDM to the Serious Game) are offered to the case studies. This is using a top-down approach, while the Serious Games are designed using the learning goals for each case study. This top-down approach had to match the bottom-up expression of questions in order to co-design the most appropriate and practical solutions. The work was planned as an iterative process, alternating between inputs and feedbacks on both sides. The case studies' reports are proof that this iterative process was implemented successfully.

Stakeholders are engaged and involved in the case studies, including the sectors/interests that are represented (and those that are not represented). The case studies share their feedback on stakeholders' engagement in the case study, to explain what worked well and what could have been improved (commitment of stakeholders on the subject, commitment over time, representativeness of the nexus domains, relevance of workshops or other forms of interaction).

Short-term and long-term policy recommendations are distinguished, including the challenges and sectors for which recommendations can be made. The stakeholder engagement processes in the 12 case studies range from expert consultation to joint strategic planning. This diversity of situations is explained by (i) existing working habits between the case study lead partner and the stakeholders, (ii) Nexus-issues expertise and (iii) on-going policy process. The main challenges faced by the case studies to engage and retain the stakeholders' interest were (i) the length of the process, (ii) the limited availability of decision-makers, (iii) the legitimacy of involved experts, and (iv) the unknown "Nexus" word.

SIM4NEXUS increases the understanding of how water management, food, energy, biodiversity and land use policies are linked together and to climate and sustainability goals. The national case studies in Sweden, Latvia, the Netherlands, Greece and Azerbaijan regard the transition to a low carbon economy as driver of change in the other nexus sectors. Water, energy and agriculture is a common focus of the regional case studies in Spain, Italy and the UK. Both transboundary cases are clustered around the themes of water, with a focus on its relation to land use (Germany-Czech Republic-Slovakia) and on biodiversity conservation (France-Germany). The European case is targeted at a low-carbon economy and the global case does link the Nexus to achieving the Sustainable Development Goals.

Changes with respect to the DoA

There are no changes with respect to the DoA.

Dissemination and uptake

The deliverable is public, but it is confirmed with the case studies the deliverable will only be released through the SIM4NEXUS website (www.sim4nexus.eu) in Month 49 (June 2020). Case studies might use content of the report for upcoming scientific papers.

Short Summary of results

Stakeholders are engaged and involved in the case studies, including the sectors/interests that are represented (and those that are not represented). The case studies share their feedback on stakeholders' engagement in the case study, to explain what worked well and what could have been improved. Tools and methodologies are offered to the case studies. This is using a top-down approach, while the Serious Games are designed using the learning goals for each case study. Short-term and long-term policy recommendations are distinguished, including the challenges and sectors for which recommendations can be made.

Evidence of accomplishment

The report is developed by the 12 case studies and drafted since October 2019 (and discussed during the round of interviews during that time). A draft is discussed during the most recent round of interviews held in February/March 2020.

Glossary / Acronyms

TERM	EXPLANATION / MEANING
BECCS	BIO-ELECTRICITY WITH CARBON-CAPTURE AND STORAGE
BEON	BIO-ENERGY CLUSTER EASTERN NETHERLANDS (BIO-ENERGIE CLUSTER OOST NEDERLAND)
BTG	BIOMASS TECHNOLOGY GROUP
BW	BADEN-WÜRTTEMBERG
CAP	COMMON AGRICULTURAL POLICY
CAPRI	COMMON AGRICULTURAL POLICY REGIONALISED MODELLING SYSTEM
CBD	CONVENTION ON BIOLOGICAL DIVERSITY
CCS	CARBON CAPTURE AND STORAGE
CE	CAMBRIDGE ECONOMETRICS
CS	CASE STUDY
CSF	CATCHMENT SENSITIVE FARMING
DCF	DISCOUNTED CASHFLOW FORECAST
DEFRA	DEPARTMENT FOR ENVIRONMENT, FOOD & RURAL AFFAIRS
DNO	DISTRIBUTION NETWORK OPERATOR
DWMP	DRAINAGE AND WASTEWATER MANAGEMENT PLAN
E3ME	ENERGY-ENVIRONMENT-ECONOMY MACRO-ECONOMETRIC MODEL
EASAC	EUROPEAN ACADEMIES SCIENCE ADVISORY COUNCIL
ECN	ENERGY RESEARCH CENTRE OF THE NETHERLANDS
EEA	EUROPEAN ECONOMIC AREA
EFFAT	EUROPEAN FEDERATION OF FOOD, AGRICULTURE AND TOURISM TRADE UNIONS
ERM	ENVIRONMENT AND RESOURCE MANAGEMENT MASTERS OF THE VRIJE UNIVERSITEIT AMSTERDAM
ETS	EMISSIONS TRADING SYSTEM
EU	EUROPEAN UNION
EUROSTAT	STATISTICAL OFFICE OF THE EUROPEAN UNION

FAO	FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
FCM	FUZZY COGNITIVE MAPPING
FIT	FEED-IN TARIFFS SCHEME
GDP	GROSS DOMESTIC PRODUCT
GE	GRAND EST
GHG	GREENHOUSE GAS
GTAP	GLOBAL TRADE ANALYSIS PROJECT
IEA	INTERNATIONAL ENERGY AGENCY
IPCC	INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE
ISI-MIP	INTER-SECTORAL IMPACT MODEL INTERCOMPARISON PROJECT
ISTAT	ISTITUTO NAZIONALE DI STATISTICA
JFF	JOINT FACT FINDING
LULUCF	LAND USE, LAND-USE CHANGE AND FORESTRY
MAGNET	MODULAR AGRICULTURAL GENERAL EQUILIBRIUM TOOL
NGO	NON-GOVERNMENTAL ORGANISATION
NIMBY	NOT-IN-MY-BACKYARD
NUTS	NOMENCLATURE OF TERRITORIAL UNITS FOR STATISTICS
OFWAT	WATER SERVICES REGULATION AUTHORITY
OSeMOSYS	Open Source energy MOdelling SYStem
PBE	DUTCH BIOENERGY ASSOCIATION (PLATFORM BIO-ENERGIE)
PBL	NETHERLANDS ENVIRONMENTAL ASSESSMENT AGENCY (PLANBUREAU VOOR DE LEEFOMGEVING)
PIK	POTSDAM INSTITUTE FOR CLIMATE IMPACT RESEARCH-
RBD	RIVER BASIN DISTRICT
RCP	REPRESENTATIVE CONCENTRATION PATHWAY
RED2	RENEWABLE ENERGY DIRECTIVE II

RES	RENEWABLE ENERGY SYSTEMS
RDPE	RURAL DEVELOPMENT PROGRAMME FOR ENGLAND
RGAFRD	REGIONAL MINISTRY OF THE AGRICULTURE, FISHING AND RURAL DEVELOPMENT (ANDALUSIA)
RHI	RENEWABLE HEAT INCENTIVE
RIVM	THE NATIONAL INSTITUTE FOR PUBLIC HEALTH AND THE ENVIRONMENT (RIJKSINSTITUUT VOOR VOLKSGEZONDHEID EN MILIEU)
RMETP	REGIONAL MINISTRY OF THE ENVIRONMENT AND TERRITORY PLANNING (ANDALUSIA)
RVO	NETHERLANDS ENTERPRISE AGENCY (RIJKSDIENST VOOR ONDERNEMEND NEDERLAND)
SDE+	INVESTMENT SUBSIDY SCHEME FOR RENEWABLE ENERGY (NETHERLANDS)
SDG	SUSTAINABLE DEVELOPMENT GOAL
SDM	SYSTEM DYNAMICS MODEL
SER	SOCIAL AND ECONOMIC COUNCIL OF THE NETHERLANDS
SIM4NEXUS	SUSTAINABLE INTEGRATED MANAGEMENT FOR THE NEXUS OF WATER-LAND-FOOD-ENERGY-CLIMATE FOR A RESOURCE-EFFICIENT EUROPE
SG	SERIOUS GAME
SOCAR	AZERBAIJAN OIL COMPANY
SRACC	REGIONAL ADAPTATION STRATEGY TO CLIMATE CHANGE (SARDINIA)
SSCRA	STATE STATISTICAL COMMITTEE OF THE REPUBLIC OF AZERBAIJAN
SWIM	SOIL AND WATER INTEGRATED MODEL
SWW	SOUTH WEST WATER
TOE	TONS OF OIL EQUIVALENT
UAA	UTILISED AGRICULTURAL AREA
UK	UNITED KINGDOM
UNCCD	UNITED NATIONS CONVENTION TO COMBAT DESERTIFICATION
UNFCCC	UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

UNISS	UNIVERSITY OF SASSARI
UVW	DUTCH WATER AUTHORITIES (UNIE VAN WATERSCHAPPEN)
VNCI	THE ROYAL ASSOCIATION OF THE DUTCH CHEMICAL INDUSTRY (KONINKLIJKE VERENIGING VAN DE NEDERLANDSE CHEMISCHE INDUSTRIE)
VVNH	ROYAL ASSOCIATION OF DUTCH TIMBER COMPANIES (KONINKLIJKE VERENIGING VAN NEDERLANDSE HOUTONDERNEMINGEN)
WP	WORK PACKAGE
WPD	WESTERN POWER DISTRIBUTION
WRMP	WATER RESOURCES MANAGEMENT PLAN
WS	WORKSHOP
WECR	WAGENINGEN ECONOMIC RESEARCH
WUR	WAGENINGEN UNIVERSITY AND RESEARCH
WWF	WORLD WILDLIFE FUND

1 Introduction

1.1 Objective of the report

This report presents the outcomes of Task 5.2 for all 12 case studies. The objective of Task 5.2 (Supporting decision-making in 12 case studies) is to support the application of the thematic models, the complexity science modelling framework and the Serious Game through the 12 SIM4NEXUS case studies. Each case study has followed a similar step-wise approach to address the following questions:

a) What are the main Nexus challenges that are to be addressed?
b) How can existing thematic models help understanding these challenges? And what are the main gaps in understanding the Nexus that arise from the application of these thematic models?
c) How does the complexity science modelling help addressing these gaps? What improvements in understanding the Nexus emerge from the application of the complexity science modelling?
d) What improvements in understanding the Nexus emerge from playing the Serious Game ?
e) What are the policy recommendations that can then be derived? How to put them in practice, and what are the preconditions for their effective implementation?
f) What is the added value of the SIM4NEXUS concepts, framework and tools for supporting decisions and for identifying recommendations that are Nexus-compliant?

The work in Task 5.2 is divided in four sub-tasks:

- Sub-task 5.2.1 - Launching the case study processes, has been framed by Deliverable 5.1. All case studies have taken the necessary steps to get organised and carry-out the work under Task 5.2. This has been constantly verified by WP5 coordination team (WUR-LEI and ACTeon) by means of interviews with the case study leaders.
- Sub-task 5.2.2 – Identifying the main Nexus challenges, has been extensively described in Deliverable D5.2. and is not repeated here. Updates or new insights stemming from continuous interaction with stakeholders and thematic model owners are described here.
- Sub-task 5.2.3 – Modelling for addressing Nexus challenges, has been shortly presented in Deliverable D5.3. and is further addressed in this document, especially:
    - Calculating the performance of policies in contributing to resource efficiency;
    - Identifying policy recommendations and innovations that arise from the thematic model results;
    - Identifying gaps in thematic models that need to be addressed in the complexity science modelling;
    - Identifying policy recommendations and innovations through playing the Serious Game;
    - Working meetings or workshops with stakeholders.
- Sub-task 5.2.4 – Putting policy recommendations and innovations into practice is also addressed in this document.

The report includes 12 chapters, one for each case study, following the same outline.

1.2 Development of the document

An outline of the Deliverable is drafted by Wageningen Research and ACTeon (September 2019). It is discussed with the WP leaders and with the Case Studies leaders (October 2019). The template is revised in order to provide the background material for D5.6 “report summarising the policy recommendations from all case studies” and D2.5 “strategies towards a low-carbon and resource efficient Europe”. The figure below describes how the different deliverables of WP5 and WP2 interact. See also: Figure 1.

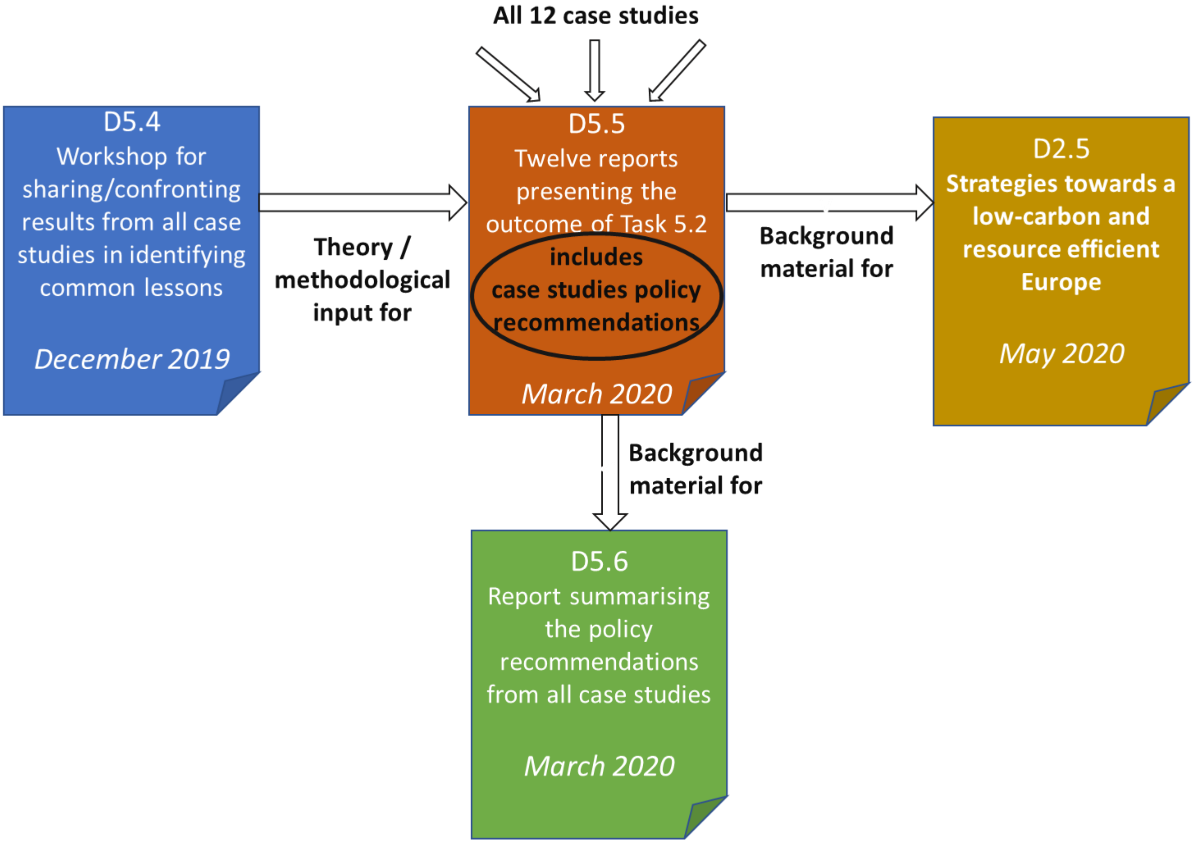


Figure 1 Position of Deliverable D5.5 among the other deliverables in WP5 and WP2

Intermediate reports from the 12 case studies are collected until end of December 2019, including contributions on chapters 1 to 4 for each case. Final reports are collected until end of February 2020, with updates and contributions on all chapters. Conclusions are written once case studies reports are received and the draft of the deliverable is reviewed (April 2020).

1.3 Outline case study presentation

The case studies are presented in a harmonized way, with the following parts:

- Introduce the case study, present a map, with names of case study lead organisation, names of main stakeholders involved, introduce the nexus domains addressed as well as the key Nexus challenges. The main research questions are summarized.
- Overview of tasks performed and how carrying-out Task 5.2 is organised, including among others the number of persons mobilised and how responsibilities are shared. The case studies do reflect on the challenges and benefits of the transdisciplinary work to achieve results, and the planning of tasks performed and the main steps / bottlenecks are described.
- Engagement of the stakeholders involved, including the sectors/interests that are represented (and those that are not represented) by stakeholders involved. The (approximate) number of unique persons involved in the case study are estimated. The case studies share their feedback on stakeholders' engagement in the case study, to explain what worked well and what could have been improved (commitment of stakeholders on the subject, commitment over time, representativeness of the nexus domains, relevance of workshops or other forms of interaction).
- Summarize the modelling work, including the conceptual model and the steps to System Dynamics Modelling. The process of how the conceptual model was built is summarized,

and policy scenarios are introduced and how they are addressed in the SDM. The different steps to fill data gaps are summarized, including data available from the thematic models and what local data are collected. Some screenshots of the SDM are in the Annex of the chapter.

- Summarize the flow of work from the SDM to the Serious Game, including among others (i) the learning goals of each case study, and explain how the learning goals for the case study have influenced the way the Serious Game has been developed, (ii) how the policy cards were developed (who was involved, influence from stakeholders), and (iii) describe how the SG interface was shaped and adapted to the specificities of the case study, add screenshots to illustrate.
- Present the steps from the SDM and Serious Game to policy recommendations, answering the main research questions of the case study. This part also presents insights about policy coherence, and explains what has been learnt from testing different policy scenarios. This section also explains how the case study does address Nexus challenges by the SDM and SG.
- Short-term and long-term policy recommendations are distinguished, including the challenges and sectors for which recommendations can be made (where appropriate). Policy recommendations do distinguish between (i) changes in policy outputs (e.g. topics addressed, targets, goals), (ii) changes in policy contents (e.g. instruments, ways of implementation, eliminate inconsistencies and ambiguities), (iii) innovations (e.g. technical, social and governance), (iv) changes in the policy process (e.g. advice, success factors and failing risks) and (v) changes in the science-policy interface (e.g. knowledge gaps and knowledge sharing).
- In addition to the concluding remarks and references, annexes include the conceptual models, some screenshots of the SDM and its components, policy cards and mapping stakeholders.

2 Sardinia

2.1 Introduction

The main economic sectors of the island are industry, agriculture and tourism. Industry accounts for a large share of the regional GDP mainly because of a petrochemical industry of national relevance. Agriculture and tourism account for a much smaller share of the GDP, but provide a large share of the employment.

As for the energy sector, total energy consumption in 2012 was of 3M TOE. Electricity production is in the order of 14000 GWh/year with a RES share that increased form 9% in 2009 to 26% in 2013. However, due to the closure of a high power demanding industry in 2012 and global economic crises, export of electricity has increased from 3000 GWh/year to 8200 GWh/year. Energy costs in Sardinia are the highest in Italy. The high cost for energy combined with transport costs make the region of low interest for investors and pose a strong barrier to economic development. Presently, the region does not have access to methane which would strongly reduce energy costs (and emissions). Building the necessary infrastructures to bring methane to the island is an on-going debate. Many consider that investing on the necessary infrastructures could not be the best option in view of the zero carbon emissions to be reached by 2050 and that investments should rather aim at promoting RES, energy accumulators and electricity for transport. Presently, the electricity of the region is mostly provided by two power plants running mostly on coal and, while the government declares that all coal power plants should be closed by 2025, the owners of the power plants declare that such objective is not an option. The economic development, nexus efficiency and reaching CO_2 emission targets are strongly linked to these choices.

Sardinia has a very low population (1.6 Million), with trends that clearly indicate a possible decline to 1.3 Million by 2030. 50% of the region is covered by forests that provide biomass for domestic heating which mostly uses low efficient technologies, while biomass for energy production is mostly imported.

As in many Mediterranean areas, the balance between water demand and availability has reached critical and unsustainable levels of exploitation. A sharp increase in agricultural productivity over the last 50 years has been associated with both intensification and mechanization of agricultural processes, with a strong adoption of irrigation practices. Currently, agriculture reaches a share of about 70% of total water consumption in Sardinia, due to a strong dependence on irrigation to support and increase yields of different crops. In southern Europe, soil water content will decrease, while saturation and runoff be limited to winter and spring periods. This translates into a reduction in the flow of rivers and surface and ground water resources, with negative impacts on various ecosystems. A reduction in water resources is often associated with deterioration in water quality, because less water is available to dilute pollutants. Furthermore, saline intrusion is affecting coastal aquifers, especially those more overexploited.

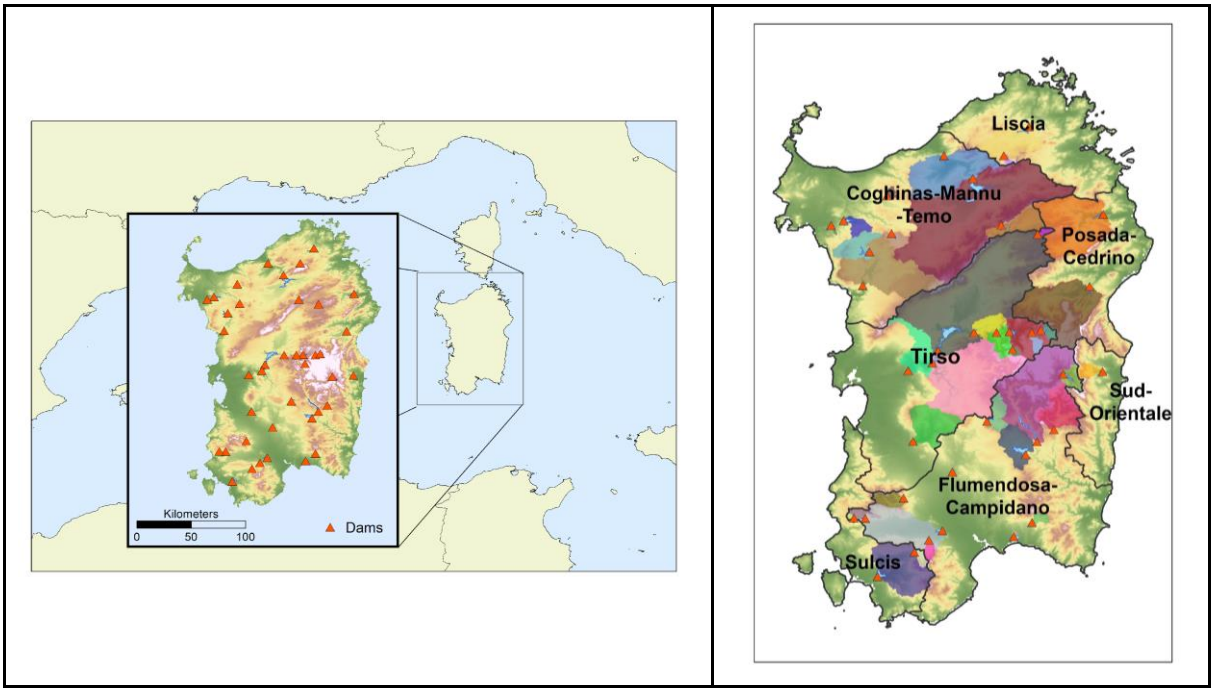


Figure 2 Sardinia Case Study. The figure on the left represents the position of Sardinia in the middle of Mediterranean. The figure on the right shows both the 7 Hydrographic districts, and the water basins upstream to the different red Dams/Reservoirs are represented as red triangles

Name of case study lead organisation: UNISS - University of Sassari

Main stakeholders involved

Several public servants from the most relevant regional ministries were involved as stakeholders: the Regional Ministry for the protection of the Environment; the regional Ministry of Tourism, Crafts and Trade; the Regional Ministry for Agriculture and Agro-pastoral reform. Among other stakeholders several public authorities were also included: Water Authority for Sardinia (ENAS); the Basin Authority (ADIS); Regional agency for scientific research, experimentation and technological innovation in the agricultural, agro-industrial and forestry sectors (AGRIS); the agency for integrated development of rural areas (LAORE); and several Irrigation Consortia. Moreover several bodies and union of stakeholders across the private sectors were included in the workshop and discussion, which brought particular attention to specific issues in the agri-food chain and rural interests, and in particular several labour unions of farmers (COPAGRI, CONFAGRI and COLDIRETTI).

A number of private businesses, branch associations and NGOs are involved, such as the main energy company operating in Italy and Sardinia (ENEL) and World Wildlife Fund (WWF). Furthermore, other interested and competent research bodies were included to share existing knowledge and provide valuable insight on research opportunities to explore relevant Nexus interlinkages in Sardinia (Department of Electrical and Electronic Engineering and the Department of Social Sciences of the University of Cagliari).

Nexus domains addressed and main Nexus challenges

Water and Climate, are the most critical and relevant Nexus domains, and all their interlinkages with energy, food and land domains are addressed. Links are related to relevant policies and management rules, especially those considering the main Nexus challenges in Sardinia. As in many other Mediterranean areas, water resources are often constrained by climate variability and subject to several and critical conflicting uses all together limiting and leading to overexploitation, especially under critical climate conditions (recurrent periodical droughts). The agricultural sector is one of the most demanding sector for water availability, accounting for most of 50% of total water withdrawal, while other relevant demand satisfy needs for domestic, industrial and tourism sectors. All of these sectors have a really high relevance to the economic and social needs, including food security, and resolving these issues is crucial to sustain resilience of the system to climate variability and anticipated climate change impacts. Aside, energy production is characterized by endemic difficulties driven by insularity that leads to high energy prices hampering economic competitiveness across all sectors. Expansion of methane use has been highly praised to lower energy costs, as well as optimization of hydro-power resources by regional water authorities to reduce costs associated to water deployment and treatments. In addition, the island has set ambitious goals to reach low-carbon economy in 2050, which can be achieved by implementation of renewable energy production at large scale and development of land use practices that enrich carbon sinking.

Main research questions

The regional government has set a number of objectives and policies for the energy, water, and agriculture sectors. Shortly, these include the optimization and sustainability in the use of water resources, above mentioned use of methane, implementation of smart-grids that would allow to increase their loadings in the grid, incentives to increase irrigation efficiency, policies to guarantee minimum environmental flows, strategies to promote tourism during the low season. Although these objectives, especially those for the energy sector, mention climate change mitigation strategies and are designed to reduce CO_2 emissions in line with EU targets, as of today there is a lack of policies or plans directly addressing a climate change mitigation or adaptation strategy.

2.2 Overview of tasks performed

2.2.1 Organisation to carry-out Task 5.2

University of Sassari (UNISS) was the lead of the Sardinia case study of SIM4NEXUS. There were 6 researchers who conducted the work in the Sardinia case study, see Table 1.

Table 1 People from UNISS involved in the Sardinia case study

Name	Responsibilities
Donatella Spano	Conceptual model, policy analysis, policy cards preparation, stakeholder interaction, Conducting workshops/expert meetings,
Antonio Trabucco	Conceptual model, SDM and analytical development, policy cards preparation, SG instructions, WP3/WP4 teleconference, contribution to SIM4Nexus meetings
Simone Mereu	Case study lead, Conceptual model, policy analysis, coherency analysis, stakeholder interaction, reviewing policy cards, Conducting workshops/expert meetings, contribution to SIM4Nexus meetings
Lourdes Morillas	Conceptual model, preparing SDM (first version), Data collection by other sources
Serena Marras	Data collection from other sources and contribution to alternative policies
Costantino Sirca	Data collection from other sources and contribution to conceptual framework for the SDM

UNISS collaborated closely with Stefania Munaretto (PBL), Janez Susnik and Sara Masia (IHE Delft), Lydia Vamvakeridou-Lyroudia (EXETER), see Table 25, with which we had regular meetings to develop the conceptual model of the Sardinia case study and the interaction with stakeholders.
Sardinia Case Study was chosen as a "fast track" case study: a case where to test first implementations of the SDM and SG. Following this role, UNISS has actively participated to the WP3/WP4 teleconferences, coordinated by EXETER, in the first two years of the project. The results of this first

period were used as a roadmap for other case study that gradually entered the discussion. As the SDM and SG progressed, additional partners joined the meetings bringing in their expertise on thematic models and the SG. Consequently, UNISS interacted closely with several partners of SIM4NEXUS (see Table 2 for details on the main interactions).

UNISS also closely collaborated with Maria Witmer and Stefania Munaretto (PBL) on the stakeholder analyses, and the policy coherence analyses for the Sardinia case study.

Table 2 People from partners organisations involved in the Sardinia case study

Organization	Name	Responsibilities
Netherlands Environmental planning agency (PBL)	Maria Witmer	Policy analysis, policy cards preparation
		Policy coherence analysis, stakeholder mapping, Structuring workshops/expert meetings
EXETER	Lydia Vamvakeridou-Lyroudia	Conceptual model, SDM, SG, policy cards
University of Madrid	Maria Blanco	Development of scenarios for the agricultural sector in the region
Bocconi UNiversity	Roberto Roson	Development of socio-economic scenarios for the region
Cambridge Econometrics	Eva Alexandri	Development and implementation of scenarios for the energy sector
IHE Delft	Janez Susnik	Conceptual model, SDM construction
	Sara Masia	Conceptual model, SDM construction

For the necessary data for the case study, we had irregular contacts with Eva Alexandri (Cambridge Econometrics) for the E3ME data, Maria Blanco (University of Madrid) for the CAPRI data and Roberto Roson (Bocconi University) for the GTAP data.

2.2.2 Schedule of Task 5.2

Table 3 presents the list of tasks/activities conducted by the Sardinia case study team. The tasks/activities include the modelling, analytical structure, data collection, policy analysis, stakeholder interaction, reporting and project meetings. In addition, additional activities have been undertaken such as contributions to conferences, papers and other projects.

Table 3 Overview of tasks performed in the Sardinia case study

Tasks	Description
Modelling	
Conceptual model	Preparation of the conceptual model in ppt
SDM	Development of the SDM
Results	Production of first results and highlighting possible bottlenecks
Serious Game	Contributions on how to link SDM to SG and structure of the SG
Data	
Data collection	Data collection for calibration of thematic models
Data collection	Data collection for SDM parametrization and calibration
Baseline scenarios	Inclusion of information from the Thematic models
Data collection	Data collection for policy analysis
Policy	
policy analysis	Policy analysis of the nexus-related policies in Sardinia/Italy
policy coherence analysis	policy coherency analysis in Sardinia/Italy

policy cards	Preparation of policy cards to be included in the SDM/SG
stakeholder interaction	
See	
Reporting	
D1.6	Use cases
D2.2	Report on Policy analysis
D2.3	Report on Policy coherence analysis
D4.1	Learning goals of Sardinia case study
D4.8	Update on Learning goals of Sardinia case study
D5.2	Intermediate report on the case study progress
D5.5	Final report on the case study
MS18	
Project meetings	
July 12-13, 2016	SIM4NEXUS project meeting in The Hague
March 12-14, 2018	SIM4NEXUS project meeting in Athens
July 3-5, 2019	SIM4NEXUS project meeting in Riga
March 25-27, 2020	SIM4NEXUS project meeting online
Other activities	
Article	Masia S, Sušnik J, Marras S, Mereu S, Spano D, Trabucco A (2018) Assessment of irrigated agriculture vulnerability under climate change in Southern Italy. Water, 10(2), 209.
Article	Sušnik J, Chew C, Domingo X, Mereu S, Trabucco A, Evans B, Vamvakeridou-Lyroudia L, Savić DA, Laspidou C, Brouwer F (2018) Multi-stakeholder development of a serious game to explore the water-energy-food-land-climate nexus: the SIM4NEXUS approach. Water, 10(2), 139.
Conference contribution	Trabucco A, Sušnik J, Vamvakeridou-Lyroudia L, Evans B, Masia S, Blanco M, Roson R, Sartori M, Alexandri E, Brower F, Spano D, Damiano A, Virdis A, Sistu G, Pulino D, Statzu V, Madau F, Strazzera E, Mereu S (2018) Water-Food-Energy Nexus under Climate Change in Sardinia. 3rd EWaS Conference. Oral
Conference contribution	Masia S, Sušnik J, Mereu S, Spano D, Marras S, Blanco M, Trabucco A (2017) Water-Food-Energy nexus and climate change for multipurpose reservoirs in Sardinia. Dresden NEXUS Conference. Oral
Conference contribution	Sušnik J, Mereu S, Trabucco A, Evans B, Khoury M, Chew C, Domingo X, Vamvakeridou-Lyroudia L, Savić D, Laspidou C, Brouwer F (2018) Serious gaming to explore the water-energy-food-land-climate nexus with multi-stakeholder participation: the sim4nexus approach. CCWI/WDSA 2018
Conference contribution	Evans B, Vamvakeridou-Lyroudia L, Susnik J, Trabucco A, Mereu S, Albin XD, Chew C, Savic D (2018) SIM4NEXUS – Coupling a System Dynamic Model with Serious Gaming for policy analysis. HIC 2018 Conference
Conference contribution	Trabucco A, Masia s, Sušnik j, Spano d, Mereu s. The Water-Land-Energy-Food-Climate Nexus In Sardinia. EGU 2020

2.3 Engagement of stakeholders in the process

2.3.1 Overview of stakeholders' engagement in the case study

The main challenge of the Sardinia case study requires the participation of stakeholders coming from all different NEXUS domains. Consequently, we have identified organizations and experts from all domains, but only a part of them actively participated to the activities. It is important to remind that all the involved experts previously participated to a multitude of projects characterized by interactions with other organizations, so that they were able to partially substitute the expertise of the missing participants. Figure 3 reports the map of the main stakeholders relevant for the Sardinia NEXUS challenges.

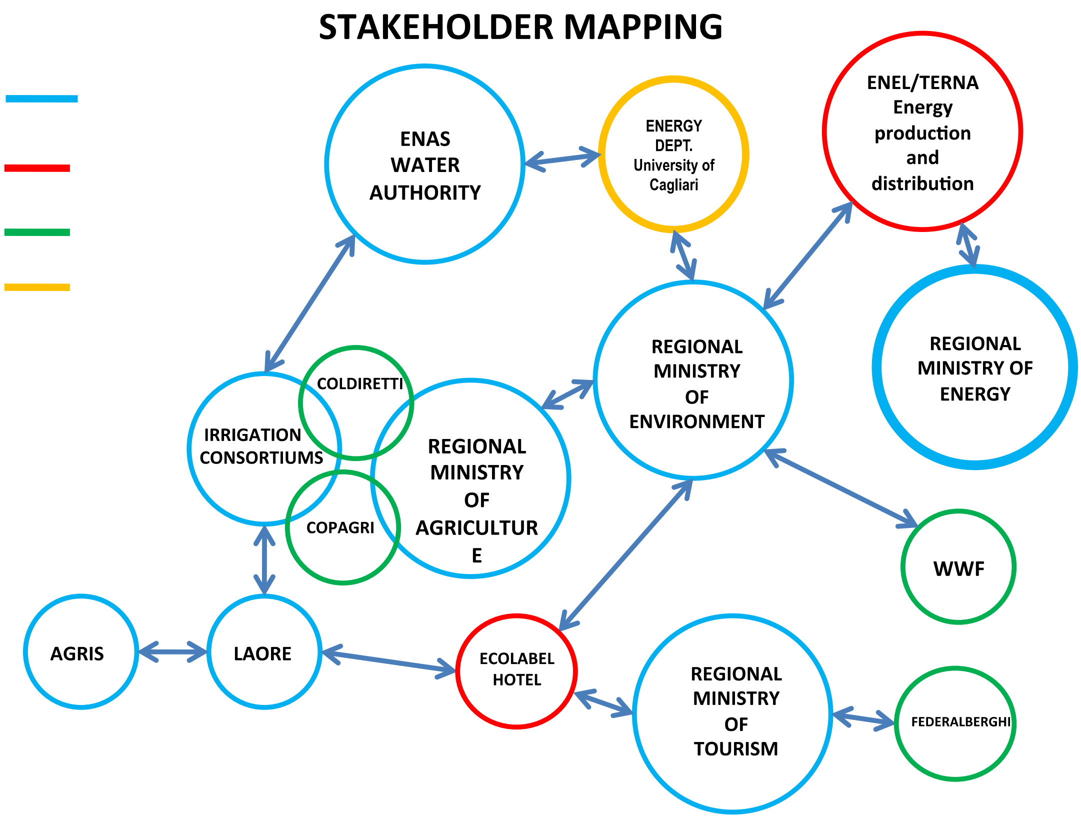


Figure 3 Stakeholder Map

Table 4 presents the list of stakeholders and their interest in the nexus challenges. The main categories of stakeholders throughout the activities were regional government, research, business sector, unions and associations. Despite the broad range of stakeholders involved in the project, only a part of these was steadily engaged in the project.

Table 4 List of Sardinia stakeholders involved in the project

Type of organization	Name of organization	Description	Core Nexus Interest W-F-E-C-L

Regional government	Basin Authority-ADIS	Safeguard and rational use of all water resources and protection of ecosystems	W
	Water Authority for Sardinia – ENAS	Monitoring, managing and planning of water bodies so as to safeguard and improve the quality of water resources for different purposes	W-E
	Regional Ministry for Agriculture and Agro-pastoral reform	Land reclamation, agricultural transformation and rural improvements as well as rural development planning, credit incentives	F-L-W
	Ministry for the protection of the environment	Environmental Impact Assessment (EIA); Safeguarding and enhancing the flora and fauna; Regulation of hunting activity, environmental authority, forests and parks	L-W-C
	Ministry of Tourism, Crafts and trade	Hotel industry. Programming the infrastructures of tourist interest	L-W
	IRRIGATION CONSORTIA	Management of water for irrigation granted by ENAS, the distribution of water to the consortium, the implementation of efficiency measures and irrigation savings	W-F-L
	LAORE – SARDEGNA	It promotes the integrated development of rural areas and the environmental compatibility of agricultural activities	F-L
	AGRIS – SARDEGNA	Regional agency for scientific research, experimentation and technological innovation in the agricultural, agro-industrial and forestry sectors	F
Unions	COPAGRI-Confederazione dei Produttori Agricoli	A labour union of farmers	F-W
	CONFAGRI	A labour union of farmers	F-W
	COLDIRETTI	Main Regional and national labour union of farmers	F-W
Associations	World Wildlife Fund (WWF)	Association for the conservation of nature	W-L-C
Research	Department of Electrical and Electronic Engineering (DIEE) – University of Cagliari	Received a mandate from the regional government to develop the Regional Energy Plan	E-W-C
	Department of Social Sciences (University of Cagliari)	Social and economic issues about water management	W
Business	ENEL	Energy company	E

Stakeholders are engaged in different activities during the project. An event in the form of a Focus Group was organized to first engage the main identified stakeholders and the main interlinkages to account for in the SDM (i.e. conceptual framework). The engagement was maintained and enlarged to further stakeholders through interviews (telephone or physical) to quantitatively define the interlinkages for the SDM and workarounds when the SDM could not account for them explicitly. After a policy analysis, interviews were also performed to reach a common view of the existing synergies and incoherencies as well as to define possible alternative policies to include in the SDM and Serious Game (SG). However, this interaction didn't produce the level of quality and accuracy desired: most interviewed were clearly not at ease with the Nexus concept and tended to bring the discussion on policies for their sector of expertise. Consequently, few had Nexus relevant policies to propose (i.e. policies in one sector that would influence other sectors). Nevertheless, progress was made in this direction. All stakeholders asked to share at least preliminary results of the SDM before organizing further events or interviews as the perception was that no further advancement was possible without this component. Furthermore, this request implied a halt in the stakeholder engagement process putting their commitment at risk. Before a shareable SDM was reached, a turn in regional government further disrupted the continuity in the interaction. Further information for the policy analysis and SDM was acquired through the participation to research activities and stakeholder engagement of other projects with which synergies were sought. Most relevant was the participation of the UNISS team to the development of the Regional Adaptation Strategy to Climate Change (SRACC), funded by the Sardinia Region, and to the MedForHUB project funded by Climate-KIC. The SRACC focused on Agriculture, Forestry and Water resources, and the developed SDM was used to analyse interlinkages between the water and agricultural sectors. But, most importantly, the SRACC was developed with a multi-actor approach including researchers and stakeholders allowing to add insights on both policy issues as well as technical. The main goal of the MedForHUB project was a feasibility study for the establishment of a Mediterranean hub for the forestry sector. In addition, this project included stakeholder interaction activities the results of which were of interest for the policy analysis and challenges of the Sardinia case study.

Stakeholder interaction was precious to have insights and find possible workarounds on how to include important dynamics in the SDM accounting for available data and modelling limits. A great interest was clear for the inclusion of thematic models, but this interest partially declined when it became apparent that the results of thematic models would only "drive" the regional SDM and not the opposite. Stakeholder interaction was also important for validation and production of realistic figures in including the effect of some policies in the SDM. Table 5 summarizes the main stakeholder engagement activities in Sardinia. In the Sardinia case study approximately 30 different people have participated.

Table 5 Activities with stakeholders involved in the Sardinia case study

Interactions with stakeholders	Date Location	Number of participants and indicative distribution by nexus sector	Main topics discussed	Outcomes / Achievements
Workshop n°1 (focus group)	26-06-2017	13 (8 outside project), a variety of stakeholders from all NEXUS domains excluding CLIMATE	Inter-linkages between domains (base for conceptual framework)	A first picture of main nexus interlinkages to consider for the case study
interviews	From Autumn 2016 to 2018	17 (all sectors)	Main interlinkages and policies between the domain of the interviewed and other domains	A broad picture of strengths and weaknesses of both policy and practice affecting the NEXUS
One –to- one meetings	From 2018 to now	More than 10 researchers, governmental agencies mainly from Domains of WATER-ENERGY-FOOD-CLIMATE	Modelling aspects policy cards	Good balance between modelling detail and reality. Relevant policy cards for the Case Study.

Workshop n°2	April 2019	40 people from all NEXUS domains	Discussion on SDM results/SG	Validation of SDM results and presentation of the SG potential

2.3.2 Feedback on stakeholders' engagement in the case study

The stakeholders appreciated the trans-disciplinary and multi-sector approach, however to different degrees, all stakeholders had difficulties in absorbing the NEXUS concept and were all biased by a "traditional" silos-thinking. Furthermore it was difficult to bring together people at events coming from different pre-existing communities. One to one interviews allowed for a more multifaceted view of the nexus inter-linkages. Nevertheless, some progress was made in this direction. For a more penetrating result, it would have been ideal to have final SDM results to show and comment at early events. It was difficult to organize further events to have feedbacks as most stakeholders requested to have results to comment on before guaranteeing their participation. To work around this, one to one discussions were held on specific points when necessary. Furthermore, a turn of regional government in March 2019 undermined the established network of stakeholders, with regional authorities halting their participation. As the SDM is now providing results on the application of policies, UNISS was planning to organize an event to show and discuss the results. However, as of today, the emergency for the coronavirus is postponing this event.
As the SG is also likely to be at a good stage in the coming months, it could be possible to also have some stakeholders play the game at least from remote. Additional stakeholders contributed, coming form other research institutes. It is in the Italian and regional tradition for ministries to require reports on possible strategies for different sectors to the research community. The researchers external to the UNISS unit involved in the case study were all involved in producing relevant reports to the region as for example Prof. Alfonso Damiano that is the author of the Sardinian Energy Plan or Donatella Spano that, for a great part of the project duration, was on leave to act as regional minister for the environment. The contribution from these stakeholders was extremely valuable for the project and provided a high continuity in the collaboration.

2.4 From conceptual models to System Dynamic Modelling

2.4.1 Case study conceptual model

The conceptual model for Sardinia case study was built based upon a comprehensive review of relevant literature, expertise of the project team members and experts interaction, inputs from stakeholders at the first stakeholder meeting, a short review of the policy debate in Sardinia and information coming from the activities related to the SRACC and MedForHub projects.

A review of relevant scientific literature over the web reported ongoing and past research studies over Nexus sectors to derive insights about the most important Nexus interlinkages in Sardinia and highlighted quantitative mechanisms already set in place to define these interlinkages. Meanwhile, discussion with several scientific experts at University of Sassari, University of Cagliari and Euro-Mediterranean Centre of Climate Change brought a strong background on which processes and connections could be derived and better simulated given the data availability and physical interactions between nexus sectors. After discussions with experts in the field of agriculture, water, energy and climate policy, it was decided to focus on the role of water and energy to sustain productivity of the most relevant sectors, and in particular by using solutions that allow transition to a low-carbon economy

in 2050. An attempt was made to include forestry in the analysis, however the wood biomass and non-wood products value chains are scarcely developed in the region. That is reflected in the knowledge gaps and scarce available data that would not allow a full inclusion in the SDM. However, given the relevance of forestry in reaching net CO2 emission targets, changes in forested area were included. In 2019, participation to the MedForHUB activities allowed to have an insight on the potentials of forestry in the Mediterranean and in Sardinia. These were not included in the SDM, but allowed to draw some conclusions for the policy analysis and recommendations.
The conceptual model was then discussed with a group of stakeholders on the first stakeholder workshop. The most relevant links across the Nexus were also discussed with stakeholders in the first stakeholder meeting, where several additional inputs confirmed the first outline of the conceptual model and detailed some specific functions which were rather sectorial (silo-thinking). This process helped to specify outputs of the conceptual model that would be more beneficial to specific policies or management rules. Climate was also a great concern by the stakeholders, and so a great effort was made to specify functions that were relative to climate and climate variability. Afterwards, the conceptual model was refined and improved with scientific expertise to develop specific functional interlinkages within the System Dynamics Modelling, and in particular in relation to the available data.
During the project a new regional government was elected, whose priorities were rather more oriented towards enhancing economy and employment and less sensitive to climate policies (i.e. Paris agreement). However, much of the targets towards the deployment and use of methane and alternative source of energies were left untouched by the new regional administration. Both stakeholders and policymakers were particularly interested in developing a better understanding of nexus interlinkages and feedback, since to their knowledge these are quite underestimated and unaccounted in the regional policy framework. The serious game was accepted with rather particular interest, as it was intended to facilitate understanding and discussion on the interoperability of policy mechanisms.

The Conceptual Complexity Science Graphs of 6 systems (energy, land, food, water and climate as well as a socio-economic system) are included in the Annex in Section 2.9.1.

2.4.2 Modifications introduced to model policy scenarios

2.4.2.1 Development of policy scenarios for the case study

Policy scenarios for Sardinia were developed based on 1) modelling output for several socio-economic variables derived from thematic models driven at global scale, 2) projected trends developed at local scale and based on demographic distributions, 3) expert judgement and stakeholders opinions. Several aspects of the ongoing government agenda were also taken into consideration to characterize different instruments, which could be applied to reach policy objectives.

The focus of the final scenarios is on all nexus sectors, however with particular focus on climate, water, energy and food sectors. Scenarios were generally discussed with experts evaluating how realistic were these scenarios, and how feasible were particular instruments to achieve the objectives in the scenarios. These scenarios are thus aligned with several policy objectives established by government agenda, but also include future potential innovative instruments/measures, which have not necessarily been implemented or promoted yet.

Climate projections for Sardinia predict both warmer and mostly drier conditions by 2050. There are consistent projected trends, which are warmer as we move from scenarios with lower GHG emissions (and radiative forcing) to scenarios with higher emissions, giving a limited uncertainty on predicted temperature changes between RCPs scenarios. However there is a more consistent variability among climate models to define change of mean annual temperature, with most climate models agreeing on increases from 1 to 2 degrees by 2050 compared to historical levels under scenario RCP 4.5, and from

2 to 3 degrees under scenario RCP 8.5. Meanwhile most climate models predict on average a mild decrease in annual precipitation (0 to 100 mm less in annual rainfall). However there are few climate models that can foresee either a slight increase (up to 50 mm) or a more relevant decrease (between 100 and 150 mm) of annual precipitation. These consistent increases in temperature lead to major evapotranspiration demand from vegetation and soil, but also evaporation from open water sources. These trends are also coupled with a minor rainfall, which lead to generally state of enhanced aridity with minor availability of freshwater supplies and larger water crop requirements, and thus larger agriculture water demand.

Agricultural production is linked to food security objectives, and has clearly a high priority in government agenda. Still the extent of agricultural production is functionally and financially linked to many exogenous constraints often dictated by the global market in terms of crop product prices and costs of the materials and labour needed to grant the needed agricultural inputs. In addition, agricultural yields are also conditioned by climate conditions and water availability for irrigated agriculture that in turn do affect not only productivity, but also economic income and competitively over the global market. In order to account for all these drivers and forces, we rely on the CAPRI outputs to define trends of agricultural area distribution by crop types in Sardinia up to 2050. Based on these outcomes, agriculture distribution in Sardinia may be subject to contractions of rainfed and also irrigated agriculture for specific crops. In particular, several cereal types and also pastureland will be affected by reducing their area up to 50% by 2050. Few crops will see a stable presence compared to actual values and namely crops with high economical values such as grapevines, fruit trees and vegetables.

Sardinia population suffers a prevalence of population in the older classes and a consistent emigration trend of young people in search for economic opportunities elsewhere. These conditions lead to a general trend of decreasing population, with some average projections foreseeing a decrease from 1.6 million to 1.4 million, while other more dramatic projections with less optimistic economic conditions foresee a decrease to 1.2 million inhabitants in 2050. This is a dramatic threat to the livelihood of the island and political agenda are trying to push economic opportunities as far as possible in order to keep and attract permanence of young people.

Energy projections up to 2030 both in terms of energy sources and energy demand were characterized by the E3ME model. Energy production, because of climate mitigation impacts, economic incentives, and national security, will move towards renewable sources, and in particular will favour a major upscaling of wind power farms, with an additional contribution driven by photovoltaic. A noticeable downside of energy forecast from E3ME model is that modelling outputs were generated at national level and then scaled down to regional level based on energy data for baseline period (2000-2010). Thus these projections take partially into consideration typical regional trends (e.g. decreasing population), which are unlikely at national levels. The political agenda of Sardinia has been and is still highly betting on methane deployment and use, promoting an infrastructure made of gasifiers and pipeline for the import and use of natural gasses. Energy costs in Sardinia are among the highest in Italy, giving a high financial disadvantage to regional activities and competitiveness over the national and international market. The use and deployment of natural gasses is meant to reduce consistently energy costs, while still giving a strong reduction of GHG emissions over other traditional fossil fuels (e.g. coal).

The political agenda is aiming at resource use efficiency through structural funds and economic incentives. Monitoring and sustainable use of water resources is foreseen by the implementation of the Water Framework Directive, and is facilitated now by water accounting systems at district level. Efficiency of water use in agriculture has been promoted by widespread use of efficient irrigation methods. Yet, distribution of water resources (for agricultural and domestic uses) witnesses a high rate of water losses (50%). The latest requires heavy investments in infrastructures.

Energy sources are also shifting heavily towards renewable sources (wind and solar power). Still the efficient use of these renewable sources concentrates and peaks production rather heavily, with some of this excess energy production discarded. Smart grids are thus heavily required to take advantage of the energy production from the upscaling of these renewable energy sources. Anyhow, the larger share of renewable sources together with carbon sequestration promoted over abandoned or widespread (extensive) agricultural and silvo-pastoral land in Sardinia, imply a great opportunity to reach carbon neutrality by 2050, as foreseen by recent ambitious political programmes within the EU.

Table 6 Policy objectives of the nexus sectors in the Sardinia case study

Nexus sector	Policy objective	Policy objective: description
Water	Increase water efficiency in agriculture	Change in leakage of conveyance system for Agriculture sector
		Change in Irrigation Efficient systems
		Increase resilience of water supply
Energy	Optimal use of renewables for energy	Increase RES share in the energy mix
		Increase energy and insulating efficiency in private housing and public buildings
		Import methane for heating and electricity generation
Food	Viable financial and sustainable agriculture sector	Improving area with high value crops
		Increase resilience of water supply to grant food crop productivity
Land	Sustainable land use	Keep or increase protected area (Natura 2000)
		Recover abandoned agricultural area
Climate	Climate policy	Reduction of Emissions from Energy sources through Renewable sources
		Increase carbon sequestration over abandoned (reforestation) and extensive agricultural area (Agro-Forestry)

2.4.2.2 Introduction of policy scenarios in the SDM

The identified policies goals have been structured to be functional within the SDM. To this end, policies have been translated into variables, which could alter the availability of specific resource supplies or the efficiency to which certain resources are used to given policy objectives. Policy objectives promoted by stakeholders indications could not always be implemented as "wished" given the lack of functional knowledge or data, but in the latter case have been altered to specific variables present in the SDM. Thus, policy measures have been adjusted to find specific targets and modelling means to achieve these targets.

The SDM includes information, as processes and variables, which were referenced to be associated to policy measures by introducing new parameters that could alter (amplify or reduce) the effect of these processes and variables. Finally, the significance of these policy parameters was tested to verify the relevance within the SDM for the serious game. Nevertheless, any given step of implementation of these variables was verified to be feasible for its implementation within plausible ranges in the realm of the policy measures.

Policy measures were established in the modelling structure of the SDM as switches, which regulate if the policy measures are activated and their effects spread across the nexus including feedback and interlinkages. Certain policies act simultaneously with different parameters on the same variable in the SDM, and as such enforce each other independently without any constraints. Thus, most of these policy objectives were structured with parameters to modify linearly Nexus variables to avoid overarching and exaggerating polynomial effects in the equations. Implementation without particular policy intervention delineates a rather baseline scenario, as delineated by the thematic models, while the implementation of the different policy cards trigger and promote intervention measures to an extent where 2°C climate scenario can be achieved.

2.4.3 Modifications introduced to account for data availability

2.4.3.1 Data available from the thematic models

Based on the above conceptualisation, it was possible to identify relevant 'thematic models' from which data would be required: CAPRI (a global agricultural and production model), GTAP project database (www.gtap.agecon.purdue.edu/), E3ME (a global economic and energy model), downscaled climate data from ISIMIP made available from PIK within the project. The data from these models provided advanced outcomes of different variables to analyse the different domains of the Nexus consistently.

The Common Agricultural Policy Regionalised Impact modelling system (CAPRI) is a global agro-economic partial equilibrium model designed for impact assessment of agricultural, environmental and trade policies with a focus at regional level on European Union. CAPRI runs sequential iterations to solve combinations of regional supply-side models with a global market model for many different agricultural products with simulated results for the EU at subnational and regional level within the global agricultural markets. Among a large number of economic, yield and environmental indicators for the agricultural sector provided by CAPRI, we were interested mostly for the Sardinia case study at dynamics of irrigated and rainfed agriculture for different crop types, in terms of areal distribution and total emissions, income and employed labour forces. Data provided by CAPRI were available instead at regional level, but by comparing the figures with national and regional statistics we have assessed that CAPRI underestimate by almost 50% the extension of irrigated area by crop. Thus, data from CAPRI were rather used to understand the percentage change of irrigated area for the different crops, using regional statistics to define absolute values for current conditions.

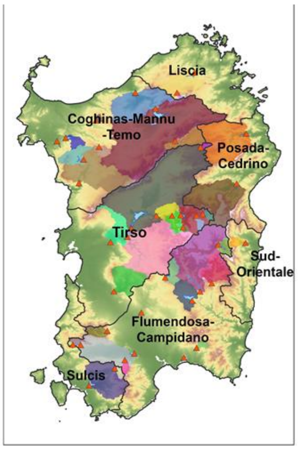
E3ME is a global, macro-econometric model designed to address major economic and economy-environment policy challenges. It can fully assess both short and long-term impacts and the close integration of the economy, energy systems and the environment, with two-way linkages between each component. The contribution of E3ME was really important and relevant to assess energy production/demand and scenarios for different energy sources. However, most of E3ME scenarios are originally developed at country level, and needed to be scaled down to Sardinia case study by means of proportional scaling based on the actual shares of Sardinia relatively to the national figures. This proportion is then kept fixed through future projections, and does not follow an independent general equilibrium. Further resources should be granted in the future to develop such scenario at regional scale.

GTAP (Global Trade Analysis Project) is a general equilibrium model, with an additional focus for analysis of trade, agricultural and bioenergy policies, socio-economic trends and climate at regional scale. For the Sardinia case study, GTAP provided several socio-economic indicators both in terms of population demography, consumption behaviour in terms of demand for different resources, GDP for different sectors and imports/exports of food and energy.

Climate projections are made available through the Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP) by compiling linear bias correction based on simulations of five Global Circulation Models (GCMs) from the CMIP5 archive: HadGEM2-ES, IPSL-CM5A-LR, MIROC-ESM-CHEM, GFDL-ESM2M and NorESM1-M. From each model, four scenario realisations based on the Representative Concentration Pathway (RCP) emission scenarios had been released and used in SDM simulations: RCP2.6, RCP4.5, RCP6.0, and RCP8.5. Several variables were made available at daily scale, and rescaled at monthly time-steps (the time-step used in SDM simulations): Precipitation, Minimum and Maximum Temperature, Relative Humidity, Wind Speed and Incoming Solar radiation. These variables were used in several climate driven processes articulated explicitly in the SDM such as, net water inflow in the reservoirs, open water evaporation, water demand for the most relevant crops, potential for wind and solar energy production, Tourist Climate Index, etc.

2.4.3.2 Local data to be collected

Local data at regional level was collected from several sources: ISTAT (Istituto Nazionale di Statistica), several regional ministries (Ministry of Environment, Ministry of Agriculture, Ministry for Industry and Tourism), Sardinia Water Authority (ENAS) and several agriculture reclamation consortia present in Sardinia. Most of the data collected at local scale represents observations in place from several monitoring efforts, and was used thus to 1) validate information available from modelling thematic tools and 2) reconstruct spatial variability of several variables when possible. In order to account for different distribution of critical water sources, Sardinia was subdivided in 7 hydrological districts, and most information available at municipality level was then aggregated to district level. Unlike water, information related to energy sources and production was aggregated to regional level, since energy is homogenously unified by a unique energy grid system.



2.4.4 Case Study SDM in Stella / R

To implement a conceptual framing in SDM for the Sardinia case, interactive workshops with local experts and stakeholders, including academics, public authorities, decision makers and unions, were carried out to define the key nexus sectors to consider, identify sector drivers, relevant key policies, and crucially, how sectors and policies interact. At the end of a preliminary process a conceptual diagram was expanded in terms of: i) nexus sectors, which include energy, land and food; ii) spatial scope, from district level to integrating sectorial interactions for the whole Sardinia region; and iii) increasing the detailed representation of nexus sectors in the model, including the policies that affect them. Figure 4 shows the conceptual system diagram developed for Sardinia, on which further quantitative SDM model was developed in R.

For the Sardinia case study, the main focus was the representation of the reservoir water balance for the island, accounting predominantly for water supply and for water demand related to agricultural, energy and domestic/tourist consumption. On the water supply side, the model accounts for inflows to the reservoirs based on precipitation partitioning to runoff over the catchment area upstream of reservoirs. The final model disaggregates the water supplies and multiple demands in seven hydrological districts. For water demand, the model considers: 1) open-water evaporation from reservoir surfaces; 2) discharges for hydroelectric generation; 3) spillways in times of overflow; 4) irrigation requirements; 5) industrial demand; 6) domestic and tourist water requirements and; 7) environmental flows (i.e. the minimum amount of water needed to preserve ecological functions and values in watercourses). With irrigated agriculture being the largest water consumer, this sector was modelled in more detail. The crop water requirements per unit-area, and the area planted, were taken into consideration for 13 major crops on Sardinia as a function of current and changing climatic conditions. Touristic fluxes, and relative water demands, are modelled based on a Touristic Climate Index and socio-economic scenarios.

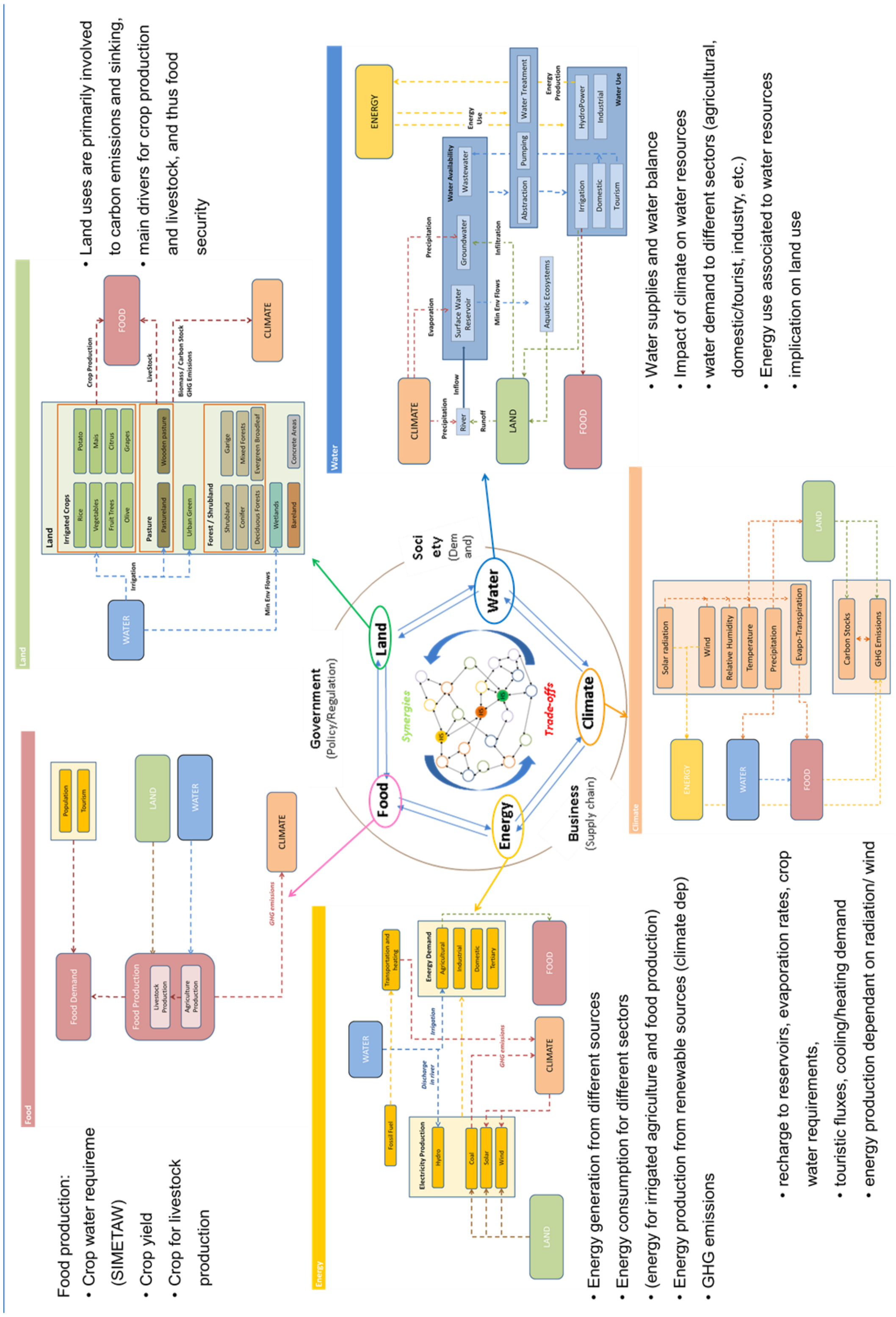


Figure 4 The main structure of the Sardinia conceptual model

While water is the central focus, this model is not only concerned with Sardinian hydrology and is not a hydrological model, but considers other nexus sectors including energy, climate, food and land use. Energy generation and consumption were also important along with the mode of generation and sector of consumption, as was modelling the change in crop types (i.e. land use and food production changes) and the crop water requirements associated with potential crop and cropped area changes, and in response to change in the local climate. Energy production is modelled from sources including oil, coal and methane, solar, wind and hydropower, while energy demand comes from the agricultural, domestic, industrial and service sectors (including transportation). The production of energy, especially related to non-renewable energy sources, have a direct implication on land uses both because energy farms imply land appropriation and also because the use of hydropower “limit” water availability that can indirectly sustain hydrological and physiological processes of ecosystem and reduce land degradation. The use of energy from the different sectors and using different energy sources, either renewable or not renewable, have different implication adding to emission of Greenhouse Gasses with specific impacts on climate change.

Climate change will have an impact on evaporation rates, crop water requirements, precipitation recharge to reservoirs, but also touristic fluxes, but also on the energy production dependant on solar radiation and wind. Land uses are tied to various Nexus components. In general, land availability is quite large in Sardinia given its low population density. However, given the semi-arid conditions, relevant land productivity is necessarily in needs of other resources, such as water, energy and labour. Land uses are primarily responsible for carbon emissions and sinking, in addition to emission due to energy consumption, and are main drivers for crop production and livestock, and thus food security. Finally, different socio-economic variables have been included and influence several demands over the NEXUS sectors and thus bio-physical trends and sustainability of natural resources and feedback across NEXUS sectors.

2.5 From the System Dynamic Modelling to the Serious Game

2.5.1 Case studies learnings goals

For each relevant Nexus domain the following learning goals have been set for Sardinia:

Water - Water use efficiency and sustainable management of water resources

Stakeholders from different sectors have stressed the high relevance that water resources supplies has to grant services related to different sectors (Agriculture, Industry, Domestic, Tourism). Therefore, a sustainable use of water has been put at the forefront of initiatives and management rules, structured as case study. Efficient use of water supplies is particularly relevant in Agriculture, which is by far the sector with largest consumption in the island. Two different actions are envisioned, namely change to more (most) efficient irrigation systems and improvement in water conveyance to reduce leakages. These two actions are in line with policy actions promoted by the regional government, and funded through European Structural Funds. The most direct goals aim at improving water productivity (more crop per drop), and by optimizing water use, avoid peaks in water demand causing overexploitation and conflicts among the competing sectors.

Energy - Sustainable use and management of energy resources

Energy is of particular interest to Sardinia goals to reduce GHG emissions, while boosting production from renewable sources and reducing dependence from imported fossil fuels. A crucial aspect of the energy market is high energy costs, which add up to the lack of financial competitiveness of Sardinia products and services. Major policy actions have promoted use of natural gas with the projected development of few very large stockpiles (gasifiers) along the coast and a capillary deployment of pipeline within the island. Replacement of coal and oil in thermal power plant with natural gasses, together with expansion of wind and solar power plants, will favour the goal towards reduction of GHG emissions and a carbon neutral society by 2050. Several specific actions and indicators are defined in Sardinia SDM for learning purposes, although other studies in Sardinia are available with much more detailed (sub-daily scale, and integration over multiple sources over the grid, etc.) for purpose of policy advices.

Food - Promote market of agricultural products
The primary goal is to promote sustainable crop food production, based on selecting and promoting specific crop types, whose growing season and irrigation requirements do not sensibly affect water demand in critical periods for water supplies, and furthermore crop types with positive economic outcomes for the future (grapes, vegetables, fruit trees, olive, etc.). The related use case is linked to the use case on land reforestation, as it is foreseen a gradual abandonment in the future of large agricultural areas actually devoted to cereals and pastureland.

Land - Reforestation of abandoned agricultural land
The reforestation of agricultural areas under abandonment would reduce risks of land degradation and contribute to climate change mitigation. Land degradation is an issue particularly felt and of interest to different stakeholders as it affects seriously several ecosystem services, such as soil productivity, biodiversity, sediment losses, etc. Reforestation would aim at ecosystem carbon sequestration, and thus a partial offset of emissions from energy use and agriculture. Different indicators are available to show the effects of the actions and to give a meaningful experience in the serious game, as increasing ecosystem carbon stocks and sequestration.

Climate - Effects of reducing greenhouse gas emissions through energy savings and reforestation
Use cases related to climate change mitigation are extremely relevant in the current debate, as to show feasibility of several measures in the energy, industrial and agricultural sectors and land use management options that can facilitate carbon neutrality by 2050. The main goal of the use case is to reduce GHG emissions. The use case will be beneficial to support the learning experiences.

2.5.2 From generic to specific use cases

The premise for such articulation in the project has been set with the following definition: "A use case defines which the different paths of interaction between the user and the SG are. It captures possible ways the user may follow to achieve a specified goal, as well as alternative paths and/or results if feasible, such as things that can go wrong in the process". Thus, the articulation of the Sardinia case study reflects quite well this general definition, and has been made more case specific taking into consideration the most relevant interlinkages among nexus components for the region. Therefore the implementation with use cases reveals to users what are the general impacts and problems associated to any specific sector, the rule and relevance of different policies and use cases to reach specific goals, and possible impacts on other nexus components.

Use cases specify three basic elements for the SG user: goal to be achieved, possible measures and interventions to be implemented, and indicators to measure successful implementation of each action/intervention. Indicators are thus a crucial factor for the user to understand performance of the actions. In the case study SG implementation, use cases were implemented with learning goals for Water, Energy, Land, Food (Agriculture) and Climate. Deliverable D1.2 describes in detail these use cases for relevant sectors with relevant characteristics for the user experience in the SG (annex 2.9.2). The same use cases can easily be adapted to other sectors, when actions are rather implanting measure of efficiency in use for a specific resource. It is worthwhile to stress that the general relevance of these measures have been co-designed and validated based on expert judgement by involved researchers and feedback/suggestions from stakeholders.

2.5.3 Policy cards

The package of policy interventions, behind each policy scenario, were translated and transformed into policy cards for the serious game. For each policy scenario different interventions and levels of implementations are assumed. Thus, 8 different policy scenarios were elaborated, which resulted in 21 policy cards related to ongoing policy initiatives and governmental agenda, as identified with stakeholders, as well as possible future foreseeable technological evolution from expert judgments.

The Policy cards were evaluated based on different criteria according to the feasibility of their implementation, possible range and degrees of implementation, how much it could influence the accomplishment of the policy goals, costs and acceptability by society. All these evaluations are needed criteria that are required to "regulate" the use of the policy cards in the serious game. Most policy cards were in line with concrete measures in the agricultural sector, domestic and tourism, and focus on water and energy measures, followed by climate and land. However, these evaluations presented a certain degree of subjectivity, as they were mostly driven by stakeholder and expert perception, which could change sensibly across different policy scenarios. It is clear that there is quite a confined intra-sectoral competence of many stakeholders which resulted in different evaluation of the interlinkage between different objectives and instruments depending on the expertise background, coming from various sectors of human activity. Although, many different policy interventions were suggested as policy cards into the serious game, it was not always possible to translate, as the same perception experts resulted in quite detailed and intrinsic solutions not simple to link to analytical functions developed and established for the SDM.

Ultimately, it was important to define and establish if the policy cards in the serious game should be placed as 1) temporary solutions in a timeline or as 2) permanent policy or transformations, to reach policy objectives and policy goals. Most policy cards related to measures that do not require a structural change (e.g. subsidies, taxes, etc.) were applied as temporary solutions, and afterward their effect vanishes. On the other side, other measures establish a permanent transformation (e.g. improving water infrastructure, housing energy efficiency, reforestation, etc.) whose effects last long after the policy card has been played.

2.6 From the SDM and SG to policy recommendations

2.6.1 Answering main research questions of the case study

The main nexus challenges in Sardinia are linked to water, agriculture, energy, land and climate sectors. Since tourism is an important economic activity in the region and also has environmental impacts, a focus was dedicated to this as well. All these sectors were included in the policy analysis, development of the conceptual model, implementation of the SDM and the policy cards implemented in the SG. In an initial version, Land was not explicitly considered, but implemented in the SDM at further stage.
Water supply and satisfaction of multi-sectoral demands is one central challenge in Sardinia that is also interlinked with the agricultural and energy sector and also has environmental consequences (i.e.

Minimum Environmental Flows; MEF). The other main challenge is the interlinkage between Energy and Climate that is fundamental for the reduction of CO2 emissions.

Irrigated areas show a constant and positive trend in the past 50 years. However, models suggest an inversion of trends further increase. In fact, baseline trends of irrigated area in Sardinia show a relevant decrease between 2010 and 2030, according to CAPRI model outcome. A modest expansion of irrigated land by crop types is expected for vegetables, identifying several cash crops that can be promoted by high prices in the market. Furthermore, both grapes and fruit trees could encounter an expansion of their irrigated distribution, while the largest decreases in irrigated areas are foreseen for cereals and pastureland.

At the same time, climate change scenarios are projecting a decrease of precipitations. In the past, the number of reservoirs has increased, many of them have been inter-connected and the water management has improved thus increasing the resilience of the system. Nevertheless, after repeated consecutive years with low precipitations, the reservoir system was not able to satisfy all demands, with water shortages not only for crops but also for domestic use and hydropower production. Policies insist on improving the drop for crop ratio, but these policies do not account for the fact that increased water efficiency in agriculture may actually have a positive effect on the expansion of irrigated areas thereby cancelling the purpose of the policy itself in the long term. A knowledge gap on the extent to which irrigated areas may increase without compromising the sustainability of the system is a major challenge in the region. This includes concerns on the impacts of water management rules and climate change for downstream wetlands.

For the energy sector, the baseline scenario of E3ME projects a strong increase in energy production from wind (256%) and a reduction from coal (-45%) for 2030, compared to 2013. Under this scenario, and in agreement with the simulations performed for the development of the Regional Energy Plan, reduction of CO_2 emissions will not meet regional targets. The introduction of methane in the regional energy system would strongly contribute to the reduction of CO_2 emissions if used both for heating and electrical production. The introduction of methane has been debated for decades at regional level. Such long time has opened a reasonable question on the benefit of introducing methane today: the use of methane would reduce CO_2 emissions however it might not be sufficient to reduce them enough to meet Paris agreement targets. To reach them, it would be necessary to invest much more on renewable energies in a very short time. Based on such target, the introduction of methane is still questioned. On the other hand, energy prices in the region are well above national and European levels. A major challenge in Sardinia is to understand the cost-benefits of alternative energy strategies. An estimation of the reduction of CO_2 emissions with the use of methane can be quite accurate. Instead, it is extremely complicated estimating CO_2 emissions and energy security in a scenario composed of multiple renewable resources, the potential increase for each technology, its environmental impacts that are low for each single device but spread over the territory, uncertainties of the costs and consequences of each technology, not to mention its implications for energy prices and the strong reactions of NIMBYs.

The SDM was designed to address these main challenges and accounting for the main interlinkages between sectors. The interlinkages considered were the outcomes of stakeholder interactions and include:

Climate to water: Climate influences basin run-off and thus the amount of water stored in reservoirs. It also has an influence on crop irrigation requirements and on evaporation from open bodies.

Climate to tourism: Climate influences the destination and season choices of tourist by affecting the climatic comfort.

Climate to energy: Climate influences the amount and timing of energy use for heating and cooling of buildings. Climate change will reduce energy requirements in winter and increase them in summer. Climate will also influence the productivity of solar and wind power plants.

Water to agriculture: The amount of water stored in reservoirs and the resilience of the reservoir system sets a limit to the expansion of the agricultural sector and at times of water scarcity it also determines a yield loss. Amount of water stored in reservoirs and its management determines yield production.
Water to energy: Some reservoirs are used for the production of energy from hydroelectric plants. As precipitations decrease with climate change, and water demands from other sectors increase, the production of this clean energy can be preserved to some extent with an optimal water management scheme.
Water to Environment: Reservoirs reduce the natural run-off and this reduction has an impact of the health of downstream ecosystems. Minimum environmental flows (MEF) constitute at least 10% of the natural run-off but this MEF is not met under severe water scarcity. An optimized water management would allow for the conservation and health of the downstream ecosystems which are often areas used for fisheries and offer important ecosystems services as purification of water and conservation of biodiversity.
Energy to climate: The present emissions of CO2 for energy production must be reduced to meet EU targets to mitigate climate change.
Energy to water: water pumping to bring irrigation systems to pressure and to transfer water between reservoirs require high amounts of energy that ultimately determine the real price of water. Water saving and cheaper energy would allow to reduce the price of water.
Agriculture to water: Choice of crops, irrigation systems, and expansion of irrigated areas determine the demand of water for irrigation.
Tourism to water: tourist flows and infrastructures for tourists create a demand of water resources

We acknowledge that reality is disproportionally more complex that the developed SDM and that its results must be taken with extreme caution. Most importantly, while the bio-physical part of the model could be considered fairly accurate, its interactions and feedback with socio-economic variables is weak and the SDM is consequently not able to accurately simulate evolution of the inter-linkages in the future. A major challenge for the development of the SDM was to estimate the effect of policies for water pricing or understanding the change in energy prices under different scenarios. Given the complexity of such problems and the limited available time and funding, these processes are at the moment the weakest points of the SDM and SG. Mostly because of this, Stakeholders consider the SG not suitable for decision-making but as a fantastic tool to raise awareness, increase the understanding of the NEXUS paradigms and suitable for education purposes. Instead, the biophysical part of the SDM and its results would be an interesting tool to evaluate thresholds on specific process and their interdependencies. Because of lack of data and information, it was not possible to establish inter-linkages between forestry and energy (i.e. wood biomass). The addition of this inter-linkage could modify some of the outputs of the SDM since wood biomass is an important fuel for household heating.

2.6.2 Supporting policy coherence

The key analysis of policy coherency took place at a relatively early stage of the case study development, during which the SDM and SG were not developed yet. Thus, the results of coherency analysis, coming from literature review, expert judgement, survey of stakeholders and stakeholder workshops, were instrumental in informing development of the conceptual model of the Sardinian nexus and, in turn, the Sardinian SDM. The analysis also helped to develop the scenarios to be run in the SDM.

The stakeholder interaction, among other issues, highlighted the strong Silos thinking and a diffused knowledge gap on how to include climate change scenarios in regional plans (e.g. the energy plan does not include the effects of climate change on the energy sector in terms of energy demand and production). In this context, the NEXUS approach was extremely relevant to promote a new paradigm and moreover, the importance of strengthening interactions among stakeholders of different sectors.
Most synergies identified in the policy analysis as well as from stakeholders, are confirmed by the SDM runs. For example, reducing water losses in the hydraulic conveyance system and improving irrigation

efficiency both increase the resilience of the water supply. The simulation also shows the extent to which irrigated area (and crop type) can be extended without encountering possible water shortages and highlighted that only one of the 7 hydraulic districts would pose an important limit to agricultural expansion.
Policies improving the resilience of reservoirs are also synergic with energy policies aiming at increasing the production electricity from renewables and reducing CO2 emissions. This is because, increased resilience of single reservoirs reduces the needs for water pumping between reservoirs (high energy costs) and allow for a higher hydropower production.
Policies improving the resilience of reservoirs are also synergic with policies aimed at increasing food production as well as containing the land abandonment phenomena. However this last is not fully implemented in the SDM or SG.
The SDM also allowed identifying tipping points in the synergies between policies after which they could trigger conflicts. Indeed, the SDM allowed to understand that synergies and trade-offs between policies shouldn't be considered as an absolute reference but synergies take place only at a specific equilibrium between policies.

2.6.3 Testing policy scenarios

To reach water resilience and a low carbon economy different combinations of policies can be applied, although some of them appear to be unavoidable. Furthermore, the combination used and the sequence with which they are applied strongly influences the rate at which the targets are reached. Unfortunately, the costs for their implantations and even more the economic effects (both positive and negative) could not be accurately estimated. This lack of accuracy implies that the best solutions might not be economically viable or that they might need strong financial support.
One mandatory intervention is the reduction of water losses from the conveyance system, this action alone would strongly improve the resilience of reservoirs, reduce energy demand for water pumping, allow for the expansion of irrigated area, increase food production while guaranteeing MEF. Without this intervention, the resilience of reservoirs and all the connected activities will be put at more frequent water shortages under climate change scenarios.
Another mandatory intervention is the strong improvement of energy efficiency of both private and public buildings. Independently from the choices for the energy mix and the pathways to 2050, Paris agreement targets cannot be reached without this intervention that should also take place as soon as possible. Note: important incentives (50 to 65% refund in 10 years) are given to improve the energy efficiency of households, but this policy is not used as much as desired fundamentally because of economic constraints in anticipating the initial costs.

Some policies need to be carefully used. An ideally perfect reservoir system combined with efficient irrigation would be able to satisfy all demands even under severe droughts and at least most of them under future water demands scenarios. However, the results of the simulations, showed that irrigation demands could be satisfied under climate change scenarios at the expenses of energy production from hydropower plants. Policies that tend to increase irrigated area, must be used only if water supply can be guaranteed whereas, at the moment, policies increasing food production disregard water availability in the present and in the future that could lead to exacerbating conflicts for water and could potentially bring to unsteady food production highly dependent on the hydrological cycle of a specific year.

These examples were chosen to exemplify how energy and climate policies are in general agreement, although some energy policies might have a positive effect on climate, it is also true that some technological choices might represent lock-ins in the future, posing additional difficulties in reaching Paris agreement targets (under 2 degrees target). Instead, food and water policies must find an equilibrium (e.g. central long term planning?) to avoid exacerbating conflicts.

2.6.4 Addressing Nexus challenges

Since all possible NEXUS interactions could not be inserted in the SDM, a selection was made considering inputs from stakeholders, expert knowledge and technical issues. The inter-linkages were reduced to a relatively low number, but a strong effort was given to assure direct or indirect feedbacks among components. Most components of the SDM have an effect on at least one of its components and are in turn affected by it directly or through its effect on other components. As a result of the high number of feedbacks, all policies have an effect on all other components.

An example is the effect of irrigated area on the water supply, but also the effect of water shortages on food production.

One important challenge for the Sardinia case study is not only the limited precipitation and high evapotranspiration, but also the high inter and intra annual variability that is also projected to increase with climate change. Adapting and planning to a higher variability is perhaps much more difficult than adapting to increased or reduced precipitations. This is in part already occurring as precipitations have shifted to winter months as opposed to the usual autumn and spring peaks.

In the SDM, climate scenarios are used as input and influence all NEXUS components. In turn, the model estimates net carbon emissions as affected by policies to help the decision maker understand how its policies would help reaching specific emission targets.

According to SDG indicator for Integrated Water Management, Sardinia is well positioned, nevertheless it is increasingly encountering water scarcity events that undermine food production, economic growth and environmental quality. The SDM includes the main feedbacks between the water component and all other components and in this sense it allows to resolve for coordinated policy interventions between sectors. For example, it can be used to identify limits to irrigated area above which other sectors would be negatively affected. Furthermore, Sardinia was sub-divided in 7 districts, so that policies may not have the same effect on each of them and this is why policies can be used separately for each district as far as the water and food sectors are considered.

In general the SDM provides the possibility to introduce policies at different levels of intensity and those to identify the optimal intensity required, in order to guide policy makers on the intensity they should target. Interestingly, some policies in the past were perfectly agreeable and in line with resource efficiency targets, but their intensity was by far too low.

2.7 Short-term and long-term policy recommendations

2.7.1 Summary of the Nexus issues in the case study

From stakeholder interaction and expert knowledge, it was possible to define an inter-linkage between all nexus components, however it also clearly emerged that the strength of interactions was strongly heterogenous. Bringing the general visualization to an extreme simplification, it can be said that the main feedbacks are between the Water and Food components and the Energy to Climate. Energy has weak, but not negligible, inter-linkages with water and very weak with food. In brief, these two groups can be seen as almost independent. This weak interdependency is also reflected by the policy interaction analysis that revealed how current policies for Energy have numerous interactions with the climate component but very few with the other components. Instead policies for water and food strongly influence each other. Importantly, climate strongly influences both Water and Food components, so that policies on Energy indirectly influence Water and Food through the Climate component. Such NEXUS structure is reflecting the main socio-economic and natural resources that characterize the region.

Low population and a high availability of land (forest and agriculture) give a general perception that Land use is not a major concern. Additionally, forests, despite their extension appear to be undervalued. This is a common issue in Mediterranean countries that also emerged during interactions with several stakeholders. Wood biomass could play an important role in increasing resource efficiency in the region, however the wood biomass value chain is nearly inexistent in the region: all pellet is imported, while wood is used for heating mostly using low efficient systems (fire place). The low, small scale and partially submersed market of wood is reflected in the low availability of information for the sector and for this reason it was not possible to include it in the SDM and SG. Which is unfortunate, as wood biomass would establish a much stronger link between land, food and energy components.

Consequently, the Sardinia Nexus issues have focused on two main challenges. The first being the effects of climate change on water availability and the sustainable use of water resources. Specifically, understanding how integrated water management could be realized avoiding competition between economic sectors and environment. The other being, understanding how emission targets could be reached, which strongly implies actions directed to the energy sector.

Two important issues that were highlighted by the analysis were a generally low level of awareness and a weak coordination between sectors. These could not be included in the SDM, but nonetheless are included in our recommendations.

Some of the recommendations presented in the following paragraphs are based on the results of the SDM and account for inter-linkages between all components to the extent that it was possible to translate them in numerical algorithms, while others are based on the results of policy analysis, conceptual framework and stakeholder interactions, which allowed to identify gaps in the policy structure, lack of information, potential development of value chains that would be relevant to increase resource efficiency. For a more detailed overview of inter-linkages, please refer to the conceptual model shown in Annex 2.9.1.

2.7.2 Description of the policies targeted for recommendations

A map of key stakeholders in the Sardinia case study was produced at the beginning of the project (see Appendix 2.9.3). These include: Regional agencies, research institutes (universities), private companies, and environmental associations. Key policy objectives of interest in the case study come from all five nexus sectors and are presented in Table 7.

Table 7 Key policy objectives of interest

Nexus component	***Policy Goal***	***Description***
Water	Improve water use efficiency in agriculture	The policy aims at reducing the water scarcity issues while increasing food production
	Sustainable water management	The policy aims at managing supply and demand from multiple sectors without endangering economic activities of the following years nor environmental status of ecosystems
Climate	Zero net emissions by 2050	The policy aims at implementing multiple measures in order to reach zero net emissions by 2050 with a main focus on energy efficiency of buildings
Energy	Increase RES share in the energy mix	The policy aims at further increasing the energy production from RES by increasing RES power plants as well as accumulators
	Reduce costs for energy	Energy costs pose a major limit the economic development in the region, the goal is to reduce their costs

Food	Promote market of agricultural products	Agricultural products are weakly exported also because the production of specific products is limited, the goal is to increase the crop production
Land	Protection of ecosystems	The policy aims at increasing the extension of protected areas in the region
	Regulate coastal landscape	The policies aims at minimizing the land use change in the coastal areas
Nexus	Increase social awareness and skills	The goals is to increase awareness and skills in order to increase the efficient use of resources and adopt measures to contrast climate change
	Increase coordination between sectors	The goals is to establish an institutional body or procedure that allows better communication and coordination among sectors including monitoring and data sharing

The possibility that drought events will increase in future climatic conditions raise a major concern in all regional authorities, private sectors and citizens. Since the most water demanding sector is agriculture (70% of the share), actions that would reduce its demand are a priority to avoid water scarcity issues as recognized by all stakeholders. Difficulties in sustainable water management are also due to the high inter and intra-annual climatic variability that is characteristic of Mediterranean climate and projected to increase with climate change. Guaranteeing resilience to variability entails changes in water management rules. These rules are strongly influenced by politicians as a higher resilience to variability can only be reached by posing restrictions to the maximum annual water supply with a consequent limit on extension of irrigated area.

Sardinia has signed the under 2 degree Memorandum of Understanding and as such aims at reaching carbon neutrality by 2050, if not before. Development of alternative energy sources (mostly wind), is increasing at a fast rate. However, to reach the goal other fundamental actions must be taken. Among these the improvement of energy efficiency in buildings (including heating systems) is a priority.

Increasing the share of RES in the region requires a faster rate to reach carbon neutrality but also has potential trade-offs with energy costs that in the region are already higher than the rest of Italy.

Agriculture is an important sector in the region both for its employment but also cultural heritage. The relatively small farms, high energy costs, and relatively low production are determining a general land abandonment and contraction of the market. Increasing food production and improving value chains to extent to allow not only internal consumption but also export is an important challenge for the region with relevance for all nexus components.

Tourism highly contributes to the regional GDP but its consequences are controversial as many identify a high risk for degradation of coastal ecosystems. What could be called a "sustainable tourism" is only sought by a part of decision makers and posing limits to the construction of tourist infra-structures and buildings in coastal areas is a long standing debate.

Low level of awareness and skills on how to account for climate change and inter-linkages with other sectors when developing plans is perhaps posing limits to an effective pathway towards a circular economy. Capacity building and increasing awareness are recommendations that influence the whole nexus. There is also a relatively low exchange of information and communication between decision makers of different sectors, not to mention interoperability of databases and access to data. The promotion of this policy would also have an influence on the whole nexus.

2.7.3 Policy recommendations

2.7.3.1 Changes in policy outputs

In general, policies and policy instruments should have a stronger focus on the environmental benefits provided by both forests and agriculture and a focus on water degradation as tools for adaptation to climate change. This would have synergies with the water (improvement of water quality and productivity of wetlands) and land sectors (reduced land abandonment).

In short	Ecosystem services
Target group	Ministry of agriculture and ministry of the environment
Target policy goal	Increase and preserve environmental quality
Target policy instrument	Payments for Environmental services
Target policy process phase	Implementation
Administrative level	region, country, EU
Time scale	middle-term till 2050
Cost-effectivity	
Social implications	

Policies focusing on sustainable forestry tailored for the Mediterranean are lacking and should be implemented by ministry of agriculture and ministry of the environment. Such policies would have effects on the Energy and Climate sectors.

In short	Promote the forestry sector
Target group	Ministry of agriculture and ministry of the environment
Target policy goal	Promote market of wood and non-wood products while mitigating climate change
Target policy instrument	Payments for Environmental services
Target policy process phase	Implementation
Administrative level	region, country, EU
Time scale	middle-term till 2050
Cost-effectivity	
Social implications	

2.7.3.2 Changes in policy contents

Policies goals are clearly set by the region for most nexus components, but clear regulations and standards are not as clear, leaving administrative gaps that hamper effective actions. An important gap is an unambiguous role of responsibility over water resources. The ministry for the environment and the regional water authority both have role in the protection and management of water resources, but the geographical boundaries of the resource are different for the two institutions. Furthermore, the definition and computation of the Minimum Environmental Flows (MEF) are not clear. Solving this issue with clear regulations would have effects on land and food components of the nexus.

In short	Definition of standards and responsibilities
Target group	Ministry of the environment and water authority
Target policy goal	Defining coherent boundaries of responsibility and computation protocols for MEF
Target policy instrument	Legal regulation
Target policy process phase	Implementation
Administrative level	region, country
Time scale	short term till 2030,
Cost-effectivity	
Social implications	

2.7.3.3 Innovations

There are several technical innovations for the water, food and energy sector that came from the case study analysis. Most of these were introduced in the SDM as policy measures.

For the water sector: reduction of water losses from the hydraulic conveyance system is a mandatory prerequisite to achieve a sustainable water management that has strong positive feedbacks on food production both in terms of quantities and stability of production and on environmental issues of wetlands downstream of reservoirs. But it also gives the possibility for a higher energy production from hydropower. The policy requires investments from the regional government.

In short	Water losses
Target group	Regional Government and water authorities
Target policy goal	Reduce water losses from the hydraulic conveyance system
Target policy instrument	Economic investment from the region
Target policy process phase	planning
Administrative level	region
Time scale	short term till 2030,
Cost-effectivity	
Social implications	

Sustainable water management cannot be reached without improving irrigation efficiency in agriculture. This can be achieved using more efficient irrigation systems but also sensor based farm level services to improve irrigation scheduling and applied water per irrigation event (Agriculture 4.0). Such technological improvements could not only reduce water demand per irrigated hectare to an estimated 30 to 50%, but also reduce fertilization requirements with economic benefits for the farmer and for the environment by reducing nutrient loads to water bodies. Incentives for more efficient irrigation exist but farm level services based on sensors are limited in number and in quality. This technological improvement has an effect on the food sector and on the energy sector (less energy for pumping water).

In short	Irrigation efficiency
Target group	Water authorities and Ministry of agriculture
Target policy goal	Reduce irrigation requirements
Target policy instrument	Incentives for farmers and promotion of sensor based service
Target policy process phase	Implementation
Administrative level	region
Time scale	short term till 2030,
Cost-effectivity	
Social implications	

Whether the phasing out from coal power plants is achieved by introducing methane in the island or by an even stronger promotion of RES, energy efficiency and carbon neutrality would be achieved by increasing the efficiency of energy distribution systems and accumulation capacity (i.e. smart grids and accumulators including reservoir recharge). The region has access to experts in energy issues that have already in part assessed potential and requirements. The policy addresses the need for a step forward from research to practice and would have important effects on climate as well as water (hydropower).

In short	Smart grids
Target group	Regional government and ministry for energy and transport

Target policy goal	Increase RES share
Target policy instrument	Funds for R&I and pilot sites
Target policy process phase	Implementation
Administrative level	Region
Time scale	short term, till 2030
Cost-effectivity	
Social implications	

2.7.3.4 Changes in the policy process

Achievement of sustainable use of water resources entails coordination of multiple actors ranging from the water authority to the farmer and including users of water bodies (e.g. fisheries), irrigation consortia, environmental associations that must agree on the rules to be set. A multi actor approach would allow to reach a shared vision and rules for sustainable water management also accounting for adaptation to climate change. These rules need to have a soft legal regulation as the management of system requires some flexibility. More effective water management rules would have a positive effect on environmental quality, food production, energy production, adaptation to climate change. Such goal requires also the aid of science based simulations.

In short	Water management rules
Target group	Regional government
Target policy goal	Sustainable water management
Target policy instrument	Legal regulation (management regulation) based on multi-actor approach
Target policy process phase	Implementation
Administrative level	Region
Time scale	short term till 2030,
Cost-effectivity	
Social implications	

The average energy efficiency of buildings in Sardinia is relatively low and its improvement would significantly decrease energy requirements for heating and cooling. Incentives for improving energy efficiency of private buildings exist (National policy set them as 50 to 65% return on taxes over 10 years) but are not used at the wanted rate in Sardinia. The slow rate is mostly due to the relatively low income per inhabitant (i.e. you need to pay enough taxes to have a return from the incentive and in any case the initial investment may be too high for many). The policy focuses on a change in mechanism to achieve the goal. The incentive is given to the construction company and the client receives immediate 50 to 65% discount regardless of its income. The mechanism is already partially working as of today for the installation of solar panels. The policy would have an effect on energy and climate.

In short	Energy efficiency of buildings
Target group	Regional government and ministry for energy
Target policy goal	Emission reduction
Target policy instrument	Policy implementation
Target policy process phase	Implementation
Administrative level	Region
Time scale	Short term, till 2030
Cost-effectivity	
Social implications	

2.7.3.5 Changes in the science-policy interface

Environmentalists often have an unwanted result of their actions as they often appear not to be guided by science based information. An example is the difficulties that are encountered by the forestry sector where wood cutting is heavily criticized (also with legal actions against who authorized) per se, with a clear lack of understanding that sustainability of forests, increasing yields (carbon sequestration) and biodiversity require tree cutting. Furthermore, the Not In My Backyard phenomena did not allow the construction of important RES production plants. There is a clear need to increase awareness and allow policy makers for a science informed decision making process. The policy focuses on frequent (monthly?) meetings between science and policy as well as awareness campaigns and dedicated courses at all educational levels.

In short	Increase awareness and science based options in society and public administration.
Target group	Regional ministries and education institutes
Target policy goal	Improved trust
Target policy instrument	Communication/education
Target policy process phase	Agenda setting
Administrative level	Eventually all: community, region, country, EU
Time scale	short term till 2030, middle-term till 2050, long-term till 2100
Cost-effectivity	
Social implications	

2.7.3.6 Changes in data sharing protocols and agreement

A main challenge in developing the SDM and SG for Sardinia was access to data both because of lack of digital information and access rights issues. Some authorities were extremely rapid in providing data while for other it was not simple to understand where they could be acquired, and other data were not available in digital form. Lack of easy to access Digital DB (most often the DB cannot be downloaded or explored, as even meta-databases are missing, and access requires authorizations) is not only limiting research but also simpler coordination between sectors. A policy that regulates data access and DB interoperability would be beneficial to coordination between sectors both horizontally and vertically. Even data transmission from subordinated authorities to higher authorities is weak and often results in slow responses to planning or emergency moments. The policy recommendation here targets national government and regional authorities and agencies. It would have effect on all nexus components.

2.7.3.7 Conclusion on coherent, Nexus-compliant policies

The recommendations reported above do not include all possible actions and many more could be added or refined in the type of policy instrument to use. The real complexity of the nexus is greater than the one considered in the analysis and not all inter-linkages could be included in the SDM. The forestry sector was not included because of lack of data, nevertheless the UNISS team participated to several workshops dedicated to the role of forestry in the region and in the Mediterranean area. A large amount of information emerged on possible policies and the multitude of inter-linkages between forestry and all nexus components and this information was used for some of the policy recommendations provided here.

The recommendations provided here would improve the pathway to a resource efficient Europe but might not be sufficient to reach emission targets especially for a 1.5°C scenario. Systematically including climate change scenarios to regional planning as well as inter-linkages with all sectors would certainly improve policy coherence and achieving a low carbon economy. Such inclusion should be targeted by promoting a constant communication between research, the private sector and public authorities.

2.8 Conclusion

The main challenges in Sardinia are to reach carbon neutrality, while achieving a sustainable use of water resources and a stable food production accounting for climate change and the increasing inter and intra-annual climatic variability. Sardinia has a low population, which is also projected to further reduce in the next 20 years because of socio-economic factors, and a high percentage of natural or semi-natural areas. As such, land use is not perceived as a limiting factor and few policies refer to this issue. Instead, water is perceived as the most limiting factor, a perception shared across all stakeholders. Development plans for the food, water and energy sectors are designed to meet EU, national and regional targets, however regional planning does not account for the effects of climate change on these sectors and adaptation strategies are just beginning to be considered, mostly at urban level.

Precipitations are projected to decrease with climate change, while water demand will increase. An emerging concern is the increasing inter and intra-annual climatic variability. Indeed, adapting to variability and achieving high resource efficiency under these circumstances is a relevant added challenge.

Significant advances have been made in the region to increase resource efficiency and reduce CO2 emissions. However, a nexus approach could significantly accelerate the process, increase cost effectiveness of measures, and realize a degree of efficiency that would be higher than the one without the nexus approach. Most stakeholders had and have difficulties in shifting from a sectorial view of the issues to a nexus compliant view, e.g. relevance of sharing data between sectors is not perceived as a priority for most. To be effective, the nexus approach requires to be implemented at multiple levels starting from education and training, governance, research and technological (e.g. digitalization). Despite the difficulties encountered, all stakeholders demonstrated a high interest in the concept and some progress was observed towards a nexus approach. The developed SDM, has been a great step forward in understanding the inter-linkages between sectors and identifying possible policies for the region. However, it was only possible to account for a limited number of inter-linkages compared to those that exist in reality, because of missing data and because it became apparent that their inclusion would require an effort that is beyond the possibility of a single project. Nevertheless, the developed SDM is a first important step in implementing nexus compliant policies: it is in the intention of the UNISS team to continue the development of the SDM beyond the SIM4NEXUS timeframe also leveraging the network of researchers and stakeholders that has been consolidated so far. Although the missing components in the SDM could significantly influence the results especially for some sectors, the present version already allowed understanding that goals can be reached in multiple ways and that all pathways entail some trade-offs between sectors and that there isn't one single optimal strategy. Choice of which sectors, actors and portion of population should be more advantaged than others remains in the hands of politicians and decision makers as influenced by their political sensitivity and degree of acceptance by citizens. The policy analysis and stakeholder interaction also clearly highlighted how policy goals are mostly nexus compliant and some incoherencies begin to appear at the level of policy measures. Strong incoherencies may actually appear only at an even lower policy level (e.g. how they are implemented, adequate funds, restriction rules for the typology of users). Such level of detail in the analysis goes beyond the project goals and would require an enormous effort to analyse and even more to resolve the incoherencies. It is likely that, a completely coherent policy structure is not possible and that nexus compliance requires a clear understanding of the issues at stake and a shared vision of the goals and possibilities, thus relying on a case by case interpretation of the context. Finally, a stronger coordination of actors is needed to increase the resource efficiency of the region at multiple levels to avoid that single actors make contrasting choices with actors in the same sector (e.g. farmers and foresters) and reminding that some actions - to be effective - require to be synchronised with others.

2.9 Annexes

2.9.1 Conceptual model

The SDM of the Sardinia case study consists of six subsystems: socioeconomic, land, food, energy, water and climate subsystems.

The socioeconomic subsystem includes different socio-economic variables influencing trends and mostly demand over the NEXUS sectors, see Figure 5.

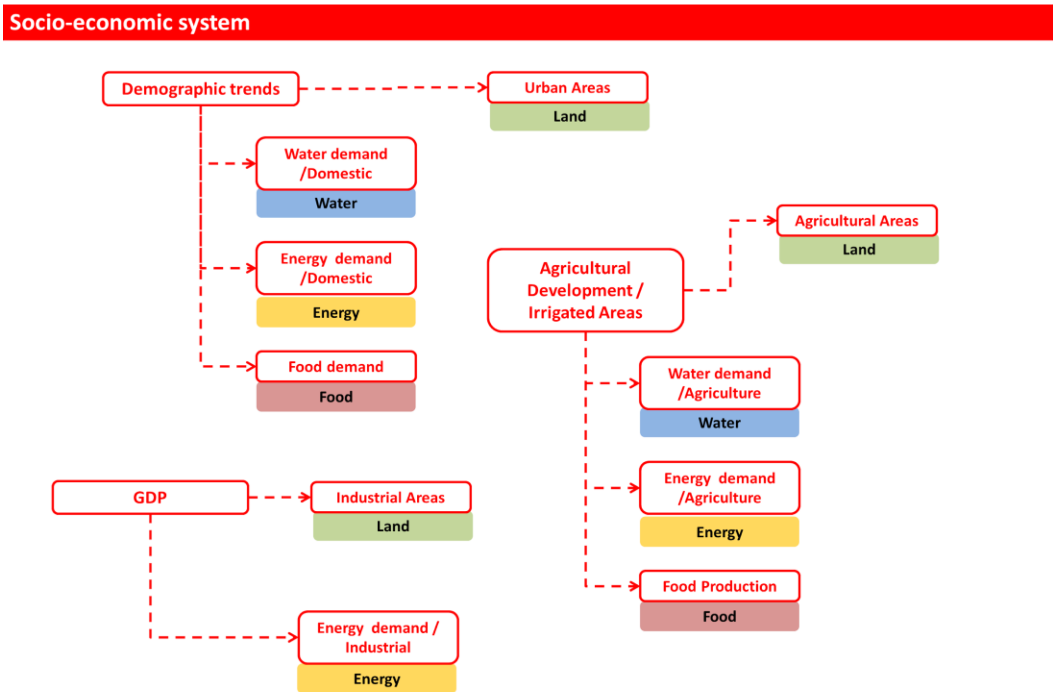


Figure 5 The socioeconomic subsystem

The land subsystem considers four main land covers: cropland (irrigated and rainfed), Pastureland, Forest/Shrubland, wetland and urban areas, see Figure 6.

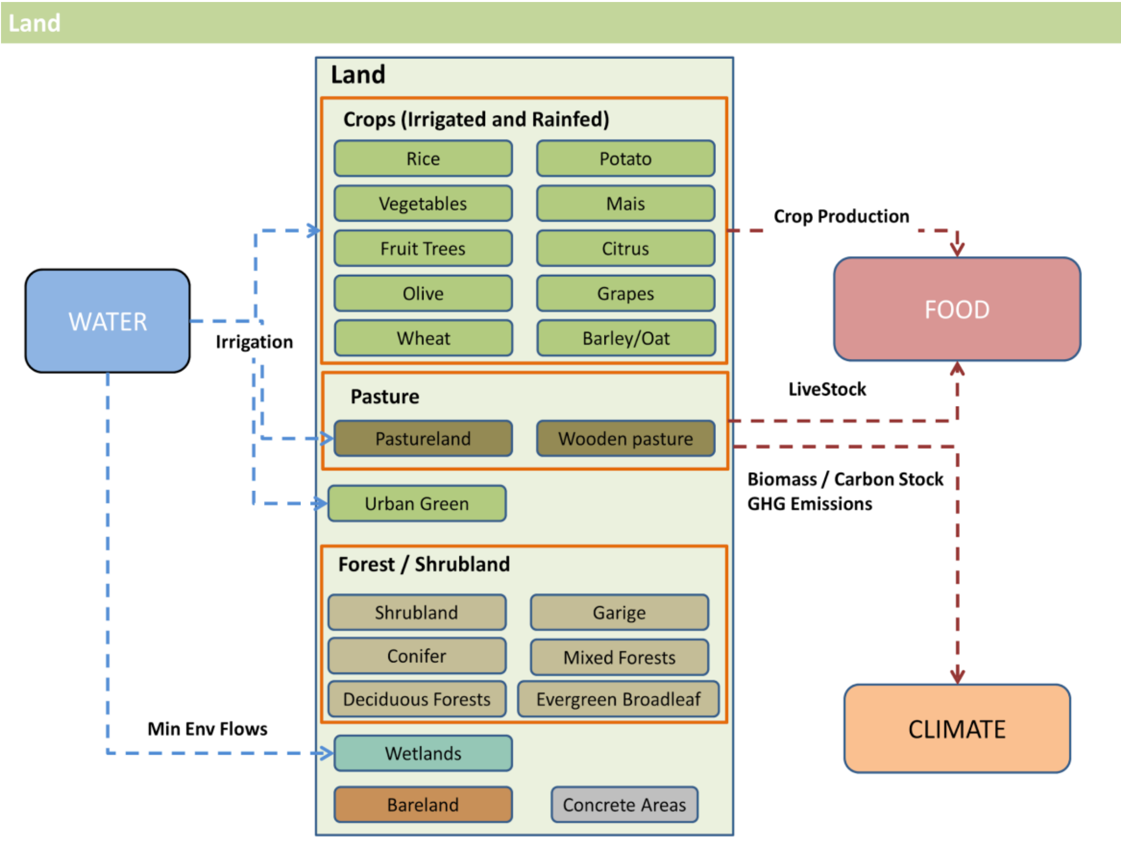


Figure 6 The land subsystem

The food subsystem consists of the agricultural production of food and fodder and the food consumption/food demand, see Figure 7.

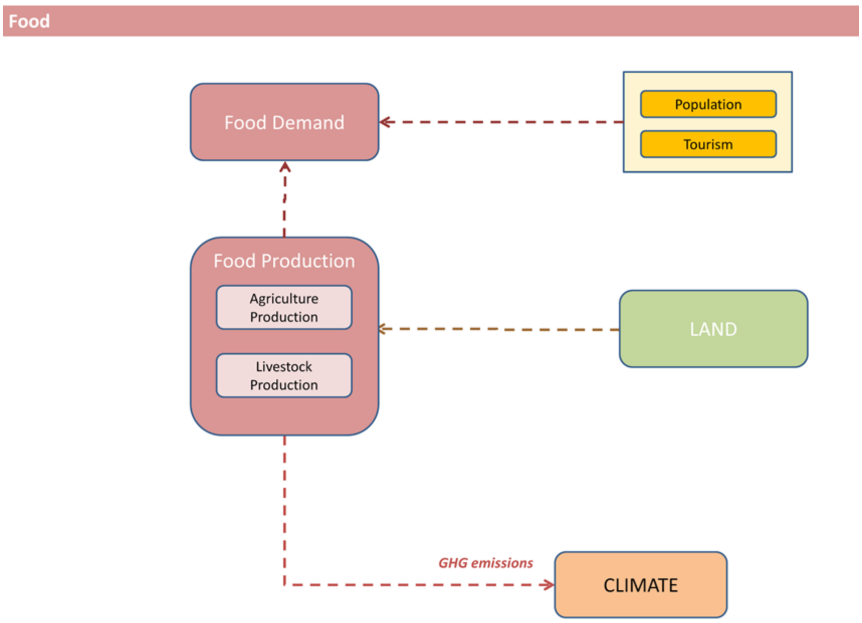


Figure 7 The food subsystem

The energy subsystem (Figure 8) includes the energy production and the energy consumption. Energy generation and consumption were important along with the mode of generation and sector of consumption, as was modelling the change in crop types (i.e. land use and food production changes) and the crop water requirements associated with potential crop and cropped area changes, and in response to change in the local climate. Energy production is modelled from sources including oil, coal and methane, solar, wind and hydropower, while energy demand comes from the agricultural, domestic, industrial and service sectors (including transportation). The production of energy, especially related to non-renewable energy sources, have a direct implication on land uses both because energy farms imply land appropriation and also because the use of hydropower "limit" water availability that can indirectly sustain hydrological and physiological processes of ecosystem and reduce land degradation. The use of energy from the different sectors and using different energy sources, either renewable and not renewable, have different implication and loading to GHG emissions with specific impacts on climate change.

Energy

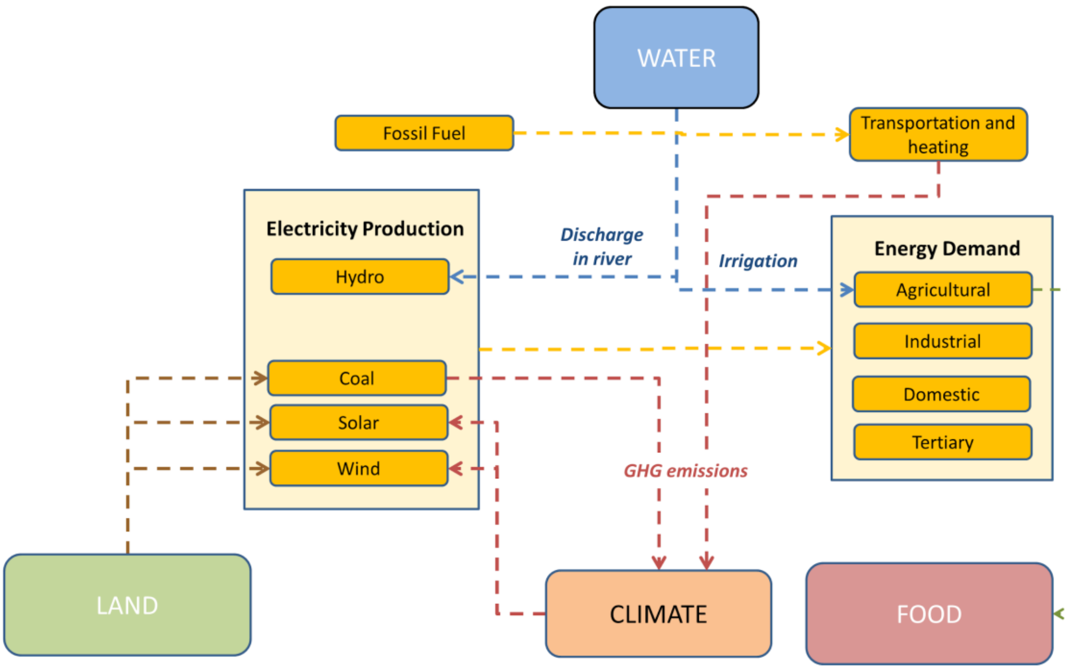


Figure 8 The energy subsystem

For the Sardinia case study, the main focus was the representation of the reservoir water balance for the island (Figure 9), accounting predominantly for water supply and for water demand related to agricultural, energy-related, and domestic/tourist consumption. On the water supply side, the model accounts for inflows to the reservoirs based on precipitation partitioning to runoff over the catchment area upstream of reservoirs. The final model disaggregates the water supplies and multiple demands in seven hydrological districts (figure 16). For water demand, the model considers: 1) open-water evaporation from reservoir surfaces; 2) discharges for hydroelectric generation; 3) spillways in times of overflow; 4) irrigation requirements; 5) industrial demand; 6) domestic and tourist water requirements and; 7) environmental flows (i.e. the minimum amount of water needed to preserve ecological functions and values in watercourses). With irrigated agriculture being the largest water consumer, this sector was modelled in more detail. The crop water requirements per unit-area, and the area planted, were taken into consideration for 13 major crops on Sardinia as a function of current and changing climatic conditions. Touristic fluxes, and relative water demands, are modelled based on a Touristic Climate Index and socio-economic scenarios.

Water

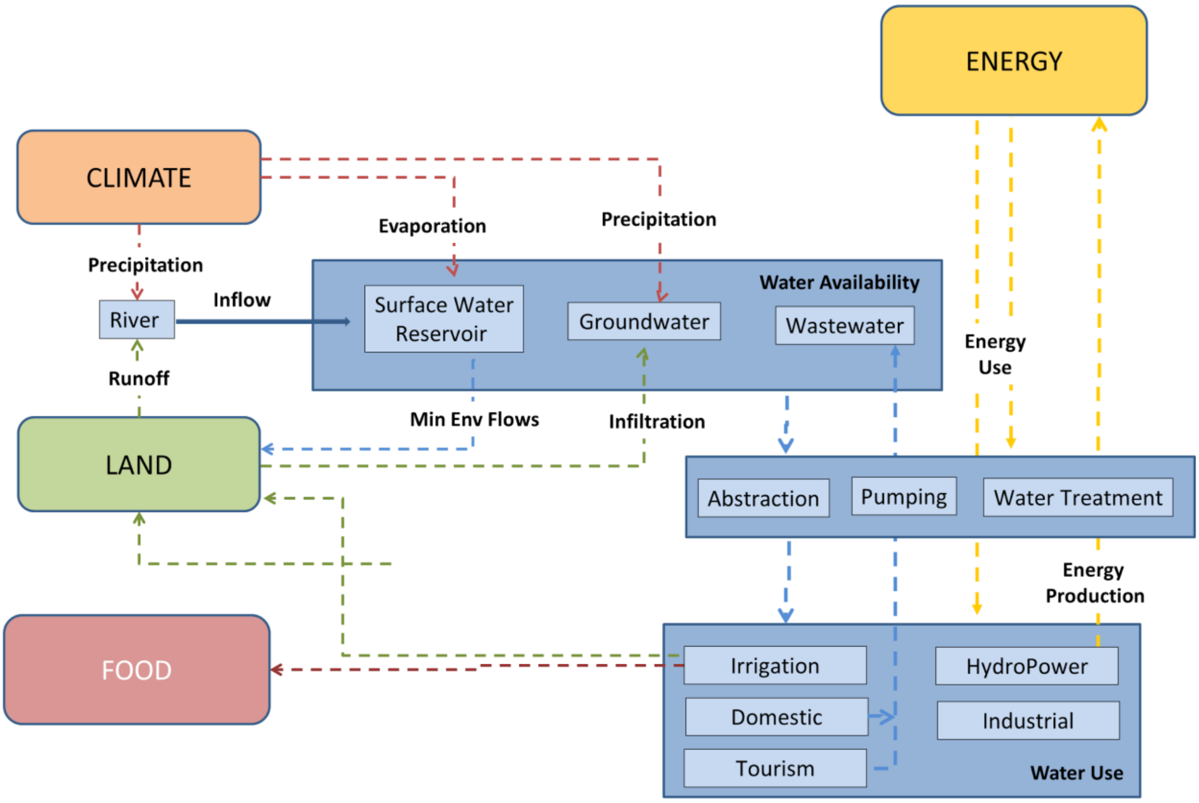


Figure 9 The water demand/supply subsystem

Climate change will have an impact on evaporation rates, crop water requirements, precipitation recharge to reservoirs, touristic fluxes, but also on the energy production dependant on solar radiation and wind. The climate subsystem reflects the GHG emissions from the whole system, see Figure 10. It includes GHG emissions from energy production, GHG emissions not related to energy production from economic sector and agricultural GHG production related to agricultural activities.

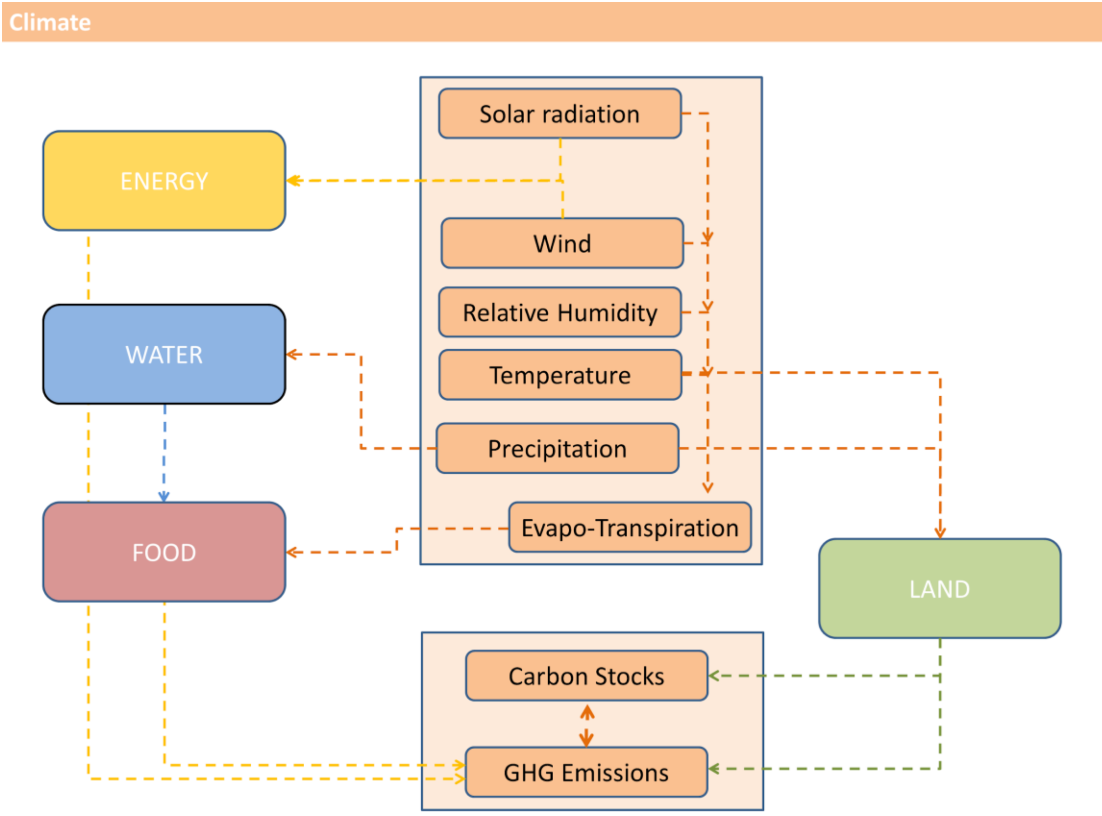


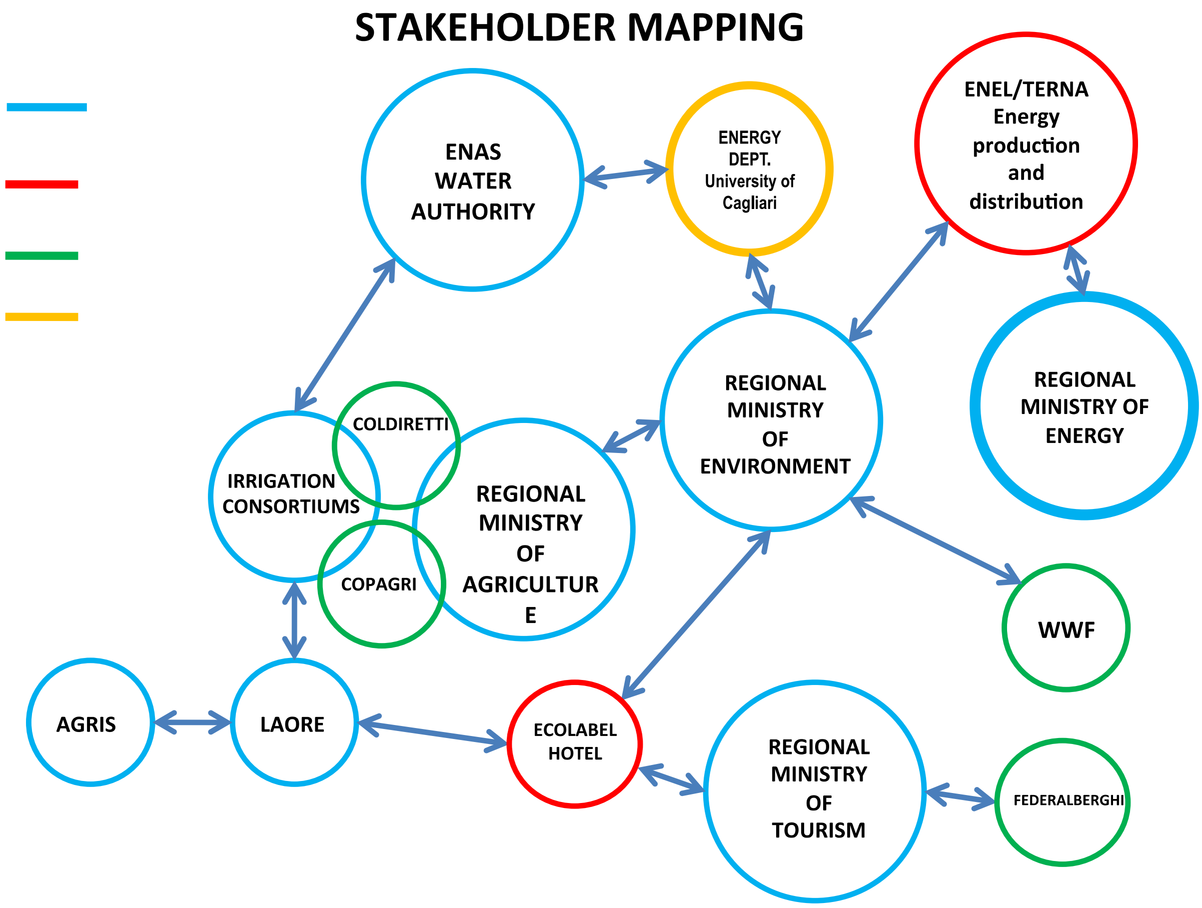
Figure 10 The climate subsystem

2.9.2 Policy cards

List of policy cards for the Sardinia case study

Policy Goal (PG) - Name	*Policy Goal (PG) - Description*	*Policy Goal id*	PolicyId	Nexus Sector	Name	Description of intervention as captured by the policy card
Improve water use efficiency in agriculture	The policy aims at reducing the water scarcity issues while increasing food production	PG1-W	O1	Water	Efficient irrigation system	Adoption of new (alternative) irrigation methods (change of irrigation systems).
			O2	Water	IoT service for irrigation	Impmentation of IoT services for optimal irrigation
			O3	Water	Leak reduction in conveyence system for agriculture	Renewal of conveyence system
Sustainable water management	The policy aims at mancìging supply and demand form multiple sectrors without endagering economic activities of the following	PG2-W	O4	Water	Guarantee Minimum Environmental flows	Water management accounts for fully satisfieng minimum environmentla flows even in case of short water supplies
			O5	Water	Increase resilience of water supply	Water management accounts for predicted water demand of the follwoing year and ensures water supplies for the following year
Zero net emissions by 2050	The policy aims at implemetning multiple measures in order to reach zero net emissions by 2050	PG3-C	O6	Climate	Increase energy efficiency of households	Incentives to improve isolation of households
			O7	Climate	Increase energy efficiency of pubblic buildings	Incentives to improve isolation of Pubblic buildings
Increase RES share in the energy mix	The policy aims at further increasing the energy production from RES by incrasing RES power plants as well as accumulators	PG4-E	O8	Energy	Increase energy production from Wind	Increase energy production from Wind
			O9	Energy	Increase energy production from Solar	Increase energy production from Solar
			O10	Energy	Increase energy production from biomass	Increase energy production from biomass
			O11	Energy	Increase energy production from Hydropower	Increase energy production from Hydropower
			O12	Energy	Implement smart grid and accumulator systems	Implement smart grid and accumulator systems
Reduce costs for energy	Energy costs pose a major limit the the economic development in the region, the goal is to reduce their costs	PG5-E	O13	Energy	Import Methane for heating and electricity production	Import Methane for heating and electricity production
Promote market of agricultural products	Agricultural producits are weakly exported also becasue the production of specific products is limited, the goal is to increase the crop production	PG6-F	O14	Food	Increase production of fruits	Increase production of fruits
			O15	Food	Increase production of vegetables	Increase production of vegetables
			O16	Food	Increase production of crop feed	Increase production of crop feed
			O17	Food	Increase production of grape	Increase production of grape
			O18	Food	Increase irrigated area	Increase irrigated area
Regulate coastal landscape	The policies aims at minimizing the land use change in the coastal areas	PG7-L	O19	Land	moderately increase number of hosting facilities	moderately increase number of hosting facilities
			O20	Land	increase new hosting facilities	increase new hosting facilities
Reforastatio n	Increase forested cover	PG8-L	O21	Land	Reforastation of marginal lands	Increase forested area by reforastaion plans focused on marginal lands
			O22	Land	reforastation of abondoned land	Increase forested area by reforastaion plans focused on agricultral abondoned lands

The above table presents the list of policy cards considered in the SDM for the Sardinia case study. The ID of the policy cards identifies the connection of the policy card to the nexus sectors and the economic sector(s). The first character relates to the nexus sectors: energy ("E"), climate ("C"), land ("L"), food ("F"), and water ("W"). The second character relates to the economic sectors: agriculture ("A"), manufacturing industry ("I"), transport ("T"), Service sector ("O"), and domestic sector or households ("D"). IN addition, there are some policy cards for all sectors. Then, the second character is a "W". See also Figure 11 for the stakeholder mapping.



Legend : green = unions ; red = private ; orange = research; Blue = public

Figure 11 Stakeholder map for the Sardinia case study

3 Andalusia

3.1 Introduction

Andalusia is an autonomous region located in Southern Spain (Figure 12). It has a total area of 8.76 million hectares (17.4% of the Spanish territory) of which half is Utilized Agricultural Area (UAA), including one million hectares of irrigated land (Massot 2016). Andalusia´s population is approximately 8,4 million people (2015). Andalusia is the second largest region in Spain and the fourth largest region in EU28. It´s orographic and hydrographic features, climate types and biodiversity vary considerably (Massot 2016). In Andalusia, the primary sector, including agriculture, accounts for 5.5% and employs 263.1 thousand people (AWUs or Annual Work Units) in 2017 (Junta de Andalucía 2018). In particular, olive oil, both in terms of turnover (5292 million Euro) and value added (662 million Euro) is crucial for Andalusia´s agri-food industry, with exports worth of 2 288 400.70 thousand Euro, making Andalusia the global market leader for olive oil (Massot 2016).

The gross water demand is 3357 hm^3 taken into consideration the efficiency of water transport, distribution and application (type of irrigation system). Approximately 74% of the irrigated land in Andalusia currently uses localised irrigation systems, 17% drop irrigation and to a lesser extent sprinkler irrigation. Irrigation agriculture derives approximately 64% of the agricultural production in Andalusia, and has also high socioeconomic importance (generates 63% of agricultural employment and 67% of farm income) (Massot 2016). While irrigation agriculture is crucial for Andalusia´s socioeconomic development, it also puts pressure on the limited water resources in the province. Andalusia has a negative water balance and, in some areas, faces problems of erosion (with risk of desertification).

Irrigated land in the region is mainly concentrated in the Guadalquivir RBD (856429 ha). The Guadalquivir RBD is the main river basin of Andalusia with a watershed area of 51500 km^2, that represents 58.8% of the geographic area of Andalusia. Irrigation water is largely drawn from the Guadalquivir river, the longest river in Andalusia and the fifth longest in Spain with 657 km. Total water demand in the Guadalquivir RBD is estimated to be 3815 hm^3 in 2015 with agriculture being the main water user with 3356 hm^3 (88% of the total demand). With regard to the origin of water, approximately 2498 hm^3 correspond to surface water (74.0% of the total water demand) and approximately 913 hm^3 to groundwater (26% of the total water demand). The Guadalquivir RBD includes approximately 86% of the total irrigated land in Andalusia, of which olive trees are the most predominant (52%), followed by extensive crops (30%), fruit trees (7%) and rice (4%). The olive groves, which are mostly located in the Guadalquivir RBD, are the largest farming system in Andalusia. They account for 25% of total UAA and 42.6% of holdings in Andalusia, with often highly mechanized production and irrigation systems.

Regarding efficient energy use in irrigation facilities, high energy costs are a huge conundrum for irrigators (Lopez-Gunn et al. 2012). As a result of modernization of the irrigation system, the Spanish water delivery system was changed from surface irrigation to pressurized systems. This required the installation of electric pump systems to guarantee sprinklers or drip irrigation to function properly. Energy has, thus, turned into an essential resource for irrigation agriculture with huge increases in energy consumption. Moreover, the Ministry of Industry subsidized energy for irrigation with a special rate (R rate) until July 2008. After July 2008, the energy market was liberated and brought about higher (unsubsidized) energy prices for irrigators to the benefit of power companies (González-Cebollada 2015).

Against these trade-offs in the WEF nexus and the importance of irrigation agriculture in Andalusia, the Andalusian case study assesses the economic aspects of the agricultural sector and respective land use changes. Key indicators to be assessed for each agricultural product (olives, cereals, wine, sunflower, citrus fruits, among others) include cultivated area (1000 ha, irrigated and rainfed), income (Eur ha^{-1}), supply (1000 t), per hectare water use (m3 ha^{-1}), and energy consumed per unit of irrigated area (kWh ha^{-1}). Moreover, water demand from reservoir (surface water) and groundwater is assessed, as well as energy production and consumption.

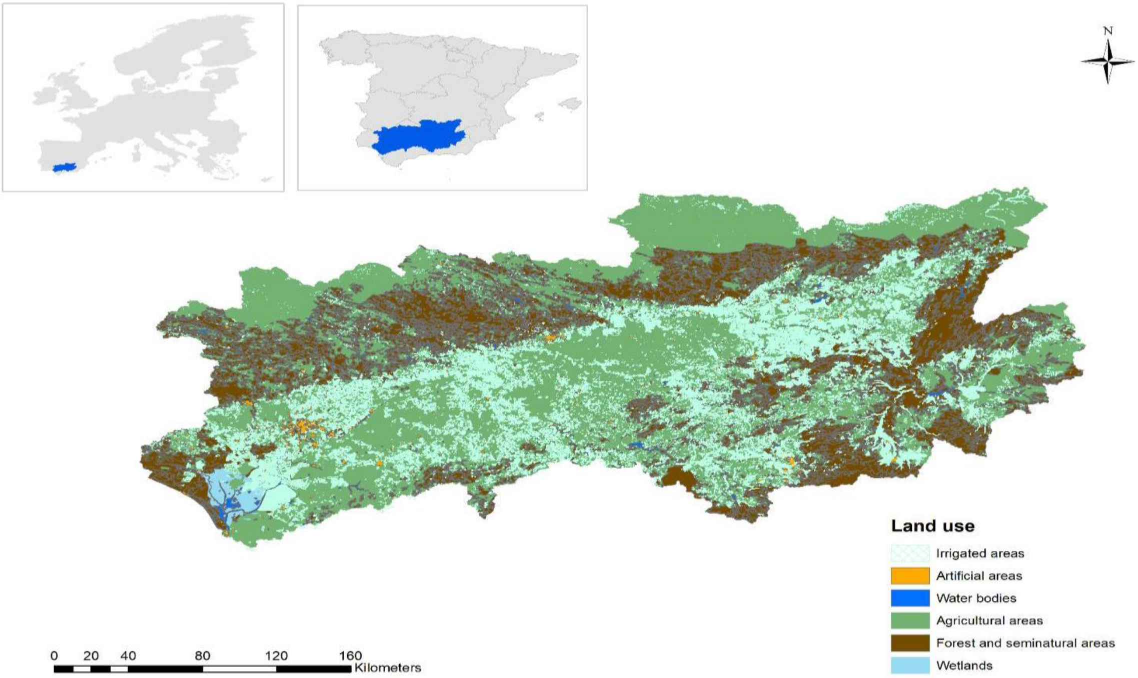


Figure 12 Map showing the SIM4NEXUS Andalusian case study

Altogether 14 stakeholders were interviewedon 26 October 2017 in Seville (Spain)., including six from the public sector (1. Regional Ministry of the Environment and Territory Planning (RMETP), 2. Regional Ministry of the Agriculture, Fishing and Rural Development (RGAFRD), 3. Environment and Water Agency of Andalusia (EWAA), 4. Andalusian Energy Agency (AEA), 5. Provincial Council (PC), 6. Guadalquivir River Basin Authority (GRBA)); four from the private sector (7. National Federation of Water Users Associations (FENACORE), 8. Andalusian Federation of Water User Associations (FERAGUA), 9. Farmer Organisation Coordinator (CAOAG), 10. Andalusian Association of Promoters and Producers of Renewable Energy (APREAN); one NGO (11. WWF), and three from the research and university sector (12. Andalusian Institute of Agricultural and Fisheries Research and Training (IFAPA), 13. University of Cordoba (UCO), 14. University of Almeria (UAL)).

After a general overview (brainstorming) of the interrelationships among nexus components as seen by the stakeholders. After that, the most important challenges of the case study have been summarized.

<u>Climate – Water</u>

- Climate change will affect water availability in the region in such a way that runoff will decrease by 8% in 2027, according to the river basin management plans, and by 10-12% according to other studies from the Regional Government. Furthermore, an increase in extreme events has already been observed, particularly more and longer droughts.
- Reduction in water availability together with the rise in temperatures will lead to an increase in water demand and, therefore, to more pressure on water resources.

Climate – Agriculture

- Changes in temperatures and precipitation will produce an increase in crop evapotranspiration that will affect crop water requirement and crop yields. The impact will be higher in rain-fed agriculture, which is more reliant on precipitations than irrigated agriculture. Therefore, crop yields are expected to decrease in rainfed crops and increase in irrigated crops (if there is water available). In a context of climate change and scarce water resources, shifting towards more cost-effective crops (e.g., almonds) is likely to occur.
- Changes in climate may also affect sowing and harvesting dates and induce introduction of new crop varieties.

Climate – Land

- Irregular precipitation will increase the current soil erosion problems in Andalusia.

Climate – Energy

- The increase in wind and radiation, together with the need to reduce fossil fuels consumption, may lead to an increase in solar and wind energy production. Furthermore, changes in energy demand are also likely to occur in the future because of climate change.

Water – Climate

- Water bodies may affect climate at local level. According to Guadalquivir River Basin Authority, 25% of precipitation in the basin come from evaporation in internal water bodies.

Water – Agriculture

- Irrigation increases crop yields and production, if there is water available. However, considering the reduction in water availability, the agricultural sector must optimise water use and might most probably reduce the irrigated area by 10-15%.

Water – Land

- Soil erosion and salinization because of agricultural activities
- Land use change as a result of variation in water availability: reduction in irrigated area, shift to rain-fed agriculture and even to forest use.

Water – Energy

- Reduction in water availability will negatively affect hydropower production and energy production (cooling systems).

Agriculture – Climate

- Agriculture emits and absorbs greenhouse gases, although the balance is ambiguous (depending on the person interviewed).

Agriculture – Water

- Overexploitation of water resources, particularly in the main basin (Guadalquivir river). In terms of water quality, pollution of water resources by nitrates in agricultural areas is very significant. Nowadays, only 50% of water bodies present a good environmental status, while the Water Framework Directive (WFD) set the target of 100% by 2010.
- In coastal areas, overexploitation of groundwater resources is leading to aquifer salinization (e.g., in Almeria).

Agriculture – Land

- Agricultural activities contribute to soil pollution and soil productivity losses. Promotion of conservation agriculture may help to protect the soil.

Agriculture – Energy

- The current agricultural model is highly dependent on energy (irrigation, machinery, fertiliser production, transport). Irrigation energy demand has trebled in the last years from 200-300 Kwh/ha to 1100-1200 Kwh/ha. This is not only an environmental issue but also an economic issue as it may challenge the economic sustainability of agriculture highly dependent on energy. Energy cost (300-400 €/ha) has turned into a more limiting factor than water cost (60-90 €/ha).

Land – Climate

- Carbon sink capacity is closely linked to land use: agriculture and forest uses contribute to the absorption of greenhouse gases (GHGs).

<u>Land – Water</u>

- Competition over water resources between different uses is significant or not significant depending on the person interviewed. This is because 1) high agricultural water demand is concentrated in winter (greenhouses) whilst tourist water demand is concentrated in summer; and 2) coastal areas have access to desalinated water. Nevertheless, desalinated water is expensive (0.6-0.7 €/m^3) and the majority of desalination plants work far below capacity.

<u>Land – Agriculture</u>

- Competition over land use between agriculture and urbanization in tourist areas (mainly coastal areas).

<u>Land – Energy</u>

- Land planning affects energy production (fracking, mining, renewable plants installations, etc.).

<u>Energy – Climate</u>

- Energy production emits great quantities of GHGs. At the same time, promotion of renewable energies can help to reduce this type of emissions.

<u>Energy – Water</u>

- Energy is used in water pumping (groundwater, water supply, and pressure on irrigation systems) and in desalination and water reuse

<u>Energy – Agriculture</u>

- Energy cost has turned into a liming factor in irrigated agriculture because of increases in energy demand and energy prices. The energy price has increased substantially over the last years. Therefore, there is a need to improve energy use efficiency as well as to introduce renewable energies in agriculture.

<u>Energy – Land</u>

Land use to install renewable energy plants.

The major nexus challenges that had been raised during the interviews were discussed and amended further in the first workshopon 26 October 2017 in Seville (Andalusia). Altogether six general challenges, including major measures to overcome these challenges, were discussed:

- Sustainable management of water resources
- Inclusion of water quantity and quality issues
- Consideration of the water/energy ratio in all decision-making processes
- Mitigation and adaptation to climate change
- Integration of climate change goals in policies related to water, energy, land, and agriculture
- Adaptation to climate change should be considered transversal policy
- Energy efficiency and promotion of renewable energies
- Consideration of the energy (water) footprint of water (energy)
- Downsizing the machinery park and outsourcing to service companies
- Reduction of VAT (21%) for companies that follow Certificates of Compliance with Regulatory Requirements (CCRR)
- Fight against soil erosion and desertification
- Integral soil management
- Sustainable urbanization
- Consideration of climate change impacts (e.g., soil biota, absorption capacity)
- Competition for land use
- Resource efficient food production

- No subvention for natural resource use in food production (e.g., water)
- Green taxation
- Sustainable socioeconomic development
- Holistic management that should be sustainable, intelligent and inclusive

3.2 Overview of tasks performed

3.2.1 Organisation to carry-out Task 5.2

The case study is led by the UPM team. UPM is responsible for organizing the work and keeping in touch with stakeholders. Although not initially planned, UPM is also developing the SDM for the Andalusian case study. The UPM team has meetings almost daily and also meets with other partners, either in bilateral meetings or in the weekly meetings organized every Monday. The work is developed in close contact with relevant stakeholders from Andalusia.

3.2.2 Schedule of Task 5.2

The main steps of tasks performed are:

- Analysing water-agriculture-energy interrelationships in Andalusia

In this part, we provide an overview of the interrelationships between the components of the nexus, and the main challenges in the water-agriculture-energy nexus that have been identified through collaboration with stakeholders.

- Analysing policies related to the nexus

The analysis of policies related to the nexus has been done at both European and regional level. Research has investigated how agricultural and environmental policies can be integrated to cope with pressures on land and water, while promoting their sustainable use and economic development. The work is based on a detailed review of the policies of the different nexus sectors in both Europe and Andalusia, as well as the opinions of interest groups and the knowledge of researchers.

- Application of thematic models

We have applied sectoral models (agriculture and energy) to obtain results on the future trends of different agricultural, socioeconomic, environmental and energy variables in the particular case of Andalusia. The baseline scenario has been simulated, which is the reference scenario with which to compare future policy scenarios and therefore assumes the continuation of current policies (e.g. CAP 2014-2020, Renewable Energy Directive) and the most likely scenario of socio-economic and climate projections.

- Definition of the conceptual model

The first step in the development of the Andalusian systems dynamics model is the conceptual model, which represents the main interrelations in the water-agriculture-energy nexus in the region.

- Development of the system dynamics model

Based on the interrelation map, policy analysis and historical and projected data obtained, a systems dynamics model is being developed that allows joint analysis of the different sectors of the nexus and simulate future policy scenarios. The model is being validated through a participatory process.

- Application of the system dynamics model

Once the system dynamics model has been developed, it is being used to simulate policy scenarios, identified by the stakeholders.

- Upcoming activities

The system dynamics model is the basis for the creation of the Serious Game on the nexus.

3.3 Engagement of stakeholders in the process

Within the Andalusian case study, progress has been made through stakeholder participation in research activities: 1) preliminary interviews were conducted, 2) the first stakeholder workshop was held in October 2017 in Seville (Andalusia), and a roundtable. Stakeholders were identified through online research and snowball sampling. All stakeholders received the SIM4NEXUS brochure in digital format (25 brochures distributed) and were informed by telephone about the project and the case study in the first quarter of 2017.

3.3.1 Overview of stakeholders' engagement in the case study

Key stakeholders were selected and 14 institutions were contacted again by telephone/scheme for semi-structured interviews. Seven guiding questions have been developed to gain a first understanding of stakeholders' views on the main challenges of NEXUS.

The first workshop took place on 26 October 2017 in Seville (Andalusia). It began with a keynote speech followed by a presentation of the SIM4NEXUS project and the Andalusian case study. Written information was given to each participant, including the workshop schedule, the nexus flyer and the E3ME and CAPRI model fact sheets. The actual workshop steps were described below. The objective of the workshop was to obtain stakeholder views on the relationships and challenges of the linkages. It was divided into three sessions: 1) individual mapping, 2) group mapping, 3) roundtable discussion on nexus challenges and policy scenarios. A confidentiality agreement was read out and agreed upon by all participants.

In individual mapping, each participant had to draw their vision of the interrelationships of the nexus by selecting variables, signs (+/-) and magnitudes of relationships (-1 to +1). The aim was to use an inductive approach similar to grounded theory.
A total of eleven individual maps were produced. Without providing additional information, each participant included an average of 18 self-defined variables in their individual map. In total we obtained 142 variables that are now combined into categories for further analysis (diffuse cognitive mapping and SD modeling).

After each participant completed their individual map, a group map was developed based on input from all stakeholders.

Together, stakeholders have identified six general challenges in the scope of the nexus in Andalusia: 1) Sustainable management of water resources, 2) Mitigation and adaptation to climate change, 3) Energy efficiency and promotion of renewable energies, 4) Combating soil erosion and desertification, 5) Food production efficient in the use of resources, 6) Sustainable socio-economic development.
Together with these six major challenges of the nexus, three crucial political scenarios were identified to face the challenges of the nexus in Andalusia in the medium and long term: 1) Reduction of diffuse emissions by 18% in 2030, 2) Reduction of the demand for water for irrigation, and 3) Improvement of governance, transparency and information.

After each participant completed their individual map, a group map was developed based on input from all stakeholders.

After the individual and stakeholder group maps were taken into consideration, all conceptual models have been elaborated. In addition, we have developed a nexus conceptual map that integrates the visions of the different stakeholders.

Moreover, stakeholder assessments have also been used to select crucial policy objectives. Last but not least, during the last workshop the results of the SDM have been discussed and validated by stakeholder.

Interactions with stakeholders	Date Location	Number of participants and indicative distribution by nexus sector	Topics discussed	Outcomes / Achievements
workshop 1	26 October 2017 in Seville (Andalusia)	14 stakeholders from different Regional Ministries, public agencies, river basin authorities, professional agricultural associations, water user associations, environmental NGOs and research centers.	The event allowed for presenting in detail SIM4NEXUS project to the stakeholders, as well as discussing about the water-food-energy Nexus in the region.	As a result of the application of diverse participatory methodologies, the main interlinkages and challenges in the Nexus were identified and different potential policy scenarios were selected.
Workshop 2	in Seville on November 21st, 2018	12 stakeholders from the water, energy, and food sectors	identification of the main policy objectives to address the Nexus Presentation of the preliminary results derived from the thematic models, CAPRI and E3ME, applied to the case study	Selection of the main policy objectives in Andalusia. Validation of the conceptual model.
Workshop 3	in Seville on November 27, 2019.	11 stakeholders from the water, energy, and food sectors.	Discussing model results, and validating the SDM. An example of Serious Game was presented.	Recommendation about: Simulation scenarios (energy, water...). Source of regional data related to the nexus components.

3.3.2 Feedback on stakeholders' engagement in the case study

From the preliminary steps, the stakeholders see the nexus issues pertinent to their own interests as most relevant to be tackled. For example, those stakeholders in charge of water believe that water is the main nexus issue, while those stakeholders in charge of energy believe energy is the main nexus issue. Moreover, some stakeholders mentioned land use change as a pressing nexus issue, while others believe land use change is no pressing issue.

During the individual mapping, each participant has developed his/her vision of the nexus interlinkages by selecting the variables, signs (+/-) and magnitudes of relationships (-1 to +1). Altogether eleven individual maps were produced.

Through interviews, individual and group mapping, as well as round tables, the actors have identified the water-agriculture link as the most crucial component of the nexus in Andalusia.

The first workshop with stakeholders also helped to identify six nexus challenges and three crucial policy scenarios (pathways) to meet the nexus challenges in Andalusia in the medium and long term.
In the second workshop, stakeholders have been validated the conceptual model. Furthermore, based on the opinions of stakeholder and the policies in Andalusia, the main policy objectives have been selected with the assessments of stakeholder and also in the third workshop the stakeholders have been validated the results of the SDM.

3.4 From conceptual models to System Dynamic Modelling

3.4.1 Case study conceptual model

Similar to the other case studies, this section describes the evolution of the conceptual diagram. The first version of the conceptual model (Figure 13 and Figure 14) was developed based on information gathered through interviews with stakeholders from the water, energy and food sectors in Andalusia. Bilateral interviews were conducted by phone or face-to-face following seven guiding questions that helped to get a preliminary understanding of main nexus challenges in Andalusia.

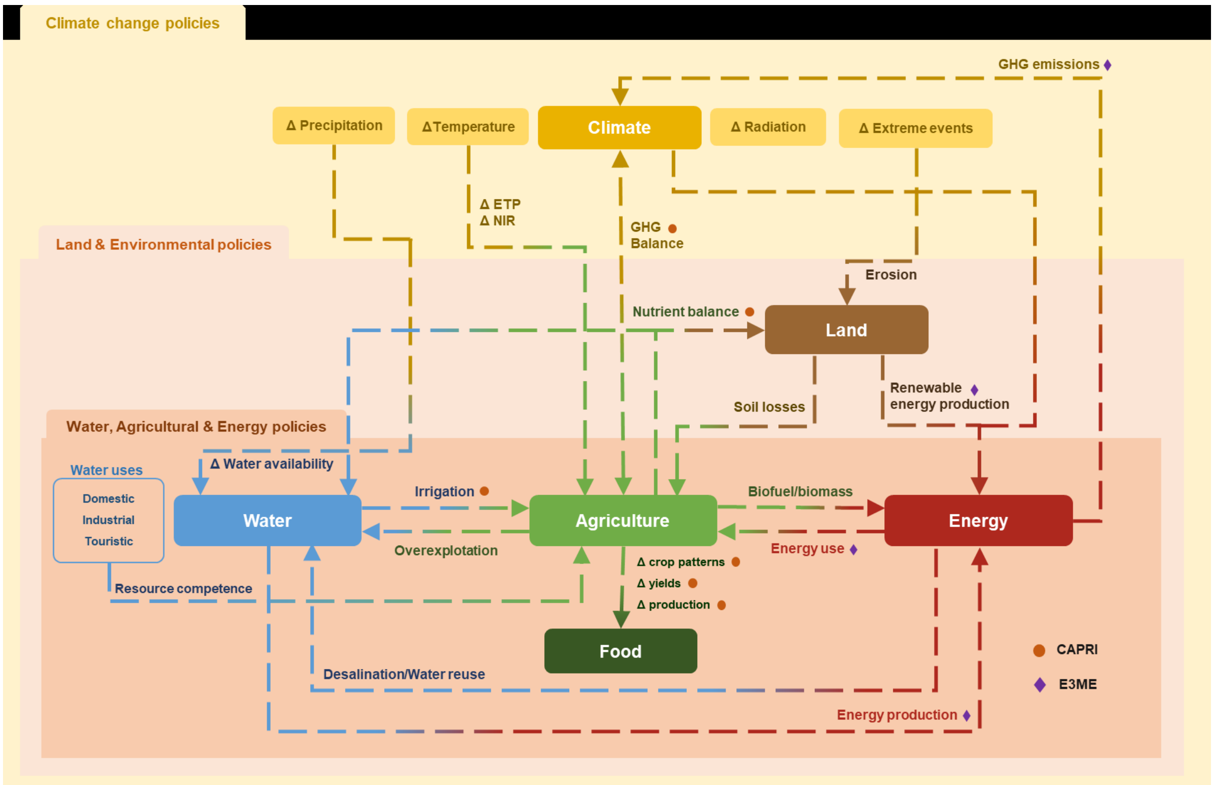


Figure 13 First version of the conceptual model for all Andalusian Nexus components

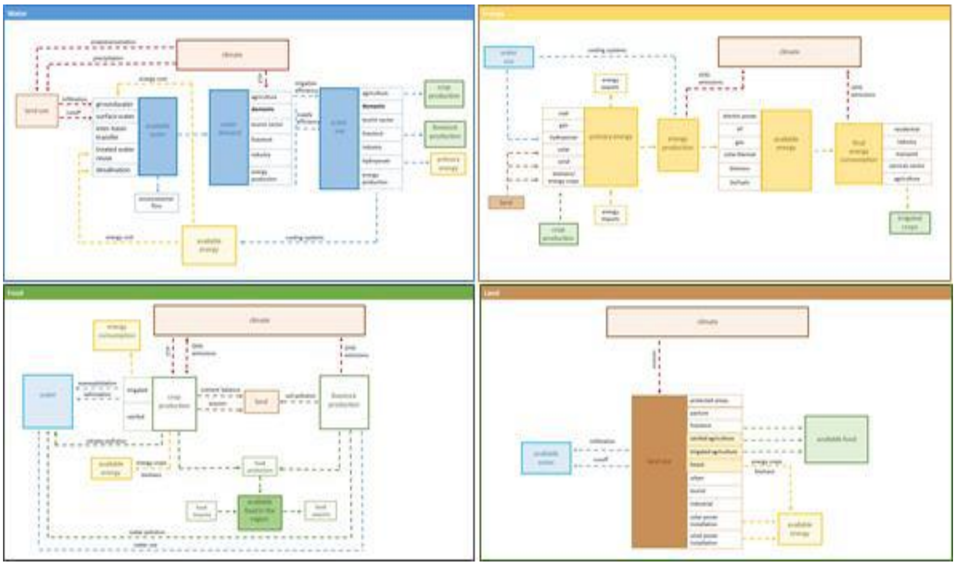


Figure 14 First version of the Andalusian conceptual model: water, energy, food and land sub-models

The validation of the conceptual model was performed through a stakeholder workshop held in Seville in October 2017. The methodology of Fuzzy Cognitive Mapping (FCM) was applied to elicit stakeholder's knowledge on the nexus. Each participant developed a cognitive map considering the main interrelations in the water-energy-food nexus in Andalusia according to their views. Participants unrestrictedly selected variables in the map and depicted causal relationships between them using arrows. Causal relationships were further detailed with a sign that reflects a positive (+) or negative (-) relationship and a weight between 0 and 1 (Figure 16), The eleven individual maps obtained were then processed and analysed to extract the key factors and interdependencies in the nexus. To that end, variables from individual maps were processed to eliminate similar names and less repeated variables were aggregated into wider categories according to similarities. Each individual map was converted into matrix form by using the variables and magnitude of the causal relationship. All individual matrices were merged into an augmented matrix to create a group map, which represents the views of all the participants. The analysis of matrix indices enabled to identify the main variables and interactions in the group map. Additionally, this exercise constituted an extremely great opportunity to gain insight into the system performance by running preliminary scenarios using the FCM software FCMapper (for further information, please see Martinez et al. 2018). Results from the analysis were used to refine the first version of the conceptual model with the introduction of new variables and interrelations.

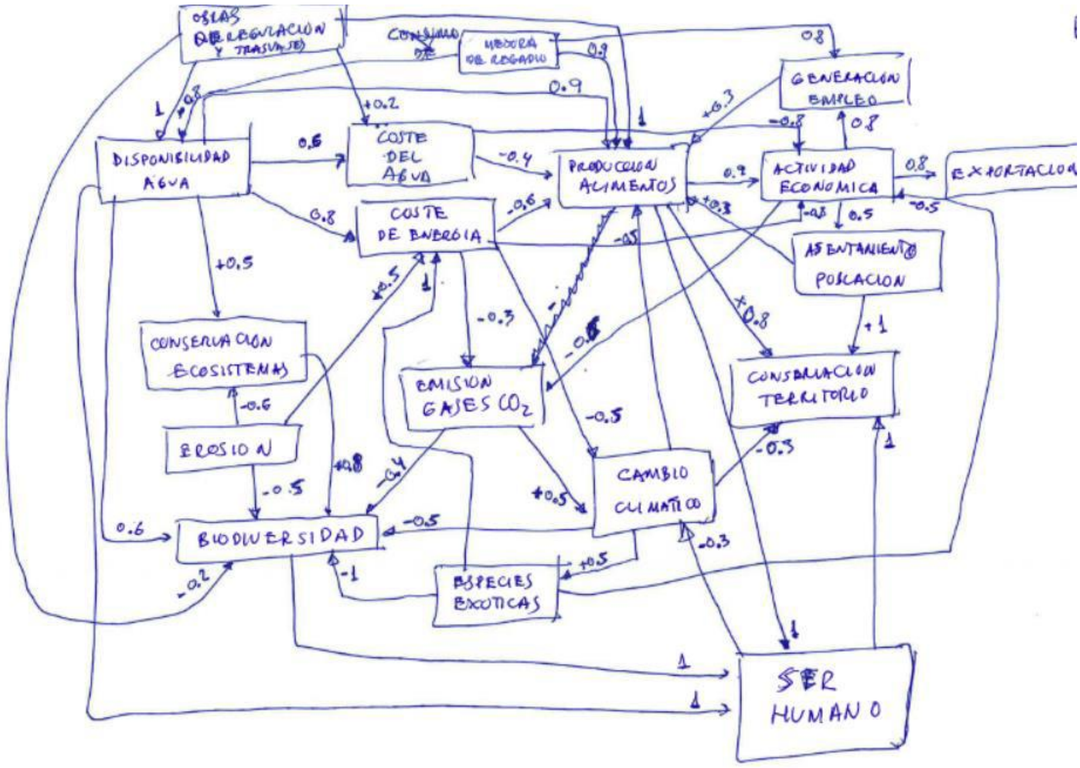


Figure 15 Example of individual maps drawn by stakeholders

The validated version of the conceptual model is presented in the following Figures. The water sub-model (Figure 17) attempts to capture climate change effects on water availability and their implications for the economic sectors, with special focus on irrigation and energy production. Environmental concerns such as water quality and environmental flow are also reflected. Furthermore, energy needs for water abstraction, desalination and reutilisation are included.

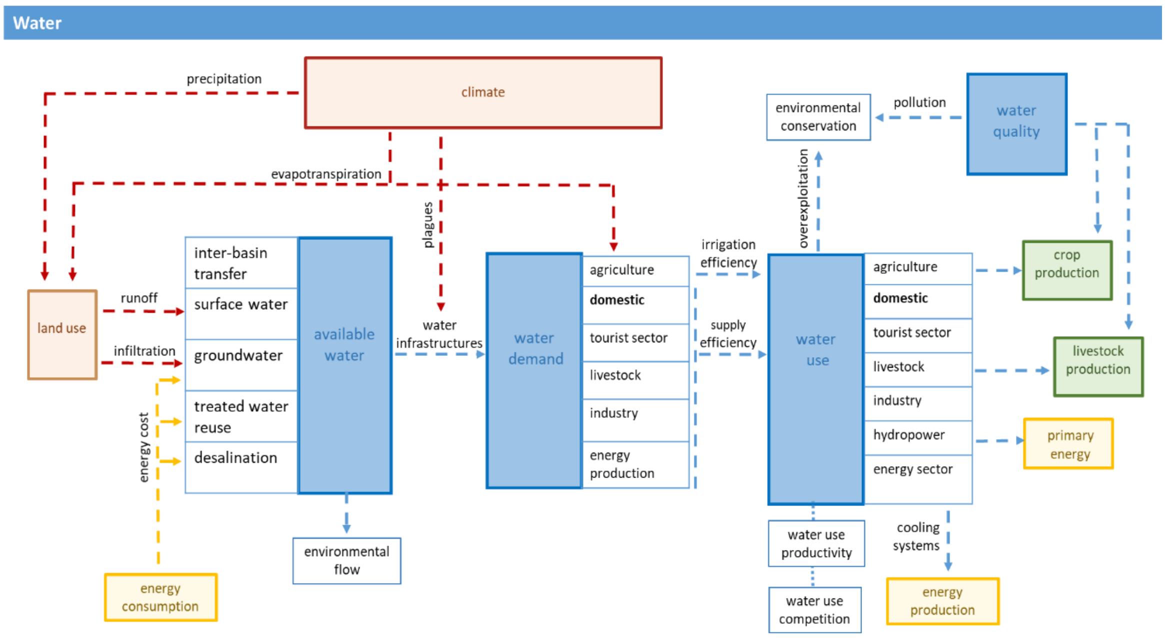


Figure 16 Validated Andalusia Conceptual model for water

Figure 17 presents the energy sub-model where the main energy sources (renewable and non-renewable) and energy consumption sectors are represented. Water is required to produce energy (hydropower and cooling systems), as well as land and bioenergy crops. On the other side, energy is needed for irrigation. Another important interrelation depicts impacts of the energy sector on climate through greenhouse gas emissions.

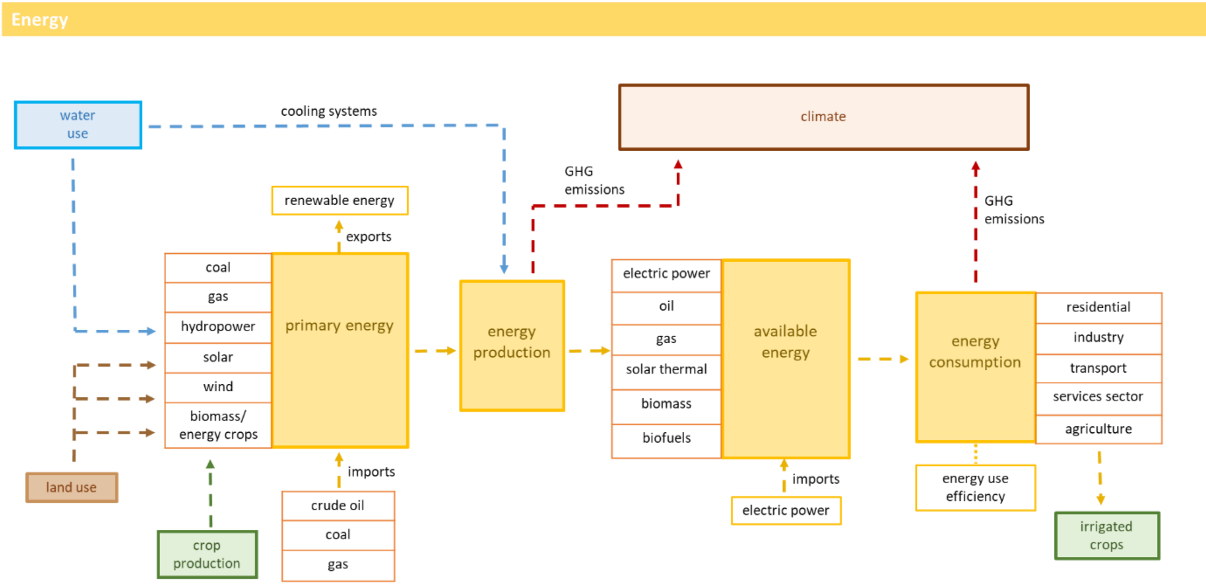


Figure 17 Validated Andalusia Conceptual model for energy

Figure 18 shows the food sub-model with a number of interdependencies between the different nexus sector. Whereas water is essential for crop and livestock production, agricultural activities might lead to overexploitation and water quality degradation. Energy is a key factor in irrigation in Andalusia because of the high-energy dependence of pressure irrigation systems and the elevated energy prices. Agriculture is highly sensitive to climate change and, at the same time, is an important contributor to greenhouse gas emissions, mainly methane and nitrous oxide.

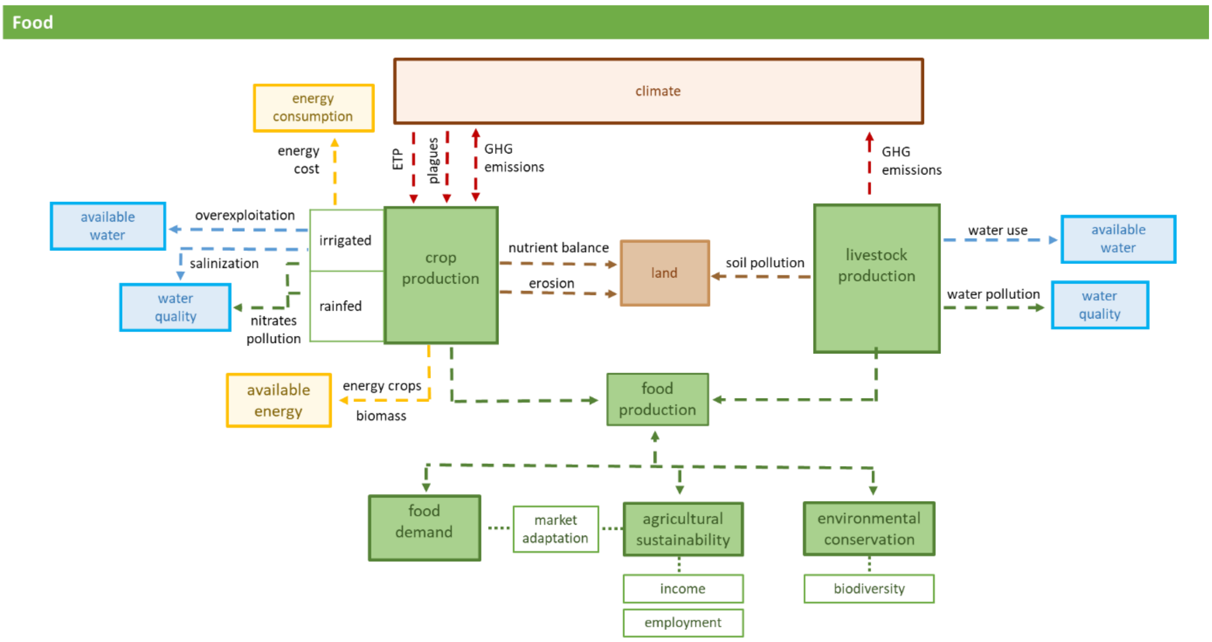


Figure 18 Validated Andalusia Conceptual model for food/agriculture

Figure 20 represents the land sub-model with the main types of land uses and their interrelations with the nexus sectors. Land is crucial for agricultural production but also to energy production. Climate affects land mainly through erosion and land contributes to climate change mitigation as a carbon sink (e.g. forest). Water availability is linked to land through infiltration and runoff, whereas water quality is affected by the different types of land use.

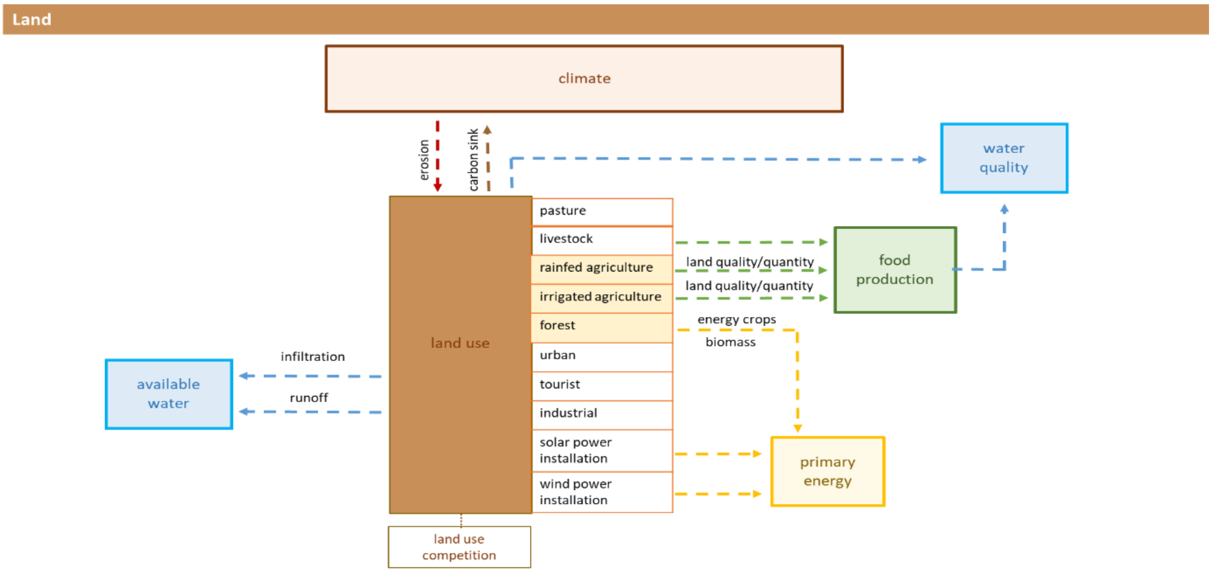


Figure 19 Validated Andalusia Conceptual model for land use.

3.4.2 Modifications introduced to model policy scenarios

3.4.2.1 Development of policy scenarios for the case study

The analysis of policies related to the nexus has been done at both European and regional level. Research has investigated how agricultural and environmental policies can be integrated to cope with pressures on land and water, while promoting their sustainable use and economic development. The work is based on a detailed review of the policies of the different nexus sectors in both Europe and Andalusia, as well as the opinions of interest groups and the knowledge of researchers. The relevant policy scenarios for this study have been defined according to these analyses. The nexus analysis in Andalusia reflects how agricultural and environmental policies can be integrated to address pressures on land and water, while promoting their sustainable use and economic development. Through interviews, individual and group mapping, as well as roundtable discussions, stakeholders identified the main challenges in Andalusia (mentioned above in part 2.3). In this section, we use the critical nexus variables and interrelationships identified by stakeholders to reduce the large number of policy objectives. As Figure 9 shows, stakeholders identify the following variables as particularly relevant to Andalusia: 1) climate change, 2) energy cost, 3) water availability, 4) irrigation water use, 5) water quality, 6) soil erosion, 7) food production, 8) irrigated agriculture, 9) socio-economic factors. To reduce the large number of policy objectives, these nine crucial variables were used to select the most important objectives for the analysis of policy coherence in Andalusia. As a result of the selection process, we identified 32 objectives that are presented in Table 8. The policy objectives include both general and specific goals.

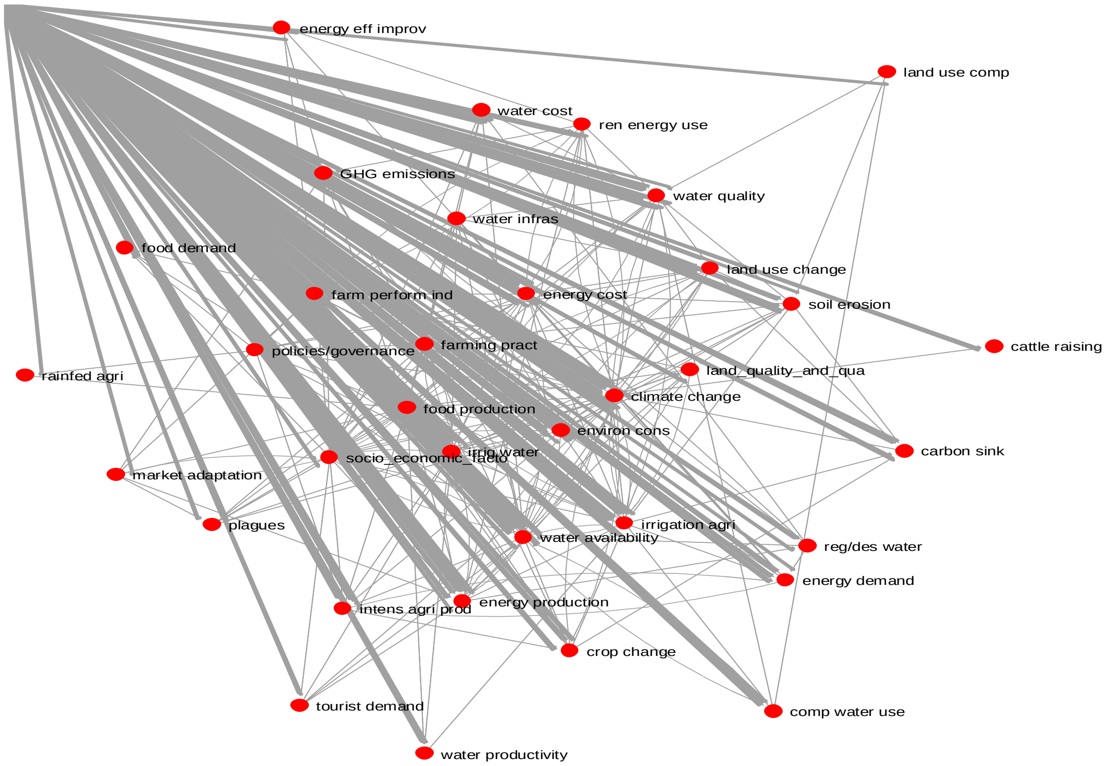


Figure 20 Representation of nexus critical objectives and nexus critical systems in Andalusia

Table 8 Selected policy objectives for the assessment of interactions in the WLEFC-nexus

ANDALUSIAN WATER POLICY	
W1	GOOD ECOLOGICAL STATUS OF ALL WATER BODIES
W5	RATIONAL WATER USE TO ENSURE LONG TERM WATER SUPPLY
W15	MODERNIZE EXISTING IRRIGATION SYSTEMS
W16	IMPROVE WATER AVAILABILITY IN IRRIGATED AREAS IN PARTICULAR THROUGH REGENERATED AND DESALINATED WATER
W23	PROMOTE TRAINING AND IMPROVE PROFESSIONAL KNOWLEDGE TRANSFER TO IRRIGATION COMMUNITIES AND IRRIGATORS ESPECIALLY IN AREAS CONSIDERED FOR MODERNIZATION OF THE WATER DISTRIBUTION AND IRRIGATION SYSTEMS
W26	ACHIEVE AN EFFECTIVE AND EFFICIENT USE OF WATER FOR IRRIGATION THROUGH IMPROVING WATER SAVING AND ENERGY EFFICIENCY
W27	REDUCE IRRIGATION WATER USE THROUGH IMPROVING IRRIGATION INFRASTRUCTURE AND MONITORING SYSTEMS
W29	ILLEGAL ABSTRACTIONOF WATER IS CONTROLLED
W31	INTRODUCE MEASURES TO REDUCE DIFFUSE POLLUTION, BOTH FOR GROUND AND SURFACE WATER, CAUSED BY INADEQUATE USE OF FERTILIZERS, ESPECIALLY NITROGEN AND PESTICIDES, THROUGH INTEGRATED PRODUCTION AND ORGANIC FARMING
W33	GUARANTEE EFFICIENT ENERGY USE IN IRRIGATION FACILITIES AND PROMOTE RENEWABLE ENERGY USE TO DECREASE ENVIRONMENTAL IMPACTS
ANDALUSIAN LAND USE POLICY	
L1	CLOSER COORDINATION OF URBAN AND LAND USE POLICIES AND INSTRUMENTS
L8	IMPROVE ANDALUSIA'S COASTAL WATER QUALITY
L9	RATIONALIZE INLAND WATER USE AND DECREASE WATER DEMAND
L12	PRESERVE NATURAL RESOURCES TO ENSURE FUTURE ECONOMIC DEVELOPMENT OF THE ANDALUSIAN COASTLINE
L13	PROTECT THE ANDALUSIAN COASTLINE'S NATURAL AND CULTURAL HERITAGE

ANDALUSIAN ENERGY POLICY	
E1	OBTAIN 25% OF PRIMARY ENERGY SAVING
E2	PROVIDE 25% OF TOTAL ENERGY CONSUMPTION FROM RENEWABLE SOURCES
E3	OBTAIN 5% SELF-CONSUMPTION OF ELECTRICITY GENERATED FROM RENEWABLE SOURCES
E4	DECARBONIZE 30% OF THE ENERGY CONSUMPTION WITH RESPECT TO THE VALUE OF 2007
ANDALUSIAN AGRICULTURE & FOOD POLICY	
A1	IMPROVE THE SUSTAINABLE COMPETITIVENESS OF THE ANDALUSIAN AGRICULTURAL AND AGRO-INDUSTIAL SECTOR
A6	IMPROVE SOCIAL AND ECONOMIC CONDITIONS TO GENERATE STABLE AGRARIAN EMPLOYMENT
A9	ADVOCATE MORE SUSTAINABLE AGRICULTURAL PRACTICES (ORGANIC PRODUCTION, INTEGRATED PRODUCTION AND CONSERVATION AGRICULTURE) AND TECHNIFICATION OF FARMS AND AGRO-INDUSTRIES TO IMPROVE PRODUCTION EFFICIENCY
A13	IMPROVE KNOWLEDGE TRANSFER AND INNOVATION IN AGRICULTURE, FORESTRY AND RURAL AREAS THROUGH THE DEVELOPMENT OF INNOVATIVE SOLUTIONS AND TRAINING COURSES
A16	RESTORING, PRESERVING AND ENHANCING ECOSYSTEMS RELATED TO AGRICULTURE AND FORESTRY
A17	ENHANCE RESOURCE EFFICIENCY AND CLIMATE
A18	IMPROVE SOCIAL INCLUSION AND LOCAL DEVELOPMENT IN RURAL AREAS BY CREATING 590 KILOMETRES OF NATURAL PATHWAYS
ANDALUSIAN CLIMATE POLICY	
C1	PROMOTE AGRICULTURAL SUSTAINABILITY THROUGH ENERGY SAVING AND RENEWABLE ENERGY IN THE AGRI-FOOD INDUSTRY
C2	SUPPORT ECOLOGICAL AND CONSERVATION AGRICULTURE
C3	INCREASE AFFORESTATION OF AGRARIAN LANDS
C5	REDUCE BY 18% IN 2030 THE GREENHOUSE GAS EMISSIONS COMPARED TO THE 2005 LEVEL, WHICH EQUALS APPROXIMATELY 4.28 TONS OF CARBON DIOXIDE (CO_2) PER INHABITANT AND YEAR
C6	REDUCE DIFFUSE EMISSIONS
C8	CONSERVE AND INCREASE AERIAL BIOMASS AND ORGANIC CARBON IN THE SOIL

Policy coherence analysis has been carried out to identify conflicts and synergies between pairs of objectives. The analysis of policy coherence for the water-agriculture-energy nexus in Andalusia shows that among the 32 crucial policy objectives, synergies far outweigh conflicts. The areas of agriculture/soil and climate/soil have, with 83%, the highest density of interactions. This may be to be expected given that land use objectives include specific targets for water and climate, but not for energy or agriculture.

In addition, there is an inconsistency between energy and agricultural policies. In the agricultural sector, interest groups emphasize that the cost of energy is a limiting factor in irrigated agriculture due to increased energy demand and energy prices. Energy has become an essential resource for irrigated agriculture, with a significant increase in energy consumption.

The liberalisation of the energy market in 2008 resulted in higher (non-subsidised) energy prices for irrigators. Meanwhile, the Spanish renewable energy sector suffered three main problems: 1) A large renewable energy installation in a period when the technology was not mature and required large public support, which was poorly designed and very costly; 2) a crisis that drastically reduced electricity demand and tax revenues; 3) an over-capacitated system - there is much more installed capacity than demand - based on costly fossil fuel plants and installations. To avoid adding new costs to the electricity system, the government introduced Royal Decree Law 1/2012 in 2012.The law has not only discouraged investment in renewable energy generation, but has also reduced the production of existing renewable installations, thereby limiting the reduction of CO2 emissions. These national energy policies are in conflict with the Andalusia 2020 Energy Strategy, which sets the ambitious renewable energy target of achieving 25% of total energy consumption from renewable sources and 5% of self-consumption of electricity from renewable sources.

On the relationship between sustainable agriculture and resource efficiency, there is ambiguity between the vast number of laws, specific rules and other types of regulations that affect the water-agriculture-energy nexus. In general, there may be conflicts between socio-economic and environmental objectives, as increased economic activity and development may hinder the preservation and protection of natural resources, as well as the reduction of greenhouse gas emissions.

Following the November 2019 workshop, these policy objectives have been updated based on stakeholder opinions and comments and also on references to Andalusian strategies and laws and as a result of the selection and updating process, 10 of the most important objectives identified and presented in Table 9. In each objective, we have identified the instruments we can use to reach each policy objective and also the indicators to analyse these policies.

Table 9 Policy objectives, policy instruments and indicators

C - Climate change mitigation and adaptation		
Policy objective	**Instrument**	**Indicators**
C1 -18% reduction in diffuse GHG emissions compared to 2005 levels by 2030, which equals approximately 4.28 tons of carbon dioxide (CO2) per inhabitant and year	Implementation of mitigation technologies in the agricultural sector Carbon tax	CO_2 emissions per sector CH4 emissions from agricultural sector N_2O emissions from agricultural sector Global warming potential CO_2 emissions/GDP
C2 - Increase carbon sink capacity	Subsidies for conversion agricultural land to grassland	Grassland/Total UAA
W - Sustainable water management		
Policy objective	**Instrument**	**Indicators**
W1 - Improve water availability	Economic support to construct small water reservoirs on farms Incentives to enhance water reuse in the agricultural sector	Water reuse/total water use in agriculture Water stress
W2 - Improve water use efficiency	Subsidies to apply water-efficient technologies in agriculture increase water cost recovery	% UAA under irrigation/total UAA Irrigation water use Water use per sector Water productivity (€/m^3)

W3 - Enhance the status of water resources	Introduce measures (Nitrogen fertilizer tax) to reduce diffuse pollution, both for ground and surface water, caused by inadequate use of fertilizers, especially nitrogen and pesticides, through integrated production and organic farming	Nitrogen fertilizer consumption per ha Nitrate concentration in water
E - Energy efficiency and promotion of renewable energies		
Policy objective	**Instrument**	**Indicators**
E1 – 25% final energy consumption from renewable sources by 2020	Support biomass production in the region[1] Incentives to introduce renewable energy in irrigated agriculture[4] Promote renewable energy use to decrease environmental impacts	Renewable energy production/total energy consumption Renewable energy consumption in agriculture
E2- 25% reduction in primary energy consumption by 2020	Subsidies to improve energy efficiency in agriculture	Energy consumption in agriculture Energy consumption/agricultur al GDP
F - Resource efficient food production		
Policy objective	**Instrument**	**Indicators**
F1 - Sustainable agricultural production	Direct payments reduction (to enhance market-oriented agricultural production, and promote generational renewal) Environmental payments (integrate requirements from European directives) Promote climate-resilient crops (e.g. crops with lower water footprint) Advocate more sustainable agricultural practices (organic production, integrated production and conservation agriculture)	CAP payments/total agricultural income Production Prices Area of land in agri-environment schemes Agricultural income per ha CAP coupled payments/ CAP payments
L - Fight against soil erosion and desertification		
Policy objective	**Instrument**	**Indicators**
Reduce soil erosion	Promote ecological focus areas[2] Strengthen agri-environmental measures	Surface of ecological focus areas Total land affected by erosion

[1] Andalusian Bio-economy Strategy (p.234)
[2] Andalusian Sustainable Development Strategy 2030 (p.126)

	Preserve natural resources to ensure future economic development of the Andalusian coastline	

The work is based on a detailed review of the policies of the different sectors of the nexus in Andalusia, as well as on the opinions of interest groups and the knowledge of researchers. Based on these analyses, the relevant policy scenarios for this study have been defined from the baseline scenario and the policy objectives above.

Table 10 Main policy objectives in the Water-Agriculture-Energy Nexus in Andalusia

Nexus Sector	**Name**	**Very short policy card name**	**Description of intervention as captured by the policy card**
Water	Water price in irrigation	Water price	Water price per m3 in the agricultural sector to promote water use efficiency
Water	Water-efficient technologies in agriculture	Water-efficient technologies	Promoting water-efficient technologies in agriculture
Water, Food	Efficient use of fertilisers	Efficient use of fertilisers	Implementation of technological solutions to reduce nitrates pollution
Energy, Climate	Boosting biomass production	Boosting biomass production	Support biomass production in the region to promote circular bioeconomy
Energy, Climate	Renewable energies consumption	Renewable energies promotion	Incentives to introduce renewable energies in agriculture
Energy, Climate	Energy efficiency improvement	Energy efficiency improvement	Subsidies to improve energy efficiency in agriculture
Food	CAP direct payments reduction	Direct payments reduction	CAP direct payments reduction to enhance market-oriented agricultural production and promote generational renewal
Food, Climate	Changing diets	Changing diets	Changing food consumption towards less meat-based diets
Climate	Mitigation technologies	Mitigation technologies	Implementation of mitigation technologies in the agricultural sector to reduce GHG emissions
Climate, Land	Preserving natural vegetation	Preserving natural vegetation	Preserving natural vegetation to increase carbon sink capacity

Land, Climate	Ecological focus areas	Ecological focus areas	Promote ecological focus areas to face soil erosion
Land, Climate	Agri-environmental measures	Agri-environmental measures	Strengthening agro-environmental measures within the CAP to enhance soil conservation

3.4.2.2 Introduction of policy scenarios in the SDM

In the Andalusian case study, two pathways have been used. On one hand, for the baseline, the RCP 6.0 has been selected, which implies a continuation of the current trends and the consequent increase of the temperature from 3°C to 4°C by the end of the century. This RCP is consistent with the SSP2 scenario without climate change mitigation. On the other hand, RCP2.6 has been selected for the 2-degree pathway, which is consistent with the SSP2 pathway accompanied by ambitious climate change mitigation (ambition to keep temperature increase below 2°C relative to pre-industrial levels).

The baseline and 2-degree scenarios differ only in the strategy for addressing climate change. The rest of the assumptions used in the 2050 projections, relating to sectoral policies, are common and represent existing or already agreed policies.

The reference scenario represents the foreseeable evolution of agricultural markets until 2050, under a status quo situation. In policy terms, it represents the continuation of the CAP 2014-2020, and of the Uruguay Round commitments on agriculture. In environmental and socio-economic terms, it assumes the combination of the SSP2 and RCP6.0 scenarios and their effects on the agricultural sector.

The year 2010 has been selected as the base year, and simulation results have been reported for the time periods 2020, 2030, 2040 and 2050.

The reference scenario represents the foreseeable evolution of agricultural markets until 2050, under a status quo situation. In policy terms, it represents the continuation of the CAP 2014-2020, and of the Uruguay Round commitments on agriculture. In environmental and socio-economic terms, it assumes the combination of the SSP2 and RCP6.0 pathways (mentioned above) and their effects on the agricultural sector.

For the simulation of the comparative scenarios, the most relevant variables for the Andalusian case study have been identified according to the evaluation carried out with the main actors and stakeholders in the region. Some of the main variables selected are water availability, improvement in irrigation technologies, and increases in water and energy prices in Andalusia. More details on the scenarios simulated for the Andalusia case study are provided in Martinez et al. (2019), where a sensitivity analysis is also undertaken.

3.4.3 Modifications introduced to account for data availability

3.4.3.1 Data available from the thematic models

This step is the first of the SDM building phase. Since the present research explore short-term and long-term sustainability, the simulation period is set from 2010 to 2050. Data until 2018 comes mainly from local statistical sources, stakeholders and literature. Given that water-agriculture link is the most crucial component, projections up to 2050 is built on outcomes from the CAPRI-Water for the food/agriculture sector, Andalusia hydrological management plans (provided by Andalusian authorities) for the water sector, and the energy outlook (Capros et al., 2016) for the energy sector.
Common Agricultural Policy Regionalised Impact Modelling System (CAPRI), is a partial equilibrium economic model developed to evaluate the agricultural sector and analyse the ex-ante impacts of

agricultural, environmental and commercial policies in the European Union (Britz and Witzke, 2014). CAPRI-Water is a CAPRI sub-module that differentiates between irrigated and rainfed agricultural activities. This extension enables to explore the likely impacts of climate change and water availability on agriculture at regional level (NUTS 2) in Europe, as well as the effects of the implementation of policy measure such as water pricing (Blanco et al., 2017).

In the Andalusia case study, CAPRI has been used to analyse the links between food production, water use and energy requirements. Additionally, it has been used to analyse agricultural production, prices and margins of the different crops. This analysis is carried out within a framework of comparative statics, where the results of simulation scenarios are compared with a baseline or reference scenario.

The reference scenario represents the foreseeable evolution of agricultural markets until 2050, under a status quo situation. In policy terms, it represents the continuation of the CAP 2014-2020, and of the Uruguay Round commitments on agriculture. In environmental and socio-economic terms, it assumes the combination of the SSP2 and RCP6.0 pathways (mentioned above) and their effects on the agricultural sector.

For the simulation of the comparative scenarios, the most relevant variables for the Andalusian case study have been identified according to the evaluation carried out with the main actors and stakeholders in the region. Some of the main variables selected are water availability, improvement in irrigation technologies, and increases in water and energy prices in Andalusia.

3.4.4 Case Study SDM in Stella / R

The SDM model has been developed in Stella[3] and integrates the three sectoral models of the nexus: water, energy, and food/agriculture. It allows a joint analysis of the three of them and to simulate different future scenarios. As a base year, the year 2010 has been selected, and simulations have been carried out for the time horizons 2020, 2030, 2040 and 2050. Additionally, the software uses an annual time step that allows viewing results for intermediate years.

3.4.4.1 Water module

The water sector shows the relations between the availability of water and the water consumption in Andalusia. To this end, five water stocks (Surface water, Groundwater, Desalination water, Water supply and Wastewater) and their corresponding flows are modelled. The relevant inflows of the whole system are runoff, groundwater recharge and desalinated water. The relevant outflows are agricultural irrigation, environmental flow, hydropower consumption, industrial and domestic consumption, and wastewater discharge.

[3] Stella is a visual programming language for system dynamics modelling, distributed by Isee Systems https://www.iseesystems.com/

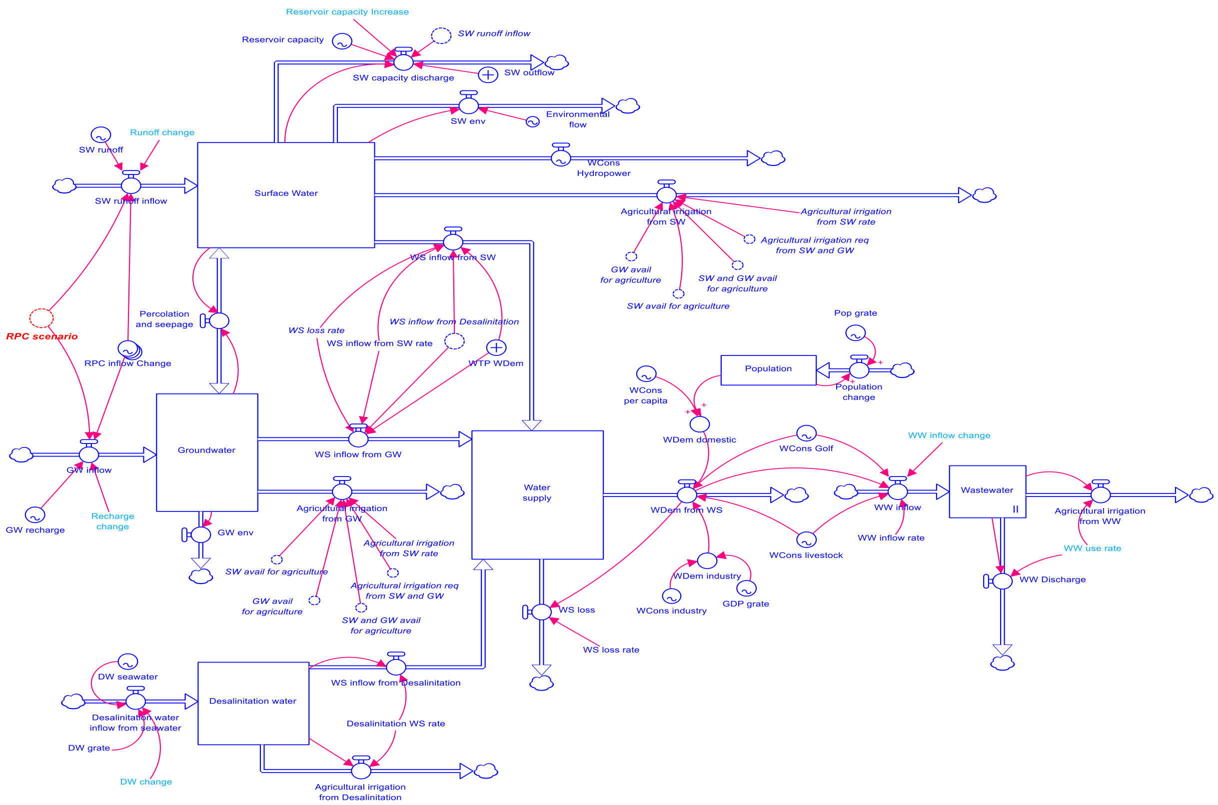
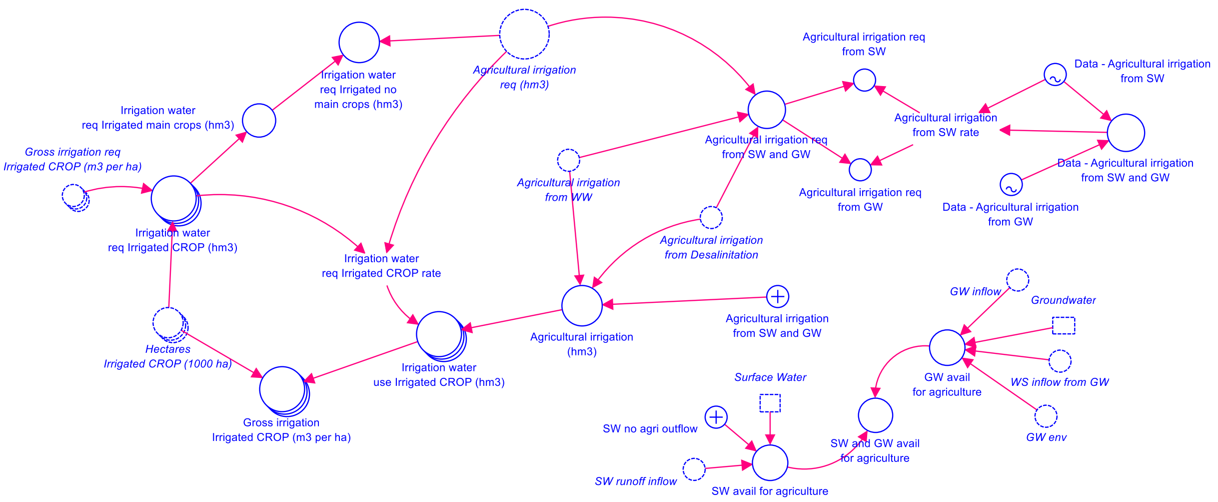


Figure 1. Water module

Source: Own elaboration

3.4.4.2 Linking water and agriculture module



3.4.4.3 Energy module

In this case, the energy inputs and outputs come respectively from energy production at primary level by source, and energy consumption by sector. Within energy consumption, the model shows in more detail the consumption of the agricultural sector and especially the consumption of irrigation, related to the water and agricultural model.

3.4.4.4 Food module - crops

It is the core of the model as it combines different agricultural aspects and is most interrelated with the rest of the modules, for example, agricultural energy consumption with the energy model and the use of water in irrigation with the water model. It focuses on the economic aspects of the agricultural sector such as costs, revenues and incomes per crop and technology variant. The crops to be modeled have been selected according to the EUROSTAT classification and the productivity importance for the region in 2010. They make up a total of 22 crops:

- Olives for oil
- Other Vegetables
- Tomatoes
- Other Fruits
- Citrus Fruits
- Apples Pears and Peaches
- Durum wheat
- Sunflower
- Paddy rice
- Other crops
- Soft wheat
- Table Olives
- Grain Maize
- Barley
- Flax and hemp
- Wine
- Oats
- Table Grapes
- Potatoes
- Pulses
- Sugar Beet
- Rye and Meslin

Each of these crops has its own sub-model in order to better represent production conditions, such as productivity function or water consumption. In addition, in each sub-model, each crop has two productions, one irrigated and the other rain-fed. Thus, the main parameters obtained with this model are income (€/ha) and water consumption (m3/ha). These parameters will vary mainly if the crop is irrigated or dry. Additionally, in this module there is also a segment where the land use is calculated, which is composed of agricultural surface, constructed areas, forests and natural areas, and water surface.

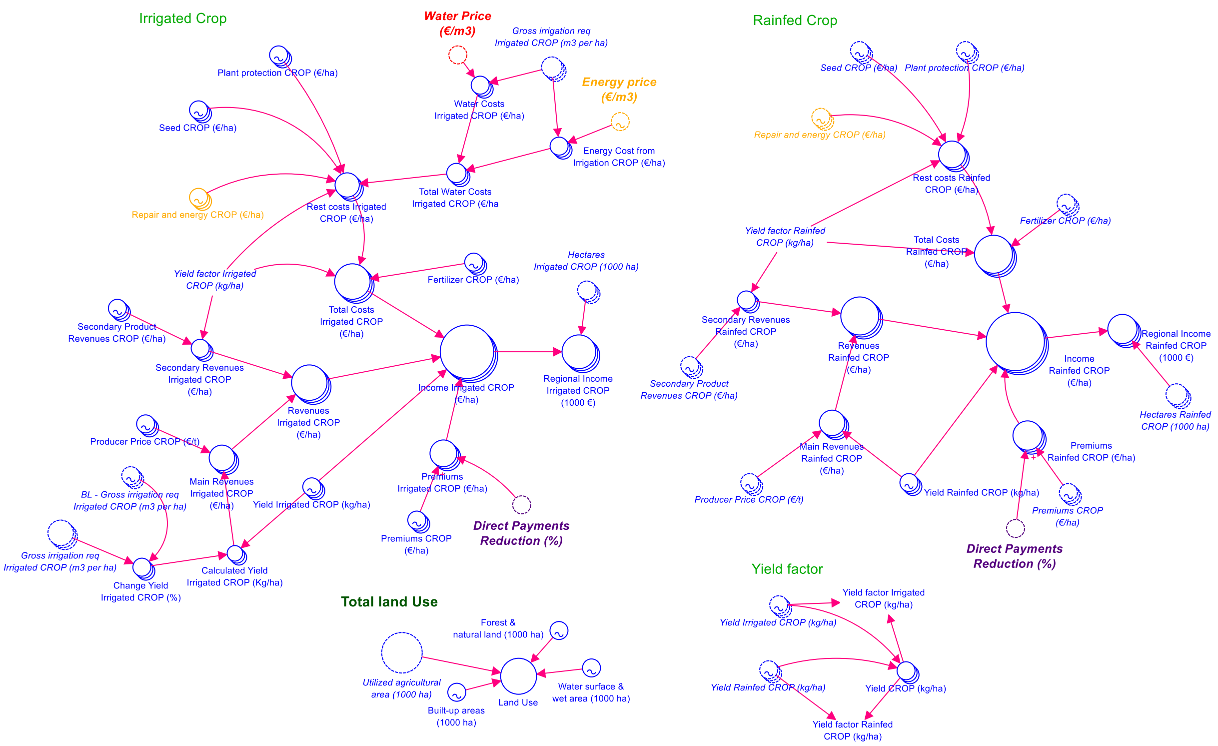
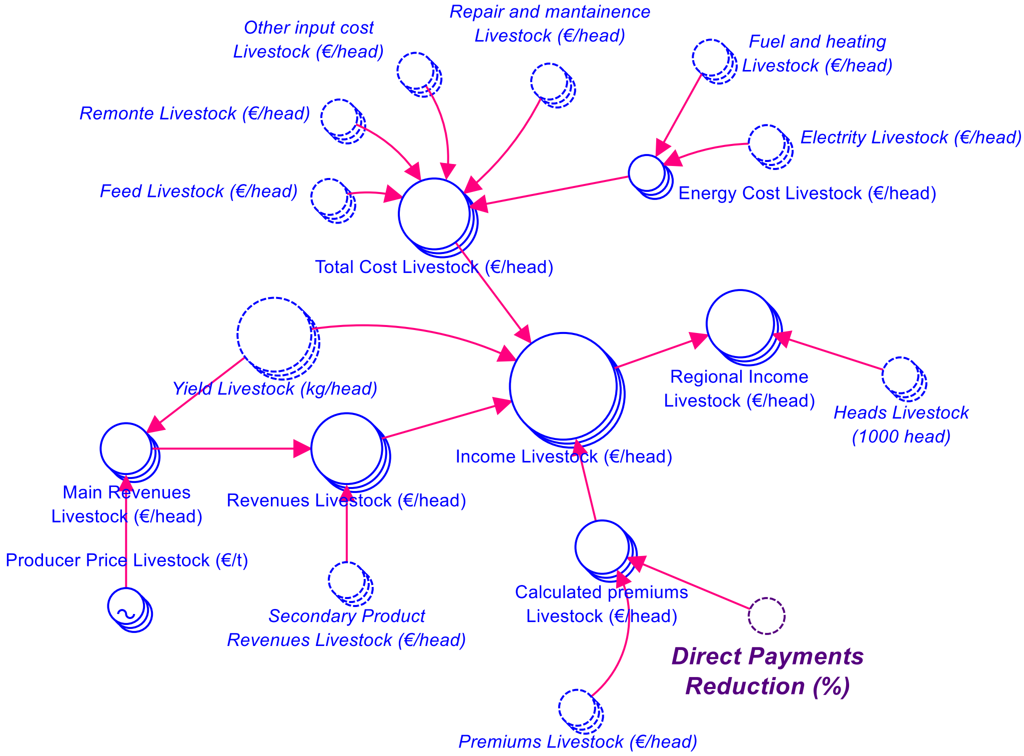


Figure 2 Food module

Source: Own elaboration

3.4.4.5 Food module – livestock



3.5 From the System Dynamic Modelling to the Serious Game

3.5.1 Case studies learnings goals

The Andalusian case study addresses how agricultural and environmental policies can be integrated to boost economic activity while reducing resource use and promoting sustainable water management, climate change mitigation and renewable energy. The main driver of the study is the water shortage problem, which has been aggravated by climate change. Tourism, as an important sector in the region has also increased the scarcity of water. The demand for water reaches its peak in summer due to tourism and agriculture. The goal is to raise awareness on the interdependence of water, energy and agriculture. A second goal is to advise local authorities. The main research question is: how can the policies become more integrated or coordinated to promote the sustainable use of water under changing climatic conditions?

The main case study learning goals consists on

- Learning how policies in the domains of agriculture, sustainable water management, and renewable energy can affect each other under climate change conditions, in a region where irrigated agriculture is competing for water with other sectors.
- Be able to compare impacts of alternative policy options.

Meanwhile, players from the serious game:

- Decide Which policies are more likely to be implemented in the region
- Compare the impacts of the implementation of some policies in the nexus health compared to the initial situation
- They will have an idea about cost of social acceptance of each policy instrument.

Table 11 Case study learning goals. source: own elaboration.

Case study learning goals	Learn how policies in the domains of agriculture, sustainable water management, and renewable energy can affect each other under climate change conditions, in a region where irrigated agriculture is competing for water with other sectors. Meanwhile, be able to compare impacts of alternative policy options.
Learning from player's decisions	Index of social acceptance of each policy instrument. Which policies are more likely to be implemented in the region. Compare the impacts of the implementation of some policies in the nexus health compared to the initial situation

3.5.2 From generic to specific use cases

A. Water

USE CASE W.1	Water
Related Learning Goals	Sustainable management of water resources
Goal	• Improve water availability • Improve water use efficiency • Enhance the status of water resources
User	Public sector: Regional Ministry of Agriculture, Livestock, Fishing and Sustainable Development Public sector: River basin management authorities Private sector: Water Users Associations, Farmer Associations NGOs
Actions	➢ Economic support to construct small water reservoirs on farms • Incentives to enhance water reuse in the agricultural sector ➢ Water pricing policy in the agricultural sector • Subsidies to apply water-efficient technologies in agriculture • Nitrogen fertilizer tax

Indicator	➢ Water reuse/total water use in agriculture • Water stress • % utilised agricultural area (UAA) under irrigation/total utilised agricultural area (UAA) • Irrigation water use • Water use per sector • Water productivity (€/m^3) • Nitrogen fertilizer consumption per ha • Nitrate concentration in water

Step in the SG:

Identify agricultural land use, agricultural water demand, surface water and groundwater availability, cost of irrigation water

Calculate hydrological water balance, given climate data and water demands

Calculate rate of change of hydrological water balance (monthly or yearly step)

Choose policies from the list of possible actions:

- Financial support for the construction of small reservoirs on farms to increase resistance to extreme weather events,
- Incentives to improve water reuse in the agricultural sector
- Implementation of technological solutions to reduce nitrate pollution

B. Energy

USE CASE E.1	Energy
Related Learning Goals	**Energy efficiency and promotion of renewable energies**
Goal	Increase RES share in the gross final energy production
User	Regional Ministry of Finance, Industry and Energy, Regional Ministry of Agriculture, Livestock, Fishing and Sustainable Development
Actions	• Support biomass production in the region[4] • Incentives to introduce renewable energy in agriculture • Subsidies to improve energy efficiency in agriculture
Indicator	➢ Renewable energy production/total energy consumption • Renewable energy consumption in agriculture ➢ Energy consumption per sector • Energy consumption/ gross domestic product (GDP) • %of energy efficiency per sector

4 Andalusian Bio-economy Strategy (p.234)

	• % of renewable energy • Energy performance €/Ktoe • Energy performance GDP/Ktoe

Step in the SG:

1. Identify current cost of electricity generation, the share of RET in the electricity generation mix; total land area used for RET infrastructure; annual CO_2, emissions from electricity generation; annual volume of water consumption for cooling systems; and, prices of selected crops.
2. Identify fuel demands in the agricultural sector
3. Identify biomass demand in the agricultural sector.
4. Identify total electricity generation (electricity produced from all types of resources, conventional and renewable).
5. Define the share of renewable energy consumption in 2030 as 25% (e.g. 25% of renewable energy consumed from a combination of RETs, e.g. solar, on-shore wind, geothermal, biomass, waste-to-energy).
6. Choose policies from the list of possible actions:

    - incentives for the introduction of renewable energies in agriculture,
    - Subsidies to improve energy efficiency in agriculture.

C. Climate

USE CASE C.1	Climate
Related Learning Goals	Climate change mitigation and adaptation
Goal	• 18% reduction in diffuse GHG emissions compared to 2005 levels by 2030[5] • Increase carbon sink capacity
User	Public sector: Regional Ministry of Agriculture, Livestock, Fishing and Sustainable Development NGOs
Actions	• Implementation of mitigation technologies in the agricultural sector • Carbon tax • Subsidies for conversion agricultural land to grassland
Indicator	➢ CO_2 emissions per sector ➢ CH4 emissions from agricultural sector

5 Law on measure to face climate change

	➢ N_2O emissions from agricultural sector ➢ Global warming potential • CO_2 emissions/GDP (gross domestic product) • Grassland/Total UAA (utilised agricultural area)

Step in the SG:

1. Identify current CO2 emissions per sector, CH4 emissions from agricultural sector, N_2O emissions from agricultural sector, and Global warming potential.

2. Identify CO_2 emissions/GDP, and Grassland/Total utilised agricultural area(UAA).
3. Choose one policy from the list of possible actions Implementation of mitigation technologies in the agricultural sector to reduce GHG emissions with the aim of reducing 18% in diffuse GHG emissions compared to 2005 levels by 2030.

D. Land

USE CASE L.1	Land and Forest
Related Learning Goals	**Fight against soil erosion and desertification**
Goal	Reduce soil erosion
User	Public Sector: Regional Ministry of Agriculture, Livestock, Fishing and Sustainable Development
Actions	➢ Promote ecological focus areas[6] • Strengthen agri-environmental measures
Indicator	➢ Surface of ecological focus areas • Total land affected by erosion • % of agricultural land • % of wetland and forest land

Step in the SG:

1. Identify current Surface of ecological focus areas, % of wetland and forest land, % of agricultural land, and Total land affected by erosion.
2. Choose one land management policy from the list of possible actions: Promote ecological focus areas to address soil erosion.
3. Run the models / Progress through time.
4. Display indicators.

E. Food

USE CASE A&F.1	Agriculture and Food
Related Learning Goals	Resource efficient food production

[6] Andalusian Sustainable Development Strategy 2030 (p.126)

Goal	Sustainable agricultural production
User	Public Sector: Regional Ministry of Agriculture, Livestock, Fishing and Sustainable Development Private sector: Water Users Associations, Farmer Associations
Actions	• Direct payments reduction (to enhance market-oriented agricultural production, and promote generational renewal) • Environmental payments (integrate requirements from European directives) • Promote climate-resilient crops (e.g. crops with lower water footprint)
Indicator	• CAP payments/total agricultural income • Crop and livestock Production • Area of land in agri-environment schemes • Agricultural income per ha

Step in the SG:

1. Identify agricultural land use, CAP payments/total agricultural income, and agricultural income per ha

2. Quantify crop production and livestock production per unit of utilized agricultural area (in physical units)

Quantify water use in agriculture (abstraction of water for irrigation) per unit of agricultural area

Select a policy from the list of possible actions: Reduction of direct payments under the CAP to improve market-oriented agricultural production and promote generational renewal

Run the models / Progress through time.

3.5.3 Policy cards

The analysis of policies related to the nexus has been done at both European and regional level. Research has investigated how agricultural and environmental policies can be integrated to cope with pressures on land and water, while promoting their sustainable use and economic development. The work is based on a detailed review of the policies of the different nexus sectors in both Europe and Andalusia, as well as the opinions of interest groups and the knowledge of researchers. The relevant policy scenarios for this study have been defined according to these analyses.

The nexus analysis in Andalusia reflects how agricultural and environmental policies can be integrated to address pressures on land and water, while promoting their sustainable use and economic development. Through interviews, individual and group mapping, as well as roundtable discussions, stakeholders identified the main challenges in Andalusia (mentioned above in part 2.3). In this section, we use the critical nexus variables and interrelationships identified by stakeholders to reduce the large number of policy objectives. As Table 9 shows, stakeholders identify the following variables as particularly relevant to Andalusia: 1) climate change, 2) energy cost, 3) water availability, 4) irrigation water use, 5) water quality, 6) soil erosion, 7) food production, 8) irrigated agriculture, 9) socio-economic factors. To reduce the large number of policy objectives, these nine crucial variables were used to select the most important objectives for the analysis of policy coherence in Andalusia. As a result of the selection process, we identified 32 objectives that are presented in Table 1. The policy objectives include both general and specific goals.

After the second workshop (November, 2018), policy coherence analysis has been carried out to identify conflicts and synergies between pairs of objectives. The analysis of policy coherence for the water-agriculture-energy nexus in Andalusia shows that among the 32 crucial policy objectives, synergies far outweigh conflicts. The areas of agriculture/soil and climate/soil have, with 83%, the highest density of interactions. This may be to be expected given that land use objectives include specific targets for water and climate, but not for energy or agriculture.

In addition, there is an inconsistency between energy and agricultural policies. In the agricultural sector, interest groups emphasize that the cost of energy is a limiting factor in irrigated agriculture due to increased energy demand and energy prices. Energy has become an essential resource for irrigated agriculture, with a significant increase in energy consumption.

On the relationship between sustainable agriculture and resource efficiency, there is ambiguity between the vast number of laws, specific rules and other types of regulations that affect the water-agriculture-energy nexus. In general, there may be conflicts between socio-economic and environmental objectives, as increased economic activity and development may hinder the preservation and protection of natural resources, as well as the reduction of greenhouse gas emissions.

Following the November 2019 workshop, these policy objectives have been updated based on stakeholder opinions and comments and also on references to Andalusian strategies and laws and as a result of the selection and updating process, 10 of the most important objectives identified and presented in Table 12. In each objective, we have identified the instruments we can use to reach each policy objective and also the indicators to analyse these policies.

Table 12 Policy objectives, policy instruments and indicators

C - Climate change mitigation and adaptation		
Policy objective	**Instrument**	**Indicators**
C1 -18% reduction in diffuse GHG emissions compared to 2005 levels by 2030, which equals approximately 4.28 tons of carbon dioxide (CO2) per inhabitant and year	Implementation of mitigation technologies in the agricultural sector Carbon tax	CO_2 emissions per sector CH4 emissions from agricultural sector N_2O emissions from agricultural sector Global warming potential CO_2 emissions/GDP
C2 - Increase carbon sink capacity	Subsidies for conversion agricultural land to grassland	Grassland/Total UAA
W - Sustainable water management		
Policy objective	**Instrument**	**Indicators**
W1 - Improve water availability	Economic support to construct small water reservoirs on farms Incentives to enhance water reuse in the agricultural sector	Water reuse/total water use in agriculture Water stress
W2 - Improve water use efficiency	Subsidies to apply water-efficient technologies in agriculture	% UAA under irrigation/total UAA

	increase water cost recovery	Irrigation water use Water use per sector Water productivity (€/m^3)
W3 - Enhance the status of water resources	Introduce measures (Nitrogen fertilizer tax) to reduce diffuse pollution, both for ground and surface water, caused by inadequate use of fertilizers, especially nitrogen and pesticides, through integrated production and organic farming	Nitrogen fertilizer consumption per ha Nitrate concentration in water
E - Energy efficiency and promotion of renewable energies		
Policy objective	**Instrument**	**Indicators**
E1 – 25% final energy consumption from renewable sources by 2020	Support biomass production in the region[7] Incentives to introduce renewable energy in irrigated agriculture[4] Promote renewable energy use to decrease environmental impacts	Renewable energy production/total energy consumption Renewable energy consumption in agriculture
E2- 25% reduction in primary energy consumption by 2020	Subsidies to improve energy efficiency in agriculture	Energy consumption in agriculture Energy consumption/agricultur al GDP
F - Resource efficient food production		
Policy objective	**Instrument**	**Indicators**
F1 - Sustainable agricultural production	Direct payments reduction (to enhance market-oriented agricultural production, and promote generational renewal) Environmental payments (integrate requirements from European directives) Promote climate-resilient crops (e.g. crops with lower water footprint) Advocate more sustainable agricultural practices (organic production, integrated production and conservation agriculture)	CAP payments/total agricultural income Production Prices Area of land in agri-environment schemes Agricultural income per ha CAP coupled payments/ CAP payments
L - Fight against soil erosion and desertification		
Policy objective	**Instrument**	**Indicators**

[7] Andalusian Bio-economy Strategy (p.234)

Reduce soil erosion	Promote ecological focus areas[8] Strengthen agri-environmental measures Preserve natural resources to ensure future economic development of the Andalusian coastline	Surface of ecological focus areas Total land affected by erosion

The work is based on a detailed review of the policies of the different sectors of the nexus in Andalusia, as well as on the opinions of interest groups and the knowledge of researchers. Based on these analyses, the relevant policy scenarios for this study have been defined from the baseline scenario and the policy objectives above.

Table 13 Policy card of Andalusia

Nexus Sector	**Name**	**Very short policy card name**	**Description of intervention as captured by the policy card**
Water	Small water reservoirs	Small water reservoirs	Economic support to construct small water reservoirs on farms to enhance resilience to extreme weather events (e.g. droughts)
Water	Water reuse in the agricultural sector	Water reuse	Incentives to enhance water reuse in the agricultural sector
Water	Water price in irrigation	Water price	Water price per m3 in the agricultural sector to promote water use efficiency
Water	Water-efficient technologies in agriculture	Water-efficient technologies	Promoting water-efficient technologies in agriculture
Water, Food	Efficient use of fertilisers	Efficient use of fertilisers	Implementation of technological solutions to reduce nitrates pollution
Energy, Climate	Boosting biomass production	Boosting biomass production	Support biomass production in the region to promote circular bioeconomy
Energy, Climate	Renewable energies promotion	Renewable energies promotion	Incentives to introduce renewable energies in agriculture

8 Andalusian Sustainable Development Strategy 2030 (p.126)

Energy, Climate	Energy efficiency improvement	Energy efficiency improvement	Subsidies to improve energy efficiency in agriculture
Food	CAP direct payments reduction	Direct payments reduction	CAP direct payments reduction to enhance market-oriented agricultural production and promote generational renewal
Food, Climate	Changing diets	Changing diets	Changing food consumption towards less meat-based diets
Climate	Mitigation technologies	Mitigation technologies	Implementation of mitigation technologies in the agricultural sector to reduce GHG emissions
Climate, Land	Preserving natural vegetation	Preserving natural vegetation	Preserving natural vegetation to increase carbon sink capacity
Land, Climate	Ecological focus areas	Ecological focus areas	Promote ecological focus areas to face soil erosion
Land, Climate	Agri-environmental measures	Agri-environmental measures	Strengthening agro-environmental measures within the CAP to enhance soil conservation

3.6 From the SDM and SG to policy recommendations

3.6.1 Supporting policy coherence

Based on primary policy coherence analysis, inconsistencies between energy and agricultural policies are detected. In the agricultural sector, stakeholders emphasize that the cost of energy is a limiting factor for irrigated agriculture due to the increase in energy demand and energy prices. Energy has become an essential resource for irrigated agriculture, with a significant increase in energy consumption.

On the relationship between sustainable agriculture and resource use efficiency, there is ambiguity between the vast number of laws, specific rules and other types of regulations that affect the water-agriculture-energy nexus. Overall, there may be conflicts between socio-economic and environmental objectives, since increased economic activity and development can hinder the preservation and protection of natural resources, as well as the reduction of greenhouse gas emissions.

In conclusion, the mechanisms for a more integrated policy currently do not sufficiently eliminate ambiguities, gaps and regulatory inconsistencies. There are regulatory conflicts between agriculture and resource efficiency and the lack of priority for renewable energy. The effects on all domains of the nexus depend largely on how well environmental, agricultural, energy and land policies are implemented. This underlines the need to formulate policy changes from a nexus perspective involving all affected stakeholders to better identify the inevitable trade-offs. The objective "improve resource efficiency and climate neutrality", an objective in the area of agriculture and food, is the most important policy objective of the nexus, as it affects and is affected by all other objectives of the nexus. If properly pursued, this objective could have positive and synergistic effects on the whole water-agriculture-energy nexus. Other strongly synergistic objectives are found in the water domain, specifically for irrigation water use.

The policy analysis shows that Andalusia is a region particularly committed to the efficient use of resources and environmental protection. Climate change and the bio-economy are at the centre of the

political agenda, with the climate change law and the bio-economy strategy under development. These policies are an opportunity to implement integrated actions to address climate change and promote sustainable economic development, based on a low-carbon economy.
In addition to successful policy coordination, there are also unsuccessful coordination examples that limited the promotion of renewable energy and sustainable water management in the region. While the promotion of renewable energies depends mainly on national decision making in Spain, sustainable water management is a challenge that is mainly addressed by regional policies.

3.6.2 Testing policy scenarios

Apart from the baseline and two-degree scenarios, several policy scenarios have been tested within the SDM. Those scenarios involve irrigation water pricing, promotion of renewable energy and agricultural policy measures. Results from those scenarios will be discussed with stakeholders in the final stakeholder workshop.

3.6.3 Addressing Nexus challenges

In the case study of Andalusia, based on the main nexus challenges identified by stakeholders during the first workshop on October 26, in Seville (Spain), a system dynamics model has been developed. The SDM is calibrated with projections based on CAPRI-Water thematic model, to evaluate the evolution of the system up to 2050 as well as its sensitivity to changes in water prices since one of the main nexus challenge consists on "Sustainable management of water resources". In this way, the SDM reproduces the foreseen trends up to 2050 and can be used to evaluate water price by comparing simulation results against the baseline. The SDM allows a joint analysis of the nexus: water, energy, and food/agriculture and to simulate different future scenarios. For example, the water module shows the relations between the availability of water and the water consumption in Andalusia. The main policy scenario simulated by the water module consists on "increasing water price in the agricultural sector" in order to guarantee sustainable management of water resources.

In the energy sector, the main nexus challenge identified "Energy efficiency and promotion of renewable energies". To address this challenge in the SDM,we account for energy balances. The energy available for final consumption by energy source (solids, oil, gas, renewable, electricity and heat) is compared with final consumption of energy for the different economic sectors (industry, transport, services, residential and, agriculture and fishing). The main policy simulated related to the energy module in response to the energy challenge identified before is to increase the share of renewable energy to 25% in Andalusia. This policy will be introduced in the policy card of the serious game in order to see the impact of its application in the water-energy-food nexus.

The Food/Agriculture module combines different agricultural aspects and is most interrelated with the rest of the sectors; for example, agricultural energy consumption with the energy module and the use of water in irrigation with the water module. It focuses on the economic aspects of the agricultural sector such as costs, revenues and income per crop and technology variant. In order to address the challenges related to food/agriculture sector identified by the stakeholders, the policy scenario simulated is a reduction of agricultural policy support (i.e. direct payments).

3.7 References

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4 South West of England

4.1 Introduction

The UK Case Study covers the region of the South West of England which is under the operational control of South West Water Ltd. The area roughly approximates to the UKK30 and UKK43 NUTS boundaries Devon and Cornwall, covering an area of approximately 10,300 km2. There are ~1.7 million residents in the region, with the majority of the population (~45%) located in just 13 urban centres (SWW, 2020).

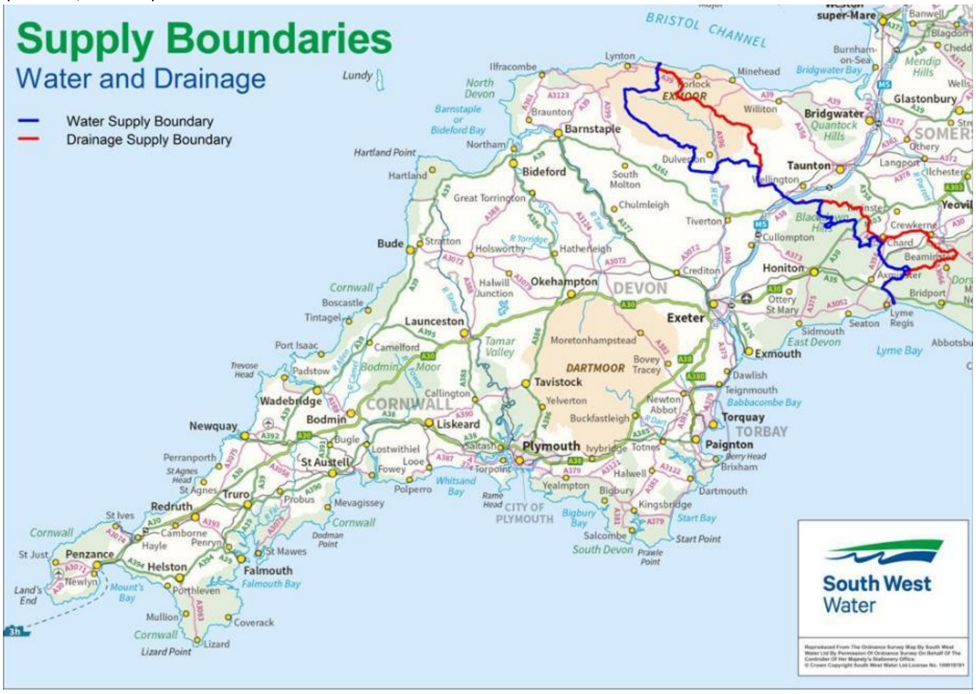

Figure 21 Southwest water operational area

The main aim of the project is to better understand the complex interactions of the Nexus components in the South-West region and develop a decision support framework to facilitate integrated resource management. The case study addresses how legislation, policy and strategic planning can be aligned to;

1. Support sustainable agriculture and the provision of Water and Energy services in a region with significant environmental sensitivities and the UK's largest tourism region.
2. Recognise the need for resilience in the face of climate change, population growth and an increasingly competitive marketplace.

The UK case study has been prepared in partnership between South West Water Ltd (SWW) and the University of Exeter (UNEXE). Both partners have a strong interest in water and energy. As a water services provider, SWW has a special interest in the influencing factors on the water sector. It is, therefore, the resource and policy interactions between water and energy which form the focus for investigation.

The main research questions are:

1. How can local and global environmental protection objectives be addressed, while meeting an increasing demand for low cost and high-quality water/wastewater services?

2. To what extent can renewable energy generation, energy efficiency and demand management reduce or otherwise offset the need for grid imported energy into the region?
3. How can SWW and the agricultural sectors work together to improve future farming practices in order to protect food security, biodiversity and water objectives, tackle GHG emissions and increase renewable energy outputs from local farms?

The major stakeholders are:

- OFWAT (water industry economic regulator)
- OFGEM (energy industry economic regulator)
- Natural England (advisory, executive non-departmental public body)
- Western Power Distribution (WPD) (electricity Distribution Network Operator)
- Environment Agency and DEFRA (Environmental regulators)
- Devon and Cornwall county councils (regional local authorities)

Nexus challenges:

The water and energy utility sectors have several commonalities in terms of the general challenges they face; security of supply, equality and environmental sustainability. These interlinked priorities are often described as a resource trilemma due to the inherent competition and inevitable need for compromise (World Energy Council, 2019). The conceptual understanding of the resource trilemma frames the nexus question as a whole and forms the basis of our modelling approach. The categorisation of water, energy and food as resource-based sectors, challenged by a trilemma, set them aside from the land and climate sectors, which can both be considered as environmental sectors. From a policy perspective, this outlook is also appropriate as we have identified few policy mechanisms exclusively tied to land or climate that outline specific objectives, the Climate Change Act being the notable exception (HM. Secretary of State, 2008). Rather we have found that land and climate focused objectives are usually included as clauses within, or wholly integrated into policies of the resource sectors.

Water sector challenges:

The delivery of drinking water and wastewater services are inextricably linked to significant demand for energy and primary resources arising from the natural environment. Furthermore, it is becoming evident that the growing pressures of climate change and population growth (WaterUK, 2015) heighten the need for efficiency and integrated solutions (DEFRA, 2012). Within this setting the UK water industry regulators expect drinking water and wastewater service providers to undertake suitable planning actives to ensure the ongoing delivery of services (HM. Secretary of State, 1989). In 2007 the Water Resource Management Planning Regulations (HM. Secretary of State, 2007)came into force enacting amendments to the Water Act, which for the first time placed a statutory obligation on water companies to prepare and maintain a Water Resource Management Plan (WRMP) . The main objective of the WRMP being to communicate a water company's intention to manage the balance of supply and demand of drinking water over a 25-year time horizon (DEFRA, 2016).
It is now expected that a similar obligation will be placed upon wastewater service providers in the near future. In anticipation of this requirement, many wastewater companies have prepared and published draft plans following the newly introduced framework for Drainage and Wastewater Management Plan (DWMP) (ATKINS, 2018). While the WRMP and DWMP are not formally aligned there are numerous linkages between the provisions of the two services, and an integrated approach to planning is likely to improve the overall service level (CIWEM, 2018).

Due to the inherent complexity of the urban water cycle, a systems-thinking approach has been suggested by the regulators (OFWAT, 2017). When such an approach is taken it quickly becomes evident that the urban water cycle is, in fact, a component of, and entirely dependent upon, a larger supply chain system. Extrapolating this philosophy results in a contextual approach approximate to that of the water, energy food nexus. The conceptual framework of the nexus used to examine the interdependencies arising from the supply of resources has gained increasing prominence in academic research (Water in the West, 2013). However, despite the growing body of literature, few real-world case studies, or examples of the practical application of the approach are available (Newel, 2019). It is hoped, therefore, that the UK SIM4NEXUS case study will provide a valuable insight for UK utilities, and point the way towards an integrated approach that goes beyond the requirements of DWMP and WRMP.

Energy Sector Challenges:

Energy is the other primary focus of the case study and faces similar challenges to the water sector. The economic regulators of the UK utilities sectors are instructed by the government to minimise the unit cost of all utilities to domestic customers, while at the same time requiring an increase in service level, resilience and environmental performance (OFGEM, 2017).

4.2 Overview of tasks performed

4.2.1 Organisation to carry-out Task 5.2

South West Water (https://www.southwestwater.co.uk/) is the case study lead. It is the licensed provider of water and wastewater services in the South West region of the UK, operating over an area of nearly 10,800 square kilometres with over 1.7 million residents. South West Water is a private water utility part of the Pennon Group that employs 1,300 people. It was born in 1989 with the privatization of the water industry in the UK and has since endeavoured to bring and maintain a water system into line with the stringent UK and EU standards.

The SIM4NEXUS project team and responsibilities were structured as follows:

Business sponsor & general management

- Director
- Project Manager
- Administrator

Lead research & development team

- Research & development lead
- Data & policy analyst

Policy research team (University of Exeter)

- Policy lead
- 2 No. Policy analysts

Technical business support

- Senior managers from within South West Water
- External stakeholders

Academic insight and guidance - as needed from professors at the University of Exeter

- Experts from other departments
- Partner leads within SIM4NEXUS

Our research and development lead, Matthew Griffey, adopted overall accountability for the development and delivery of our systems dynamic model. He was supported by the management team at South West Water but ultimately his work would not have been possible without the support and collaboration of the entire case study project team. Particularly, the University of Exeter who utilised many departments and specialists to support with the development of the conceptual model, policy research, stakeholder engagement and SDM to serious game translation. As the partnering organisation who undertook this work for all consortium members, we utilised the University of Exeter as a conduit to other partners and their projects learnings.

Engagement with other partners was critical to the success of our case study. Gaining insight, knowledge and learning from other partners via the University of Exeter, helped us to deliver. Yearly consortium meetings also supported this and provided an excellent platform to engage, communicate and challenge other partners. Other interim engagements were arranged as necessary, typically utilising conference call facilities to minimise the impact of time and travel.

Our research team primarily worked together from South West Water's head office in Exeter, where office space and equipment were provided for the purposes of the project. This included analysts from the policy research team who were established from a specialist research group connected with the College of Life and Environmental Sciences at the University of Exeter based in Cornwall.

Throughout the project we worked highly collaboratively. This project strengthened the relationships between South West Water and the University of Exeter and has led to future collaborations between us both. To facilitate collaborative working we established regularly weekly conference calls (using Skype) as well as quarterly face to face meetings and ad-hoc working sessions. Being located in the same city made it easier, however, we do not see this as a necessity for success.

Overall, the project hugely benefited from the strong leadership of Floor Brouwer. He provided the right level of guidance and organisation to focus the consortium partners towards project goals. It proved imperative that a strong leader was established with the right level of authority and gravitas to make important project decisions. Similarly, having strong leaders within each of the partners working on the case study has been critical to the success of our case study. This initially took a while to establish, but once the expectations and responsibilities were set out, the project has far exceeded our expectations.

4.3 Engagement of stakeholders in the process

4.3.1 Overview of stakeholders' engagement in the case study

Twenty-two in-depth interviews with selected stakeholders were carried out, together with a further 11 written responses to the questions posed which were collected at the workshop held in January 2018. These interviews explored which critical objectives and instruments generate conflicts and synergies in the nexus, and how conflicts, synergies and trade-offs are dealt with in practice, including how stakeholders handle conflicts, foster policy synergies and negotiate trade-offs. It is also worth noting that the departure of the UK from the EU has significantly occupied stakeholder thinking. The interviews provide valuable insights into:

- interactions between policy objectives;
- interactions between policy instruments and objectives;
- vertical interactions between relevant policies;
- how stakeholders handle conflicts, successfully foster policy synergies and negotiate trade-offs in practice.

Within each sector the following interests are represented,

Water:

Utilities, economic and environmental regulators.

Energy:
Utilities, economic and environmental regulators.
Land:
Environmental regulators, local authorities, land planners, farmers unions
Food:
Environmental regulators, local authorities, land planners, farmers unions

External stakeholders were only requested to attend workshop events and/or provide information during interviews.

South West Water is required to undertake extensive stakeholder engagement as part of the statutory planning obligations as a water services supplier (OFWAT, 2017). Information from these activities was made available to the SIM4NEXUS project team and directly influenced the focus or research, policy goals, and policy card implementation.

Table 14 Stakeholder interaction summary

Interactions with stakeholders	Date	Number of participants and indicative distribution by nexus sector	
interviews			
OFWAT	02/05/2018	Water	Public
Torbay Council	24/04/2018	Water	Public
UKWIR	04/05/2018	Water	Public
West Country Rivers Trust	03/05/2018	Water	NGO
OFGEM	08/05/2018	Energy	Public
Centrica	23/04/2018	Energy	Business
Exeter University	03/05/2018	Energy	Research
ReGen	24/04/2018	Energy	NGO
Cornwall Energy	23/04/2018	Energy	Business
Exeter Community Energy	27/04/2018	Energy	NGO
Energy Policy Group, Exeter University	01/05/2018	Energy	Research
DEFRA / Natural England	09/05/2018	Agriculture / Land	Public
Environment Agency	15/05/2018	Agriculture / Land / Food	Public
Wildlife Trust	10/05/2018	Land / Agriculture	NGO
Exeter University	29/05/2018	Land / Agriculture	Research
Tenant Farmers' Association	24/04/2018	Agriculture / Land / Food	Association
Clinton Devon Estates	23/05/2018	Land / Agriculture	Business
Linking Environment and Farming (LEAF)	01/05/2018	Food / Agriculture / Land	NGO
Exeter University	09/04/2018	Food	Research
University of Gloucester CCRI	23/04/2018	Food / Land / Agriculture	Research
Sustainable Food Systems Planning	30/04/2018	Food	NGO
South West Tourism Alliance	19/04/2018	Tourism	Association
Total = 22 interviews			

Workshops			
OFWAT	25/01/2018 and 26/06/2018	Water	Public
Greenpeace		Climate	NGO
ReGen		Energy	Business
Stephens Scown Solicitors		Energy	Legal
Torbay Council		Land	Public
Westcountry Rivers Trust		water	NGO
Yealm Community Energy		Energy	NGO
University of Exeter		water/energy	Research
South West Water		water	Business
17 unique external attendees (11 paper questionnaires answered)			

4.3.2 Engagement in the case study

Engagement with external stake holders was in all cases positive, and a few notable examples provided pivotal insight to the workings of policy within their sectors. In many cases the initial contact seemed to be hampered by the perceived complexity and unknown relevance of the SIM4NEXUS project. It was also difficult to gain traction with stakeholders who were able to influence policy at either regional or national level, and only a few senior level representatives engaged fully. The majority of participants were in roles which require the analysis of, response to, or implementation of, policies set at regional or national level. These participants had highly detailed knowledge of their respective sectors, but frequently did not have a wider view of policies or impacts to/from other sectors.

The concept of the serious game was often initially miss-understood by stakeholders but was widely embraced when its value and application was discussed during interviews or the workshop events. It appeared to be the prevailing opinion from stakeholders that the workshop events were informative, interesting and provided a valuable perspective of other sectors that they themselves would otherwise not have been exposed to. From the viewpoint of the project the workshops were invaluable. They confirmed much of the team's early assumptions and supported the notional need for the development of a common language or development tool when discussing transdisciplinary topics.

4.4 From conceptual models to System Dynamic Modelling

4.4.1 Case study conceptual model

An initial conceptual model was developed from expert knowledge within SWW and the University of Exeter, this was later validated during stakeholder workshops and interviews. The approach taken was to first examine the wider nexus and highlight relevant interactions in the South West region. Following this high level view a more specific conceptual model was developed which placed the water sector, and specifically SWW at the centre.

The conceptual model presented follows from the model prepared for the Deliverable 5.2 South West UK case study report and feedback from the first stakeholder workshops. See *Figure 22 High level conceptual model* and *Figure 23 Conceptual model of water module* which show the early conceptual model. *Figure 24 Simple context nexus* highlights the distinction between the two types of nexus sectors;

Resource sectors: The sectors *Water*, *Energy* and *Food*, represent the provision of resources which are in some way; won from the environment, stored, transported and consumed.
Environmental sectors: The sectors *Land* and *Climate* represent the environment in which the resource sectors exist or operate and are the receptors to emissions arising from those sectors.

Due to a necessity for increased detail, much of the subsequent work on the conceptual model was undertaken directly within the Stella Architect software environment. Simple visualisations and descriptions of each process have been included in Section 4.4.4 to support reader understanding and communicate the base functionality of the modelled environment.

4.4.2 Modifications introduced to model policy scenarios

4.4.2.1 Development of policy scenarios for the case study

The generalised nexus challenges typified by the resource trilemma of security of supply, equality and environmental sustainability have directly informed the structure and selection of policies for the SDM. Policy Goals have been chosen which support the priorities of security of supply and environmental sustainability, while equality (affordability) is addressed via an economic analysis of the selected policy cards.

While no predefined policy scenarios have been assembled for the case study, the resource trilemma implies three basic scenarios that might be constructed from policies that exclusively target one of the three priorities. This is a very rudimentary approach which does not yield optimised outcomes, it is therefore intended that the user will select a mixture of policies from within the trilemma to create a more balanced solution.

The selected approach to scenario analysis was driven by stakeholder feedback and the relatively large number of policy interventions identified. This method also recognises that affordability is often the determining factor where multiple solutions to an objective are found. The flexibility of this methodology also supports the approach of the UK's Government, energy (Regen SW, 2018) (National Grid plc, 2019) and water sector (Environment Agency, 2017), which have independently identified conflicting but plausible future scenarios.

4.4.2.2 Introduction of policy scenarios in the SDM

The Policy interventions and SDM where developed in parallel, resulting in policy implementation at an integral level to the structure of the SDM.

The baseline scenario (SSP2) was the only simulation run in the thematic models, CAPRI and E3ME, all other scenario analysis is conducted directly within the SDM. The user is empowered to explore narratives of interest, by selecting any combination of 55 policy interventions (policy cards) in each policy setting interval (every 5 years of model time). Scenarios are therefore created by the user and can be made appropriate to unique research objectives. Furthermore, the addition of an economic analysis layer makes it possible to evaluate the economic feasibility of key policy decisions, often demonstrating the significant financial burden of "win-win" solutions.

Policies are integrated into the SDM in several ways depending on the nature of the policy. Capacity-based interventions in the energy and water sectors, which have been identified as being of greatest economic impact to their respective sector, use a project development and economic simulation to control changes. These policies increase a capacity of a component within the SDM, such as reservoir storage, network transmission, generation etc. When the policy card is played the capacity of the appropriate variable is increased according to project development criteria such as lead time, operational life, maximum available capacity etc. and a Discounted Cashflow Forecast (DCF) is generated to enable the user to evaluate feasibility. Policies which are of relatively low economic impact or are of prohibitively complex economic structure, do not use economic analysis. For these policies when the policy card is played the capacity variable is modified directly, following predefined lead time and operational life.

For non-capacity-based policies in the energy and water sector, such as those relating to user side demand reduction, the variable influenced by the policy card represent the number of customers who have adopted a technology or behaviour. When the card is played a fixed percentage of the customers who have not adopted the technology, shift to adoption in every time step until the policy ends. If the population stays stable the absolute number of customers shifting in every time step reduces, thus modelling the effects of diminish returns.

Policies in the land management sector differ significantly from those of energy and water as they influence a rate of change. When these policy cards are played, they enable the transition of land use from one type to another. As the land resource is finite, land use change only occurs when there is imbalance between competing policies. For example, if all policy cards are played (which attempts to increase the area under all land uses), no land use change can occur. Also, where there are policies driving a particular land use, that policy inhibits land resource being diverted away to other uses.

4.4.3 Modifications introduced to account for data availability

4.4.3.1 Data available from the thematic models

The role of data provided by the thematic models was highly restricted by the number of policy interventions under investigation and the impracticality of running the thematic models for a meaningful number of the policy combinations. The difficulty arises from the static nature of the data from the thematic models once extracted, and the need to rely on a prescribe list of policy scenarios, which negatively impacts the users scope for investigation.

The baseline run of E3ME provides core data for GDP, electricity generation mix (carbon intensity), electricity price, population and commercial activity. All these data sets are converted to percentages using 2020 as the reference and are used as trend coefficients, interpolation is used to approximate monthly values. Similar data to that provided by E3ME is also publicly available from UK government databases, while there are notable differences, use of either dataset has minimal impact on the final outputs of the SDM.

The land use and food modules of the SDM rely heavily on data from CAPRI for several functions. Two categories of data 1. Land Area and 2.production yield, are extracted from CAPRI for the following:

- Utilized agricultural area
- Cereals
- Oilseeds
- Other arable crops
- Vegetables and Permanent crops
- Fodder activities
- Set aside and fallow land
- All cattle activities
- Beef meat activities
- All Dairy

- Other animals

Climate data was initially provided by PIK, however the detailed spatial analysis and hydraulic modelling required to generate realistic river flows from the precipitation data is beyond the scope of the PIK project. Thus, to enable modelling at this level of detail, river flow data which is used by SWW and other UK water companies for resource planning has been used.

4.4.3.2 Local data to be collected

All data within the water sector module, apart from river flows, has been provided by southwest water. The Future Flows and Groundwater Levels project undertaken by the Centre for Ecology & hydrology (UKCEH, 2015), provides calibrated dataset of forecast river flow in key rivers across the region. The river flow models are driven by forecast precipitation based on Hadley Centre Regional Climate Model HadRM3-PPE, and replace the use of climate thematic models.

Digest of UK Energy Statistics (BEIS, 2019) and the Renewable Energy Planning Database (BEIS, 2019) provided by the UK government are used for historic baseline energy generation data, the installed capacities, and for capacity factors. Forecast coefficient representing changes to installed capacity are derived from E3ME. Western Power Distribution (WPD), the regional electricity distribution operator, have provided network capacity analysis data (WPD, 2019).

For macro level land uses all variables are initially set based on historical data from land management statistics (HCLG, 2018) provided by the local County Councils in the southwest region, UK forestry commission's National Forestry Inventory (NFI, 2018), and the Department for Environment Food & Rural Affairs (DEFRA, 2018).

4.4.4 Case Study SDM in Stella/R

From a functional perspective, the SDM assumes a demand-led philosophy, whereby the flow of resources to meet direct societal demands (i.e. demands associated with domestic, commercial and industrial activities), and the flow of resources between individual sectors are the primary driving factors. While the demand-led approach dominates, in several situations, the model uses a supply-led approach where raw resource availability becomes the driving force, for example in the case of renewable energy generation and land use.

In both philosophies supply and demand together control the ultimate consumption of resources. However, there is a priority in terms of where the driving control signal originates and the subsequent balance of resources.

In the context of the nexus existing to meet societal demand, resource flows between sectors are analogous to system losses, i.e. they are resources which are consumed by the system but not made available to meet society's demand. Therefore, an efficient nexus seeks to minimise the cross-sector supply and demand flow, while maximising the availability of resources to society.

The SDM is structured to comprise six modules, which describe the interactions between society and the nexus sectors, and one module which is used to track metrics, see *Figure 25 Main nexus model (view from with Stella Architect)*.

Water sector module

The water sector module focuses on the demands for drinking water arising from society and the other nexus sectors, which are consider against the treatment and distribution capacity of the local supply system. The model forecasts the supply-demand relationship with respect to the stresses of seasonal variation, climate change and population growth via monthly time steps.

The water sector module is subdivided into drinking-water and wastewater supply chains which when linked via raw water resources describe the urban water cycle see *Figure 28 Drinking water processes* and *Figure 29 Wastewater processes*. The water module has been developed to suit SWW's planning objectives, and to mirror activities undertaken by SWW under the following obligations; Water Resource Management Plan (WRMP), and Drainage and Waste Management Plan (DWMP).

Determining demand levels requires an analysis of population and land use factors. These factors are overlaid with the consumption of the land user or resident and the growth or decline of the specific land use itself. The demand for water is highly seasonal with a significant increase in summer months. This seasonality is most strongly seen in domestic and agricultural contexts, where heat drives an increase in water use across the home. This is further exaggerated in the southwest due to an influx of tourists who place additional demand on the system. To account for this the model uses a seasonal demand curve derived from SWW operation data which peaks in the summer months. In addition to consumer demand, allowances for system leakage and operational losses are variables influenced by policy decisions.

Water availability is considered by evaluating the complex relationship between demand and the ability of the system to utilise and supply drinking water. Three conventional water sources and two additional sources are modelled:

Conventional sources:

1. River abstraction, 2. Reservoir storage, and 3. Borehole supply,

Additional sources:

1. Extra regional import and 2. desalination.

The model abstraction priorities follow the order;

1. River Abstraction>2. Reservoir Abstraction>3. Borehole Abstraction >4. Extra regional import >5. desalination

The wastewater module assumes that for every unit of drinking water consumed, one unit of foul water is generated. This approach is deemed valid due to the lack of foul flow data and the assumed relationship between drinking water and foul water that is used by all UK water companies for sewage billing (SWW, 2019). The other flows into the wastewater process are primarily due to external environmental factors. These are represented as a surface water drainage volume, impacted by rainfall, and intrusion rates ("inward leakage") resulting from either saline or ground water.

Energy sector module

The energy sector module seeks to examine the balance of supply and demand for electricity at the macro scale across the region. All major forms of renewable electricity generation are included as well as fossil fuel and grid electricity import. The demands for electricity arising from society and the other nexus sectors are consider against the generation and transmission capacity of the local supply system. The model forecasts the supply-demand relationship with respect to the stresses of seasonal variation, climate change and population growth via monthly time steps.

The energy module is an example of a supply lead philosophy, which is deemed to be appropriate due to the nature of renewable energy generation, which is utilised as the resource becomes available. In its current state, the Distribution Network Operator (DNO) has limited ability to limit generation from renewable energy suppliers and only a small percentage of generators connected to the network have arrangements in place to facilitate this. This, however, is likely to change in the coming years as DNO's switch to a Distribution System Operator role whereby they become responsible for balancing arrangements within the network (WPD, 2017). The SDM, therefore, provides an opportunity to examine strategies for enhancing the utilisation of renewable energy generation including the curtailment (limiting) of generation for new generating capacity.

As with the water sector, demand is a core component of the Energy sector, and it is a summation of the electricity demand from domestic, agricultural, industrial and commercial sectors, and crucially also the water sector. Following the same approach to the water sector, energy demand is determined by analysis of population and land use factors. The demand for energy is also highly seasonal with a significant increase in winter months. This is driven by the reduction in ambient temperature giving rise to a direct heating load for space and water heating. To account for this, the model uses a seasonal demand curve derived from National Grid data (Elexon, 2019) which peaks in the winter months.

At the centre of the energy sector module is the local distribution network process which models the basic activities of the distribution network operator (DNO) see *Figure 30 local distribution network process*. The distribution network receives locally generated electricity, as well as imported electricity from the transmission network which it distributes to all end-users. The primary function of this process is to balance input and output, ensuring that demand arising from across the nexus is met through a combination of available electricity sources. The balancing activity is achieved by comparing the instantaneous supply of electricity against local demand. When a surplus occurs, the additional volume is exported onto the transmission network. Conversely when a deficit occurs the shortfall volume is imported. The import and export to and from the transmission network is a major influencing factor to the effective utilisation of renewable energy and the carbon intensity of the electricity consumed.

The import and export of electricity is constrained by the available capacity of the interconnection between the two networks. In order to model this relationship a check process monitors the volume of import/export against the effective transmission network capacity. When a network capacity is exceeded a "curtailment signal" throttles output from certain electricity sources.

The renewable electricity generated in the region is managed under two distinct control philosophies; unconstrained and constrained. The unconstrained modality is the archetypal supply-led philosophy applied to pre-existing solar, wind and hydro installations. The constrained modality is applied to new installations and technologies with inherent storage functionality or dispatchability, such as biomass or energy from waste. Constrained generators are the only ones to respond to curtailment signals from the transmission or distribution network.

All generating technologies and transmission routes within the SDM are described in terms of installed capacity (maximum megawatt hours supplied per month) and capacity factor (ratio of energy supplied to theoretical maximum supply). The installed capacities and capacity factors are the main control variables driven by policy cards in the energy module.

The operational status of the planned nuclear plant Hinkley point and the proposed enhancement to network capacity are major influencing factors in the energy module.

Acting as a decision support tool, the module provides the opportunity to investigate:

- Supply/demand headroom Forecasting
- Strategic timing of capacity expansion of generation technologies and transmission
- Land use impacts for energy sources, i.e. renewables
- Regional Carbon emissions from energy and potential benefits of new renewable energy

- Potential impact of non-expansion, i.e. not meeting future energy demand and causing periods of energy outage.

A detailed economic analysis layer has been integrated into the policy card implantation processes for key variables within the water and energy sectors see *Figure 31 Discounted Cash Flow* . When a policy card is played that increases a system capacity a discounted cashflow forecast (DCF) is generated based on the calculated assumptions in the time step. The DCF enables the user to evaluate the feasibility of the policy by considering the following financial metrics;

- Time weighted value of money,
- Net present value
- Payback period.

The analysis is conducted at two levels: The first which considers the feasibility of the policy card in isolation, i.e. with no other active polices, and the second which is an aggregated analysis that includes the effect of the policy alongside all other past and current policies.

Land sector module

The land sector module has been developed to investigate the environmental impacts to water quality and climate associated with active land use and changes to land use. The model is divided into three primary processes; 1. land use, 2. run-off water quality, and 3. waste management.

The approach to land use, is to assume that the total available land resource within the spatial boundary is finite, and exists in one of only seven states see *Figure 34 land use processes*;

1. *Residential and Urban Area*: describes all land that is used for residential housing and the immediately associated activities.
    a. Urban Green space; is a subcategory parallel to residential and urban area that describes the area of parks and grassed areas within the urban environment.
2. *Commercial and industrial Area*: describes the land area used by industrial and commercial activities.
3. *Brownfield Area*: describes the area of land which has previously been occupied by some form of residential, commercial or industrial activity, but that has been cleared ready for new development.
4. *Greenfield Area*: describes the area of land which has not been previously developed but has been allocated as available for development.
5. *Utilised Agricultural Area*: describes the area of land where all agricultural activities occur. This area is used to calculate more specific agricultural uses based on utilisation data from the Common Agriculture Policy Regionalised Impact Modelling System (CAPRI) thematic model.
    a. *Land for dedicated energy crops*, is a subcategory parallel to both Agriculture Area and Forestry Area, which describes land area utilised for dedicated energy crops
    b. *Land for solar*, is a subcategory parallel Agriculture Area which describes the area of land used for ground mount solar energy.
6. *Forestry Area*: describes the area of woodland and forestry land, which is categorised as: 'managed', 'unmanaged', 'broad leaf' and 'coniferous'.
7. *Natural habitat*: describes all remaining unutilised land which has not been included in the other categories.
    a. *Restored peatland*: is a subcategory of natural habitat which describes moorland which has been restored by SWW up-stream thinking project.

Using these categories, the module simulates the transition from one state to another based on policy decisions or forecast data. To account for the different drivers for change applicable to each type of land use, the module is subdivided in three distinct sub process; 1. Residential and urban area, 2. Commercial and Industrial, and 3. Primary land resource.

The land use module is a highly simplified model and intentionally excludes from the analysis particular land types, such as ancient woodland, sites of special scientific interest and other areas designated as unavailable for land use change.

Residential and urban - The residential and urban area process utilises a demand-led philosophy that is heavily constrained by the availability of land supplied from the green field and brown field sources. The demand to expand the residential and urban area arises from a complex interplay of socioeconomic and policy-based factors. Intuitively the primary driving force is population growth and immigration to the region, however, planning policies regarding housing density are also an underlying driver. The SDM therefore takes a highly simplified approach to this complex situation by relying on a policy defined housing density. The housing density policy acts such that when it is high, less land is used per capita thus reducing demand to expand the residential area, and vice versa. In situations when the actual housing density is different from the specified desired density two mechanism facilitate the adjustment. 1. Population growth, which drives density up, and 2. Demolition of existing housing stock, which increases the supply of brownfield land ready for redevelopment at the desired density and is driven by a housing renewal policy.

Commercial and industrial -The commercial and industrial area process and its relationships to the brownfield area and greenfield area follow the same model as that of residential and urban area. In that, there is a constant transition between the commercial area and brownfield due to redevelopment and a highly regulated supply of greenfield land based on planning policy. Within this process, the simile to Demolition and its associated control variable is Decommissioning and Rate of decommissioning, which act to transfer land resource from the commercial area into brownfield.

Primary land resource - The primary land resource process attempts to model the transition of land use between agriculture, forestry and natural habitat see *Figure 36 Primary land resource process*. In the UK, forests/woodlands and natural habitats are protected from land use change. However, as these protections are policy driven legal frameworks rather than a physical barrier, were those policy mechanisms to change, then land resources would quickly be impacted due to agriculture expansion. Under the current policy climate, there are weak drivers in place to stimulate the transition of agricultural land into both natural habitat and forestry/woodland. These policies set the initial flow rates and act as the baseline for model runs. When the model is running policy cards for forestry and natural habitat that increase or decrease these rates, and where negative values are used, they allow for the transition of forestry and natural habitat into agricultural land.

Greenfield land - Greenfield land made available for development is highly sort after by land developers of all types and is tightly controlled, because this is practically an irreversible transition. The Greenfield development policy card acts as the main driving force enabling the flow of land resource into the greenfield area. The flows of forestry and natural habitat land into the greenfield stock are further constrained by those forestry and natural habitat policy cards.

Utilised agricultural area - Utilisation of agricultural land is driven most strongly by economics, this ultimately influences farmers, who attempt to generate profit from a speculative view on future crop prices. The reality of this process is highly nuanced and requires a detailed economic analysis that is beyond the scope of the SDM. Therefore, to account for this mechanic the SDM integrates data from CAPRI describing detailed agricultural land use, and the calculated utilised agricultural area from within the SDM. Data extracted from CAPRI is used to drive the trends of agricultural activities based on percentages of the whole area of utilisation. This enables the SDM to control the gross volume of agriculture land, and for CAPRI to forecast the specific more detailed agricultural land uses see *Figure 37 detailed agricultural utilisation from CAPRI data.*

Forestry & woodland - The forestry area describes the total combined area of forest and woodland. The model uses the gross area of forestry and divides it based upon the categories of Broadleaf, Coniferous and Mixed, using data from the UK forestry commission's National Forestry Inventory (NFI, 2018).

Water quality - The surface run-off water quality process uses a mass balance principle to approximate an aggregated surface water quality arising from the primary land resource see *Figure 35 Surface run-off and raw water quality.* The model considers the surface area of each land use and associated water quality coefficients, which are based on an assumed water quality index. Developed urban and industrial areas are excluded as these are assumed to be connected to the wastewater drainage network. This is a highly simplified model and does not consider detailed or specific site data but seeks to give an average view of the whole spatial boundary.

Waste management - The waste management process tracks the production of municipal waste arising from society and its disposal based upon the capacity of various waste handling routes. Policy cards can be deployed by the user to increase waste recovery technologies which offset waste disposed to landfill.

Performance Metrics

Amongst the numerous objectives of the nexus approach, resource efficiency and decarbonisation are the common priorities. Therefore, the two metrics to track performance across the nexus are:

1. Total CO2 emissions
2. the ratio between the total resources supplied by each sector and resources directly consumed by societal demand.

Within each sector, more specific objectives and metrics are considered, based on the priorities identified during the case study. The water sector, for example, is highly concerned about strategic storage of raw water, and sustainable rates of abstraction from surface water bodies. To address these areas of interest, these variables, become performance metrics which are tracked over time in the SDM.

An overall health indicator for each sector is considered by evaluating the effectiveness of meeting total demand. This health indicator is then increased or decreased according to the positive or negative impact implied on other sectors, i.e., CO2 emissions.

The financial implications of policy decisions taken within a sector, and the knock-on effect of the policy decision in other sectors, is inherently considered in the modelling. This is done by evaluating the total expenditure (CAPEX plus OPEX) impacts from the baseline level, and for major infrastructure changes use of net present value and payback period.

The main challenge faced during the development of the SDM arose from the selection of spatial boundaries and scaling of data. It was initially intended that the SDM would be structured to include two sub regional modules using two county-based subdivision of the South West Water operational area, Devon and Cornwall. it was hoped that detailed GIS analysis of the region would yield sufficient data to expand this further into an individual catchment, however it became increasingly difficult to find suitable datasets or to satisfactorily categorise land use. This approach was abandoned in favour of using national statistics and government databases, which described the region as an aggregated whole, which also greatly eased the development of the serious game.

4.5 From the System Dynamic Modelling to the Serious Game

4.5.1 Case studies learnings goals

The learning goals have been expanded upon since D4.8 and refined by framing the overall nexus question within the resource trilemma, the learning goals are summarised as:

	Water Learning goals
Security of supply	How to reduce demand for drinking water entering municipal supply, thus offsetting the need for increased capacity. How to enable the drinking water and wastewater supply chain to respond to external shocks and pressures, while maintaining service.
Equality	How to provide value for money and ensure service affordability
Environmental sustainability	How to minimise GHG emissions and the production of waste products requiring disposal to land. How to maintain or improving drinking water and wastewater quality.

	Energy Learning goals
Security of supply	How to reduce demand for electricity entering municipal supply, thus reducing need for increased generation or transmission capacity. How to enable the energy supply chain to respond to external shocks and pressures, while maintaining service.
Equality	How to provide value for money and ensure service affordability
Environmental sustainability	How to reduce the GHG emissions associated with the generation and supply of electricity

	Land Learning goals
Environmental sustainability	How to ensure that the local environment and human health is protected. How to reduce the total volume of waste disposed to landfill and the associated environmental impacts. How to improve the urban environment to provide greater public amenity.

	Food Learning goals
Environmental sustainability	How to minimise negative impacts of agriculture to the local environment and improve biodiversity. How to reduce surface run-off arising from agriculture thus protecting aquatic environment

The serious game introduces the above learning goals to the player as potential objectives at the start of the game session, and then dynamically as the game is played when conditions are breached that might result in the hidden objectives being missed.

4.5.2 From generic to specific use cases

The generic use cases contain many of the same objectives identified in the UK case study but do not align well with the structure of the SDM or the trilemma grouping of objectives. Therefore the specific uses cases arose from the combination of policy interventions implemented in the SDM which could achieve policy and learning goals within the trilemma context. This process was purely based on the capabilities of the SDM and did not require wider involvement of the team.

4.5.3 Policy cards

The policy cards were derived from the policy goals and interventions identified during the case study policy analysis stage and during stakeholder workshops. The development process was highly iterative with expert input from SWW and the university of Exeter's Energy Policy team and the Centre for Water Systems.

The original policy goals associated with the affordability of utilities and reducing costs to consumers were not ultimately made into policy cards, but remain as objectives which are tracked via the use of the economic analysis layer. Other policy goals associated with agricultural business development, food safety, and adaptations to the impacts of climate change, were dropped because no feasible way to integrate them into the SDM could be found.

Targets for policy adoption are based on the IPCC recommendations to minimise climate change and the UN sustainable development goals. Social acceptance and cost were estimated based on expert advice from SWW and the university of Exeter. It is assumed that the weightings of acceptance and cost will be adjusted following completion of the serious game during a calibration/sensitivity analysis.

4.5.4 Serious Game interface

The UK serious game largely follows the structure of the other case studies. The main notable addition is the economic analysis layer which the user can use to evaluate feasibility of certain policy decisions and facilitate investigation of the affordability of utility service provision. The economic analysis window shows three discounted cashflow forecast charts:

1. DCF1, is unique and exclusive to the policy card being played in that time interval and will show a projection of assumed economic performance to 2050, based on the conditions in that time step.
2. DCF2, is an aggregated combination of all policy cards played up to that point projecting assumed performance to 2050.
3. DCF3, tracks aggregated performance of all policy cards as conditions change, but does not include a forecast, showing progress to the current timestep only. DCF3 also acts as a final evaluation providing the user the opportunity to compare forecast performance with model performance.

4.6 From the SDM and SG to policy recommendations

4.6.1 Answering main research questions of the case study

1. How can local and global environmental protection objectives be addressed, while meeting an increasing demand for low cost and high quality water/waste water services?

Question 1 encompasses the core issues of the resource trilemma, as the objectives of the question are fundamentally conflicted. While it is technically possible to meet any one of the objectives in isolation, at least one (possibly all) other objectives are compromised. Additionally, there are numerous combinations of interventions which can achieve these objectives in part or in whole, so there is no single answer.

The simplest truth however is that to protect the environment, while meeting increasing demand and ensuring a high-quality service provision, requires more investment. The question therefore becomes, what is the least cost solution to achieving these objectives, and what is society willing to pay?

Due to assumptions, models and the inherent uncertainty with all policy decisions, this is not something that can be calculated with any degree of accuracy. The Serious game does however enable the player to explore these themes and draw their own conclusions, as to what is an affordable level of service provision and environmental protection. Most importantly, the game provides a sense of relativity amongst different policy decisions, rather than explicitly being able to quantify the true costs and benefits.

To provide an answer robust enough to offer true insight to the least cost solution, more precise economic data would be required, as would careful calibration against each of the stakeholder's relevant models, i.e., water / energy networks.

2.To what extent can renewable energy generation, energy efficiency and demand management reduce or otherwise offset the need for grid imported energy into the region?

As with question 1, there are multiple solutions to the provision of renewable energy and demand reduction within the south west region. It is therefore not appropriate to offer a single answer.
Currently the south west generates ~ 27% of its consumed electricity from renewable sources and has the potential to exploit additional resources (subject to environmental and operational constraints), which could provide up to ~87% of current demand (BEIS, 2019) see *Table 15 Renewable electricity capacity and generation.* To achieve net zero in electricity import into the region a ~15% reduction in demand would be required, which is comfortably within the potential range of abatement measures identified. Furthermore, there is sufficient abatement potential to off-set the increasing demand as a result of population growth and climate change to maintain net zero import to 2050, assuming an increased renewables capacity.

Table 15 Renewable electricity capacity and generation

South West Region (Devon and Cornwall)				
	Installed capacity (MW)	2018 generation (MWh)	Potential capacity (MW)	Potential Gen. (MWh)
PV	1,156	1,132,870	3,325	3,259,825
Wind	284	576,319	1,091	2,210,144
Hyro	9	23,230	16	39,675
AD	15	76,121	17	84,670
SG	2	6,284	2	6,284
LFG	36	139,101	36	139,101
MSW	56	176,744	78	245,981
Biomass	7	21,052	97	272,669
Totals	1,565	1,974,977	4,661	6,258,348

SW Demand (MWh)		7,277,615

percentage renewable energy		Current 27%		Potential 86 %

Were all constraints to be removed from the selection of sites for renewable energy the technically available resource would almost triple, enabling the region to become a major renewable energy exporter. However, this would require significant reinforcement of support infrastructure and potentially undesirable environmental impact to the local environment.

The SDM and serious game are structured to explore these relationships and to help develop cost effective strategies for energy delivery from the potential constrained resource.

3. How can SWW and the agricultural sectors work together to improve future farming practices in order to protect food security, biodiversity and water objectives, tackle GHG emissions and increase renewable energy outputs from local farms?

Question 3, like as with the previous two research questions, considers a highly conflicted set of objectives. Food security either relies on increasing local production or guaranteeing external sources. As the model considers external supply to be infinite the focus is purely on local production. All measures which increase the area of agricultural utilisation or production yield, have negative impacts to land, water and biodiversity. To compound this, most measures which reduce impacts, decrease yield or utilisation area, and those which do not are of very limited benefit. From the literature it is only when genetically modified crops or advanced glass house horticulture (which are both outside of the scope of the model) are used that both production and environmental protection can be significantly improved (OECD, 2014). The SDM and serious game enable the user to explore the objectives of the research question and draw their own conclusions as to the appropriate use of land and agricultural intensity.

4.6.2 Supporting policy coherence

The question of coherence with regard to the future policy arrangements of the UK's nexus sectors is exceptionally difficult to assess. Since the beginning of the S4N project the UK has been undergoing major political upheaval brought about by the protracted withdrawal from the European Union on 31st Jan 2020. By the end of the transition period which ends on 31st December 2020, the UK will be free of the obligations imposed by EU directives. The UK will then be able to rewrite all existing law and regulations previously based upon those directives. While it is fair to say this process will take several years and probably successive governments, the UK's deviation from the EU directives is inevitable. The extent and direction of deviation is likely to be driven by the prevailing political alignment and economic climate. The strength of the economy will likely act as the catalyst for change, whereby a strong economy would prove low motivation to change and a weak economy resulting in a strong motivation to change.

Two potential extremes to the deviation might be considered as; 1. Under a right-wing government and a struggling economy, it is quite plausible that deregulation will be attempted to stimulate competition and boost economic activity, 2. under a left-wing government and a struggling economy, increased regulation or renationalisation might be attempted to shift the burden to the tax payer and improve equality.

Under these conditions it seems of limited value to attempt evaluation of the current political climate or policy intentions due to the high level of uncertainty of the future direction. The SDM has however confirmed several of the incoherencies identified in D2.2, and to some extent demonstrate the impact of these incoherencies.

The two most notable conflicts of policy incoherence that the water module highlights are;

1. The increased energy and chemical demands, including their associated GHG emissions, that are driven by policies to improve local environments and human health.
2. The increased cost of service provision associated with security of supply and environmental protection.

The major incoherence within the energy sector identified within D2.2 arises from the selection of electricity decarbonisation strategy, that being nuclear or renewables. The SDM allows the user to evaluate the macro operational impacts to renewable energy generation and utilisation, of the expansion of the Hinkley point nuclear energy plant. To examine this, expansion of Hinkley point has been implemented as a policy card that can be evaluated using the DCF economic analysis. The model utilises assumed data for the project specifics of the Hinkley point, so we accept that it does not provide a fully robust analysis. However, were fully transparent economic data made available this could readily be included in the model.

By using the DCF approach it is possible for the user to compare the performance of policies in deferent sectors and evaluate their impact on one another (coherence/incoherence) using the common economic metrics of NPV, IRR and payback period. The weakness of this approach is the need for good quality, technology specific project development data.

4.6.3 Testing policy scenarios

The SDM and serious game have been developed without prescribed scenarios, making it possible to build approximations of the many different scenarios the major stakeholders have already developed. In fact, this approach enables any user, with any agenda, to approach the nexus and construct their own scenario from the baseline position of today's status quo.

One of the major lessons that both the SDM and serious game provide, is that while there might be a policy to provide a desirable outcome, economic feasibility is the prohibiting factor, and finance is as important as policy. There are numerous policy card combinations which can achieve or make progress toward the major nexus challenges, the underlaying question is how does society pay for it?

A significant trade-off to be explored is centred on the aim of energy decarbonisation, and the prioritisation of either nuclear or renewable energy, both of which have been identified as low carbon solutions. The South-west region of the UK has England's largest natural resource of wind and solar energy, with the greatest installed capacity. The southwest peninsula also has the most accessible offshore renewable resources in England including wave, tidal and wind, which is largely unexploited. The conflict, therefore, arises as the south-west has been chosen as the location for the next major nuclear energy installation, Hinkley Point.

Nuclear energy, while excellent at providing very consistent base-load output has a minimal ability to respond rapidly to fluctuations in demand. This is incongruent with the government's objective of creating a flexible energy network and the intermittent nature of renewables, which fluctuate with the available resource. Furthermore, the baseload output of the nuclear energy station will potentially act as a bottleneck limiting the capacity of the transmission/distribution network to accept more renewable energy generation. It is believed that grid capacity challenges can be mitigated by reinforcement of the network but at a significant capital cost. For nuclear and renewables to coexist in the southwest, there is a much-heightened need for mechanisms to attenuate the temporal disparities between supply and demand and increase network capacity. To compound the complexity of the problem at a national level, both new nuclear and renewables are subsidised via the same funding mechanism "Contracts for Difference", accessing the same budgetary resource. Therefor both economic and technical dimensions play a role in the trade-off between nuclear and renewables.

Nexus Synergies

Synergies between water and energy arising from the improved management of raw water resources and their potential for hydropower generation. This option is suited to the region, although there are high capital costs of new plant, and the economically viable resource is mostly fully exploited.

Similar synergies can also be created by integrating land use and water management practices. Upstream catchment management and paid ecosystem services, for example, can improve surface water quality and reduce the energy demand of drinking water treatment. A pioneering programme undertaken by SWW, involves the restoration of peatland and improving farming practices for the potential benefits of surface water quality and biodiversity. However, the benefits of such schemes are difficult to quantify, and the feasibility of maintaining such paid ecosystem agreements may be challenged. Similarly, synergies could be established through Sustainable Urban Drainage Systems (SUDS), aimed at reducing surface flood risks, sewer flood risk and sewer storm flow. This concept is not a new one and is effective at minimising wastewater pumping, treatment and consequently energy demand. Southwest water has an engagement program with local authorities and housing developers to implement SUDS, through jointly funded programmes. This helps to overcome some of the main barriers to full exploitation which arise due to the high capital cost for retrofit and the complex issues surrounding responsibility of ownership and maintenance. There is however significant economic, technical feasibility and ownership challenges associated with SUDS schemes. For example, pay-back periods can be longer than traditional civil infrastructure schemes, uncertainty exists around the schemes ability to resolve complex capacity issues upstream in the catchment and ongoing maintenance needs/responsibilities are often blurred between different stakeholders.

There are potential synergies from water to land and energy, since anaerobic digestion of sewage sludge generates methane gas suitable for energy use, and composted sludge cake from anaerobic digestion of sludge is rich in phosphates and nitrogen. When disposed to agricultural land, composted sludge cake can provide valuable fertiliser, offsetting the need for fertilisers from other sources and reducing energy consumption. Sludge passed to anaerobic digestion remains at a relatively low proportion within SWW, and the majority of sludge is 'limed', which is of lower agricultural value. The main barriers to further exploitation are the logistic challenge of sludge transport to centralised anaerobic digested treatment centre and the capital costs associated with building such facilities.

Synergies between water and energy could be created by improving resilience or security of energy supply. Energy supply in the south-west UK is critical to the water services in this region. It would enhance the resilience and security of water, but high capital costs are a barrier to further exploitation.

4.6.4 Addressing Nexus challenges

Table 16 Summery table of Nexus challenges against the trilemma priorities

	Water	Energy	Food
Security of supply	Demand reduction, Raw water availability, Raw water storage, Waste reduction, Resilience & climate adaptation.	Demand reduction, Transmission capacity, Generation capacity, Transmission flexibility, Resilience & climate adaptation.	Waste reduction, Yield increase.
Equality	Affordability of service provision and value for money.	Affordability of service provision and value for money.	customer affordability
Environmental sustainability	Global - Reduce GHG emissions, Local – Protect human health and aquatic environment.	Global - Reduce GHG emissions.	Global - Reduce GHG emissions, Local – Protect human health and local environment.

The Nexus challenges are addressed via the package of 55 policy interventions specifically tailored to meet key objectives across the nexus. The user can target specific challenges or adopt a more inclusive strategy. Within the serious game the user can select and evaluate interventions against the above objectives in each policy setting window, which occur every 5 years. Within the SDM the user can make policy selections within the normal 5-year time interval, or at every 1-month time step. Once the full model run has been completed to 2050, the final outcomes and steps taken outline a narrative of policy development, along the pathway created.

4.7 Short-term and long-term policy recommendations

4.7.1 Summary of the Nexus issues in the case study

Within the primary sectors of the UK case study (**water**, **energy** and **food**) there are three main policy priorities centre around:

1. affordability for customers
2. security of supply (i.e. resilience of the goods/service)
3. the protection of human health and the local environment.

Within the **water** sector and relating to *affordability*, policy objectives focus on creating a market and stimulating competition to ensure that value for money is provided for the through efficient capital and operational costs by the utility.

Relating to *security of supply*, the policy objectives in the water sector relate to reducing demand or water and increasing the efficiency with which it is used; increasing network flexibility and capacity; increasing treatment flexibility and capacity; improved utilisation of raw water sources and raw water storage; upstream catchment management; and improvements in sludge disposal.

Around the *protection of human health and the local environment*, objectives relate to optimised drinking water quality; and optimal aquatic environments and bathing waters.

For the **energy** sector, *affordability* involves creating the right kind of market and competition, which may involve a number of measures relating to tariffs, price caps and taxation.
Security of supply (or resilience of energy service delivery) has objectives relating to demand reduction and efficiency; network flexibility and capacity; and generation capacity and diversity of supply.
Environmental sustainability within the energy sector involves decarbonising all forms of power; electricity, heat and transport.

For the **food** sector, *affordability* relates to the maintenance of a low cost to the consumer.
Objectives relating to *security of supply* include reduction in demand from consumers; increases in productivity (yield); increased economic viability of local production; improved nutritional quality of food; and improved access to international trade.
Environmental sustainability needs to prioritise reducing surface run off and its impact on the aquatic environment; reducing GHG emissions from farming practices; and recuing waste production.

4.7.2 Description of the policies targeted for recommendations

The south west UK case study is unique because the UK is in the process of leaving the European Union. Brexit is leading to significant policy revision across all nexus sectors (this is particularly evident in the food and agriculture sector) and it is likely to continue to do so for years to come. This is a factor affecting how policies are transposed and implemented at the regional level in the UK. Some national policies are partly implemented at the regional level. Common reasons for partial implementation include difficulties in the coordination of statutory bodies and across jurisdictions. Some problems encountered at the regional level include variations in the allocation of national funding, and where national policies do not sufficiently take local needs into account. The above mentioned and other sector-specific issues with policy implementation are discussed in detail in the sections below.

Water

In the water domain, SWW complies fully with national water supply regulations, and the quality of drinking water meets regulatory standards. However, the cost of this provision is among the highest in the UK. Stakeholders provided insights into the issue of water quality. Some noted that regulation to improve water quality in catchments enforced by the national Environment Agency can be at odds with cost efficiencies at the local level. This can lead to a negative policy cycle with the water utility in the middle, if there is limited dialogue. Another stakeholder commented that there is a disparity between how point discharge of wastewater and diffuse discharge from agriculture are regulated by the national regulator because the aggregated effect of numerous discharges is often greater than that from wastewater. The specific local conditions (agriculture is a major economic sector in the region) can create disparities across the country, with regions such as the south west uk being more challenged than others to meet nationally required standards. Finally, another stakeholder suggested that there might be confusion over how the 2018 amendment of the Water Supply (Water Quality) Regulations, which implement the Drinking Water Directive into UK law, will be enforced.

Energy and climate

The National UK Energy Strategy is assessed as partly implemented at the regional level although all legal obligations are met. There are issues of inertia in moving the energy system based on fossil fuels and nuclear to a more sustainable, flexible one. For this to happen, the governance system will need to shift from supporting fossil fuels to supporting a sustainable, smart and flexible energy system.

The Climate Change Act (HM. Secretary of State, 2008) is the UK's approach to tackling and responding to climate change. Legally binding carbon budgets set a cap on GHG emissions. However there has been no progress in reducing agricultural GHG emissions over the past six years (agriculture is a major industry in the region) despite the requirement of a 36% reduction in UK emissions from 2016 to 2030. Electricity emissions have reduced, but heat and transport remain stationary. In 2016, the government recognised that significant acceleration was required to ensure the UK can meet its legally binding targets under the Climate Change Act.

At the core of the Energy Act (HM. Secretary of State for Energy and Climate Change, 2013) is the need to ensure that, as older power plants are taken offline, the UK remains able to generate enough energy to meet its needs even if demand increases. Nationwide and in the South West there is energy system transformation happening offshore – with increasing amounts of offshore wind - at a local level. There is an abundance of generation from both solar and wind in the region and this offers the opportunity to lead to the development of new localised energy networks (LEMs). However, nuclear power poses issues to the UK in the transition to a smart and flexible energy system. Not only is it a very expensive source of low carbon power but having nuclear power on the system makes it harder rather than easier for system operation with a high proportion of renewables. The variable power renewables that the UK has in abundance (such as solar and wind) requires a system that complements rather than undermines variable power output. Stakeholders raised the issue of how work on the new Hinkley power plant on the region's border will compete with local energy markets.

Stakeholders also highlighted how drastic cuts to energy support mechanisms, in particular the Feed-in Tariffs scheme (FIT), had affected implementation at the local level. These low-carbon support mechanisms have been successful in promoting the development of renewable energy generation in the region, but the policy shift has had a detrimental effect on renewable energy businesses and community energy initiatives. One related outcome of this is that it has motivated community energy groups in Devon to return to their roots by doing more on energy efficiency, fuel poverty, and community engagement, using home visits, gardening, art, housing, and food to involve people in the energy debate.

Agriculture

In the agricultural sector there are problems related to agri-environment schemes, farming-related regulation, and rules for farmers and land managers to prevent water pollution and flooding.

Agri-environment schemes provide funding to farmers and land managers to farm in a way that supports biodiversity, enhances the landscape, and improves the quality of water, air and soil. The payments received from agri-environment schemes through the Countryside Stewardship Schemes and The Rural Development Programme for England (RDPE) 2014 -2020 are highly variable because they depend on the particular environmental assets on each farm and on which elements of the available schemes have been adopted by the farmer. Also, there has been a drop off in the South West region from farmers and land-owners signing up for these subsidies because of uncertainty post 2022 when current schemes will be replaced post-Brexit.

Farming-related regulation can also be difficult to implement because of a lack of coordination, through allocation of resources across the statutory bodies, and because of a lack of adequate funding for enforcement mechanisms.

Similar reasons constrain the implementation of rules for farmers and land owners to prevent water pollution and flooding, including a lack of coordination across relevant bodies to monitor pollution from farms, and a lack of coordination across jurisdictional boundaries between local authorities for flood prevention.

One of the major concerns at present in the agricultural sector is the uncertainty related to the Brexit process. The possible outcomes of Brexit were particularly significant for stakeholders in the agricultural sector and were causing high levels of uncertainty. Currently, public funding to farming is paid from the Common Agricultural Policy (CAP). This is due to change as the UK leaves the EU in 2020 all decisions over farm funding in England will revert to the UK government. Stakeholders reported indecision in the agricultural sector as businesses do not know the parameters for making business decisions and there is uncertainty about profitability. Concerns were also expressed that small farms, that are already struggling, may not survive further consolidation of land ownership.

Other interactions that came up included the challenges for innovation and entrepreneurism because of the enforcement of food and safety regulations in local food businesses that were often seen as too complicated, and issues associated with planning. How planning interacts with farm diversification is a significant area because planning restrictions can make alternative use of farm building unviable and in the tenanted sector, successful planning applications has meant that tenant farmers lose buildings to residential use. In addition, there were also conflicts between land use planning and renewable energy initiatives.

Finally, South West Water, the regional water provider, has recognized that it is cost effective and more environmentally responsible to help farmers deliver cleaner raw water (water in rivers and streams) than it is to pay for expensive filtration equipment required to treat polluted water after it is abstracted from the river for drinking. There is also recognition that this is highly effective and, as a consequence of this, the Upstream Thinking partnership was initiated with the aim of improving raw water quality and water storage in the natural landscape in order to make the provision of drinking water more sustainable.

Trade-offs energy-agriculture

The UK Renewable Heat Incentive (RHI) provides a financial incentive to promote the use of renewable heat and is a government scheme set up to encourage uptake of renewable heat technologies amongst householders, communities and businesses through financial incentives. The RHI subsidy has been widely taken up at the regional level but as stakeholders pointed out, there is also recognition that policy support for energy generation can affect conditions in the food system as bioenergy crops compete with the food and feed sector, and with issues associated with the appropriateness of land-use for growing such crops. This has impacted on wider environmental and sustainability systems in the region. One stakeholder noted that short-term policy inducements offered by financial incentives rather than a long-term view of the impacts were 'skewing the picture' and resulting in inevitable trade-offs. Two particular issues stand out:

1. Although there are good examples of maize being grown for animal feed, some farmers have grown more maize in order to claim the subsidy for bioenergy crops. This has positive and negative nexus implications because while it may generate energy, the production of maze has a high water/chemical demand and land can be left bare and subject to soil erosion. Farmers may also use land that could otherwise grow food and livestock feed;
2. Anaerobic digestion (AD) is being used to process green waste slurries, then in order to maximise incentives and waste heat is being used for other bio-mass burnings. Bio-mass technologies may or may not provide lower carbon sources of heat. They may also be producing heat to attract income rather than to fulfill a real need.

This has resulted in trade-offs as subsidies provided for feed-in tariffs for anaerobic digestion to promote renewable energy do not take efficiency of energy use (thermal, electricity etc) into account, including long-term impacts of contracts, how this fits with agri-environmental schemes, and rent rises in the tenanted farm sector when they cannot compete for over-priced land.

The South West region is relatively distant from other counties and waste that is generated in the regions needs taking care of in the region. This can be problematic in terms of meeting energy and waste targets (the EU Waste Directive 2018/851 stipulates that by 2025 no biodegradable waste, including food waste, should be sent to landfill) but this is also driving innovation, including the use of AD (supported by the government's 'Anaerobic Digestion Strategy and Action Plan' 2011). However, there is evidence that AD plants are under-used despite their efficacy for recycling food waste. One stakeholder suggested that local authorities need to be incentivised to implement a separate food waste collection service because the costs of additional food collections and treatment are outweighed by savings made by sending food waste to AD rather than landfill (thus saving on landfill tax). There are examples of these schemes being implemented successfully, e.g. Teignbridge Council, but this is not universal.

4.7.3 Policy recommendations

This document aims to articulate policy and governance for resource efficiency across the nexus in a low carbon world. Specifically, it addresses how policy framing, policy mechanisms and institutional change could support sustainable futures across all nexus sectors.

The following policy recommendations have emerged from both interviews with stakeholders and a detailed assessment of the different policy options that exist across the components of the nexus. These recommendations consider ways forward in order to optimise synergies through the ways in which we govern energy, water, agriculture and land use.

4.7.3.1 Changes in policy outputs

From trade-offs to net reductions

Policy outputs across the nexus sectors discussions around resource efficiency in the UK are often framed in terms of meeting environmental objectives while satisfying rising demand for resources, whether water, energy or food. However, assumptions around ever-increasing per-capita demand in all three areas need to be challenged. Gradually, discussions around the climate emergency and achieving net zero are challenging policy makers to make decisions in different sectors based on this move away from trade-offs to making net reductions. This quite radical change in the climate sector will necessitate a significant reduction in demand in the water, energy and food sectors.

In short	Demand reduction
Target group	Individuals and national and regional government
Target policy goal	To reduce/realign demand for water/energy/food
Target policy instrument	Ongoing creation of citizen assemblies in the UK will be central in ensuring that policy framing and implementation is aligned with values and interests of the general public. In energy, this may relate to guiding energy infrastructure pathways (particularly for heat and transport) away from those locking us into fossil-fuel dependency and towards electric and other low carbon pathways, and continuing momentum towards an increasingly decarbonised and flexible electricity system. In terms of food and food waste, policy should promote plant based diets across our school, hospitals and public offices, as well as the reduction, separation and sustainable processing of food waste. While in the water sector, we should be focusing on utilising rainwater for domestic water systems and leading by example in state owned buildings.

Target policy process phase	Debates through up-coming white papers to lead to debates around how responses to net zero will necessitate action around lifestyle change
Administrative level	National government, local government, communities
Time scale	Middle term until 2050 to establish new norms
Cost-effectivity	Policies involving the net reduction of resources tend to be some of the most cost effective
Social implications	Coupled with lifestyle changes and social/welfare policy to support those most in need, policies around demand reduction can have added value for health/well-being and social capital in communities

4.7.3.2 Changes in policy contents

Increasing tools for the nexus

A great deal of the academic insight into the nexus challenge has focused on where the nexus challenges lie and the potential conflicts and synergies that are likely to arise from increasing disciplinary linkages. Indeed, within this project the same has been done and our increasing knowledge around the nexus is allowing for an expanded and more diverse understanding of how nexus thinking can facilitate a sustainable and fair future. In order to operationalise the solution found within this document there needs to be an adequate approach from government using tools that can elicit the desired response from different stakeholders. The government needs to ensure that the time and space exists for actors to come together for the exchange of problems, ideas and data. Setting up active, monitored and inclusive working groups, across scales, that can manage the coordination of actors and stakeholders is therefore a must. Such working groups should facilitate the clear communication of goals, practices and data monitoring. Conversations with stakeholders in workshops revealed the complexities involved in facilitating the sharing of challenges, potential solutions and data and indeed, it has been noted elsewhere that improving data access and enhancing understanding of how the nexus emerges at different scales and within different sectors allows the creation of a framework or set of tools that enable the connections and interdependences to be reliably and robustly analysed (Scott & et al, 2018) Actors within sectors need to be held to account for their decision making regarding the nexus and this can only be done with greater transparency and communication.

In short	Tools for the nexus
Target group	National government; local government; private institutions, companies
Target policy goal	To increase data availability and coordinate nexus spaces
Target policy instrument	Companies/institutions regulated to ensure engagement in nexus space activities and compliance with data release
Target policy process phase	1-2 years
Administrative level	UK national government
Time scale	Middle term til 2050
Cost-effectivity	Medium cost both financially and administrative
Social implications	Increasingly linked nexus sectors and greater transparency

4.7.3.3 Changes in the policy process

Partnership working

The most successful example of the policy process taking place across nexus sectors in the South West has evolved from partnership working across more than one type of organisation (public, private and NGO) and across multiple sectors. A good example of this is the Catchment Sensitive Farming programme (CSF). CSF is a project run by Natural England in partnership with the Environment Agency and the Department for Environment, Food and Rural Affairs. Catchment Sensitive Farming (CSF) is an approach to farming in which subsidies / incentives and advice are given to farmers at the top of a river catchment to promote sustainable farming practices (e.g. decreased use of pesticides in sensitive areas; habitat restoration, etc) leading to improvements in water quality downstream. Upstream Thinking is a programme operating in Devon and Cornwall using a CSF approach, and includes restoration of peatland. Starting in 2006, the partnership is aimed at prioritizing catchments where agricultural practices are having the most significant impact on rivers, lakes and estuaries in the SW river basin. It has two aims (to save farms money with and to deliver environmental benefits) and provides practical solutions, targeted advice and capital grants.

Crucially, it is delivered in partnership format, spanning both scales of governance and geography. This brings together a central public bodies (Defra and Natural England) with a range of organisations operating across both national and local levels (e.g. the Environment Agency, the RSPB, the Rivers Trusts, the Wildlife Trusts, local industry and local farmers). Inclusion of a range of partners is critical in ensuring that issues within catchment systems are managed with the interests of all relevant stakeholders in mind.

Complementing the general principles of awareness raising, effective partnerships between CSFO officers and farmers and use of robust evidence is a flexible approach that emphasises the importance of local contexts in determining solutions.

As described in D2.2/2.3, the success of CSF is down to not only the partnership working but also the adequate and ongoing, stable funding mechanisms in place and the very supportive policy, political and organisational environment. To transfer the success of CSF to other areas there needs to be on-going engagement with stakeholders and assurance of longstanding and committed support, both financial and administrative. Task forces could be established to identify where such partnerships could be effective in all nexus sectors, as there is currently no body with whom such arrangements could naturally be formalized. CSF has evaluation as a core part of the project, essential for assessing delivery of objectives and benefits. There is evidence that this form of 'tailor made' approach can be rolled out nationally, when engagement and support is in place and an adequate number of significant stakeholders are engaged.

In short	Partnership working
Target group	National government/local government/stakeholders
Target policy goal	To increase the interaction between individuals/groups/communities working within nexus sectors and policy makers
Target policy instrument	Creation of task force to establish where partnerships could be formed
Target policy process phase	1-2 years and ongoing from there
Administrative level	Community, region, country wide
Time scale	Short term till 2030 with ongoing assessment of effectiveness
Cost-effectivity	Low cost and potentially high return
Social implications	Assisting in breaking down top down policy making and widening the input for new policies. Leading to greater communication and more considered and effective policies.

4.7.3.4 Changes in the science-policy interface

Cross-sectoral governance

Only with the appropriate administrative and political arrangements in place can decisions be made on how to optimise outcomes across nexus sectors. At the highest levels of policy decision making more focus needs to take place across sectoral divides, e.g. government departments, to avoid fragmentation of the decision making process and misinterpretation of policies by practitioners.

Development of nexus-sensitive policy framings that a) acknowledge the complexity of managing individual systems, b) accept the inevitability of unintended outcomes and c) set out clear principles for effective nexus governance are needed as a foundation. Again, strategic energy and food government white papers - as well as the sectoral challenges presented by Brexit - provide an opportunity for such framing.

Alongside more effective cross-departmental communication, there is a need for an appropriately placed cross-sectoral body to help understand, communicate and manage trade-offs and deal with the interactions of policies between nexus components. With ongoing innovation and change within food, water and energy sectors, a cross governmental body such as this will be well placed to foresee future challenges and risks between sectors and implement policies that allow for optimal outcomes for the nexus rather than maximum outcomes for a single sector alone.

Cross-scalar governance

The context specific nature of nexus challenges and responses means that the nexus-sensitive framings and principles set at a national level should be matched by appropriate local policy framings and responses. Stakeholders emphasised that engagement was necessary at multiple levels to avoid the feeling that decisions were taken behind the scenes. Indeed, learning around nexus-sensitive framings and responses within local contexts should be important in informing more generalised national-level framings and responses to key issues. Working across scales in this way will help to coordinate local visions and plans with national strategy, ensuring a more coherent approach to nexus issues.

The creation of regional or local nexus hubs could help improve dialogue between local and central stakeholders, and help to: ensure that national policy is translated effectively within local contexts; help to mediate sticking points between multiple policy and regulatory actors. These centres could be instrumental in acting as a hub for local stakeholders to coalesce around nexus challenges and solutions, and to access guidance and data support for cross-sectoral resource optimisation, and to consolidate stakeholder links (something that was highlighted in interviews) with local research communities (e.g. universities). They would also be responsible for the enforcement of national policy at regional levels.
Alongside this, it is vital not to forget that the current nexus conceptual framework is focused on one nation and more specifically a region within this country. Any nexus framings developed at this level must be sure to address the spatial separation between resource production and consumption. For example, changes to food practices in the UK relating to both production and consumption may have implications for other nations and the achievement of resource efficiency or SDGs within these countries.

In short	Interconnecting governance
Target group	National and local government
Target policy goal	To create structures for decision making that cut across sectoral and scalar divisions to enable more coherence and amongst nexus sectors
Target policy instrument	Creation of working groups to spread policy making both vertically and horizontally
Target policy process phase	To start within the year and with implications from 2-5 years
Administrative level	community, region, country
Time scale	short term till 2030 and ongoing
Cost-effectivity	Low cost

Social implications	Joining up people and ideas across scales will have time implications and logistically could be complicated at first, it should allow for greater coherence and satisfaction amongst both policy makers and the stakeholders within the nexus

4.7.3.5 Conclusion on coherent, Nexus-compliant policies

It is increasingly clear that the task of embedding nexus thinking into research, business and policy spheres needs to happen in order to help unify global challenges and provide coherency in aims within and between countries. Knowledge regarding the benefits, costs and challenges involved in nexus compliance is increasing in both the UK and further afield yet we are still somewhat lacking in solutions around how to operationalise nexus thinking on the ground. There is consensus that we need to be including nexus thinking into policy making yet how to 'bind or tie' (the Latin, nectare; to bind, tie] the sectors together in order to increase cooperation, coordination and policy coherence is not straightforward. Presented above are ideas on how policy and the processes of forming it need to adjust to increase coherency. However, it must be noted that meaningful collaboration will require increased time, expertise, understanding and coordination.

4.8 Conclusion

The case study began with a basic premise that; the demand for water, energy and food services within the region will inevitably increase with population; and, as temperatures rise and urbanisation increases, the growing demand will become more resource intensive and challenging to service.

The initial findings of the case study strongly indicate that with appropriate capacity expansion, technological efficiencies, and plausible behavioural change, these demands can be met. These findings, which were later supported by stakeholders and during further research, highlight the need for a new approach to resource management capable of considering otherwise ignored interconnections.

The case study has found that nexus-based approach does uncover hidden or poorly described interlinkages, supports examination of their relationships, and yields benefits on multiple levels.

At its most basic level, i.e. the creation of a region-specific conceptual model, the two major benefits are:

1. Engagement with stakeholders (direct interviews, written communication, attendance at events etc), expands the knowledge, challenges traditional thinking and creates cross sectorial dialogue of stakeholder,
2. Identification of the unique challenges in the region, supporting more informed policy creation.

At the deeper levels facilitated by dynamic modelling and simulation, the approach begins to evaluate interventions and their impacts to macro resource management and policy coherence. No previously available tool, or assessment framework made this possible, which demonstrates the unique value of the project.

The nexus challenges explored in the UK case study centre around the priorities of the resource trilemma; security of supply, equality and environmental sustainability, with a view to achieving a mutually acceptable outcome. This was not explicitly intended at the start of the project but emerged as a logical consequence during the research and modelling stages.

Balancing these three objectives yields almost infinite potential outputs, it is therefore necessary to narrow the scope within the trilemma by selecting a constraint metric. The most versatile and easily understood metric, which facilitates a common means of evaluation across the sectors, is money. While both security of supply and environmental sustainability, are equally important, they are inherently more difficult to evaluate and require greater prior understanding from the user. Further justification is that security of supply and environmental sustainability require financing in order to happen, on that basis the financial element has been built as a core component of the SDM.

The development of the financial element proved to be extremely challenging, culminating in a set of modules equalling in complexity to the rest of the whole nexus model. The financial modules are designed to be independent of the activity they evaluate making duplication across all sectors and technologies possible. This functionality is of special value to commercial users such as utilities, and adds another unique feature, of this south west case study.

The stakeholders have been invaluable to the project, providing a broad range of perspectives from across the sectors. However, engagement from central government, or policy makers, would have been very useful, and might have led to further exploitation of project deliverables. Every attempt has been made to ensure that goals from across the nexus have been equally considered, but this has been influenced by stakeholder engagement, (or the lack there of). The abundance of data available from South West Water, in contrast to the other sectors, has inevitably resulted in a water utility centric view of the nexus. We consider this to be a major strength of the project, as the provision of drinking and wastewater services naturally demonstrate real world application of the nexus principles.

The use of thematic models has been challenging, as such they have only been utilised to a quite limited extent. It was discovered toward the start of the project that there would be gaps between capabilities of the thematic models and that potential challenges might arise from: spatial or temporal alignment between the models; implementing policy scenarios uniformly across the models; and reconciling contradictory or divergent outputs. These technical challenges were largely bypassed by using only a single run and a limited number of data points from the two thematic models that were used. This was justified by three drivers; 1. the number of polices under investigation, and resultant complexity; 2. The desire to create user bespoke policy scenarios; 3. The inability to implement a dynamic feedback relationship between the thematic models, based on user inputs.

The core technique of system dynamics has all the requisite functionally to develop a model as complex as that of the WEF nexus, it has greatly aided the expansion of the conceptual model and having now come to the end of the model development, it seems difficult to think of a tool other than SDM that is as well suited.

Several runs of the SDM have shown that; 1. environmental sustainability and resource management objectives can easily be reached if no attention is paid to cost, and; 2. least total cost solutions can be found if interventions are maximised in hierarchical order of behaviour>efficiency>capacity.

The nexus/SDM approach is well matched to the analysis of policy objectives, coherence, and resource management (which is particularly relevant to the UK case study). Additionally, the SDM environment made it possible to develop financial tools within the same model, significantly expanding the nexus approach and supporting investment decisions by utilities. It is hoped that with further calibration of the input data many aspects of the UK nexus SDM will be used to inform South West Waters ongoing business planning reporting obligations and stakeholder engagements.

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4.10 Annexes

4.10.1 Conceptual model

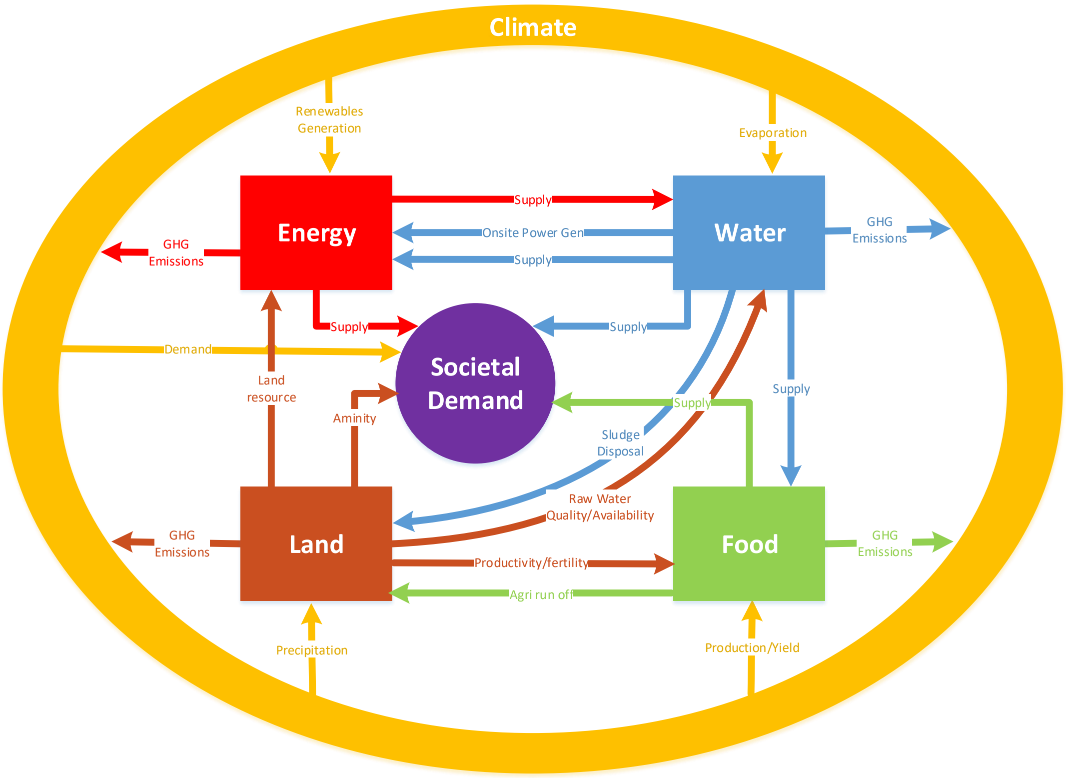


Figure 22 High level conceptual model

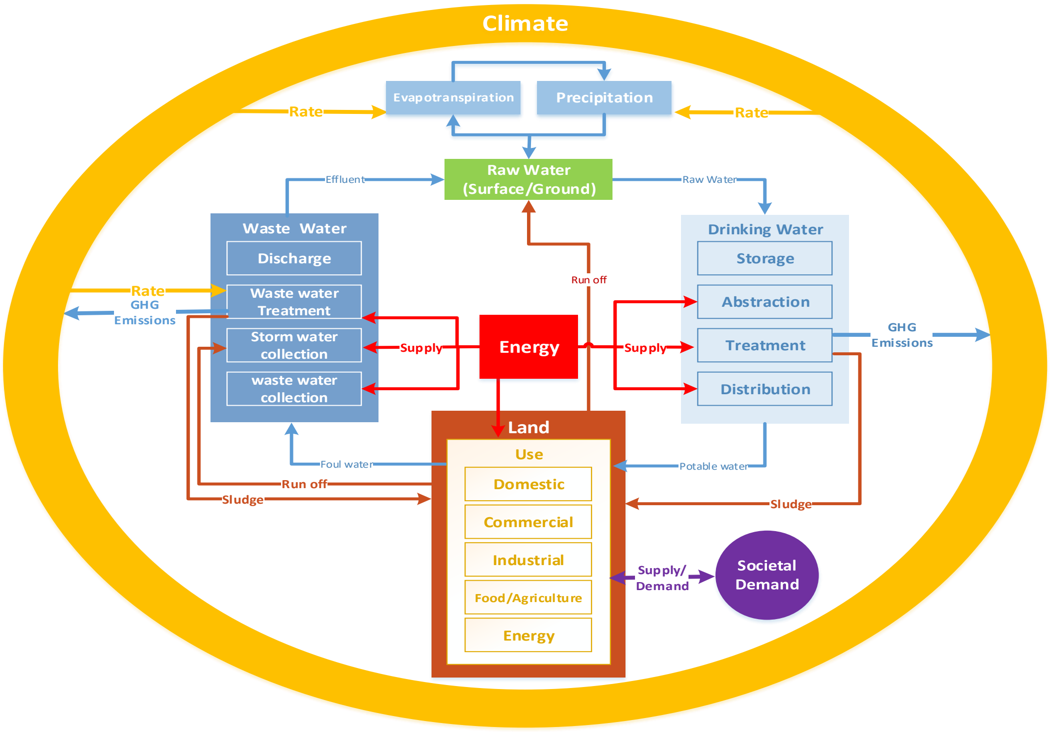


Figure 23 Conceptual model of water module

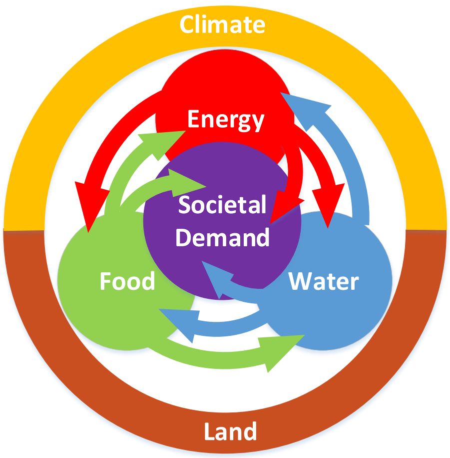


Figure 24 Simple context nexus

4.10.2 SDM screenshots

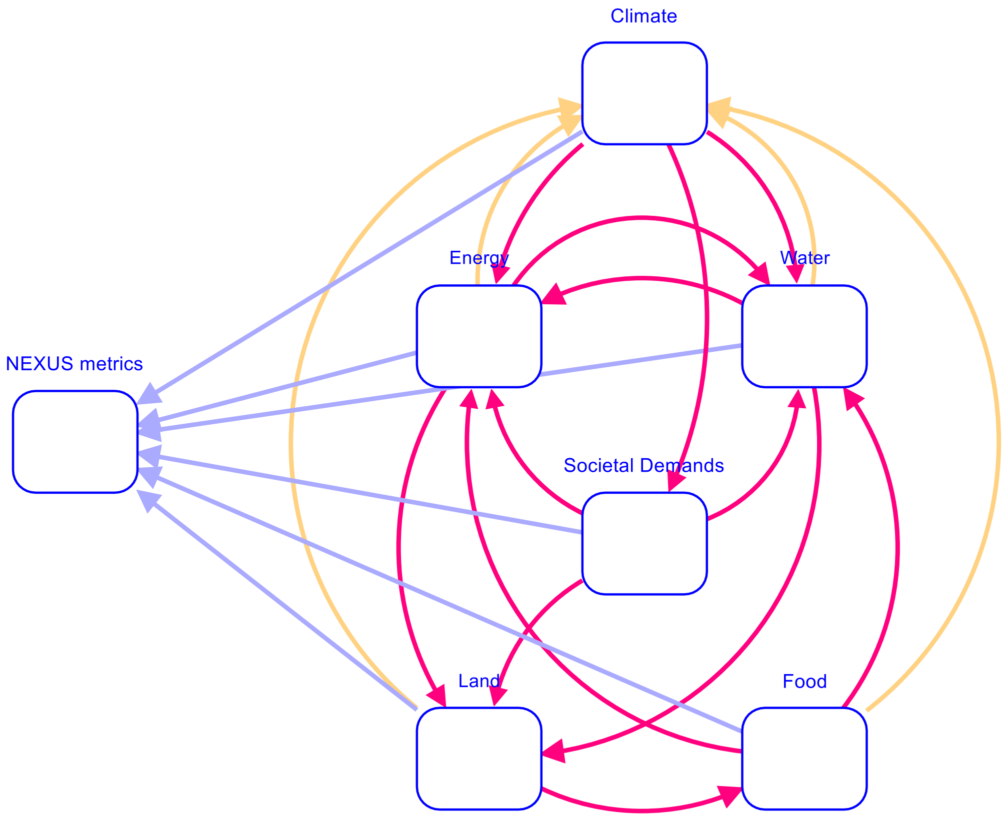


Figure 25 Main nexus model (view from with Stella Architect)

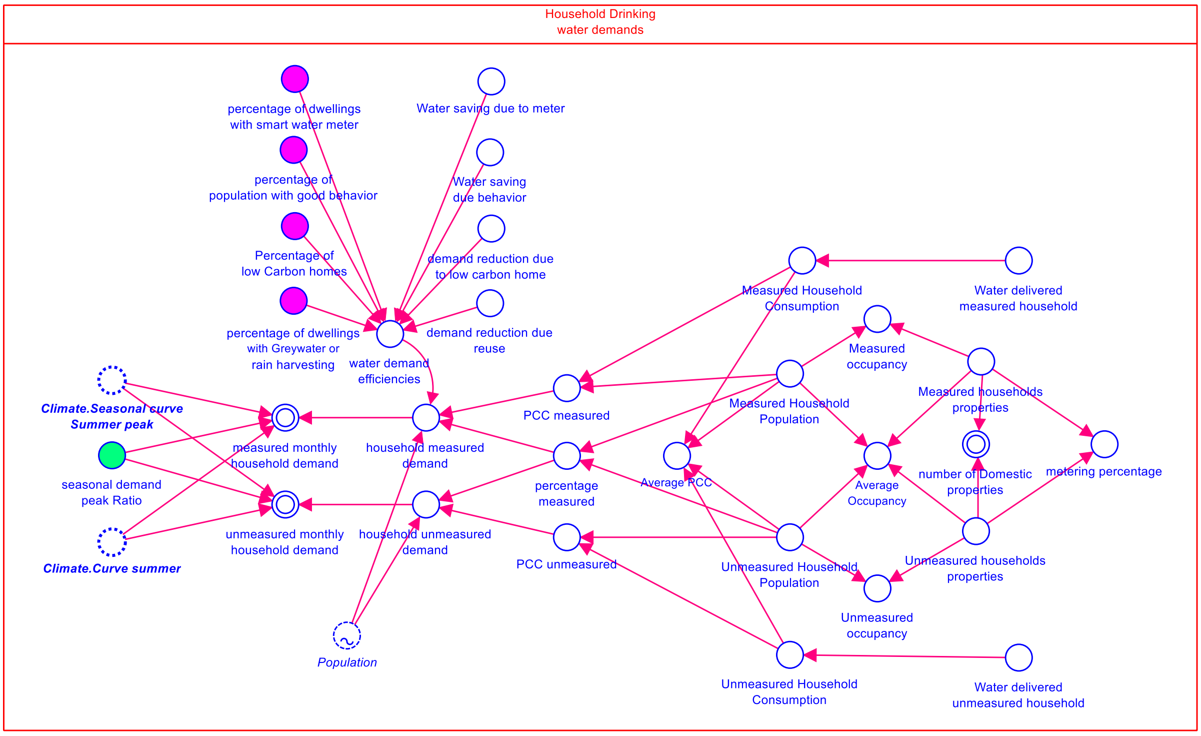


Figure 26 Household drinking water demands

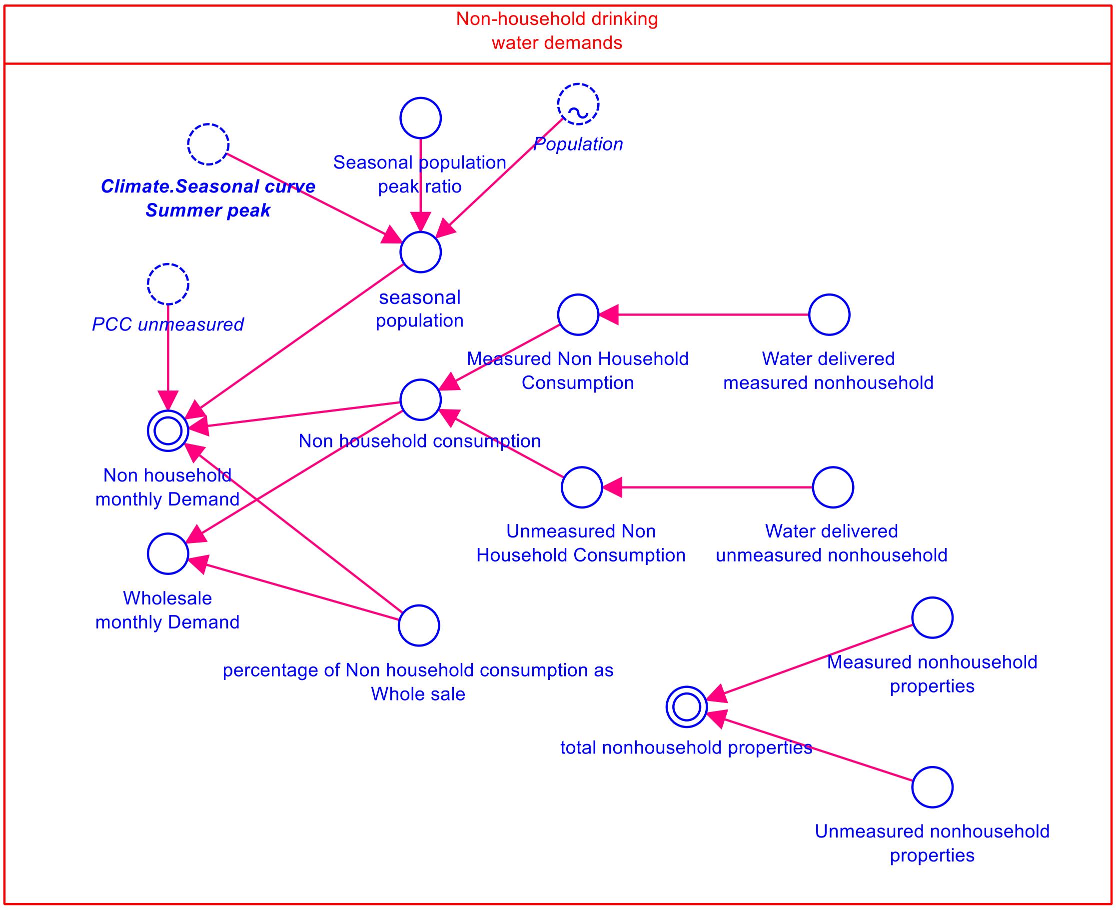


Figure 27 Non-drinking water demands

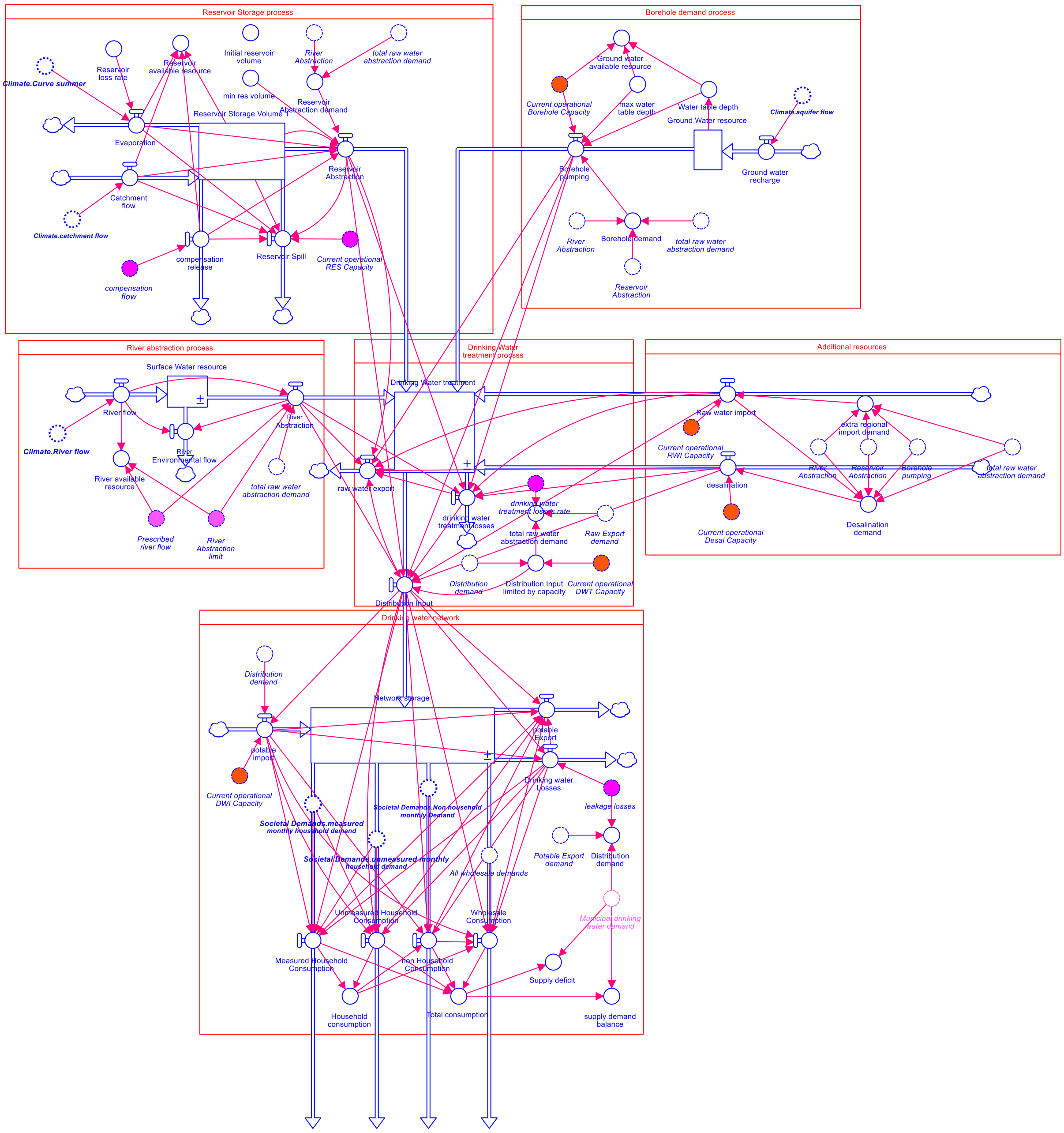


Figure 28 Drinking water processes

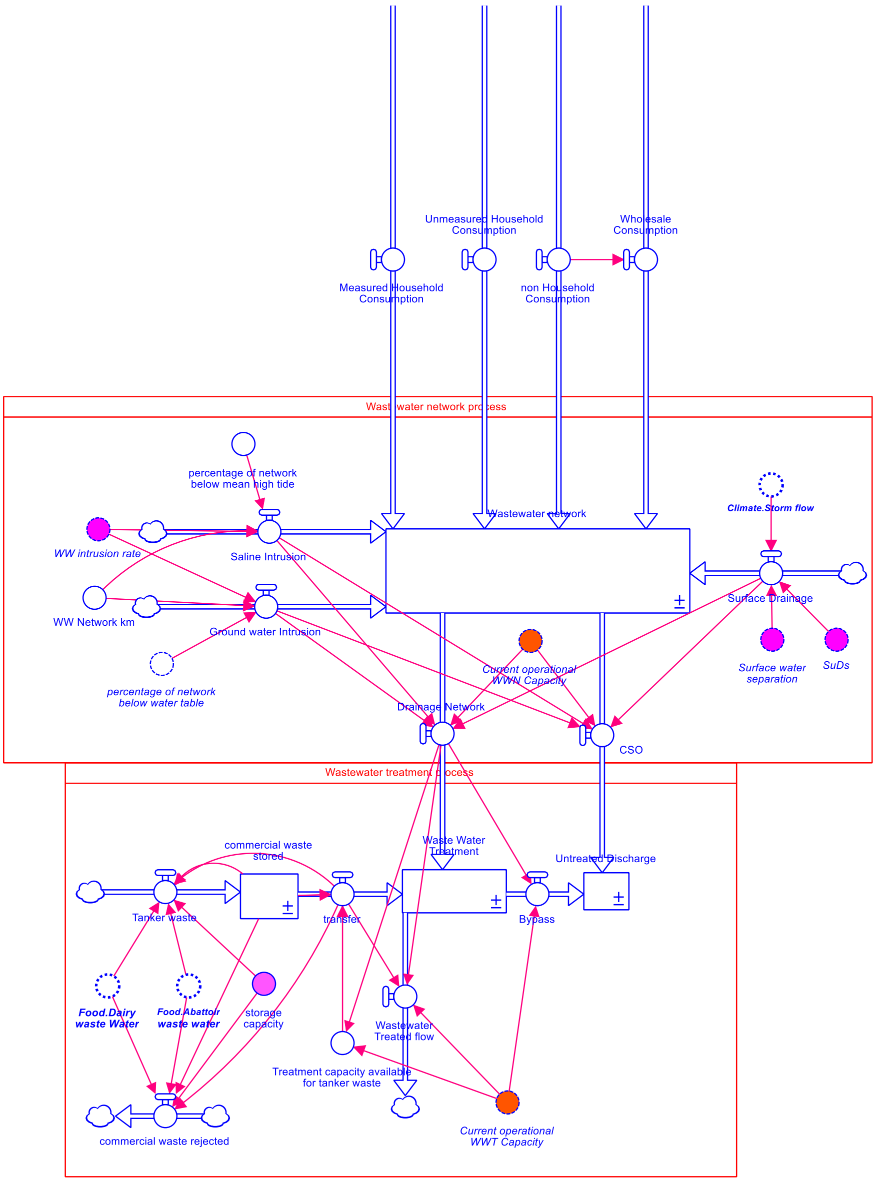


Figure 29 Wastewater processes

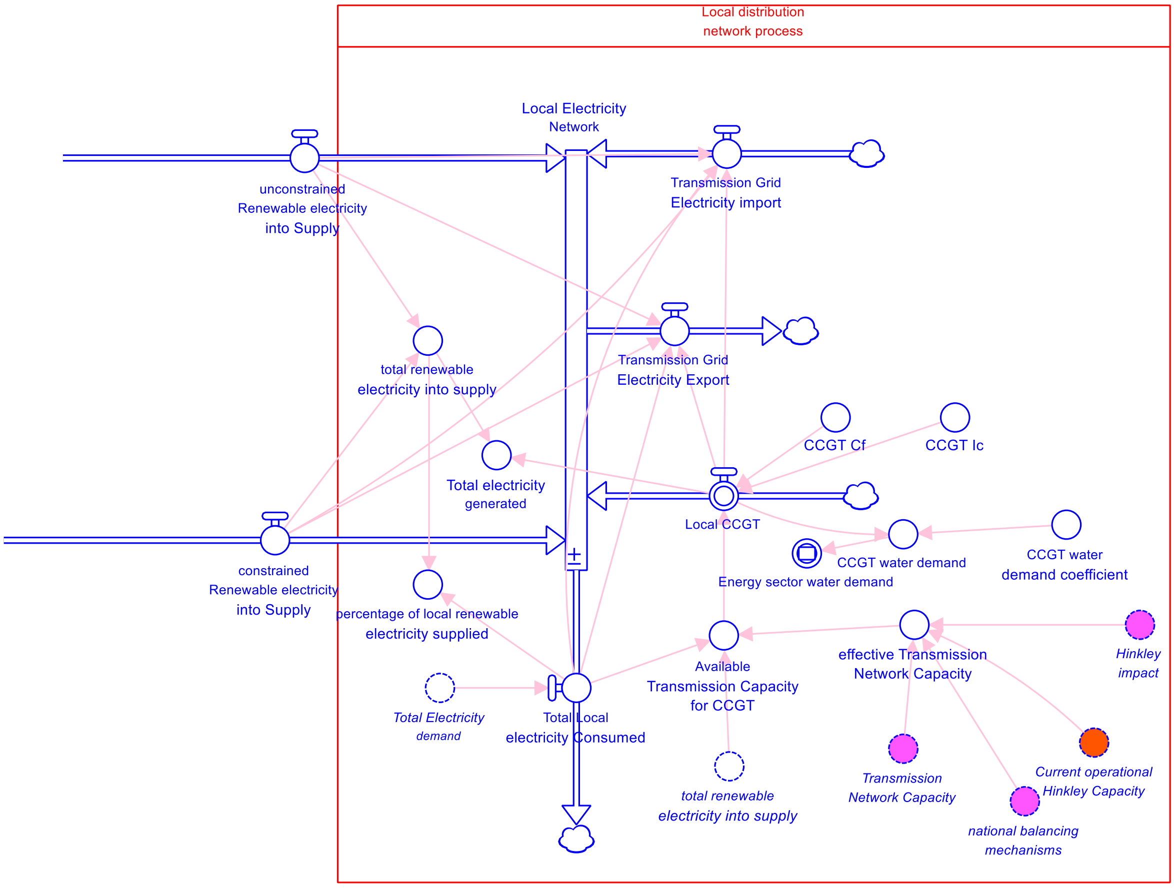


Figure 30 local distribution network process

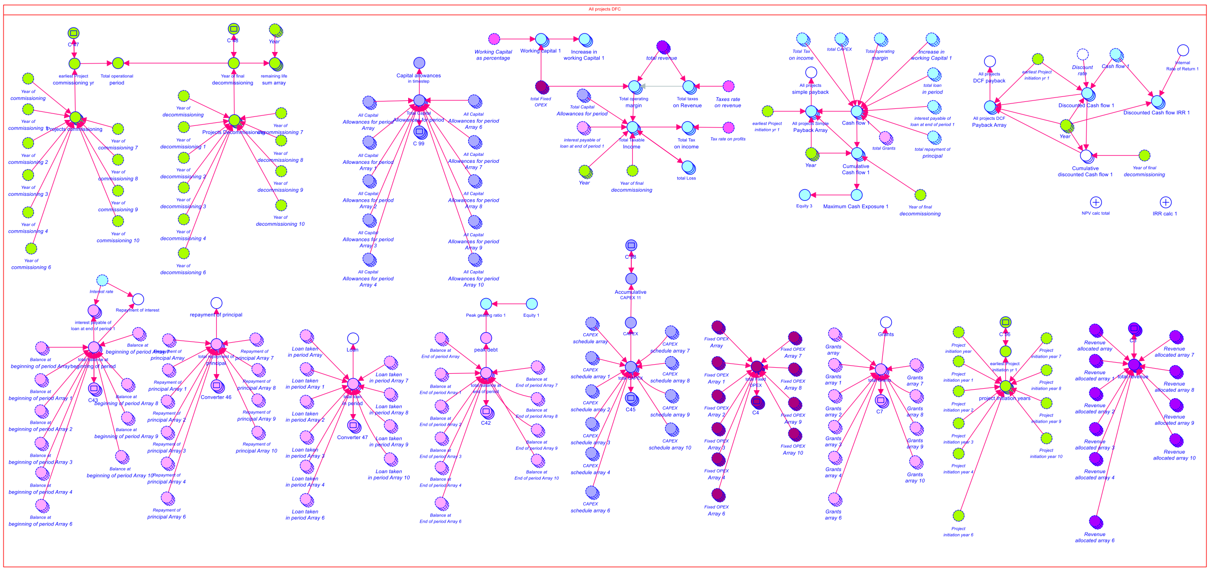


Figure 31 Discounted Cash Flow

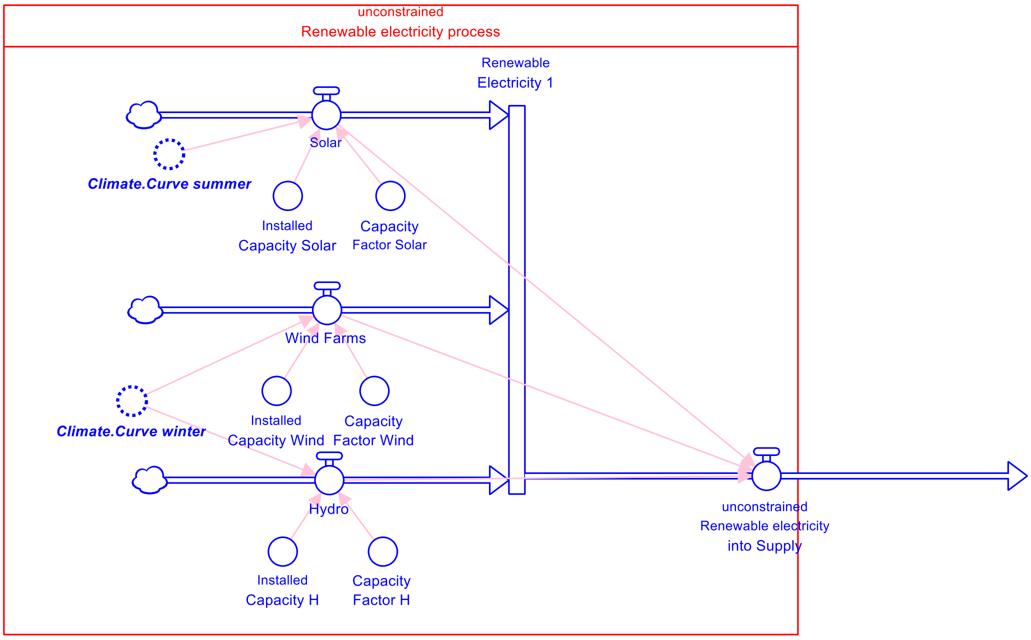


Figure 32 unconstrained renewable electricity process

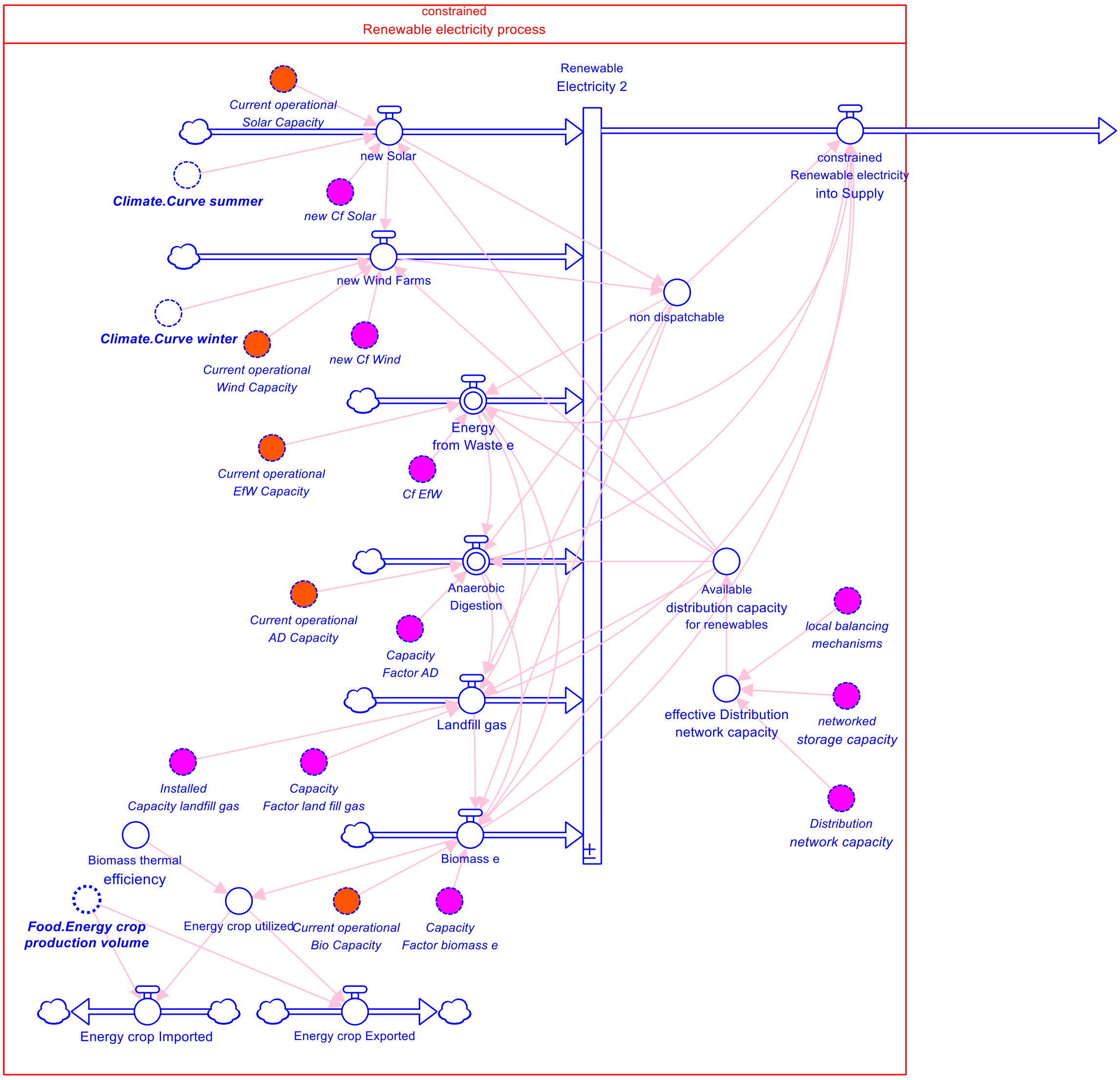


Figure 33 Constrained renewable electricity process

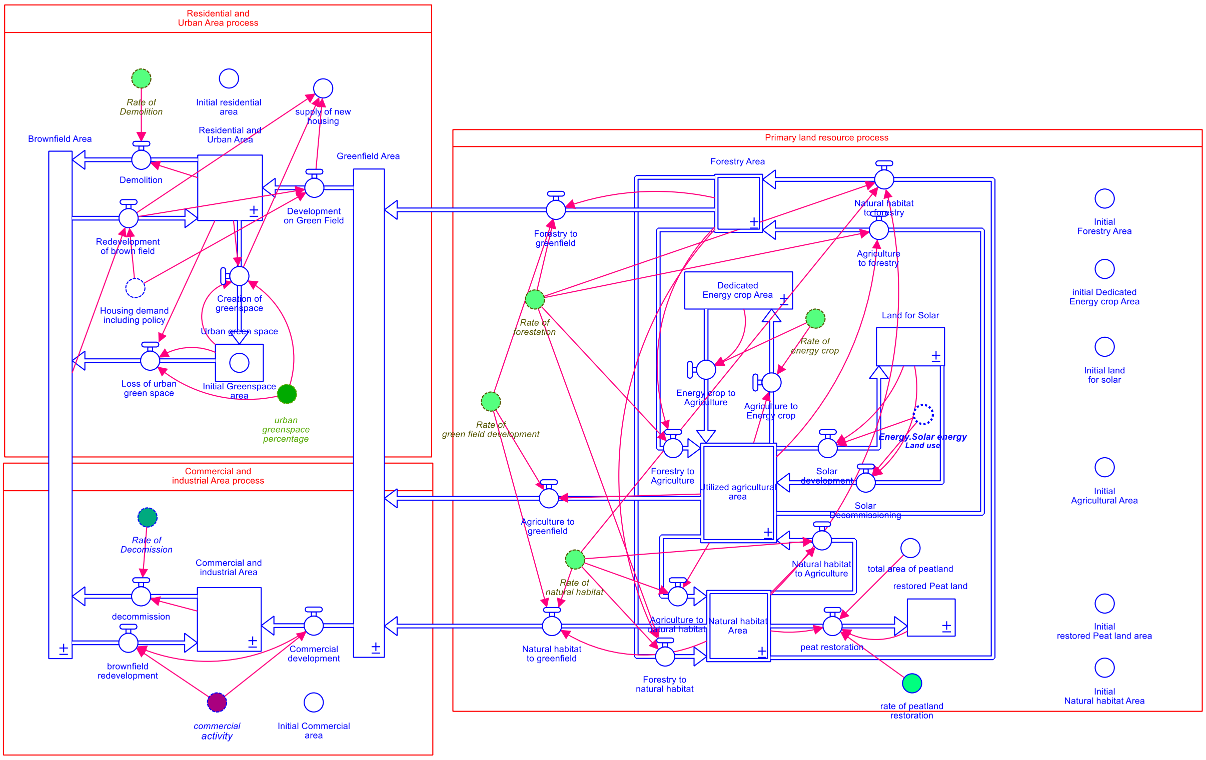


Figure 34 land use processes

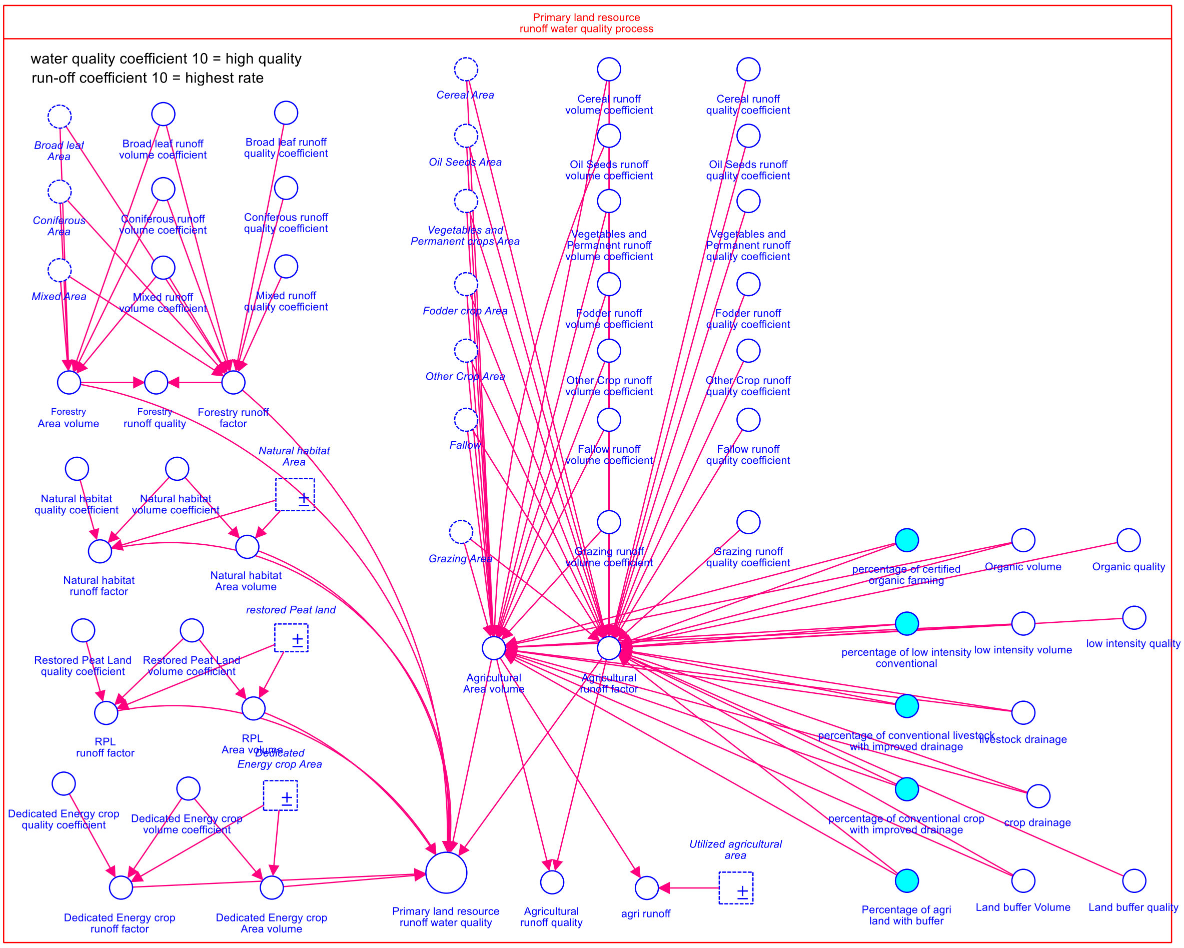


Figure 35 Surface run-off and raw water quality

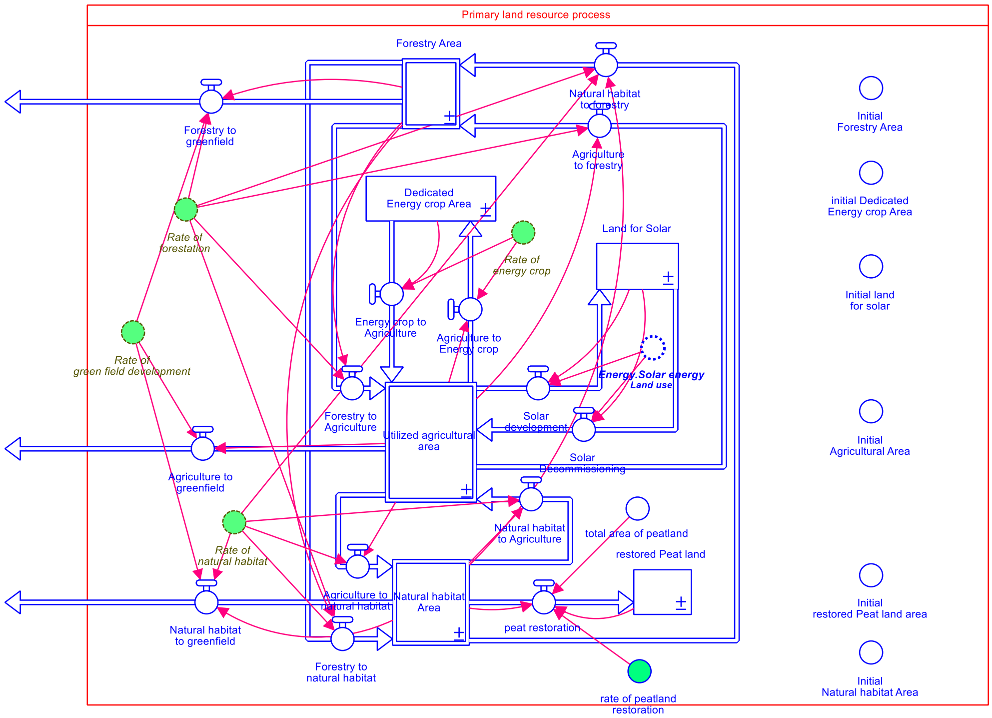


Figure 36 Primary land resource process

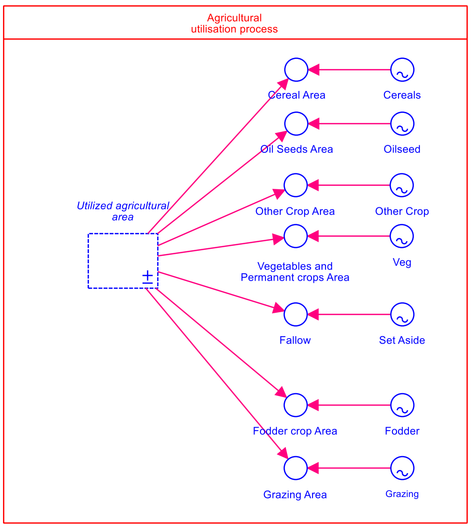


Figure 37 detailed agricultural utilisation from CAPRI data

4.10.3 Use cases

USE CASE W.1	Water
Related Learning Goals	Security of supply: Reducing demand for drinking water entering municipal supply, thus offsetting the need for increased capacity.
Goal	Demand Reduction
User	Public and Private Sector: Economic regulator, Utility providers
Actions	O1- Water saving in households: ➢ PC Next Gen smart meters, ➢ PC Water Efficient devices in homes, ➢ PC Domestic Grey water reuse and rainwater harvesting, ➢ PC Education and behavioural change programmes to reduce water consumption, O2- Reducing losses of drinking water within the supply chain: ➢ PC Reduction in treatment losses, ➢ PC Reduction of leakage from the drinking water distribution network.
Indicator	I1- Change of per capita drinking water consumption, I2- Change of ratio between raw water abstraction and drinking water consumption.

USE CASE W.2	Water
Related Learning Goals	Security of supply: Enabling the drinking water and wastewater supply chain to respond to external shocks and pressures, while maintaining service.
Goal	Flexibility and Security
User	Public and Private Sector: Economic & Environmental regulators, Utility providers.
Actions	O3- Ensure adequate water resources to meet drinking water demand: ➢ PC Interregional connection of drinking water resources, ➢ PC Sea water Desalination for drinking water, ➢ PC sustainable Surface water abstraction for drinking water, ➢ PC Use of boreholes and ground water resources for drinking water, ➢ Building new raw water reservoir storage, O4- reduce dependence on external energy supply: ➢ PC Increase use of self-generated renewable energy; Hydro and CHP, ➢ PC Energy efficiency of drinking and waste water treatment and transmission, O5- Ensure adequate capacity within the urban water cycle to meet demand

	➢ PC Improve drinking water and wastewater network capacity, ➢ PC improve Drinking water and wastewater treatment capacity. ➢ PC Separation of foul water and rainwater drainage systems, ➢ PC use of Sustainable Urban Drainage systems,
Indicator	I3- Change of ratio between drinking water entering supply and available raw water resource, I4 - Change of ratio between self-supply of electricity and gross demand of electricity, I5- Change of ratio between demand and capacity of drinking water / wastewater supply chains

USE CASE W.3	Water
Related Learning Goals	Environmental Sustainability: minimising the production of waste products requiring disposal to land and the associated emissions.
Goal	Waste Reduction
User	Public and Private Sector: Economic & Environmental regulators, Utility providers
Actions	O6- minimising the production of waste products requiring disposal to land and the associated emissions: ➢ PC Sewage sludge Incineration, ➢ PC Sewage Sludge Advanced Anaerobic digestion, ➢ PC Sewage Sludge Pyrolysis
Indicator	I6- Change of sludge volume produced per capita, I7- Change of ratio between sludge volume produced and disposed to land.

USE CASE W.4	Water
Related Learning Goals	Environmental Sustainability: Maintaining or improving drinking water and wastewater quality.
Goal	Protection of human health and local environment
User	Public and Private Sector: Economic & Environmental regulators, Utility providers
Actions	O7- Improve drinking water quality: ➢ PC Increase drinking water quality standards, O8- Improve river water quality: ➢ PC Increase wastewater effluent standards,
Indicator	I8- Change of ratio between drinking water quality and target, I9- Change of ratio between wastewater effluent quality and target.

USE CASE E.1	Energy
Related Learning Goals	Security of supply: Reducing demand for electricity entering municipal supply, thus reducing need for increased generation or transmission capacity
Goal	Demand Reduction
User	Public and Private Sector: Economic regulator, Utility providers
Actions	O9- Improving the efficiency of energy use in households: ➢ PC Next generation smart metering, ➢ PC Low carbon homes, ➢ PC Behavioural change programmes to encourage demand reduction O10- increasing the use of renewable energy in households: ➢ PC Domestic scale self-supply of renewable energy,
Indicator	I10- Change of per capita electricity demand consumption I11- percentage of domestic dwellings with self supply

USE CASE E.2	Energy
Related Learning Goals	Security of supply: Enabling the energy supply chain to respond to external shocks and pressures, while maintaining service.
Goal	Flexibility and Security
User	Public and Private Sector: Economic regulator, Utility providers
Actions	O11- ensure adequate capacity within the energy supply chain to meet demand: ➢ PC Distributed Electricity Storage, ➢ PC Electricity Network capacity reinforcement, O12- Improve the management flexibility of the energy distribution system to meet demand: ➢ PC Transition of Distribution Network Operator to Distribution System Operators, ➢ PC Support for greater Demand Side Management.
Indicator	I12- change of ratio between energy storage capacity and distribution network capacity I13- change of ratio between electricity demand and distribution & transmission network capacities.

USE CASE E.2	Energy
Related Learning Goals	Security of supply and (Global) Environmental Sustainability: reducing the carbon emissions associated with the generation and supply of electricity.
Goal	Decarbonisation of Electricity Supply
User	Public and Private Sector: Economic regulator, Utility providers
Actions	O13- Increasing the proportion of low carbon energy with the supply: ➢ PC Greater deployment of commercial scale onshore Wind Energy, ➢ PC Greater deployment of Biomass fuelled Electricity Generation, ➢ PC Greater deployment of commercial scale Solar PV, ➢ PC Development of Hinkley Point Nuclear Energy plant
Indicator	I14- change to tCO_2e per MWh electricity supplied. I15- change to the ratio between renewable electricity supplied and total electricity consumed

USE CASE L.1	Land
Related Learning Goals	Environmental Sustainability: Ensuring that the local environment and human health is protected.
Goal	Maintain and improve the natural capital of the region
User	Public and Private Sector: Environmental regulator, water Utility providers, local authorities
Actions	O14 – protection and creation of forests and woodlands. ➢ PC Reforestation, O15- protection and creation of wetlands and peatland restoration, ➢ PC wetland, O16- Protection and Creation of other natural habitats ➢ PC Natural habitats,
Indicator	I16 -ratio between total land area and forestry area I17 -ratio between total land area and wetland area I18 -ratio between total land area and other natural habitats area

USE CASE L.2	Land
Related Learning Goals	Environmental Sustainability: reducing the total volume of waste disposed to landfill and the associated environmental impacts.
Goal	Minimisation of waste to landfill
User	Public and Private Sector: Environmental regulator, local authorities
Actions	O17 – Waste recycling. ➢ PC increase recycling capacity, O18- Green Waste composting, ➢ PC Increase composting capacity, O19- Energy from Waste ➢ PC increase capacity of energy from waste facilities,
Indicator	I19 – change of ratio between total waste produced and waste disposed to landfill I20 -reduction of waste to landfill per capita

USE CASE L.3	Land
Related Learning Goals	Environmental Sustainability: Improving the urban environment to provide greater public amenity.
Goal	Improvement of the Urban environment
User	Public and Private Sector: Environmental regulator, Utilities providers, local authorities
Actions	O20 Increasing access to green spaces. ➢ PC creation of urban greenspace, O21- Increasing housing stock ➢ PC Increase demolition rate ➢ PC increase housing density,
Indicator	I21 – change of ratio between urban green space and residential area I22 - change of ratio between actual housing density and target housing density

USE CASE A&F.1	Agriculture and Food
Related Learning Goals	Environmental Sustainability: minimise negative impacts of agriculture to the local environment and improve biodiversity
Goal	Sustainable Agriculture
User	Public and Private Sector: Environmental regulator, Utilities providers, Farmers associations
Actions	O22 Improve biodiversity & Reduce agricultural chemical demand ➢ PC Agricultural deintensification ➢ PC Organic farming ➢ PC catchment sensitive farming

Indicator	I23- ratio between sum area of agricultural land modified by above PCs, and total area of utilised agriculture.

USE CASE A&F.1	Agriculture and Food
Related Learning Goals	Environmental Sustainability: Reduce surface run-off arising from agriculture thus protecting aquatic environment
Goal	Protect aquatic environment and raw water quality
User	Public and Private Sector: Environmental regulator, Utilities providers, Farmers associations
Actions	O23 Reduce agricultural run-off ➢ Improve natural drainage on agricultural land ➢ Enclosed animal pens with drainage control ➢ Implement green belt land buffers
Indicator	I24- ratio between initial rate of agricultural run-off and modified rate of agricultural run-off

4.10.4 Policy cards

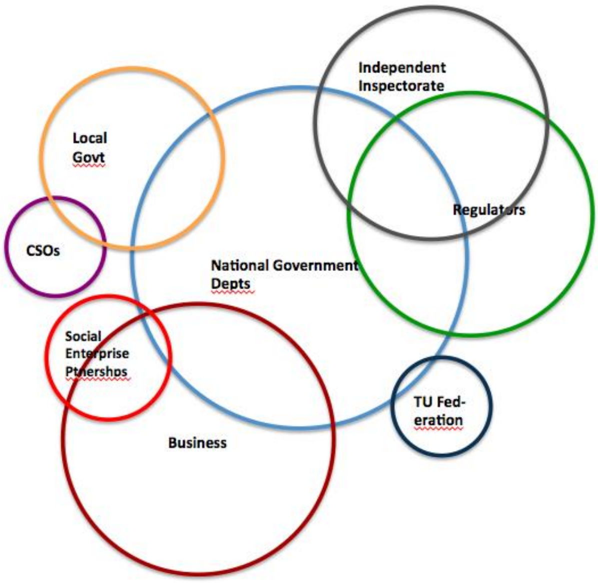
Nexus Sector	***Very short policy card name***	***Description of intervention as captured by the policy card***
Energy	Smart metering	Smart metering designed to give the householder more detailed information on their energy use and technically compatible with upcoming household energy technology
Energy	efficient homes	Legislating for new homes to be low carbon, energy and water efficient and climate resilient. Closing the performance gap between stated design standard and actual performance.
Energy	Behavioural change	Encouraging new practices through legislation, information, and behavioural economics
Energy	Domestic Renewable energy	The use domestic scale renewable energy on homes
Energy	Electricity Storage	Removing barriers to deployment for battery technologies and assisting innovation around storage
Energy	Network capacity	Substantial investment in network capacity to better deal with the two way flow of electricity
Energy	DNO to DSO	A DSO model will allow greater management of the generation and consumption of energy across the network
Energy	DSM	Implementing standards for smart appliances and mandating suppliers to offer time varying tariffs and DNOs to accommodate for DSR in network planning
Energy	Onshore Wind	Strong policy and financial support for lowest cost, least risk renewables
Energy	Biomass Electricity	Strong policy and financial support for lowest cost, least risk renewables
Energy	Solar Farms	Strong policy and financial support for lowest cost, least risk renewables

Energy	Nuclear Energy	Financial support and government backing new nuclear power stations
Nexus Sector	***Very short policy card name***	***Description of intervention as captured by the policy card***
Land	Reforestation	Implementing woodland creation grants to plant trees, build 'leaky dams' and restore heather moorland
Land	Peat land restoration	Agri-environment schemes to encourage wetland creation by land management changes that can result in increased temporary storage
Land	Habitat protection	Increased designation of protected natural habitats to avoid loss from changing farming practices, expansion of transport networks, urban development and mining and quarrying
Land	Recycling	Increase recycling efforts, update and increase the UKs recycling infrastructure and legislate against the use of non-recyclable items
Land	EfW	Planning for and approving a further number of incinerators with which to deal with increasing amounts of waste
Land	Composting	Implement drivers to encourage local authorities to invest in increased garden waste collection where it does not already happen
Land	AD	Encourage local authorities to collect food waste for anaerobic digestion
Land	Housing Demolition	The rate at which the existing housing stock is demolished ready for redevelopment
Land	Industrial decommissioning	The rate at which the existing commercial and industrial premises are demolished ready for redevelopment
Land	Green Field development	The transition of undeveloped greenfield land to developed land
Land	commercial stimulation	Stimulation to the economy driven by tax breaks or incentives, enabling accelerated development
Land	housing density	The number of dwellings per hectare of residential area
Land	Green space	The percentage of the urban and residential area used for open green spaces such as parks
Food	agricultural deintensification	Reducing the density of crops and livestock
Food	Organic farming	Stimulate demand for organic produce through public procurement in the health sector and schools and promote community supported agriculture schemes that provide open access and exposure
Food	catchment sensitive farming	Work with farmers to introduce careful nutrient and pesticide planning
Food	Energy crops	Transition of agricultural land to dedicated energycrop cultivation
Food	Natural Drainage	Incentives for the establishment of hedgerows, the creation of natural buffer zones and overland flow ponds

Food	Drainage control	Introduce mandatory requirements that ensure all pens and drains do not result in contaminents entering natural watercourses
Food	Land buffers	Install more measures to protect waterways from pollution by the installation of natural buffer zones
Nexus Sector	***Very short policy card name***	***Description of intervention as captured by the policy card***
Water	Smart metering	Smart metering designed to give the householder more detailed information on their water use.
Water	Water efficiency	The deployment of water efficient devices in the home to reduce domestic water consumption
Water	water reuse	The deployment of grey water recycling devices and rain water harvesting in the home to reduce domestic water consumption
Water	behavioural change	Encouraging new practices through legislation, information, and behavioural economics
Water	treatment losses	A reduction of drinking water used during the treatment process
Water	leakage reduction	Reducing leakage within the drinking water distribution network
Water	network capacity	Increase the capacity of the water distribution network to ensure continual supply
Water	Dual Drainage	Separation of the drainage network into storm water and foul water flows to improve operational efficiency
Water	SUDS	Deployment of Sustainable urban drainage technologies
Water	Treatment capacity	Increasing the capacity of drinking water and wastewater treatment
Water	Water Trading	Import and export of raw water resources into the region
Water	Desalination	Use of desalination plant as alternative raw water source
Water	sustainable abstraction	Limitations to the abstraction of surface water to ensure protection of the aquatic environment
Water	Ground water abstraction	Increased use of ground water sources
Water	Reservoir expansion	Building new reservoirs to store raw water
Water	onsite renewables	Increase the proportion of electricity generated on site using renewable energy technologies
Water	Energy efficiency	Increase the efficiency of treatment technologies for both drinking water and wastewater.
Water	Sludge incineration	Disposal of Sewage sludge via incineration
Water	Sludge to land	Disposal of Sewage sludge to agricultural land
Water	Sludge Pyrolysis	Conversion of sewage sludge into biochar fertiliser
Water	Effluent standards	Increasing the quality of wastewater effluent discharge to the environment
Water	Drinking water quality	Improving drinking water quality

4.10.5 Stakeholders maps

Figure 38 Stakeholder map for South-west England



Legend:
CSOs – Community Supported Organizations
Source: (Smith, Hole, Petersen et al 2018 p.38)

5 Greece

5.1 Introduction

Greece is located in the South-Eastern part of Europe (Figure 39). Its area is about 131,957 km^2 and its population is close to 10.8M inhabitants. The Aegean Sea lies to the East of the mainland, the Ionian Sea to the West and the Mediterranean Sea to the South. Greece has the longest coastline in the Mediterranean Basin (approx. 16,300 km) and more than 5,000 islands (227 inhabited). The major economic sectors supporting national GDP are agriculture and tourism.

Figure 39 Map of Greece

The case study lead organisation is the University of Thessaly (UTH). The engaged stakeholders in this national level case study were representatives of public and private organisations, NGOs and academic/research institutes. Among the main ones are: the Ministry of Environment and Energy, the Ministry of Infrastructure and Transport, the Ministry of Tourism (General Directorate of Tourist Policy), the Piraeus Bank, Greenpeace Greece, WWF Greece, The Greek Ombudsman, The School of Mechanical Engineering (NTUA) and the Department of Planning and Regional Development (UTH), the Hellenic Association for Cogeneration of Heat and Power, the National Cadastre and Mapping Agency S.A., etc. The nexus domains addressed include: water, energy, food, climate and land. Agricultural and tourist sectors were also taken into consideration as they put additional pressures on all nexus components. The main nexus challenges for the Greek case study were:

- Reduction of GHG emissions
- Reduction of coal and oil demand for energy generation
- Increased RES share in the national energy mix
- Production of qualitative agricultural and dairy products
- Rational management of water resources by the agricultural sector (irrigation)

- Mitigation of climate change impacts
- Increased adaptation ability and resilience against climate change
- Regulation of land uses
- Production of bio-fuels
- Energy prices
- Exports and imports of energy

Such challenges correspond to all nexus sectors involved and reflect strategic priorities and policy perspectives aiming at the sustainable future development of Greece, the rational use of resources and the establishment of a low-carbon economy. The main nexus question summarising all these challenges and also reflecting the learning goals of the Greek case study is: "How national policies in the domains of water management, renewable power production, and land use affect each other and result in changes in food production, tourism, greenhouse gas emissions, and quantity-quality of water resources?" The issues set in this question have been addressed through the exhaustive analysis of physical interlinkages existing among the nexus components, the analysis of policy coherence as to the nexus-related policies, the development of the Greek SDM and the design of relevant policy cards. The Greek SG will deal with all the aforementioned issues and shed light on the validation of policy recommendations and the elicitation of new ones.

5.2 Overview of tasks performed

5.2.1 Organisation to carry-out Task 5.2

To carry out Task 5.2, a large group of people was mobilized from UTH. The organization split the group in two teams, one based in Volos, Greece and the other based in Athens, Greece. The 'Volos' team was in charge of the modelling activities and was comprised by 4 people, while the 'Athens' team had 2 people that were in charge of the model conceptualization, the stakeholder involvement and the policy analysis. The two teams worked closely and complemented each other in various levels, such as contacting national-level stakeholders to collect data, implementing policies in the SDM, using software tools, such as ArcGIS to disaggregate data, etc.

The UTH team was also in close collaboration with many partners in the consortium, in the framework of the Greek case study. The latter was decided to proceed in a "fast-track" mode, meaning that it is the case study that would advance first on all fronts, all the way to completion, in order to act as an example for the other cases and deal with all issues that come up. The knowledge acquired by the Greek case study has been and will be used by all partners in the consortium, in order to set up the other case studies. The connection between the data, the modelling and the policies via the implementation of policy cards in the Serious Game were all set up for the first time and was tried out by the Greek team, following almost a trial and error approach, since this was all completely new and experimental. There was a lot of knowledge acquired from this process; mostly through recognizing that one route would not work and that another route should be investigated. The result was a lot of back and forth and a massive effort for the UTH team, which lead however to a good paradigm for the rest of the case studies to follow and a much shorter process. The Greek case study was instrumental in developing the methodology and standardization for the development of the rest of the case studies.

Communication within the Greek team was daily, while communication with the rest of the partners was done mostly through the SIM4NEXUS WP3/WP4 teleconferences, organized by UNEXE, where all case studies were present and a lively discussion was conducted on issues that were being faced, while results from the Greek team were presented. The interactions within WP3/WP4 were very transdisciplinary and this had a strong benefit for all of us, since it promoted the "nexus" thinking and helped us see that not all disciplines perceive the same problems and solutions in a similar way—this knowledge facilitated communication with our stakeholders.

5.2.2 Schedule of Task 5.2

Task 1.2: "Use cases for SIM4NEXUS" (leading partner: UTH) initiated in October 2017 and still continues to evolve. It concerns mainly the design of generic use cases that fits to all case studies and also use cases proposed by each case study based on their main learning goals defined in Task 4.1. Use cases define in detail the interaction between the user/actor and the serious game. Each use case needs the specification of a goal which has to be accomplished by the user/actor through the game steps by applying a definite number of actions. Firstly, generic use cases for the SIM4NEXUS serious game were developed and presented in D1.2: "Use cases for SIM4NEXUS". Case-specific use cases are proposed by each case study (D1.6: "Use cases for SIM4NEXUS case studies"). D1.6 is expected to be submitted to EC by the end of March 2020.

Task 2.2: "Review of nexus-related policies for each national and regional SIM4NEXUS case study" (leading partner: UNESCO-IHE). This task has been carried out from January 2017 until July 2018. It concerned the analysis of nexus-related policies and the elicitation of nexus critical policy goals and interventions that would be linked to the SDM and introduced in the serious game in the form of policy cards. Policy coherence was also assessed and deviations from the nexus rationale have been identified. Stakeholders, representing also possible future players of the serious game, supported the whole effort by offering additional knowledge and expertise. A systematic analysis of policy documents led to the elicitation of nexus-related policy objectives and instruments in Greece. The coherence between policies, among policy objectives and between objectives and policy instruments on the water-land-energy-food-climate nexus for the case of Greece, was also assessed (Papadopoulou et al, 2020[9]).

Task 2.3: "Spotlight on policy success stories" (leading partner: PBL). This task was carried out between January 2018 and December 2018 by PBL. Policy synergies, such the one in the Greek CS, between the Ministries of Energy and Environment and Foreign Affairs (Directorate of International Energy Issues) support arrangements related to energy efficient and climate change adaptation plans at national level.

Task 2.5: "Policy recommendations for a resource-efficient and low-carbon Europe" (leading partner: PBL). This task started in July 2019 and will be finalised by the end of the project (May 2020). It concerns the development of policy recommendations by each case study, targeting at improving national-level policies. EU policy recommendations will also be introduced. Policy recommendations will be elicited by playing the game and assessing the outcomes resulting from the implementation of policy cards. Policy recommendations for the case of Greece were mainly focus on the sufficient food production including the availability of freshwater for irrigation purposes and also further exploitation of RES in electricity production and not only.

[9] Papadopoulou C.A, M.P. Papadopoulou, C. Laspidou, S. Munaretto & F. Brouwer (2020), "Towards a Low-Carbon Economy: A Nexus-Oriented Policy Coherence Analysis in Greece", Sustainability, Vol. 12, Issue 1, https://doi.org/10.3390/su12010373

5.3 Engagement of stakeholders in the process

5.3.1 Overview of stakeholders' engagement in the case study

A critical number of stakeholders, representatives of public and private organisations, NGOs and academic/research institutes were involved in the Greek case study. They supported: the definition of the most important nexus challenges, the policy analysis process, the assessment of policy coherence among policy goals and between policy goals and policy instruments, as well as the identification of trade-offs and arrangements taking place during policy implementation. They also contributed to the design and validation of policy scenarios designed for the Greek case study. Bilateral interviews took place and a workshop was organised in order to elicit knowledge, exchange views, clarify misunderstandings and identify stakeholders' preferences as to the nexus issues going to be addressed by the Serious Game. Their influence on nexus-related decision making processes and policy design was explored along with their interests in managing several nexus components. Emphasis was put on investigating possible conflicts and alliances that may be developed among them. The latter may exist when stakeholders have common interests and goals whereas conflicts arise when stakeholders have contradicting agendas and/or use the same scarce resources for achieving their objectives.

Each stakeholder, according to their interests and means of power, plays a differentiated role and has a respective influence on the process of policy institution. Ministries occupy a prevalent role in the decision making and policy design process while the business sector is mainly interested in the terms and conditions defined in policy papers in order to make investments and implement their plans. NGOs act as lobbyists while academic/research institutes are engaged as consultants in policy design in order improved policies to be issued. The outcomes of stakeholders' analysis process are briefly delineated in the next table.

Interactions with stakeholders	Date Location	Number of participants and indicative distribution by nexus sector	Topics discussed	Outcomes / Achievements
Interviews	09/03/2017 Ministry of Environment and Energy: Directorate for Climate Change and Atmosphere Quality	4 Climate	• Policies for climate change, adaptation and mitigation • Impacts of climate change in Greece • Most vulnerable regions • Policy goals and instruments for managing climate change impacts	Key policies, already designed or under consultation, for the management of climate change impacts were identified. Relevant policy goals and instruments as well as EU climate policy framework were also discussed.

Interactions with stakeholders	Date Location	Number of participants and indicative distribution by nexus sector	Topics discussed	Outcomes / Achievements
Interviews	17/03/2017 Athens Labour Unions Organisation: Department of the Environment and International Relations	1 Climate Water Land Energy	• Environmental impacts on employees (urban scale) • Sustainable development policies • Waste management	Environmental impacts on employees were identified. Critical environmental impacts mainly affecting cities were also discussed.
	24/03/2017 Hellenic Association of Photovoltaic Energy Producers (SPEF)	1 Energy	• RES share in the national energy mix • Energy produced by PVs – Relevant national goals • Participation of SPEF in policy design processes concerning the sector of energy	The contribution of PVs to energy production and relevant future perspectives were discussed.
	27/03/2017 Ministry of Foreign Affairs: Directorate of International Energy Issues	1 Energy Climate	• Political diplomacy in the sectors of energy and climate • Bipartite, regional and international energy issues • International cooperation on energy and climate issues	International collaborations of Greece with respect to energy and climate issues. Issues related to EU energy policies, cohesion among policies, climate migrants and SDGs.
	28/03/2017 Piraeus Bank	4 Land/Agriculture Food/Agriculture Energy	• Investments in the agricultural and agri-food sectors • Investments in the energy sector • Funding schemes • Risk assessment	Issues concerning agricultural entrepreneurship and preconditions (terms and conditions) for investments in the energy and agricultural sectors. Green banking issues.

Interactions with stakeholders	Date Location	Number of participants and indicative distribution by nexus sector	Topics discussed	Outcomes / Achievements
Interviews	04/04/2017 Ministry of Tourism: General Directorate of Tourist Policy	2 Tourism Land	• Re-design of the specific legislative framework of spatial planning and sustainable development for the tourist sector • Tourist policy framework and its inter-relations with other nexus-related policies • Land use conflicts between tourist and agricultural sectors • Alternative tourism	Priorities set for the future development of tourism were clarified. Emphasis on: tourist entrepreneurship, tourist training and the development of alternative and sustainable tourist activities.
	04/04/2017 Multi-shareholders company: “Monopati-Monakrivo”	3 Agriculture Food Energy Water Land	• Production of high-quality and certified olive oil • Smart agriculture (energy and water saving) • Land use conflicts between agriculture and livestock	Emphasis on agricultural training. Promotion and trading of certified olive oil.
	18/05/2017 Hellenic Public Power Corporation S.A. (PPC)	2 Energy Climate	• National energy planning • Environmental policies • Connection of the islands to the national transmission network	Issues concerning the national energy goals toward 2030 were clarified. Also, issues concerning the reduction of coal and the increase of RES for electricity production.

Interactions with stakeholders	Date Location	Number of participants and indicative distribution by nexus sector	Topics discussed	Outcomes / Achievements
Interviews	23/05/2017 The Greek Ombudsman	3 Energy Climate Food Land Water	• Environmental democracy • Policy practices and policy implementation	Issues concerning trade-offs and arrangements during policy implementation were clarified.
	13/09/2017 NTUA: School of Mechanical Engineering	2 Energy Climate	• Energy strategy • Energy saving in buildings • EU policies for energy and climate	Issues concerning energy efficiency and contribution of the building sector in this goal. Implementation of EU policies at the national scale and expected effects.
	20/09/2017 Ministry of Infrastructure, Transport and Networks: Special Office of Public Works, Construction & Maintenance of Hydraulic Infrastructures	1 Water	• Water used for irrigation • Environmental flow • Municipality water supply • Water use conflicts	Sectors with competitive water uses were identified. Seasonality of water demands was also discussed.
	05/10/2017 National Documentation Centre: National H2020 Contact Point	1 Energy	• Research on energy issues • Support of business sector and research institutes on energy issues • Knowledge dissemination	Technologies supporting energy efficiency and sustainable energy planning in Greece were identified. Progress on research concerning RES.
	10/10/2017 Hellenic Association for Cogeneration of Heat and Power	1 Energy	• Geothermy • Cogeneration technologies • Energy saving	Use of cogeneration on greenhouses. Costs of relevant technologies. Penetration of cogeneration technologies in the Greek energy market.

Interactions with stakeholders	Date Location	Number of participants and indicative distribution by nexus sector	Topics discussed	Outcomes / Achievements
Interviews	24/10/2017 National Cadastre and Mapping Agency S.A.	1 Land	• Development of the Greek Cadastre	Land use conflicts among nexus sectors were identified.
	09/11/2017 Mills of Crete	1 Food	• Agri-food production	Issues concerning processing and certification of agricultural products were clarified.
	13/12/2017 WWF Greece	1 Water Land Energy Climate	• Suggestions of WWF Greece for climate change, biodiversity, CAP • Participation of WWF Greece in the design of the Presidential Decree for wetlands	Activities of WWF Greece aiming at the protection of natural resources.
	10/01/2018 Greenpeace Greece	1 Energy Food	• Energy saving • Food safety – Agricultural products • RES	Activities of Greenpeace Greece aiming at the protection of natural resources.
	05/03/2018 University of Thessaly: School of Planning and regional Development	1 Land	• Spatial planning policies • Land use conflicts • CAP	Identification of problems during the implementation of land policies. Policy gaps concerning land use management were also discussed.
	02/05/2018 Ministry of Environment and Energy: Directorate of Spatial Planning	3 Land	• Spatial planning policies • Land use conflicts	Identification of existing land use conflicts. Priorities for land use regulations.

Interactions with stakeholders	Date Location	Number of participants and indicative distribution by nexus sector	Topics discussed	Outcomes / Achievements
Survey	20/02/2019 Via e-mails	6 key stakeholders Water Energy Land Climate Food	Policy cards and relevant feedback	Stakeholders validated the content of policy cards and suggested some issues to be added. Policy cards were re-considered and issues mentioned by stakeholders were added.
Workshop n°1	23/06/2017 Zappeion, Athens	About 20 Water Energy Climate Food Land	• General framework and goals of SIM4NEXUS • Nexus components and interlinkages • Conceptual model • Presentation of Aqua Republica as an indicative case of a Serious Game • Water demand for irrigation – Waste of water in agricultural sector • Need for training activities in the agricultural sector • Smart agriculture • Water and energy pricing • Environmental training • Proactive planning • Development of the industrial sector • Bioclimatic infrastructures in the tourist sector	Stakeholders expressed their views and expectations as to the Serious Game. They mentioned indicative issues they would like to explore through the Serious Game. They also gave feedback as to the nexus-related policies and priorities for the future. Interlinkages among the nexus components were clarified.

			• Energy autonomic habitats • Implementation of SDGs • GHG emissions and EU policies	
Workshop n°2	It was planned for April 2020 due to current circumstances is postponed – Presentation and testing of the SG			

5.3.2 Feedback on stakeholders' engagement in the case study

Stakeholders engaged in the Greek case study have a deep knowledge background on the management of the nexus components as well as on the design and implementation of nexus-related policies. Their contribution was substantial as they supported the policy inventory stage, the suggestion of policies that should be embodied in the Serious Game and the identification of trade-offs and arrangements taking place at the implementation level. The overall process of involving them in the project and analysing their influence and interests as to the nexus issues worked well. However, stakeholders' engagement and analysis of the relevant feedback is a rather time-consuming process. The generation of valid and useful outcomes presupposes the collaboration of several stakeholders that should tune their actions and cooperate. Thus, despite their willingness to participate their time availability is often limited.

The majority of them were fully committed on the subject addressed and willing to inform the research team on any issue discussed. Face-to-face interviews took place at the time and place of their preference and each of them lasted about an hour. Most of stakeholders, prior to the interview, asked for a brief agenda of the issues going to be discussed in order to prepare relevant material. During the interviews, they responded to our questions and highlighted important issues that we should take into consideration. Moreover, they proposed possible other stakeholders that could be engaged and offer an additive value in the Greek case study. Stakeholders represented all nexus domains being experts on water, energy, climate, food and land issues. They are experienced scientists and professionals in organisations involved in decision making processes or interested in the terms and conditions setting the framework for the implementation of investments in the nexus domains.

During the first workshop, they expressed their interest in the trans-disciplinary approach adopted for analysing the nexus and they mentioned the effectiveness of such an approach at both policy-making and implementation level. They asserted that a nexus-oriented perspective can effectively correspond to the future challenges concerning the management of climate change impacts, the rational use of water resources, the low-carbon energy transitions, the promotion of food safety and the regulation of land uses. They also underlined the need to incorporate the nexus approach in the design of future policies based on the interlinkages existing among its components. Moreover, they mentioned that the benefits of a nexus perspective are of high importance as the nexus reflects all complex inter-relations existing among the components of modern physical/socio-economic systems. Each stakeholder expressed a high interest on the nexus components being more relevant to their expert area as well as on the inter-related components. A fruitful discussion took place and participants exchanged views upon the several nexus issues. The research team elicited knowledge and identified possible conflicts and synergies among stakeholders.

Regarding the interviews, there was not any difficulty in organising them and discuss with the stakeholders. As to the workshop, the only difficulty we had to deal with was the availability of stakeholders at the same day and time. Fortunately, the majority of them responded to our invitation.

Generally, stakeholders participate in the project voluntarily. They offer valuable information, essential for the successful accomplishment of many tasks. However, they need to dedicate time of their business day whenever their contribution is needed. This is an inhibitory factor for some of them who finally decide not to be engaged in the participatory process. Maybe some key stakeholders should be partners of the consortium of a future project proposal in order to dedicate more time in the relevant tasks.

5.4 From conceptual models to System Dynamic Modelling

5.4.1 Case study conceptual model

All critical interlinkages among the several nexus components were graphically described via the development of a conceptual model representing the main nexus issues in Greece. Its design was mainly based on literature review concerning the exploration of all possible interlinkages existing among the nexus components. An exhaustive investigation of such interlinkages took place and a list of interactions between pairs of nexus components was created. Apart from pairs of components, higher level interactions among three or four nexus components were explored. Internal discussions among the members of the Greek team offered an added value to the design of the conceptual model due to the expertise of each member and the relevant experience on several nexus issues concerning the Greek CS. Also, the engaged stakeholders played a substantial role during the conceptual model design process by unfolding new ideas and highlighting additional interlinkages that should be taken into account. Nexus-related policies and strategic priorities aiming at the sustainable development of the nexus in Greece were also considered.

Emphasis was placed on the proper and explicit design of the conceptual model as it would serve as a guide for the development of the System Dynamics Model (SDM). Thus, the conceptual model includes the five nexus components (water, energy, climate, food, land) identified in the case of Greece as well as the inter-relations existing among these components. It is presented in Annex 1. It should be mentioned that except for the general framework of the conceptual model, four sub-models (one per each nexus sector) were constructed providing more detailed information about the specific inter-relations that each nexus sector has with the rest. Among the key interactions included in the conceptual model are:

- The energy used for pumping (Energy-Water).
- The energy used for desalination purposes (Energy-Water).
- The exploitation of water resources for energy production from hydro-electric power plants (Water-Energy).
- The water demands by several land uses (Water-Land).
- The impacts of land uses on water quality (Land-Water).
- The demand of land for food production (Land-Food).
- The CO_2 emissions by several land uses/activities (Land-Climate).

5.4.2 Modifications introduced to model policy scenarios

5.4.2.1 Development of policy scenarios for the case study

About 30 policy scenarios have been developed for the Greek case study. The design of policy scenarios was based on SDM structure, strategic policy priorities, policy goals and policy instruments concerning the development of the nexus sectors up to 2050. The complete list of such policy cards is presented in the next table.

Nexus Sector	Policy Scenario	Policy Scenario – Short Name
Water	Adoption of new (alternative) irrigation methods – Change of irrigation systems	Irrigation technologies
	Diversification of crops – Cultivation of crops that are resilient to drought (less water demanding crops)	Crop types
	Water saving in households by using water saving equipment, changing consumption behaviour, etc.	Water savings in households/hotels
	Reuse of water in the industrial sector (recycled water)	Water reuse in industry
Climate	Reduction of GHG emissions derived from non-ETS sectors (agriculture, non-ETS industry, etc.) through the adoption of relevant technologies (e.g. technologies that reduce CO_2 emissions) – 2020	Non-ETS emissions reduction (2020)
	Reduction of GHG emissions derived from ETS sectors (e.g. power generation sector) - 2020	ETS emissions reduction (2020)
	Reduction of GHG emissions derived from non-ETS sectors (agriculture, non-ETS industry, etc.) through the adoption of relevant technologies (e.g. technologies that reduce CO_2 emissions) – 2030	Non-ETS emissions reduction (2030)
	Reduction of GHG emissions derived from ETS sectors (e.g. power generation sector) - 2030	ETS emissions reduction (2030)
	Reduction of GHG emissions derived from non-ETS sectors (agriculture, non-ETS industry, etc.) through the adoption of relevant technologies (e.g. technologies that reduce CO_2 emissions) – 2050	Non-ETS emissions reduction (2050)
	Reduction of GHG emissions derived from non-ETS sectors (agriculture, non-ETS industry, etc.) in order to achieve zero emissions by 2050	Zero non-ETS emissions (2050)
	Reduction of GHG emissions derived from ETS sectors (e.g. power generation sector) in order to achieve zero emissions by 2050	Zero ETS emissions (2050)
	Protection of forest land, wetland, grassland and crop land (e.g. land use regulations, effective confrontation of forest fires)	LULUCF sector
Energy	RES share in the transportation sector by 10% until 2020: use of bio-fuels (biomass)	RES transportation
	Promotion/Use of biomass in the industrial sector	RES industry
	Promotion/Use of biomass in the household/commercial sector	RES household/commercial
	Promotion/Use of biomass in the agricultural sector	RES agriculture
	Promotion/Use of biomass in other sectors	RES other sectors

	Electricity generation from PVs up to 2500 MW until 2020	PVs electricity
	Electricity generation from wind up to 7500 MW until 2020	Wind electricity
	Electricity generation from hydro-power plants up to 3000 MW until 2020	Hydro electricity
	Electricity generation from biomass power plants	Biomass electricity
	Further promotion/use of RES for electricity generation	RES electricity (2030)
	Promotion/use of natural gas in the electricity generation plants, industrial, household/commercial, transportation and other sectors	Natural gas - Energy
	Reduction of oil and use of other resources for energy production in the industrial, household/commercial, electricity generation, transportation, construction and other sectors	Oil reduction
	85%-100% electricity generation from RES using all commercially mature technologies	RES electricity (2050)
	Reduction of coal and use of other energy sources (e.g. RES) for electricity production	Coal reduction
Food	Implementation of measures (e.g. subsidies) that reinforce agricultural production in order to cover food and fodder needs as well as needs related to agri-industrial products	Agricultural production
	Implementation of measures (e.g. subsidies) that reinforce livestock production in order to cover food needs	Livestock production
Land	Land use regulations aiming at the protection of agricultural land and livestock areas – Elimination of land use conflicts	Land use regulations
	Organisation of reforestation actions in the national, regional and municipality level in order to restore biodiversity, forest land, wetlands and grasslands (often destroyed by forest fires) – Management of land use conflicts between agriculture and livestock	Biodiversity/LULUCF

Such policies were carefully selected in order to correspond to the nexus challenges identified in the case of Greece. Emphasis was placed on the implementation and successful accomplishment of policies and goals focusing on the reduction of GHG emissions, the decrease of coal and oil consumption, the increase of RES share in the national energy mix, the mitigation of climate change impacts, the increase of adaptation ability and resilience against climate change, the extensive use of bio-fuels, the regulation of land uses, the production of qualitative agricultural and dairy products, the rational management of water resources. 'Transitions towards a low-carbon economy' was the main direction upon which policy scenarios were built along with the respective forecasts having been incorporated in the RCP scenarios adopted by the IPCC.

Due to the fact that in Greece there are many vulnerable regions that will be significantly affected by climate change in the future, RES exploitation policies and policies that will contribute to the reduction of GHG emissions represent important national priorities. Moreover, climate change is expected to affect agricultural and tourist sectors, key drivers of the national GDP. Thus, policies focusing on the cultivation of crops that are resilient to climate change impacts and the smart management of irrigation water and water covering tourist needs were included in the policy scenarios. More analytically, regarding the sector of climate, the main nexus challenges expected to be addressed focus on the reduction of emissions, the mitigation of climate change impacts and the reinforcement of the country's adaptation ability against climate change impacts. Eight policy scenarios (policy cards) have been built towards this direction. Such policy scenarios concern the contribution of ETS and non-ETS productive sectors to the decrease of GHG emissions. The LULUCF sector has also been taken into consideration as it supports carbon sequestration. Production of qualitative agricultural and dairy products refers to the sector of food where two policy scenarios supporting such challenges have been designed. The first one refers to the reinforcement of agricultural production while the second one concerns the reinforcement of livestock activities through the provision of subsidies. The challenges related to the sector of energy focus on the reduction of coal and oil use for energy generation, the increased penetration of RES in the national energy mix, the regulation of energy prices, the promotion of bio-fuels and the coverage of energy needs (imports and exports of energy). The respective policy scenarios dealing with such challenges suggest the extensive adoption of RES (PVs, wind, solar, biomass) for energy production, the use of bio-fuels by the transportation sector, the extensive use of gas and other energy sources instead of oil and the reduction of coal in the electricity generation sector. The rational management of water resources, especially under climate change conditions, is another critical challenge referring to the sector of water. Such challenge is going to be addressed through the implementation of policy scenarios concerning the reduction of water losses and water needs when it comes to irrigation (modernization of irrigation systems and cultivation of less water demanding crops), the exploitation of recycled water by the sector of industry and the reduction of water waste in the case of household/commercial sector. Finally, regarding the sector of land, policy scenarios supporting the protection of agricultural and forest land, grassland and wetlands; the management of land use conflicts, and the enhancement of reforestation actions are expected to effectively address the nexus challenge concerning the explicit regulation of land uses.

The design of policy scenarios presupposed the development of the System Dynamics Model (SDM), the analysis of nexus-related policies (policy goals and policy instruments) and the assessment of policy coherence among policy goals and between policy goals and policy instruments. The SDM represents a quantitative translation of the conceptual model, built in the System Dynamics Modeling software STELLA Professional. It maps all relevant data and nexus component interlinkages, describing a complex system in a user-friendly way, appropriate for communicating the results of the model with non-expert stakeholders (Rehan et al., 2011; Sušnik et al., 2013). A thorough analysis of the nexus interlinkages and an analytical translation of such interlinkages into model terms were conducted. In addition, a really massive number of data was collected and inserted into the SDM reflecting the state-of-the-art of the nexus components in Greece.

The analysis of nexus-related policies took place through: the collection of all relevant policy papers, the identification of policy objectives and policy instruments, the selection of the most significant policy priorities (nexus-critical objectives and nexus-critical instruments), the assessment of policy coherence and the exploration of possible policy recommendations. Such process shed light on the most important future strategic directions for the sustainable development of the nexus. Moreover, it supported the investigation of policy consistency between scales (European and national), the analysis of trade-offs and synergies as well as the exploration of arrangements and conflicts occurring when it comes to policy implementation.

The basis upon which the development of policy scenarios took place was the fact that policies should be connected to the SDM and translated into quantitative terms. Moreover, they should reflect future priorities leading to a low-carbon economy. Under this framework, a reciprocal approach was adopted and a bi-directional analysis 'from policies to SDM' and 'from SDM to policies' was applied. This was accomplished by connecting each policy to the relevant variables existing in the SDM and by reversely connecting each variable of the SDM to the respective policy. Indicators measuring the performance of policy objectives were also defined. Policies concerning the future sustainable development of all nexus components were selected while interlinkages among such components were considered. D2.2 guided the selection of policies as it contains an extensive pool of policy objectives and instruments along with the assessment of their coherence. Most affecting policy objectives and instruments were included in the relevant policy scenarios as they play a significant role in the development of the nexus. Moreover, energy and climate policies, concerning the achievement of goals having been set by the EU and the sustainable management of water resources under climate change conditions, were chosen as they represent the fundamental axis towards adaptation to climate change and mitigation of its impacts. As to the food and land sectors, policies aiming at the confrontation of existing problems such as regulation of land uses, reinforcement of agri-food production and protection of forest land were included in the policy scenarios list.

Apart from the literature review and the extensive analysis of the nexus-related policy documents, stakeholders played an important role in the policy scenarios design process. They proposed policies to be incorporated in policy scenarios, they mentioned critical policy objectives that should be taken into account, they suggested possible indicators that may measure the achievement of policy objectives while they also validated the first draft of policy scenarios by proposing several improvements. The involvement of stakeholders was of exceptional importance as some of them are going to be pilot users of the game and thus issues that interest them should be addressed in the game environment. Different interests and perspectives were expressed depending on the expertise, professional and scientific background of each stakeholder. This was a real challenge for the research team as a variety of preferences and interests should be embodied in the SG in order to satisfy all stakeholders wishing to use the game.

Policy scenarios are in line with the baseline scenario described in D1.8 in terms of tourist development, agriculture and food production, going to be further developed in the upcoming years. Moreover, climate change impacts and the consequent need to diversify water and land use strategies are also incorporated in the policy scenarios concerning the sectors of water and land. More analytically, policy scenarios include several issues also mentioned in the baseline such as:

- Future water deficits that will be raised due to the growth of domestic energy and food industries.
- Water deficit for irrigation purposes.
- Increase of low-carbon energy.

According to the updated forecasts of the 2018 IPCC report, a policy scenario targeting at zero emissions in 2050 has been considered. Moreover, the LULUCF sector and its contribution to C sequestration, the reduction of coal and oil use, the development of livestock, the promotion of natural gas instead of oil, the use of bio-fuels in the transportation sector and the explicit regulation of land uses have been taken into account during the design of policy scenarios, enriching the baseline narratives. Conclusively, the basic axes upon which policy scenarios were developed are:

- The selection of the most updated and representative nexus-related policy objectives and policy instruments.
- The translation of policies into quantitative/model terms.
- The selection of policies that capture the interests of stakeholders (prospective users of the SG).
- The correspondence of policy scenarios to the relevant nexus challenges.

5.4.2.2 Introduction of policy scenarios in the SDM

An analysis of policies and instruments for Greece was first performed gathering all short- and long-term targets at national level as far as water, energy, food, land use and GHGs is concerned. Examples of such targets are GHGs reduction, water savings in agriculture, switching to Renewable Energy Sources, etc. Specific variables were identified to be used in policy scenarios and made sure to include them in the SDM. In collaboration with the UNEXE team, the concept of policy cards was developed, so policies were translated into policy cards. In the attached file named "Policy_goals_Scenarios_final.docx" a detailed list of policy cards, and associated SDM variables and KPI metrics that allow us to monitor the progress of each card is included.

5.4.3 Modifications introduced to account for data availability

At the core of this study, there is an SDM (the Nexus_SDM) that includes five modules/sub-models one for each nexus component (Water, Energy, Food, Land Use and Climate). All Nexus_SDM modules are integrated by using the STELLA software (https://iseee.com/), a high-level visual-oriented programming and simulation language. Forward Euler step was used as the integration method with a monthly time step. The modules use spatial and statistical datasets to quantify the interlinkages among components and estimate the water, energy and food productivity and carbon footprint of different land uses and of population and tourists. The model is developed in a generic format and is applied for the national case study of Greece. More details about the structure of the Nexus_SDM are provided in Laspidou et al. (2018[10], 2019[11], 2020[12]). To ensure that the uneven distribution of water resources in the country is captured—the western part of the country has abundant water resources, while the eastern part faces serious water scarcity issues (more details can be found in Mellios et al., 2018[13])—the model is subdivided and modelled in 14 River Basin Districts (RBDs). This was proven to be a valid approach, especially when taking hydrologic balances, since RBDs offer boundary conditions, i.e. they are more or less hydrologically independent; furthermore, the EU Water Framework Directive is employed at the RBD level, so such a classification is valid.

5.4.3.1 Data available from the thematic models

Various databases and models have been used to populate the Nexus_SDM with data. An important source of data for the case study of Greece has been the E3ME-FTT model (https://www.e3me.com/) from Cambridge Econometrics. E3ME is a macroeconomic simulation model that is demand-driven and characterised by non-optimisation (post-Keynesian economic principles). It includes behavioural aspects by employing macro-econometric behavioural equations, further fitted into the standard national accounting framework of Greece, in this case. E3ME is combined with FTT (Future Technology Transformations), a model of technology diffusion that enables the user to simulate the impact of detailed climate policies. E3ME-FTT models the power and transport sectors and has delivered relevant

[10] Laspidou, C. S., Kofinas, D. T., Mellios, N. K., and Witmer, M. (2018). Modelling the Water-Energy-Food-Land Use-Climate Nexus: The Nexus Tree Approach. *Proceedings*, 2(11), pp. 617, doi:10.3390/proceedings2110617

[11] Laspidou C., Mellios N., Kofinas D. (2019). Towards ranking the Water-Energy-Food-Land Use-Climate Nexus interlinkages for building a Nexus conceptual model with a heuristic algorithm, *Water*, **11**:306, doi: 10.3390/w11020306

[12] Laspidou, C., Mellios, N., Spyropoulou, A., Kofinas, D., Papadopoulou, M. (2020) Systems thinking on the resource nexus: Modeling and visualisation tools to identify critical interlinkages for resilient and sustainable societies and institutions, *Science of the Total Environment* **717**, 137264, doi:10.1016/j.scitotenv.2020.137264

[13] Mellios, N., Koopman, J. F. and Laspidou, C. (2018). Virtual Crop Water Export Analysis: The Case of Greece at River Basin District Level. *Geosciences,* 8(5), pp. 161, doi:10.3390/geosciences8050161

data for Greece by sector on GDP, employment, population, output, CO_2 emissions, energy demand for coal, oil, gas, electricity, heat, biomass & combustible waste, as well as electricity generated by all sources including renewables. Sectors include (i) power own use, (ii) industries, (iii) construction, (iv) transport, (v) households, (vi) agriculture and (vii) other final use. This "master" E3ME-FTT run was delivered in the framework of the Horizon 2020 SIM4NEXUS project (https://sim4nexus.eu/) and has provided all of the Energy module data and has allowed establishing direct interlinkages with the Climate module by associating energy demand by fuel and sector with their corresponding Green House Gas (GHG) emissions, in CO_2 equivalents.
To quantify pressures from human consumption, E3ME population data was combined with data on tourism in Greece, obtained from the Association of Greek Tourism Enterprises (https://sete.gr/). Monthly data for year 2010 for tourist overnight stays was mapped to all RBDs using Geographical Information System (GIS) software; when added to permanent population (assumed to remain constant throughout the year), a total human population was produced that varied in space and time, per RBD and per month, respectively.
A detailed power plant dataset was based on the OSeMOSYS dataset (www.osemosys.org), allowing the mapping of all power plants in Greece into the 14 RBDs along with their capacity and fuel type. The following fuel types were listed: coal, oil, gas, biomass and combustible waste, as well as the renewables wind, hydropower and solar for the production of electricity. Figure 40 shows a map of the 14 RBDs along with power plant data and corresponding fuel used.

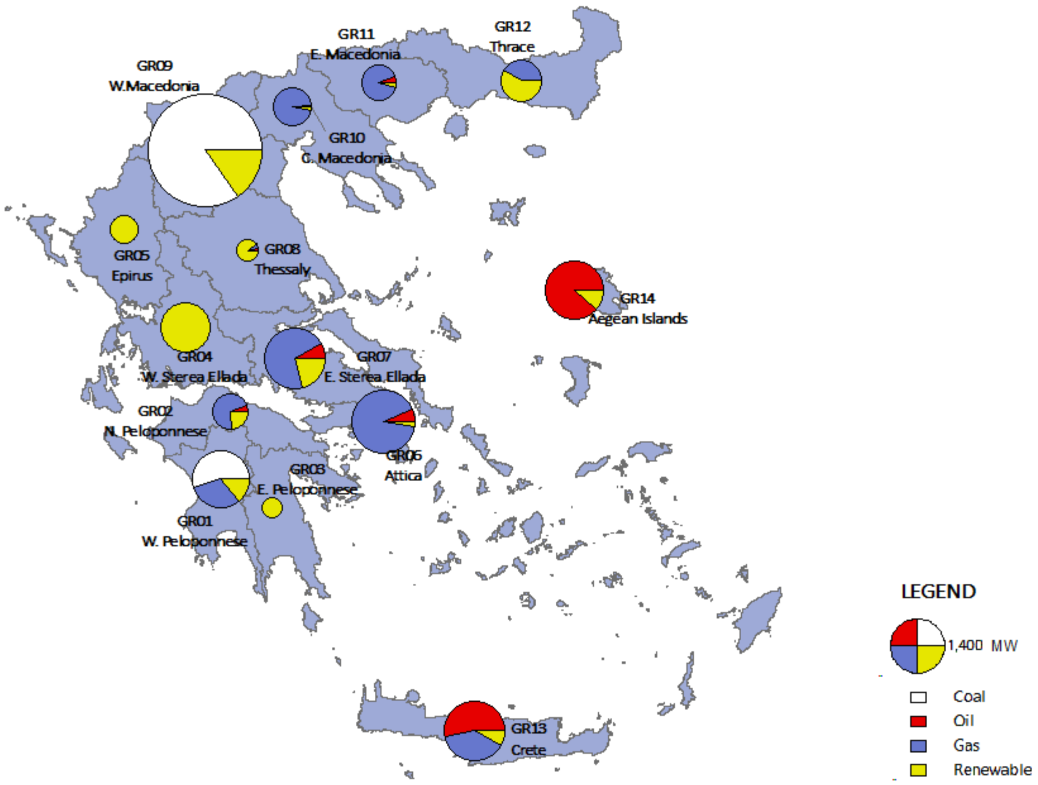


Figure 40 Map of power plants per RBD in Greece. The size of the circle corresponds to the total wattage of power generated, while pie charts show fuel types used.

Modeling the hydrological cycle as a whole includes a climate dataset provided by Potsdam Institut Klimatologie (PIK), which provides regional climate change projections for Greece within the timeline of the Fifth Assessment Report (AR5) and beyond at a spatial resolution of EUR-11: 0.11° (12 km). The relevant climate model used is the GFDL-ESM2M. For the calculation of actual evapotranspiration (ETa), the thematic model SWIM is used. SWIM is spatially discretized by hydrotopes, areas characterized by unique combinations of soil profiles, distance between soil surface and groundwater level, land use, crop rotation (if agriculture), elevation, and sub basin. allocation. According to the daily meteorological variables, potential ET (ETp) is calculated at the individual locations of the hydrotopes. This is the first step and is based on a Turc-Ivanov approach with monthly tuning factors. In a second step, Eta is derived from ETp for the two components soil evaporation and plant transpiration in an approach similar to Ritchie[14].

The hydrological cycle is modelled as follows (Figure 41): precipitation and actual evapotranspiration are mapped on RBDs as input (a single value per RBD calculated from given spatial resolution using Thiessen polygons); for each time step, surface and ground water balances are calculated using precipitation, evapotranspiration, aquifer recharge, return water, wastewater recharge and runoff to the sea, while exerting demands on surface and ground water by all sectors.

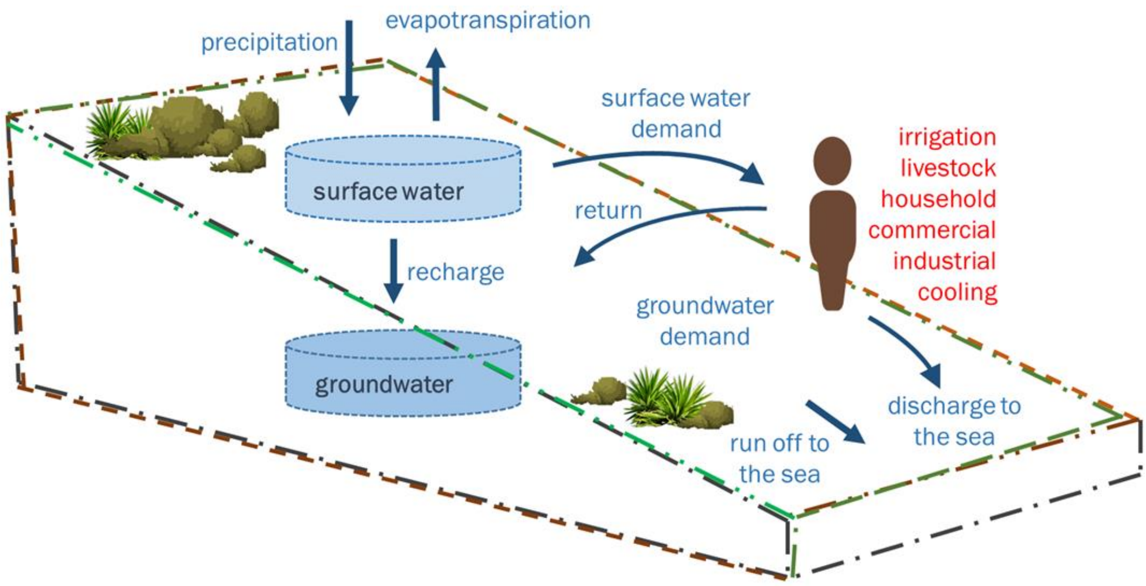


Figure 41 The water cycle as modelled in the Nexus SDM

5.4.3.2 Local data to be collected

Land use is divided in Agricultural (includes Cropland and Livestock Area, with the former being further divided into Irrigated, Non-Irrigated crops and Fallow area), Wetland, Grassland, Forest and Artificial Area. Table 17 lists crop types and animal types included under each land use. All agricultural data was obtained from the Hellenic Statistical Authority ELSTAT (https://statistics.gr), while data on other land uses was obtained from the CORINE database (https://land.copernicus.eu/). Agricultural water demand was computed from a variety of sources, including historical irrigation data for typical irrigated crops in the region and statistical data (ELSTAT; Agricultural Research Institute, 2019[15]), as described in Mellios et al. (2018). Datasets were calibrated to match reported crop areas and types and agricultural water demand for base year 2010. Food is included through yields for each crop and each animal type and for

[14] Ritchie, J., 1972.Model for predicting evaporation from a row crop with incomplete cover. *Water Resour. Res.* **8 (5)**, 1204–1213.

[15] Agricultural Research Institute (2019). Online irrigation demand tool assessed in March 2018: http://news.ari.gov.cy/irrigation_v1.html

beehives (shown in Table 17), obtained from ELSTAT. Results are data for animal products including meat (cattle, buffaloes, sheep, goat, swine, rabbits, poultry), milk, eggs and honey.

Table 17 Land Use categories included in the Nexus_SDM

<table>
<tr><td rowspan="3">Cropland Area</td><td>Irrigated Crops: Fruits, rice, fodder temporary, fodder permanent, tobacco, pulses, cotton, potatoes, vegetables, olives, other cereals, citrus, maize, sugar beet</td><td rowspan="4">Agricultural Area</td></tr>
<tr><td>Non –Irrigated Crops: barley, cotton, vegetables, citrus, fruits, nuts, olives, wheat</td></tr>
<tr><td>Fallow Area</td></tr>
<tr><td colspan="2">Livestock: Cattle, buffaloes, sheep, goat, swine, horses/donkeys, rabbits, poultry, beehives</td></tr>
<tr><td colspan="3">Wetland</td></tr>
<tr><td colspan="3">Grassland</td></tr>
<tr><td colspan="3">Forest</td></tr>
<tr><td colspan="3">Artificial Land</td></tr>
</table>

An important data set was provided by the Independent Power Transmission Operator (DEDDIE) (https://deddie.gr/) and included a monthly electricity consumption set for 10 years (2005 to 2015) for all municipalities in Greece for different sectors (household, industrial, agricultural, etc.). Firstly, municipality data was aggregated to RBD level and then the produced data set (ADMIE data set) was used to disaggregate E3ME-FTT data: for all sectors and categories, E3ME outputs provided a single national value per year. This single yearly value was further disaggregated spatially (to 14 RBDs) and temporally (over 12 months), using the consumption pattern extracted from the spatially and temporally detailed energy consumption ADMIE data set, using the corresponding categories (household, industry and agriculture).

The Water module includes, for each RBD, a mapping of all water uses—public water supply covering household and commercial water uses, irrigation, livestock, industrial, cooling water for thermoelectric power plants and desalination. A further distinction on all categories is done between surface water and groundwater sources. Data originate from Eurostat databases, which report national and RBD water data, while calibration ensures consistency between different regional (ELSTAT), national (ELSTAT) and European (EUROSTAT) datasets that span all water uses. Water availability on surface water and groundwater is mapped on each RBD with data from the National Programme for Water Resources Management and Preservation (Koutsogiannis et al., 2008[16]), while parameters such as river flows, transboundary water bodies, groundwater infiltration rates and outflow to the sea also come from Koutsogiannis et al. (2008). A series of groundwater level values for 2010 were obtained from the Ministry of the Environment and Energy and provided several values per RBD, which were aggregated to a single aquifer value per RBD with Thiessen polygon analysis. Depending on aquifer level, all groundwater demands exert a corresponding pumping energy demand (a Water-Energy Nexus interlinkage).

[16] Koutsogiannis, D., Andreadakis, A., Mavrodimou, R., Christofides, A., Mamassis, N., Efstratiadis, A., Koukouvinos, A., Karavokiros, G., Kozanis, S., Mamais, D. and Noutsopoulos, C. (2008). National Programme for Water Resources and Preservation, National Technical University of Athens, Athens, http://dx.doi.org/10.13140/RG.2.2.25384.62727

5.4.4 Case Study SDM in Stella / R

Results of the application of the thematic models are incorporated in the Nexus_SDM, the System Dynamics Model developed for the case study of Greece. All data provided by the thematic models, along with data from published databases have been disaggregated and processed to produce the 2010 baseline. All data are included in the published data set (Mellios and Laspidou, 2020[17]), while results from the case study of Greece that includes all thematic model data are published in Laspidou et al. (2020[18]).

Nexus interlinkages are modelled in the Nexus_SDM by reducing all major variables to a "per unit" basis, producing relevant factors that could be used for different scenarios, when the "unit" changes. On the Energy module, for example, an aggregate national yearly oil demand figure for agriculture was provided by E3ME-FTT. This value was disaggregated in 14 RBD values and each one of the RBD values was further disaggregated in a time series of 12 monthly values per year, using the ADMIE dataset. For each RBD, the Land Use module includes the cropland area in m^2, so dividing the disaggregated oil demand time series by the agricultural area produces a time series of factors that express agricultural oil demand units per m^2 of cropland, used mainly for tractors and other oil-burning agricultural machines. This factor establishes the interlinkage between cropland area and agricultural oil demand and enables the user to quantify this interlinkage and try out scenarios either extending or limiting cropland and seeing the effect on oil demand. A comprehensive list of such factors that establish interlinkages throughout the Nexus is presented in Table 18 Interlinkage factors may be used either within each module, or linking two different modules.

Changes in quantities listed in the first column of Table 18 triggers, in a domino-like fashion, changes in all variables listed in the second column, which in turn may bring about changes to other variables, thus quantifying the interlinkages among Nexus components. As a result, we can see for example that a change in population or tourism will trigger a series of changes in various different variables and different Nexus sectors. This way, cross-sectoral implications are identified and quantified and critical interlinkages can be singled out.

Table 18 List and description of nexus interlinkages factors

Unit	**Nexus Interlinkage Factors: Ratios of quantities in this column per *Unit* listed in column to the left**
Per capita (including population and tourists)	Public water supply (distinguishing origin of water—surface or groundwater, according to current practice) Household/commercial electricity demand Urban wastewater produced Industrial wastewater produced GHG emissions from urban wastewater treatment plant Fuel demand for transportation GHG emissions from transportation Fuel demand for construction GHG emissions from construction Fuel demand for other final uses GHG emissions from other final uses

[17] Mellios, N., Laspidou, C., 2020. Water-Energy-Food-Land-Climate Nexus Data for the CaseStudy of Greece: National and River Basin District Scale. V1. Mendeley Data.https://doi.org/10.17632/9x7wn24rrp.1.

[18] Laspidou, C., Mellios, N., Spyropoulou, A., Kofinas, D., Papadopoulou, M. (2020) Systems thinking on the resource nexus: Modeling and visualisation tools to identify critical interlinkages for resilient and sustainable societies and institutions, *Science of the Total Environment* **717**, 137264, doi:10.1016/j.scitotenv.2020.137264

Unit	**Nexus Interlinkage Factors: Ratios of quantities in this column per *Unit* listed in column to the left**
Per power plant CAPACITY (either new installations, or retirements, or increase/decrease of power in plants)	Fuel demand for power generation per MW of power plant (different factor for each fuel type: coal, oil, gas, biomass) Cooling water for power plants (different factor for each fuel type; numbers based on Macknick et al. (2012)) Electricity generated (different per power plant, depending on fuel type used) GHG emissions (different factor for each fuel type)
Per agricultural land area	Fuel demand for agricultural land use GHG emissions from agriculture energy use
Per specific crop type area	Agricultural water demand for different crop types (irrigated only) Yield for each crop type (Food/Feed/Industrial crop produced); different yields for irrigated and non-irrigated crops.
Per irrigation technology (sprinkler, drip, or furrow)	Losses in irrigation network Agricultural water demand Fuel demand for agricultural land use GHG emissions from agriculture energy use
Per livestock land use	GHG emissions associated with manure management
Per animal head and/or beehive	Livestock water demand Yield for animal products (Food produced)
Per m3 groundwater pumped	Electricity demand for every meter of pumping head
Per m3 surface water pumped	Electricity demand
Per INDUSTRIAL CAPACITY (either new installations or retirements of industrial plants, or increase/decrease of power in plants)	Industrial water demand Industrial demand for fuel GHG emissions from industrial fuel use (different for ETS and non-ETS industries) Industrial wastewater produced GHG emissions from industrial wastewater treatment.
Per managed agricultural soil area	Agricultural GHG emissions
Per irrigated rice area	Agricultural GHG emissions (Rice emissions)
Per burning area	Agricultural GHG emissions (Field Burning emissions)
Per forest area	GHG emissions (Land Use Land Use Change and Forestry—LULUCF emissions)
Per wetland area	LULUCF GHG emissions
Per grassland area	LULUCF GHG emissions

Some sample screen shots of the Greek SDM are presented in Annex 5.10.2. As mentioned above, the model was developed both on an RBD level and on a national level.

5.5 From the System Dynamic Modelling to the Serious Game

5.5.1 Case studies learning goals

The learning goals set the general framework for the design of the Serious Game for the Greek CS by supporting the selection of nexus-related data involved in the SG, the range of actions that a player has the chance to test in the game, the definition of the players' profiles as well as the determination of the relevant information provided to the player after completing a game session. More analytically, the learning goals of the Greek CS involve five nexus sectors: water, land, energy, food and climate. Agricultural and tourist sectors have also been considered, being the main sectors supporting national GDP and putting extra pressures on all five nexus sectors.

The learning goals of the Greek CS are summarised as follows: ***"You will learn how national policies in the domains of water management, penetration of RES to electricity production, and land use management affect each other and result in changes in food production, electricity production patterns to cover the increased demand, expansion of tourist season, adaptation of agricultural practices and tourist services to climate change conditions"***. In other words, the Greek CS focuses on: a) the exploration of interactions among water, energy and land policies and b) the impacts of water, energy and land policies on food production, energy needs and the development of tourist and agricultural sectors under climate change conditions.

Accordingly, data concerning: water consumption by several sectors (e.g. agricultural, domestic, industrial, etc.); energy production and consumption; area of agricultural and forest land, wetland and grassland; amounts of GHG emissions, and; food production have been added in the Serious Game in order to estimate relevant parameters and indicators. Nexus-relevant data, included in the SDM, are massive and reflect the state-of-the-art of the nexus sectors in Greece. Thus, the level of detail of the game is very high and corresponds to existing needs and future trends.

Learning goals, along with the data and policies incorporated in the SG, determine also the actions taken by the player and the number of iterations needed in order to estimate the relevant impacts and achieve the respective goals. Actions have to do with the accomplishment of the goals, the sustainable management of the nexus sectors and the efficient use of resources. In this sense, the player has the chance to test a number of actions aiming at the establishment of a low-carbon economy such as reduction of GHG emissions derived from the industrial and transportation sectors, reduction of water losses by the agricultural sector, extensive use of RES for electricity production, protection of forest land, etc. Also, the number of iterations is directly related to the temporal scale and actions may be repeated until 2050 in order goals to be achieved to the highest possible degree. The completion of each step in the game is accompanied by the estimation of the impacts of the action taken and the level of achievement of the respective goal.

The profiles of the players are connected to the learning goals and the nexus sectors they refer to. Players are representatives of the public and private sectors, NGOs and academic/research institutes. They are interested in the management of the nexus sectors and the efficient use of resources while some of them affect decisions concerning the design of nexus-related policies. Specifically, they are decision makers (e.g. Ministries) managing water, energy, land, food, climate policies and their implementation; private businesses (e.g. the bank sector) establishing investments in the agricultural, tourist and energy sectors; NGOs focusing on the protection of natural resources, and; academic/research institutes acting as consultants when formulating environmental policies. Players are willing to test the game and explore the impacts of several nexus-related policies. Such impacts guide their decisions and future plans as they reveal actions that are feasible and actions that should be avoided in the future. They also inform decision makers on existing policy gaps that should be covered and policy issues not managed by the current policy framework. Moreover, the game provides information on: the risks of possible investments, the pressures that changes in one nexus component may put on the rest and the key priorities that should be taken into consideration when designing future policies. Such information is of utmost importance as it serves as a guide for the integrated and sustainable management of all nexus components.

5.5.2 From generic to specific use cases

In the case of Greece, five use cases were designed. Such use cases concern the sectors of water, energy, climate, land and forest, agriculture and food. Use cases were adapted from the generic ones, presented in D1.2, in order to incorporate the specific characteristics, needs and peculiarities of the Greek CS. First of all, the Greek team focused on the nexus sectors involved in the Greek CS and the learning goals reflecting Greece's national priorities. Then, the goal of each use case, the related learning goals, the possible users/players, the actions that should be taken towards the accomplishment of each use case's goal as well as a set of indicators measuring the performance of each action and the level of goal's achievement were defined.

More specifically, regarding the sector of ***water*** the goal of the relevant use case is water saving in the agricultural sector. The corresponding learning goal refers to the sustainable management of water resources while the possible users of such use case are the Ministry of Rural Development and Food and the Local Organisations of Reclamation Services (Public Sector). The primary action proposed by the use case is changing the existing irrigation systems while the indicators measuring its successful outcome are: a) change of water losses and b) change of total water volume used for irrigation purposes.

For the sector of ***energy*** an increase of the share of RES in the gross final energy production is pursued while the relevant learning goals promote the renewable power production and the reduction of GHG emissions. The key player of this use case is the Ministry of Environment and Energy (Public Sector), the main policy maker in Greece on issues related to the sector of energy. The actions towards the achievement of this goal encourage electricity generation from PVs, wind and hydro-power plants, the use of biomass by the sector of agriculture and the use of bio-fuels by the transportation sector. The respective indicators measure the share of electricity generated from PVs, wind parks and hydro-power plants, the amount of biomass used by the agricultural sector and the amount of bio-fuels consumed by the transportation sector. As for the sector of *climate* the learning goal aims at the reduction of GHG emissions and the respective goal of the use case focuses on the reduction of emissions derived from non-ETS sectors. A target for a 60% reduction compared to 2005 emissions has been set. Again, the Ministry of Environment and Energy (Public Sector) is the player of the use case and the actions proposed include: the decrease of oil used by the agricultural sector, the non-ETS industry, the non-ETS transportation, the household/commercial sector, the construction sector and other non-ETS sectors. Indicators measuring the performance of these actions are: change of GHG emissions derived from all non-ETS sectors and change of GHG emissions derived from agriculture, non-ETS industry, non-ETS transportation, household/commercial sector, construction and other non-ETS sectors.

The next use case concerns the sector of ***land*** and focuses on the sustainable management of forest land, wetland and grassland. The relevant learning goal refers to the sustainable management of land and the player is a Land Management Authority (Public Sector). The actions of this use case have to do with reforestation initiatives, effective management and confrontation of forest fires and management of land use conflicts. The respective indicators are: change of forest land, change of wetland and change of grassland.

The last use case concerns the sector of ***agriculture and food***. The goal is the coverage of food needs, fodder needs and needs related to industrial crops while the corresponding learning goal concerns the sustainable production of food. The player is the Ministry of Rural Development and Food (Public Sector) and the actions proposed are: strengthening agricultural production and protection of agricultural land.

The indicators of the use case include: crop food production, crop feed production and crop industrial production.

Generic use cases, presented in D1.2, were used as a guide for the development of case-specific use cases. Such use cases were adapted to the particular requirements of the Greek case study based on existing problems, national policy priorities, stakeholders' targets and data included in the Greek SDM. A critical issue was the identification of possible players and their expressed preferences as to the Serious Game. The Greek team took into consideration the interests of stakeholders and their role in the management of the water-energy-land-food-climate nexus. Semi-structured interviews and the first stakeholders' workshop enriched the Greek use cases with additional information emanating from stakeholders and reflecting their experience, expertise and willingness to explore several nexus-related issues in the Serious Game environment. Also, broad discussions took place between the Greek team and modelers in order to explicitly clarify the role of use cases as a means of interaction between the player and the game, their functionality in the Serious Game environment and the form of their structure. Such discussions shed light on what should be taken into account when defining the goal, the player, the actions and the indicators of a use case as well as on the way the elements of a use case are inter-connected.

5.5.3 Policy cards

The Greek CS developed thirty policy cards referring to the sectors of water, energy, climate, land, agriculture and food. The design of policy cards was based on: a) the policy objectives and the policy instruments identified in the national policy papers of Greece and b) the data of the Greek SDM. Policies were 'translated' into quantitative terms (variables in the SDM) and, indicators, estimating the relevant results after testing a policy card in the game, were defined. More analytically, the process of developing a policy card includes: the definition of a general policy goal and a specific policy objective; the definition of an indicator measuring the performance of the objective (level of accomplishment); the determination of a weight reflecting the contribution of the specific objective to the achievement of the general policy goal; the identification of policy interventions through which the accomplishment of the objective will be pursued; the 'translation' of the intervention into model inputs and its connection to variables existing in the SDM; the definition of the intervention's implementation and building time, and; the determination of economic and social costs required for and gained by the implementation of a policy intervention.
The policy cards developed in the case of Greece per each nexus sector were:

Water

- Adoption of new/alternative irrigation methods (change of irrigation systems).
- Diversification of crops or cultivation of crops which are resilient to drought (less water demanding crops).
- Water saving in households by establishing water saving equipment (e.g. smart taps), changing consumption behavior, etc.
- Reuse of water in the industrial sector (recycled water).

Climate

- Reduction of GHG emissions derived from non-ETS sectors (agriculture, non-ETS industry, etc.) through the adoption of relevant technologies (e.g. technologies that reduce CO_2 emissions) until 2020.
- Reduction of GHG emissions derived from ETS sectors (e.g. power generation sector) until 2020.

- Reduction of GHG emissions derived from non-ETS sectors (agriculture, non-ETS industry, etc.) through the adoption of relevant technologies (e.g. technologies that reduce CO_2 emissions) until 2030.
- Reduction of GHG emissions derived from ETS sectors (e.g. power generation sector) until 2030.
- Reduction of GHG emissions derived from non-ETS sectors (agriculture, non-ETS industry, etc.) through the adoption of relevant technologies (e.g. technologies that reduce CO_2 emissions) until 2050.
- Reduction of GHG emissions derived from non-ETS sectors (e.g. agriculture) in order to achieve 0 emissions through the adoption of relevant technologies (e.g. technologies that reduce CO_2 emissions) until 2050.
- Reduction of GHG emissions derived from ETS sectors (e.g. power generation sector) in order to achieve 0 emissions until 2050.
- Protection of forest land, wetland, grassland and crop land (e.g. land use regulations, effective confrontation of forest fires).

Energy

- RES share in the transportation sector by 10% until 2020: use of bio-fuels (biomass).
- Promotion/Use of biomass in the industrial sector.
- Promotion/Use of biomass in the household/commercial sector.
- Promotion/Use of biomass in the agricultural sector.
- Promotion/Use of biomass in other sectors.
- Electricity generation from PVs up to 2500 MW until 2020.
- Electricity generation from wind up to 7500 MW until 2020.
- Electricity generation from hydro-power plants up to 3000 MW until 2020.
- Electricity generation from biomass power plants.
- Further promotion/use of RES for electricity generation until 2030.
- Promotion/Use of natural gas in the electricity generation plants, industrial, household/commercial, transportation and other sectors until 2050.
- Reduction of oil and use of other resources (e.g. RES) for energy production in the industrial, household/commercial, electricity generation, transportation, construction and other sectors until 2050.
- 85%-100% electricity generation from RES using all commercially mature technologies until 2050.
- Reduction of coal and use of other energy sources (e.g. RES) for electricity production until 2050.

Food

- Implementation of measures (e.g. subsidies) that reinforce agricultural production in order to cover food and fodder needs as well as needs related to agri-industrial products.
- Implementation of measures (e.g. subsidies) that reinforce livestock production in order to cover food needs.

Land

- Land use regulations aiming at the protection of agricultural land and livestock areas – Elimination of land use conflicts.
- Organization of reforestation actions in the national, regional and municipality level in order to restore biodiversity, forest land wetlands and grasslands (often destroyed by forest fires).

A more detailed description of the policy cards developed for the Greek CS is presented in Annex 2.10.3. Policy cards were firstly designed by the research team and then presented to representative group of key stakeholders for validation. Relevant comments were embodied in the final version of policy cards. The contribution of stakeholders was necessary as they represent the final users of the game and thus policy cards should correspond to their interests. Moreover, they mentioned several issues that researchers did not have in mind regarding conflicts, synergies and trade-offs when it comes to policy implementation. They highlighted several issues at stake and they supported the identification of the nexus-related policy objectives and interventions. Targets set reflect important nexus policy priorities in Greece aiming at the transition to a low-carbon economy and the efficient use of resources. At this point, it should be mentioned that some policy cards were left out due to the lack of relevant data. Accordingly, only policies that could be 'translated' into model terms were included in the list of policy cards. Finally, acceptance and costs were estimated by using a scale from 0 to 1000 (0-10: low cost/acceptance, 10-100: medium cost/acceptance, 100-1000: high cost/acceptance). Approximate values were defined based on existing knowledge, regarding the socio-economic profile of Greece, as well as on the experience and inputs of the involved stakeholders.

5.5.4 Serious Game interface

The serious game for the case study of Greece was particularly complex, since it contains several thousand variables and even though it is developed for the national case, there is further analysis at the River Basin District (RBD) level. In essence, it is a national game that includes 14 regional games under it. Therefore, it was important to capture this complexity and to allow the user to explore the information he/she needs to find in order to make the most out of the game.

The map of Greece, divided into the 14 RBDs, is the first shot of the game, with the RBDs visualised as squares arranged roughly as they would be on the map. On each RBD, but also for the national scale, there is a quick overview of the data at a first glance. Thus, the following variables are listed:

- Total Water Demand
- Total Energy Demand
- Total Food production (in terms of total agricultural value)
- Total land (surface area)
- Total GHG emissions
- Total Population
- Total Tourism

The player can choose to see more specific views for each one of the Nexus components (Water, Energy, Food, Land, Climate); thus, there is a breakdown that categorizes the data. For example, under Water, demands are distinguished among Household/commercial, Industrial, agricultural, livestock, etc., while under Energy there is a distinction among different uses (power generation, transportation, industry, households, etc.) and different fuels (coal, oil, gas, biomass, renewables, etc.). A detailed list of what is shown in the game is included below. For each quantity to be depicted, there is an association with the corresponding variable from the SDM. When the abbreviation GRXX appears, it refers to the different RBDs, so it corresponds to GR01, GR02, etc.

For Water--we have 2 views, one for water **demand** and the other for hydrological cycle. For water demand on each card we have the following demands:
1) Agricultural = Agri_WD_GRXX_Total_Irrig_Water
2) Industrial = Industrial_WD_GRXX.Total_Monthly
3) Household/Commercial = Household/Commercial_WD_GRXX.Total_Household/Commercial
4) Cooling Water = Cooling_Water_GRXX.Total
5) Livestock = Livestock_WD_GRXX.Total_WD

All these demands need to be split between "surface water" and "groundwater".

For **Hydrological cycle**

1) Precipitation = RBD_W_GRXX.Precipitation
2) Actual Evapotranspiration (AET) = RBD_W_GRXX.Actual_ET
3) Aquifer recharge = Aquifer_Recharge_GRXX.Aquifer_Recharge
4) Runoff to the sea = RBD_W_GRXX.Run_off
5) Wastewater produced = RBD_W_GRXX.WWTP_to_SW_GRXX

For **Energy**--we have 2 views, one for **energy demand** and the other for **power plant capacity**.

For **Energy Demand**, we show the following:

1) Electricity = RBD_En_GRXX.Electricity_Demand_GRXX
2) Oil = RBD_En_GRXX.Oil_Demand_GRXX
3) Gas = RBD_En_GRXX.Gas_Demand_GRXX
4) Biomass = RBD_En_GRXX.Biomass_Demand_GRXX
5) Coal = RBD_En_GRXX.Coal_Demand_GRXX
6) Heat = RBD_En_GRXX.Heat_Demand_GRXX

For **each one of these 6 demands**, we show which sector exerts this demand. So, under each Demand, we show data for :

i) Power Generation = RBD_En_GRXX.Total_Power_Generation_Dem_GRXX
ii) Construction = RBD_En_GRXX.Construction_OD
iii) Agriculture = RBD_En_GRXX.Total_Agricultural_Dem_GRXX
iv) Industrial = RBD_En_GRXX.Total_Industrial_Energy_Dem_GRXX
v) Household / Commercial = RBD_En_GRXX.Total_Household/Commercial_Dem_GRXX
vi) Transportation = RBD_En_GRXX.Total_Transportation_Dem_GRXX
vii) Other = RBD_En_GRXX.Total_Other_Dem_GRXX

For **power plant capacity**, we have classification by fuel:
i) Coal = RBD_En_GRXX.Coal
ii) Oil = RBD_En_GRXX.Oil
iii) Gas = RBD_En_GRXX.Gas
iv) Hydropower = RBD_En_GRXX.Hydropower
v) Biomass = RBD_En_GRXX.Biomass
vi) Solar = RBD_En_GRXX.Solar
vii) Wind = RBD_En_GRXX.Wind

Out of these, we identify as Renewable Energy Source (iv), (v), (vi) and (vii).

For **Land Use**--we have 1 basic view for surface areas:
1) Agricultural Land = RBD_LU_GRXX.Total_Agri_Area
2) Livestock = RBD_LU_GRXX.Livestock_Area_GRXX
3) Forest = RBD_LU_GRXX.Forest
4) Wetland = RBD_LU_GRXX.Wetland
5) Grassland = RBD_LU_GRXX.Grassland
6) Fallow Area = RBD_LU_GRXX.Non-Irrig_Fallow_Area_GRXX
7) Burning Area = RBD_LU_GRXX.Burning_Area
8) Managed Agricultural Soil = RBD_LU_GRXX.Managed_Agri_Soil_Area

For Agricultural Land, we can see surface areas for all crop categories (separate for irrigated and non-irrigated):

Irrigated
i) Maize = RBD_LU_GRXX.Irrig_Maize_GRXX
ii) Fruits = RBD_LU_GRXX.Irrig_Fruits_GRXX
iii) Rice = RBD_LU_GRXX.Irrig_Rice_GRXX
iv) Fodder permanent = RBD_LU_GRXX.Irrig_Fodder_Permanent_GRXX
v) Fodder temporary = RBD_LU_GRXX.Irrig_Fodder_Temporary_GRXX
vi) Tobacco = RBD_LU_GRXX.Irrig_Tobacco_GRXX
vii) Pulses = RBD_LU_GRXX.Irrig_Pulses_GRXX
viii) Cotton = RBD_LU_GRXX.Irrig_Cotton_GRXX
ix) Potatoes = RBD_LU_GRXX.Irrig_Potatoes_GRXX
x) Vegetables = RBD_LU_GRXX.Irrig_Vegetables_GRXX
xi) Olives = RBD_LU_GRXX.Irrig_Olives_GRXX
xii) Other Cereals = RBD_LU_GRXX.Irrig_Other_Cereals_GRXX
xiii) Citrus = RBD_LU_GRXX.Irrig_Citrus_GRXX
xiv) Sugar Beet = RBD_LU_GRXX.Irrig_Sugar_Beet_GRXX

Non-Irrigated
i) Wheat = RBD_LU_GRXX.Non-Irrig_Wheat_GRXX
ii) Cereal = RBD_LU_GRXX.Non-Irrig_Cereal_GRXX
iii) Cotton = RBD_LU_GRXX.Non-Irrig_Cotton_GRXX
iv) Fodder Temporary = RBD_LU_GRXX.Non-Irrig_Fodder_Temporary_GRXX
v) Vegetables = RBD_LU_GRXX.Non-Irrig_Vegetables_GRXX
vi) Citrus = RBD_LU_GRXX.Non-Irrig_Citrus_GRXX
vii) Fruits = RBD_LU_GRXX.Non-Irrig_Fruits_GRXX
viii) Nuts = RBD_LU_GRXX.Non-Irrig_Nuts_GRXX
vix) Olives = RBD_LU_GRXX.Non-Irrig_Olives_GRXX

For Food--we have 1 basic view for these products and for their corresponding agricultural value:
1) Food/Feed by crops = RBD_F_GRXX.Total_Food_Production_GRXX
2) Meat = RBD_F_GRXX.Meat_GRXX
3) Honey = RBD_F_GRXX.Honey_GRXX
4) Milk = RBD_F_GRXX.Milk_GRXX
5) Eggs = RBD_F_GRXX.Eggs_GRXX

For **Climate**--we have 1 basic view for these GHG Emissions:
1) Livestock = Livestock_GRXX.Total Emissions
2) Agriculture = Agriculture_GRXX.Total Emissions
3) LULUCF = LULUCF_GRXX.Total_Emissions
4) Wastewater = RBD_Cl_GRXX.Wastewater_GRXX_Total_Emissions
5) Coal = COAL_GRXX.Total_Emissions
6) Oil = OIL_GRXX.Total_Emissions
7) Gas = GAS_GRXX.Total_Emissions
8) Biomass = BIOMASS_GRXX.Total_Emissions

5.6 From the SDM and SG to policy recommendations

5.6.1 Answering main research questions of the case study

The main research questions of the case study focus on an important number of issues concerning the efficient and sustainable management of the nexus water-energy-land-food-climate. Pressures derived from both the agricultural and tourist sectors on all five nexus components are also taken into consideration. The main research questions having been set, along with the respective answers, are:

Which are the interlinkages among the components of the nexus water-energy-land-food-climate?
Interlinkages among the nexus components considered in the case of Greece, have been deeply explored and identified in order to be quantified and incorporated into the SG. It was not possible to quantify all of them due to the lack of data (e.g. socio-economic data), so interlinkages were quantified according to data availability. Some indicative interlinkages for the Greek CS are: a) climate-water: climate change affects precipitation and evapotranspiration, increases intensive storms and the risk of floods and drought, b) climate-land: climate change affects land uses, c) energy-climate: energy consumption increases GHG emissions and contributes to the increase of greenhouse effect, d) food-water: food production needs vast amounts of water especially when it comes to agricultural production, e) land-water: land uses affect water quality and quantity while agricultural land use entails enormous irrigation needs, etc.

Which are the effects of land uses on water resources and how they should be managed?
Land uses require vast amounts of water in order several activities to take place. In Greece the largest water consumer is the agricultural sector as about 85% of the available freshwater volumes is consumed for covering agricultural needs. Moreover, water losses have been detected in many cases while water consumption for irrigation is significantly increased during the summer due to the extreme decrease of rainfall. Actions aiming at the elimination of water losses and the reduction of irrigation water have been incorporated in the Greek SG. Such actions concern the renovation/change of irrigation systems and the cultivation of crops that are less water-demanding and more resilient to drought. Regarding household and industrial water consumption, the proposed actions have to do with the extensive use of water saving equipment (e.g. smart taps) and the use of recycled water respectively.

Which actions should be implemented in order to reduce GHG emissions?
The reduction of GHG emissions represents one of the core priorities of EU and specific goals have been set for each Member State. In Greece, the efforts towards the accomplishment of such a goal include: the reduction of emissions derived from both ETS (e.g. power generation sector) and non-ETS sectors (e.g. agriculture, non-ETS industry); the protection of grassland, forest land, crop land and wetland (LULUCF sector) contributing to CO_2 sequestration; the extensive use of RES (PVs, wind parks, hydro-power plants, biomass) in the sectors of transportation, industry, household/commercial and agriculture; the use of natural gas instead of oil, and the reduction of coal use for electricity generation.

Which are the main energy sources that may be used in the future for energy production?
Greece has the potential to exploit RES for energy production. Such renewable energy sources are: solar (PVs), wind (wind parks), water (hydro-power plants) and biomass (e.g. agricultural biomass). Such alternative energy sources and their potential for energy production are included in the Greek SG.

How food needs may be covered in the future?
Covering population's existing and future food needs is a critical issue involving land uses and agricultural production. In the case of Greece, two actions are proposed for strengthening the food sector; the first one concerns the implementation of measures (e.g. subsidies) that reinforce agricultural production in order to cover food and fodder needs as well as needs related to agri-industrial products.

The second one refers to the reinforcement of livestock production, again through the mobilisation of subsidies.

Which are the main priorities concerning the sector of land?
Regarding the sector of land, the main research questions focus on: the elimination of land use conflicts, the establishment of regulations aiming at the protection of agricultural land and livestock and, the organisation of reforestation actions in order to restore biodiversity and forest land, often destroyed by forest fires.

5.6.2 Supporting policy coherence

The assessment of policy coherence was completed through the identification of nexus-related policy objectives and policy instruments (included in the relevant national policy papers), the assessment of interactions among policy objectives and the assessment of interactions between policy objectives and policy instruments. Also, discussions with stakeholders revealed existing conflicts and synergies when it comes to policy implementation and not forecasted by the respective policy papers. Policies selected per each nexus sector concern the following issues (Papadopoulou et al., 2020):

- Climate: Reduction of GHG emissions, protection of atmosphere quality, climate change adaptation and mitigation options.
- Energy: Sustainable use of energy sources, development of infrastructures that exploit RES for energy production, penetration of RES in the country's energy mix, implementation of energy saving practices and promotion of energy efficient solutions.
- Land: Land use regulations and management of land use conflicts.
- Water: Protection and sustainable use of surface water and groundwater, mitigation of pollution in natural ecosystems.
- Food: Food production, food and fodder quality, preservation of traditional and scarce seeds.

Policies concerning the agricultural and tourist sectors were also taken into consideration. The relevant policy issues include: the future resilience and development of agriculture and tourism against climate change impacts; the limitation of pesticides' use; the future development of livestock; the management of agricultural land and pastures; the promotion of tourist entrepreneurship, and; the establishment of alternative tourist activities.

Regarding the assessment of policy coherence among the nexus-related objectives, the overall analysis showed that the majority of interactions are positive and thus progress on most objectives positively affects progress of the rest. Most synergies exist among objectives falling within the same nexus domain and characterised by a high level of complementarity. Synergies also exist between: energy and climate objectives; food/agriculture and land objectives; water and climate objectives (Papadopoulou et al., 2020). Indicative pairs of strongly coherent objectives are:

- Achievement of the national energy goals (energy sector) *and* Reduction of GHG emissions (climate sector).
- Sustainable development of agricultural sector (food/agriculture sector) *and* Promote sustainable spatial integration so as to eliminate spatial inequalities (land sector).
- Combating floods and droughts (water sector) *and* Increase climate change adaptation and resilience (climate sector).

Inconsistencies were detected between objectives concerning: the extensive use of natural gas (energy sector) *and* the reduction of GHG emissions (climate sector), the sustainable management of water resources (surface water and groundwater) (water sector) *and* the limitation of pesticides' use (food/agriculture sector), the sustainable development of agricultural sector (food/agriculture sector) *and* the spatially balanced distribution of industry (land sector).

As to the assessment of policy coherence between policy objectives and policy instruments, results were fairly similar to those of the objectives vs. objectives policy coherence assessment. Instruments and objectives referring to the same nexus domain are very consistent while synergies exist also between: climate instruments and energy objectives; water instruments and climate objectives; land instruments and food/agriculture objectives (Papadopoulou et al., 2020). Indicative pairs of strongly coherent instruments and objectives are:

- Funding R&D initiatives in the sector of renewables (climate instrument) *and* Achievement of the national energy goals including penetration of RES in the national energy mix (energy objective).
- Constitution of national plans (scientific reports and maps) aiming at the effective assessment and management of flood effects and impacts of possible droughts (water instrument) *and* Increase of climate change adaptation and resilience (climate objective).
- Land use regulations including completion of the Greek Cadastre (land instrument) *and* Sustainable development of agricultural sector (food/agriculture objective).

Representative inconsistencies exist between the instrument concerning the provision of incentives for further exploitation and use of natural gas and the objective concerning the decrease of GHG emissions, and; the instrument referring to the establishment of funds for RES use in the building sector and the objective promoting the extensive use of natural gas in buildings.

Policy coherence assessment was conducted by the research team and validated by the involved stakeholders. It served as a guide for the development of the SDM and the design of the Greek SG. Both consistent and inconsistent pairs of objectives and objectives-instruments were incorporated in the SG in order to explore their impacts through a learning process. Such impacts are expected to shed light on issues that should be managed by future policies under a nexus rationale. Compared to D2.1 and D2.2, there is an update regarding the objective and the relevant instrument promoting the extensive use of natural gas. The use of natural gas is proposed as a solution in order to replace oil but extra attention should be paid on its extensive use as it entails GHG emissions.

All in all, the SDM and SG confirmed the policy coherence analysis as the research team took into account important policy priorities and input from stakeholders' interviews and workshop. Such elements were embodied in the SDM and SG in order to be investigated through the nexus approach. Results indicated that a nexus rationale guarantees the integrated and efficient management of resources by considering the interlinkages and interactions existing among the several nexus components. Moreover, it brings the potential for gaining new insights during policy making through the design of policy decisions leading to a low-carbon economy.

5.6.3 Testing policy scenarios

Based on the analysis carried out so far and the issues discussed in the relevant workshop that took place in Riga, the main policy recommendations in the case of Greece, reported also by our stakeholders, concern:

- The connection of policy goals with SDGs.
- The reduction of emissions derived from all GHGs.
- The incorporation of the new CAP's priorities (2021-2017).
- The cultivation of crops that are resilient to climate change.
- The improvement of energy efficiency in the industrial sector.
- The improvement of energy efficiency in the transportation sector.
- The design and implementation of an advanced regulation aiming at the improvement of buildings' energy stock.

Important policy recommendations refer also to:

- The minimisation of water losses in the agricultural sector.
- The decrease of water-consuming crops and the cultivation of less water-demanding crops.
- Further promotion and use of RES for electricity generation by 2030.
- The explicit regulation of land uses targeting at the protection of agricultural land and land occupied by livestock.

Testing policy scenarios in the SG is expected to validate policy recommendations and reveal new ones that will set the ground for the design of integrated strategies, targeting at the establishment of a low-carbon economy and the efficient use of resources. It will also contribute to assess the efficiency of current policies, the level of policy integration under a nexus rationale, existing policy gaps and critical nexus issues that should be addressed by future policies. Policy synergies and trade-offs will also be assessed. In other words, the SG and the SDM may be seen as learning tools supporting policy assessment and decision making. This is achieved through the quantification of policies and their translation into model terms (variables), allowing for their testing in the SG and the elicitation of useful policy recommendations.

The most successful combinations of policy interventions, where strong synergies may be developed, include:

- Adoption of new (alternative) irrigation systems for minimising water losses (water sector) – Land use regulations aiming at the protection of agricultural land and livestock areas / Elimination of land use conflicts (land sector).
- Land use regulations aiming at the protection of agricultural land and livestock areas / Elimination of land use conflicts (land sector) – Implementation of measures (e.g. subsidies) that reinforce agricultural production in order to cover food and fodder needs as well as needs related to agri-industrial products (food sector).
- Land use regulations aiming at the protection of agricultural land and livestock areas / Elimination of land use conflicts (land sector) – Implementation of measures (e.g. subsidies) that reinforce livestock production in order to cover food needs (food sector).
- Organization of reforestation actions in the national, regional and municipality level in order to restore biodiversity, forest land wetlands and grasslands (often destroyed by forest fires) (land sector) – Protection of forest land, wetland, grassland and crop land (e.g. land use regulations, effective confrontation of forest fires) / Mitigation of climate change impacts through activities in the LULUCF sector (climate sector).
- Further promotion / use of RES for electricity generation by 2030 (energy sector) – Reduction of GHG emissions derived from the non-ETS sectors (agriculture, non-ETS industry, etc.) through the adoption of relative technologies (e.g. technologies that reduce CO_2 emissions) (climate sector).
- Further promotion / use of RES for electricity generation by 2030 (energy sector) – Reduction of GHG emissions derived from ETS sectors (e.g. power generation sector) (climate sector).

On the other hand, conflicting policy interventions concern:

- Reduction of GHG emissions derived from the non-ETS sectors (agriculture, non-ETS industry, etc.) through the adoption of relative technologies (e.g. technologies that reduce CO_2 emissions) (climate sector) – Promotion / Use of natural gas in the electricity generation plants, industrial, household/commercial, transportation and other sectors (energy sector).
- Reduction of GHG emissions derived from ETS sectors (e.g. power generation sector) (climate sector) - Promotion / Use of natural gas in the electricity generation plants, industrial, household/commercial, transportation and other sectors (energy sector).

Conflicts are observed between policy scenarios referring to: a) the reduction of GHG emissions and b) the extensive use of natural gas for energy production. This is due the fact that the use of natural gas entails the release of GHGs in the atmosphere. The majority of policy scenarios are rather synergistic.

5.6.4 Addressing Nexus challenges

As already mentioned in previous sections of the report, the challenges going to be addressed by the Greek SDM and SG, per each nexus sector are:

- Climate: Reduction of GHG emissions from both ETS and non-ETS sectors; increase the adaptation ability and resilience against climate change; increase awareness as to climate change issues.
- Water: Protection and sustainable management of surface water and groundwater; water saving practices; rational use of water resources by the agricultural, domestic and industrial sectors.
- Agriculture and food: Protection of agricultural land; spatial organisation of livestock; coverage of food needs (agri-food and livestock products).
- Energy: Electricity production from RES (PVs, wind parks, hydro-power plants, biomass); replacement of oil by natural gas; reduction of coal use for electricity production.
- Land: Protection of biodiversity; land uses regulation; protection of forest land, grassland, wetlands and crop land.
- Tourism: Sustainable use of resources (e.g. water, energy) by the tourist sector.

Towards this direction, a vast amount of data has been collected, refined and introduced into the SDM. Moreover, nexus-related policy objectives and policy interventions were identified and linked to the SDM through a policy quantification process. Policies were 'translated' into model terms (variables) and introduced into the SG in order to be tested on the basis of indicators, estimating the level of accomplishment of the relevant policy objectives. Policy recommendations were elicited and pathways were built.

From the outcomes of thematic models, SDM, SG, data mining and workshops with stakeholders, the main pathways and strategies towards low-carbon and resource efficiency in 2050 are the following:

- Coordinated efforts by both ETS and non-ETS sectors targeting at the reduction of GHG emissions.
- Extensive use and promotion of RES for energy production.
- Reduction of coal use for electricity generation.
- Protection of agricultural land and land occupied by livestock in order to secure sufficient food production.
- Reinforcement of actions related to the LULUCF sector and supporting CO_2 sequestration.
- Minimisation of water losses by the agricultural sector.
- Cultivation of less water-demanding crops.

5.7 Short-term and long-term policy recommendations

5.7.1 Summary of the Nexus issues in the case study

In the case of Greece, the nexus challenges having been set, concern the sectors of water, energy, agriculture and food, land, climate and tourism. Such challenges are closely related to policy priorities determined in the national policy papers and have been integrated in the SDM and the SG. Thousands of data referring to water consumption, energy generation and consumption, food production, agricultural and tourist development, GHG emissions and land uses fed the Greek SDM. Nexus-related policy objectives and instruments embodied as policy cards in the SG in order to be tested and their impacts to be explored under a nexus rationale. The overall challenge is the sustainable management of the nexus, the efficient use of resources and the establishment of a low-carbon economy. Moreover, the SG intends to simulate a learning process that will shed light on issues that should be considered by future policies. In this context, existing policy gaps are investigated and future needs are revealed.

The nexus challenges are strongly related to the main nexus goals, i.e. climate goals in 2050 and resource efficiency goals. The reduction of emissions, the extensive use of RES, the adaptation of productive sectors to climate change and the rational use of the available resources reflect priorities of utmost importance in Greece. More analytically, the challenges that the Greek CS is willing to recommend about, per each nexus sector are:

- Climate: Reduction of GHG emissions from both ETS and non-ETS sectors; increase the adaptation ability and resilience against climate change; increase awareness as to climate change issues.
- Water: Protection and sustainable management of surface water and groundwater; water saving practices; rational use of water resources by the agricultural, domestic and industrial sectors.
- Agriculture and food: Protection of agricultural land; spatial organisation of livestock; coverage of food needs (agri-food and livestock products).
- Energy: Electricity production from RES (PVs, wind parks, hydro-power plants, biomass); replacement of oil by natural gas; reduction of coal use for electricity production.
- Land: Protection of biodiversity; land uses regulation; protection of forest land, grassland, wetlands and crop land.
- Tourism: Sustainable use of resources (e.g. water, energy) by the tourist sector.

Such challenges are expected to be addressed under the nexus approach as they are inter-related through a complex system of interlinkages. The main connections among the nexus sectors in the case of Greece are:

- Climate to water: Climate change affects precipitation and evapotranspiration. This entails the reduction of the available quantity of surface water and groundwater. The risk of drought increases.
- Climate to land: Climate change affects land uses, especially agricultural land and the type of cultivated crops.
- Climate to food: The production of agricultural and dairy products depends on weather conditions. Consequently, the coverage of food needs is straightforwardly affected by climate change.
- Energy to climate: Energy generation and consumption entails increase of GHG emissions, especially when it comes to the broad use of coal and oil.
- Food to water: The production of food needs vast amounts of water, especially when we are talking about agri-food products. In Greece about 85% of the available fresh water resources is used by the agricultural sector.
- Food to land: Food production presupposes the availability of land for the development of agricultural and livestock activities.
- Land to water: Land uses affect quality and quantity of surface water and groundwater. Agricultural land use (enormous irrigation needs), urban land use and industrial land use are the main consumers of water that simultaneously have negative impacts on water quality.
- Land to climate: Several land uses (e.g. industrial land use) produce GHG emissions that affect climate. On the other hand, the LULUCF sector contributes to CO_2 sequestration.
- Water to energy: The availability of surface water resources affects energy production from hydro-power plants.

Such connections were taken into account during the development of the SDM and the design of the SG. Thus, the relevant issues are expected to be addressed by the Greek SG.

5.7.2 Description of the policies targeted for recommendations

The actors we are going to target for our policy recommendations are mainly representatives of the public and private sector. NGOs and academic/research institutes will also be engaged. Some of them have a strong influence on nexus-related policy decisions while all actors are interested in the management of the nexus components. Among our key actors are the Ministry of Environment and Energy (Directorate for Climate Change and Atmosphere Quality and Directorate of Spatial Planning), the Ministry of Foreign Affairs (Directorate of International Energy Issues), the Ministry of Tourism (General Directorate of Tourist Policy), the Ministry of Infrastructure, Transport and Networks (Special Office of Public Works, Construction and Maintenance of Hydraulic Infrastructures) and the Piraeus Bank. Other involved actors influenced by and interested in the relevant policy recommendations include: the Hellenic Association of Photovoltaic Energy Producers, the Hellenic Public Power Corporation S.A. (PPC), the Athens Labour Unions Organisation (Department of the Environment and International Relations), the Greek Ombudsman, Greenpeace Greece, WWF Greece, the National Cadastre and Mapping Agency S.A., the School of Mechanical Engineering of NTUA, the School of Planning and Regional Development of UTH, the National Documentation Centre (National Horizon 2020 contact point on energy issues), the Hellenic Association for Cogeneration of Heat and Power, the food company 'Mills of Crete' and the multi-shareholders company 'Monopati-Monakrivo'.

All these actors have been engaged in the project and supported, through semi-structured interviews and a stakeholders' workshop, the definition of nexus issues at stake, the identification of policy objectives and instruments going to be embodied in the SG, the determination of the nexus-critical policy priorities as well as the validation of the policy cards designed by the research team. The SG will serve as a guide in order actors to test their future plans, based on their behaviors or future agendas.

Briefly, policy recommendations of the Greek CS include:

- The connection of policy goals with the SDGs.
- The reduction of emissions derived from all GHGs.
- The incorporation of new CAP's priorities (2021-2027) in the national agricultural policy.
- The cultivation of crops which are resilient to climate change.
- The improvement of energy efficiency in the industrial sector.
- The improvement of energy efficiency in the transportation sector.
- The introduction of advanced buildings' regulation for improving buildings' energy stock.

Policies that are relevant to each policy recommendation, also listed in D2.2, are:

Connection of policy goals with the SDGs: Cover food needs, fodder needs and needs related to industrial crops (policy goal related to SDG2); protection of agricultural land and land occupied by livestock (policy goal related to SDG2); water saving in agricultural sector (policy goal related to SDG6); water saving in households (policy goal related to SDG6); water saving in the industrial sector (policy goal related to SDG6); increase RES share in the gross final energy consumption by 32% until 2030 (policy goal related to SDG7); effort sharing decision for Greece / Non-ETS emission reduction target by 2030: -16% compared to 2005 emissions (policy goal related to SDG13); effort sharing decision for Greece / ETS emissions reduction target by 2030: -2.2% compared to 2005 emissions (policy goal related to SDG13); Sustainable management of forest land, wetland and grassland (policy goal related to SDG15).

Reduction of emissions derived from all GHGs: Effort sharing decision for Greece / Non-ETS emission reduction target by 2020: -5% compared to 2005 emissions; ETS emission reduction target by 2020: 1,74% per year compared to 2005 emissions; effort sharing decision for Greece / Non-ETS emission reduction target by 2030: -16% compared to 2005 emissions; effort sharing decision for Greece / ETS emission reduction target by 2030: -2.2 % compared to 2005 emissions; effort sharing decision for Greece / Non-ETS emission reduction target by 2050: -60% compared to 2005 emissions; mitigation of climate change impacts through activities in the LULUCF sector; increase RES share in the gross final energy consumption by 20% until 2020; increase RES share in the gross final energy consumption by 32% until 2030; decrease of oil for energy production in the several economic sectors; total penetration of RES in the gross final energy generation by 2050 at a rate of 60%-70%; decrease of coal for electricity production.

Incorporation of new CAP's (2021-2027) priorities: Protection of agricultural land and land occupied by livestock; sustainable management of forest land, wetland and grassland.

Cultivation of crops that are resilient to climate change: Diversification of crops / Cultivation of less water-demanding crops.

Improve energy efficiency in the industrial sector: Promotion/Use of biomass in the industrial sector; use of natural gas in the industrial sector; reduction of oil use in the industrial sector.

Improve energy efficiency in the transportation sector: Use of RES (biomass, bio-fuels) in the transportation sector; use of natural gas in the transportation sector; reduction of oil use in the transportation sector.

Introduction of advanced buildings' regulation for improving buildings' energy stock: Promotion/Use of biomass in the household sector.

The main policy processes taking place in Greece towards the transition to a low-carbon economy and resource-efficient society include: the reduction of GHG emissions from both non-ETS and ETS sectors; the reduction of coal and oil use for energy production; the protection of forest land, grassland and crop land (LULUCF sector) contributing to CO_2 sequestration; the adoption of water saving practices in the agricultural, household and industrial sectors; the broad adoption of RES for energy production; the protection of agricultural land and land occupied by livestock, and; the coverage of food and fodder needs. Such issues are of significant importance in the current policy agenda. The key requirements that these issues face, refer to the rational and effective use of natural and socio-economic assets in order the relevant goals to be achieved. SIM4NEXUS sets the broad framework for the integrated management of the available resources by proposing a holistic approach focusing on the interlinkages existing among the nexus components and the impacts of pressures put on all these components. SIM4NEXUS builds on a learning process that will shed light on policy impacts and reveal existing inconsistencies that should be addressed in future policies. Thus, SIM4NEXUS has the potential to unfold policy recommendations and existing policy gaps, synergies and trade-offs, uncompromised discrepancies and future policy issues at stake.

5.7.3 Policy recommendations

The below policy recommendations are indicative and need be confirmed by playing the Serious Game and analysing results.

5.7.3.1 Changes in policy outputs

In short	Minimisation of water losses by the agricultural sector
Target group	Ministry of Rural Development and Food, Local Organisations of Reclamation Services

Target policy goal	Water saving in agricultural sector
Target policy instrument	Adoption of alternative irrigation methods
Target policy process phase	Change of irrigation systems / Selection of the most water-saving irrigation system
Administrative level	Country
Time scale	Middle-term till 2050
Cost-effectivity	200 (High)
Social implications	High (positive)

This policy recommendation aims at the minimisation of water losses and the efficient use of irrigation water in agriculture. The Ministry of Rural Development and Food and the Local Organisations of Reclamation Services support coordinated efforts in order to modernise irrigation systems and promote water-efficient solutions for irrigation. Economic barriers should be removed and relevant subsidies should be given to individual farmers and farmer's unions as a supporting policy tool, encouraging the implementation of the suggested recommendation. Cost-effectivity is expected to be high as farmers will pay less for agricultural water. Social implications are also expected to be positive as water resources protection and sustainability will be reinforced.

In short	Decrease of water-**consuming crops and cultivation of less** water-**demanding crops**
Target group	Ministry of Rural Development and Food, Local Organisations of Reclamation Services
Target policy goal	Water saving in agricultural sector
Target policy instrument	Diversification of crops
Target policy process phase	1. Replacement of water intensive crops by less water-demanding crops 2. Replacement of irrigated crops by non-irrigated crops
Administrative level	Country
Time scale	Middle-term till 2050
Cost-effectivity	200 (High)
Social implications	Medium (positive)

This policy recommendation aims at the diversification of crops and the cultivation of species that are less water-demanding and more resilient to climate change. The Ministry of Rural Development and Food and the Local Organisations of Reclamation Services support coordinated efforts in order to replace water-consuming crops with less water-consuming ones. Economic barriers should be removed and relevant subsidies should be given to farmers as a supporting policy tool, encouraging the implementation of the suggested recommendation. Cost-effectivity is expected to be high as farmers will pay less for using agricultural water. Social implications are also expected to be positive as water resources protection and sustainability will be reinforced. Moreover, sufficient food production will be secured under climate change conditions.

In short	**Further promotion and use of RES for electricity generation**
Target group	Ministry of Environment and Energy
Target policy goal	Increase RES share in the gross final energy consumption by 32% until 2030
Target policy instrument	Increase electricity generation from PVs, wind parks, hydro-power plants and biomass power plants
Target policy process phase	More infrastructures that produce electricity from RES are established according to the comparative advantages and available energy resources in each region in Greece

Administrative level	Country
Time scale	Short term till 2030
Cost-effectivity	600 (High)
Social implications	High (positive)

This policy recommendation aims at the further exploitation of RES for electricity generation. It also reinforces the reduction of GHG emissions. The Ministry of Environment and Energy supports and funds the development of wind parks, photovoltaic parks and roofs, hydro-power plants and biomass power plants. Economic barriers should be removed and coordinated efforts towards reducing prices of electricity produced from RES should take place. Cost-effectivity is expected to be high as costs for confronting possible hazards caused by climate change will be mitigated. Social implications are also expected to be positive through the protection of atmosphere quality and the mitigation of climate change impacts related to GHGs.

In short	**Explicit regulation of land uses targeting at the protection of agricultural land and land occupied by livestock**
Target group	Ministry of Environment and Energy, Ministry of Rural Development and Food
Target policy goal	Protection of agricultural land and land occupied by livestock
Target policy instrument	Explicit regulation of land uses (e.g. completion of the Greek Cadastre)
Target policy process phase	Elimination of land use conflicts
Administrative level	Country
Time scale	Middle-term till 2050
Cost-effectivity	90 (Medium)
Social implications	High (positive)

This policy recommendation aims at the explicit regulation of land uses and the elimination of land use conflicts. The Ministry of Environment and Energy and the Ministry of Rural Development and Food proceed with the design of spatial plans regulating land uses and the completion of the Greek Cadastre. Cost-effectivity is expected to be medium. Social implications are expected to be positive through the protection of land uses serving food production and contributing to CO_2 sequestration (e.g. cropland and grassland).

5.7.3.2 Conclusion on coherent, Nexus-compliant policies

Based on the analysis of policy coherence, the main policy conflicts for the Greek CS are observed between policies promoting the elimination of GHGs and further adoption of RES for electricity production and the one encouraging the extensive use of natural gas. Natural gas is currently used in order to replace oil. However, its extensive use entails the release of GHGs in the atmosphere. Such conflict could be solved by limiting the use of natural gas in the near future and encouraging, through subsidies and funding, the exploitation of RES for electricity production. Thus, in the same way oil has been limited by using natural gas in the past, natural gas use will be limited by the further use of RES in the future.

Most policies are synergistic but a more integrated nexus-oriented approach is recommended to be adopted by decision makers so that a holistic and systemic framework, regulating resource use and low-carbon solutions, is established. The added value of adopting a nexus approach is strongly related to the effective management of synergies, conflicts and trade-offs taking place at both decision making and policy implementation level. Nexus-compliance is achievable through the deep investigation of interlinkages and interactions existing among the several components of a system and the adoption of approaches encouraging system analysis.

5.8 Conclusion

Conclusively, the nexus challenges addressed by the Greek CS involve several critical issues and policy priorities as to the efficient use of resources and the transition to a low-carbon economy. Greece has adopted the European strategy for the sectors of climate and energy while it also enhances the efforts towards the rational management of water resources, the coverage of food needs, the elimination of land use conflicts and the sustainable development of agricultural and tourist sectors under climate change conditions. In this context, the relevant nexus challenges concern: the reduction of GHG emissions derived from both ETS and non-ETS sectors; the reduction of oil and coal use for energy production; the increased penetration of RES in the national energy mix; the protection of agricultural land and the production of qualitative and sufficient agri-food products; the protection of land occupied by livestock and the production of sufficient dairy products and meat; the rational management of irrigation water and the elimination of water losses; the adaptation of the several productive sectors to climate change; the increased use of bio-fuels by the transportation sector, and; the protection of grassland, wetlands and forest land. Such issues set the base for the development of policy cards and addressed by the SG through the application of relevant policies and the estimation of indicators based on the data existing in the SDM.

The process of SG development offered the chance for an in-depth analysis of the relevant nexus sectors not only at practical but also at policy level. First of all, an extensive investigation of the interlinkages existing among the nexus components took place and revealed important interactions among them. It also led to a better understanding of how pressures on one nexus component may entail pressures on the others. Secondly, the exploration of the nexus-related policies, nexus-critical policy objectives and nexus-critical policy instruments contributed to the clarification of the policy framework governing the nexus and revealed several policy gaps that should be addressed in the future under an integrated nexus approach. Thirdly, the engagement of stakeholders supported the analysis of the nexus issues as they offered additive knowledge, emanating from their experience and expertise. Their influence on the management of the nexus sectors and their interests as to the future evolvement of the nexus served as a guide for the development of the Greek use cases. They also contributed to the development of the SG by recommending important policies that should be taken into consideration and validating the content of policy cards. Finally, it was clarified that a nexus approach brings the potential for a more efficient and effective management of natural and human assets as it builds upon an integrated perspective and supports the exploration of synergies, trade-offs and conflicts among the relevant nexus sectors.

Participative actions put an additive value to the development of the Greek CS through the enrichment of the available knowledge stock, the in-depth analysis of the nexus governance, the stakeholders' recommendations as to the nexus issues at stake and the incorporation in the SG of issues falling within stakeholders' interests. Stakeholders represent the potential players of the SG and thus the SG should capture their interests and correspond to their needs.

Thematic models and SDM supported the development of the SG by providing a pool of quantitative data that reflect the state-of-the-art of the nexus sectors, forecast future trends and allow for the estimation of indicators representing the impacts of implemented policies. Thousands of data were taken into account and fed the Greek SDM. Such data refer to water availability and consumption, electricity generation, emissions, food production, land uses, etc. Data included in the SDM connected to the relevant policies through a 'policy quantification' process (translation of policies into model terms) and relevant indicators were determined. Data from thematic models / SDM and indicators supported nexus understanding through the quantification of interlinkages and impacts.

Regarding policy recommendations, these include: the connection of the case study's policy goals with the SDGs; the reduction of GHG emissions; the incorporation of the new CAP's priorities (2012-2017) in the national agricultural policy; the cultivation of crops which are resilient to climate change, and the improvement of energy efficiency in the building, transportation and industrial sectors. The preconditions for the effective implementation of such recommendations should build on the principles of a low-carbon and resource-efficient economy, namely: the limitation of fossil fuels use, the extensive use of RES, the adaptation of productive sectors to climate change, the rational management of irrigation water and the production of sufficient amounts of food. The Greek SG intends to explore all such preconditions and shed light on their possible implementation and relevant impacts.

Overall, the nexus approach establishes a holistic framework under which sectoral policies may be engaged and improved. This may be accomplished through the adoption of an integrated nexus orientation where interlinkages and interactions among the several nexus sectors are considered during policy making and policy implementation. The systemic base of the nexus allows for the integrated use of resources and deals better with the management of conflicts, synergies and trade-offs existing among the nexus sectors.

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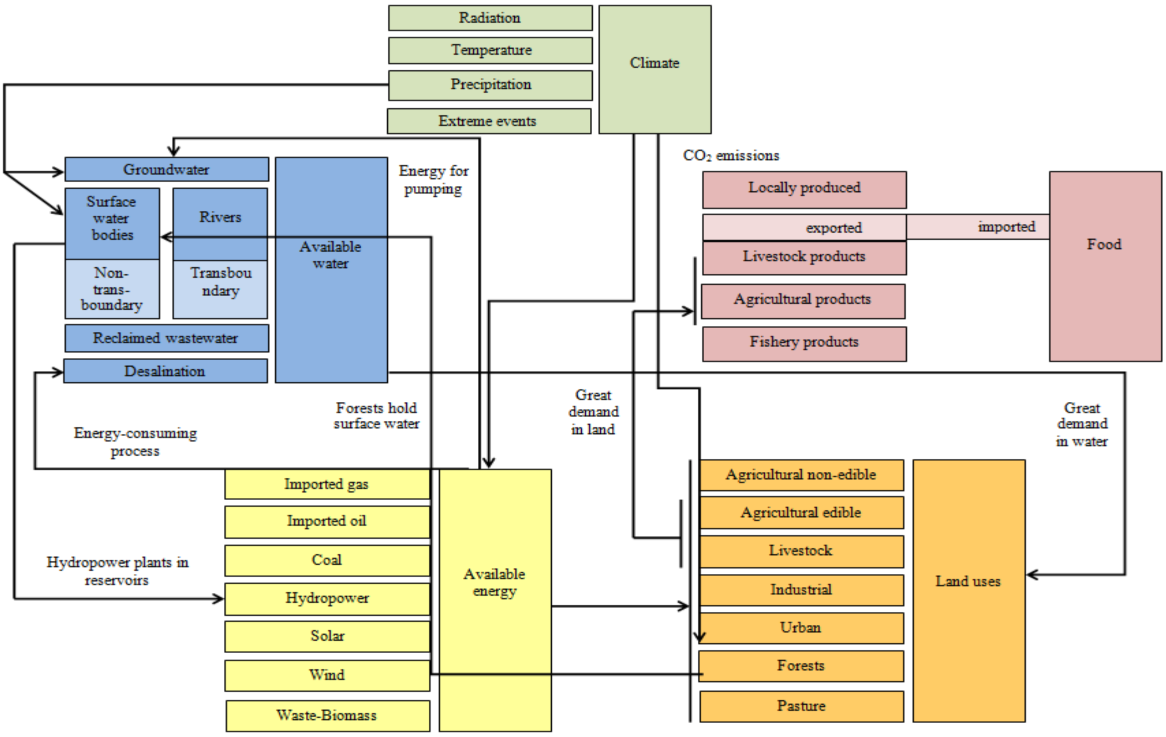
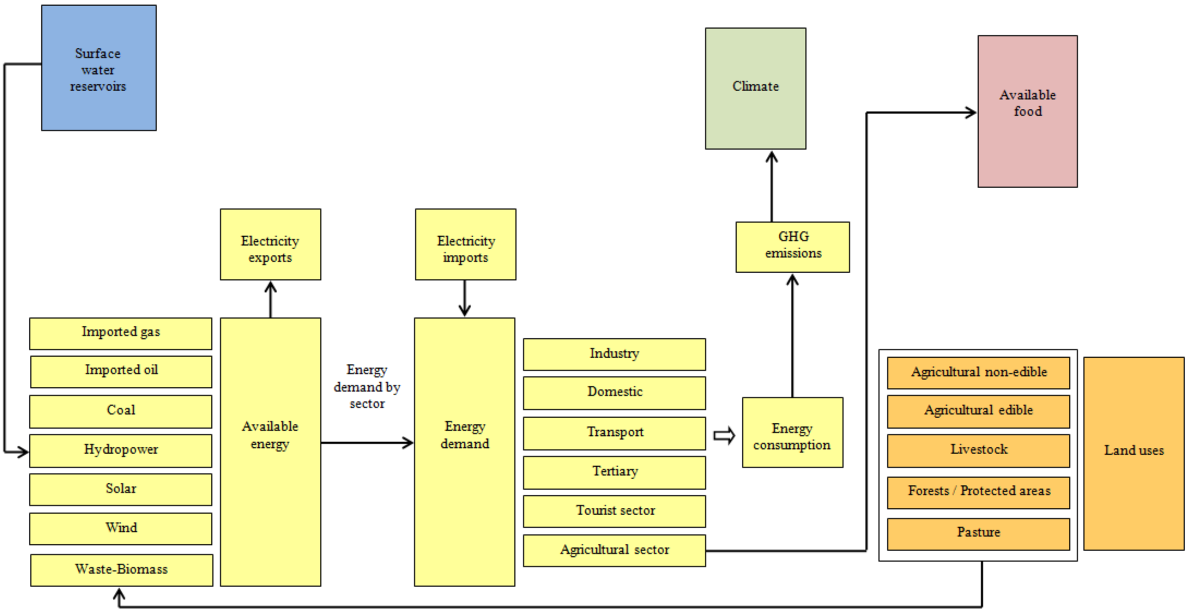
5.10 Annexes

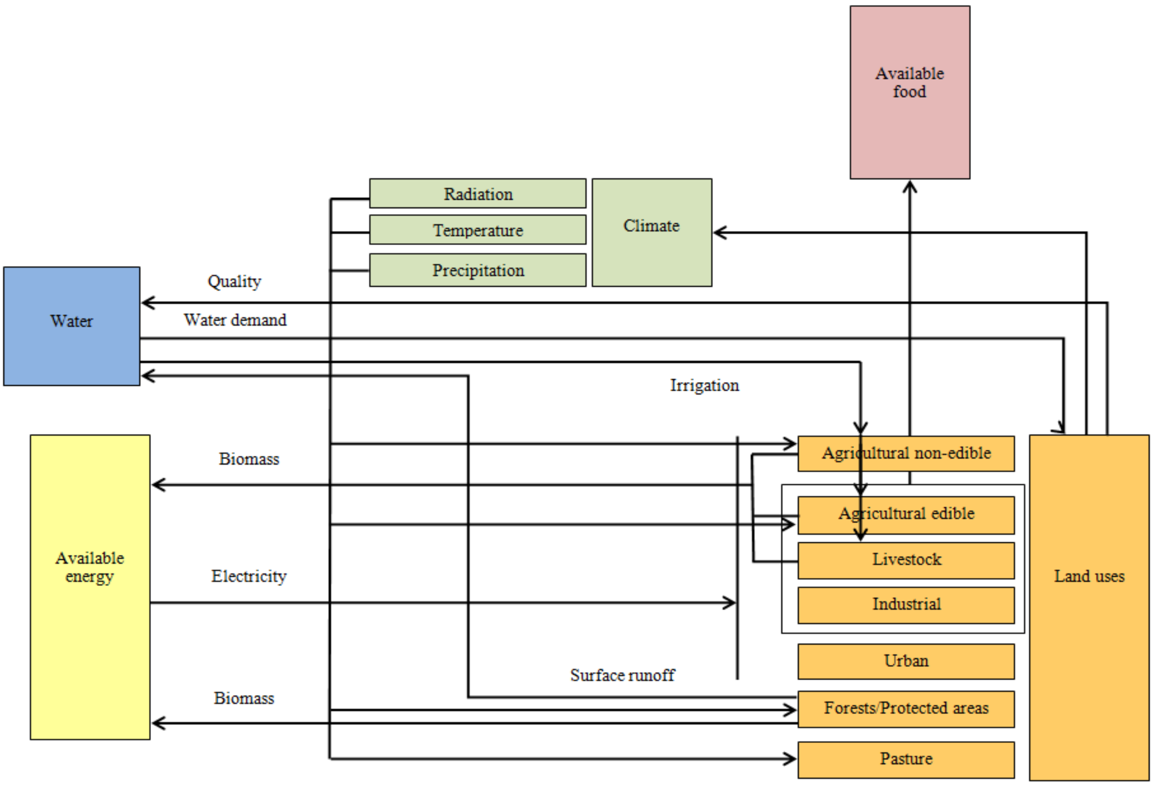
5.10.1 Conceptual model



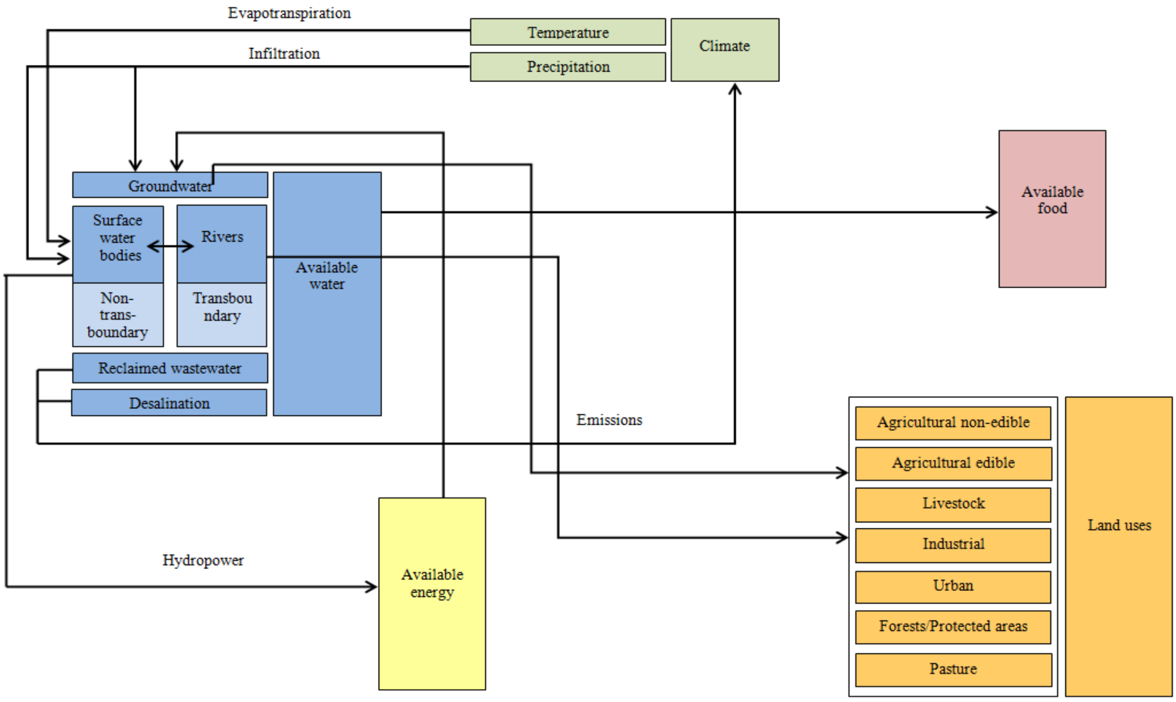
Greece: Conceptual model – General framework



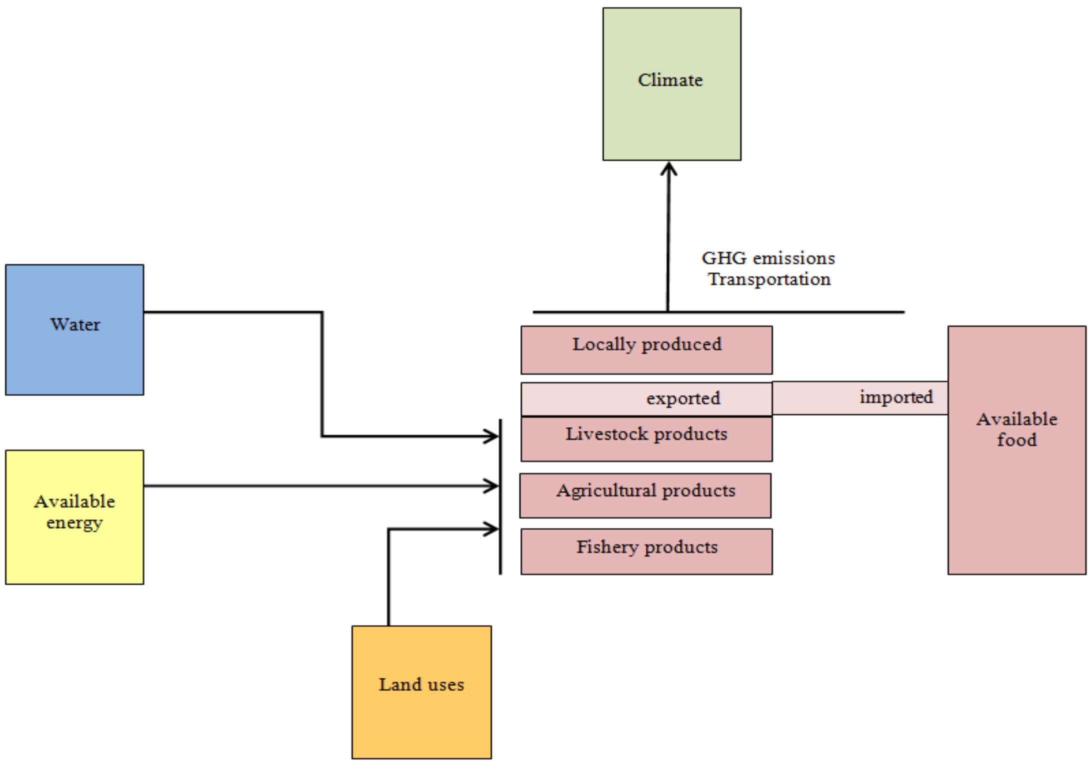
Greece: Conceptual model – Energy sector



Greece: Conceptual model – Land sector



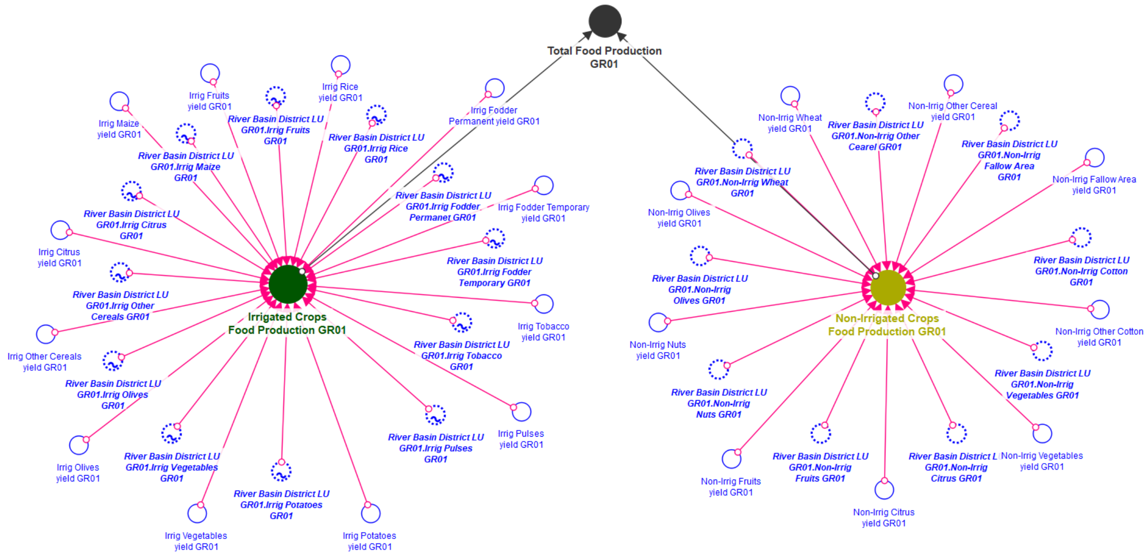
Greece: Conceptual model – Water sector



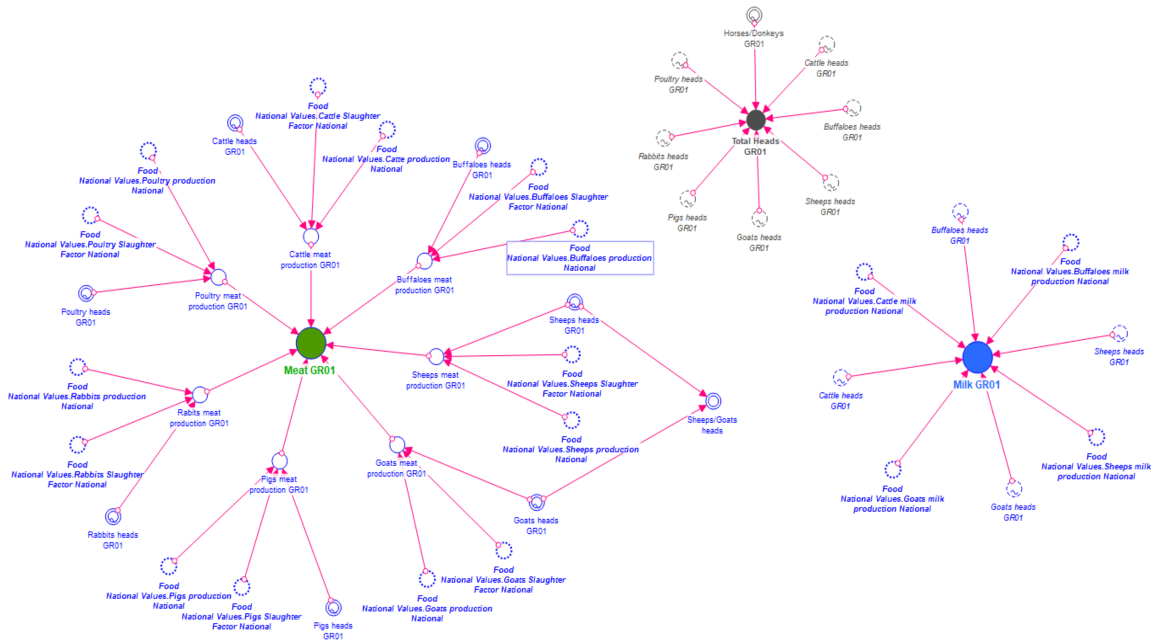
Greece: Conceptual model – Food sector

5.10.2 SDM screenshots

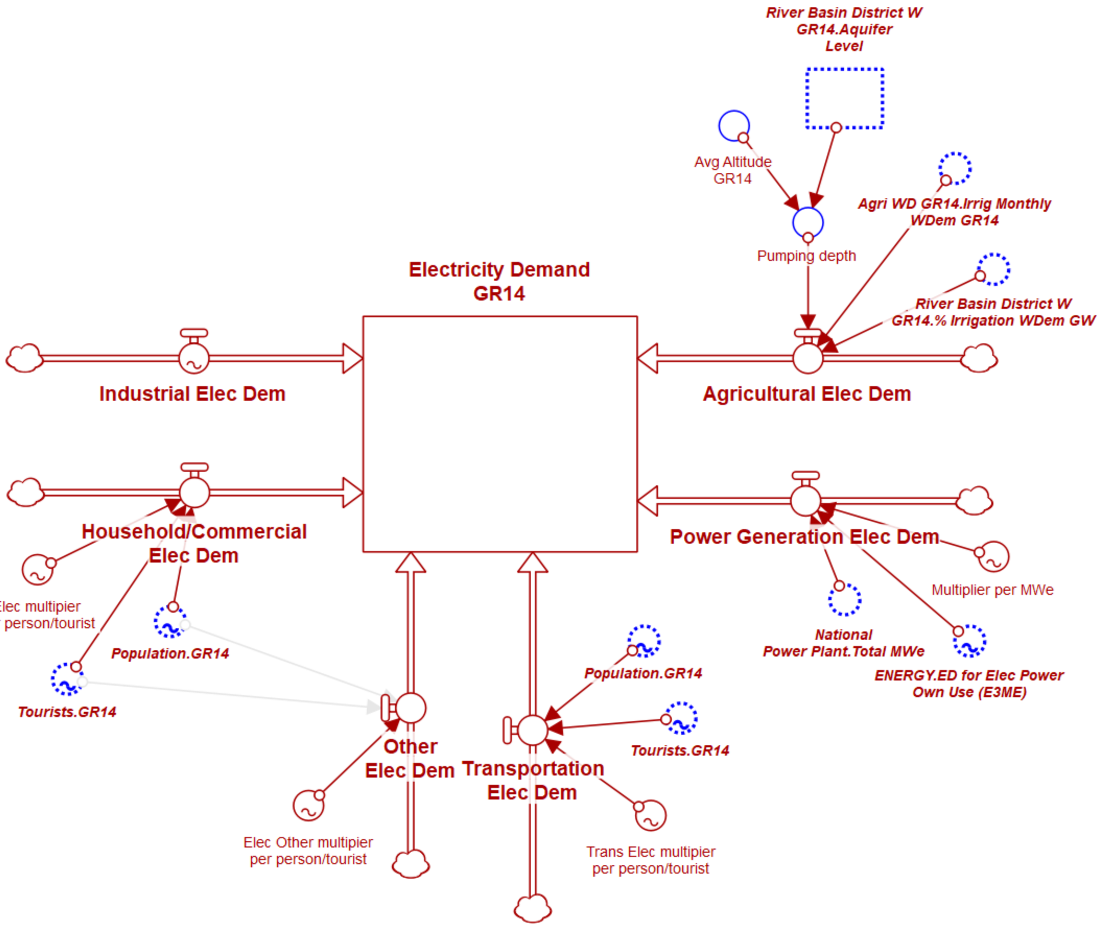
FOOD



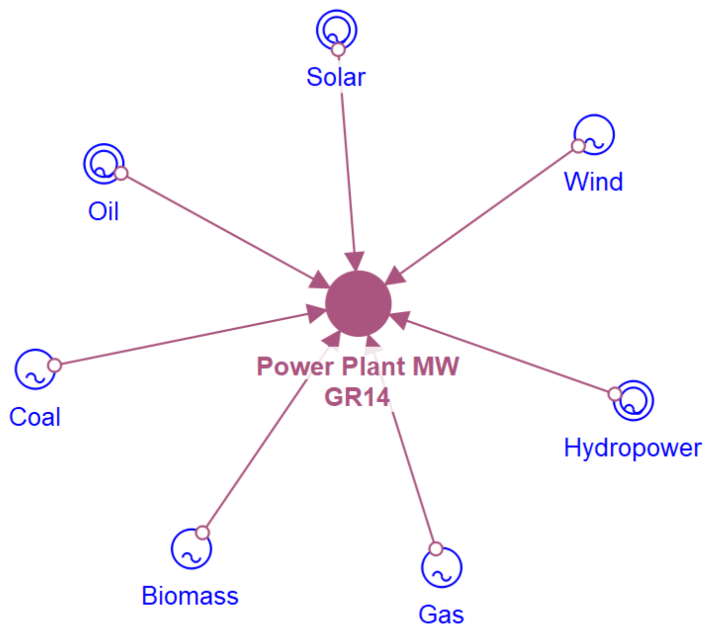
FOOD-Livestock



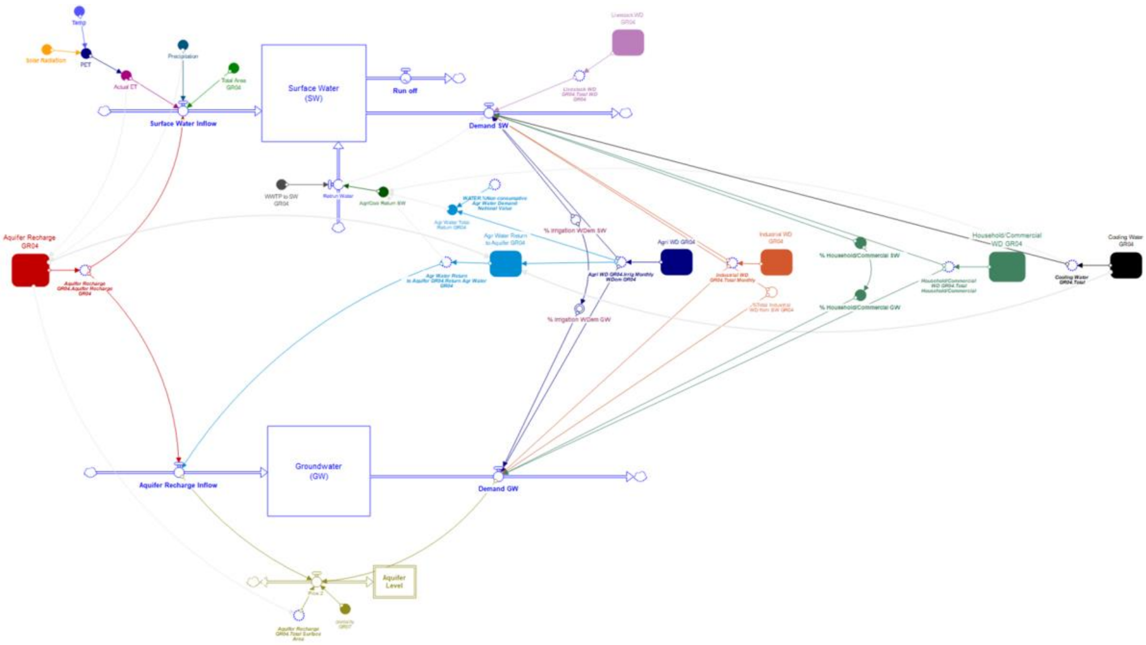
ENERGY



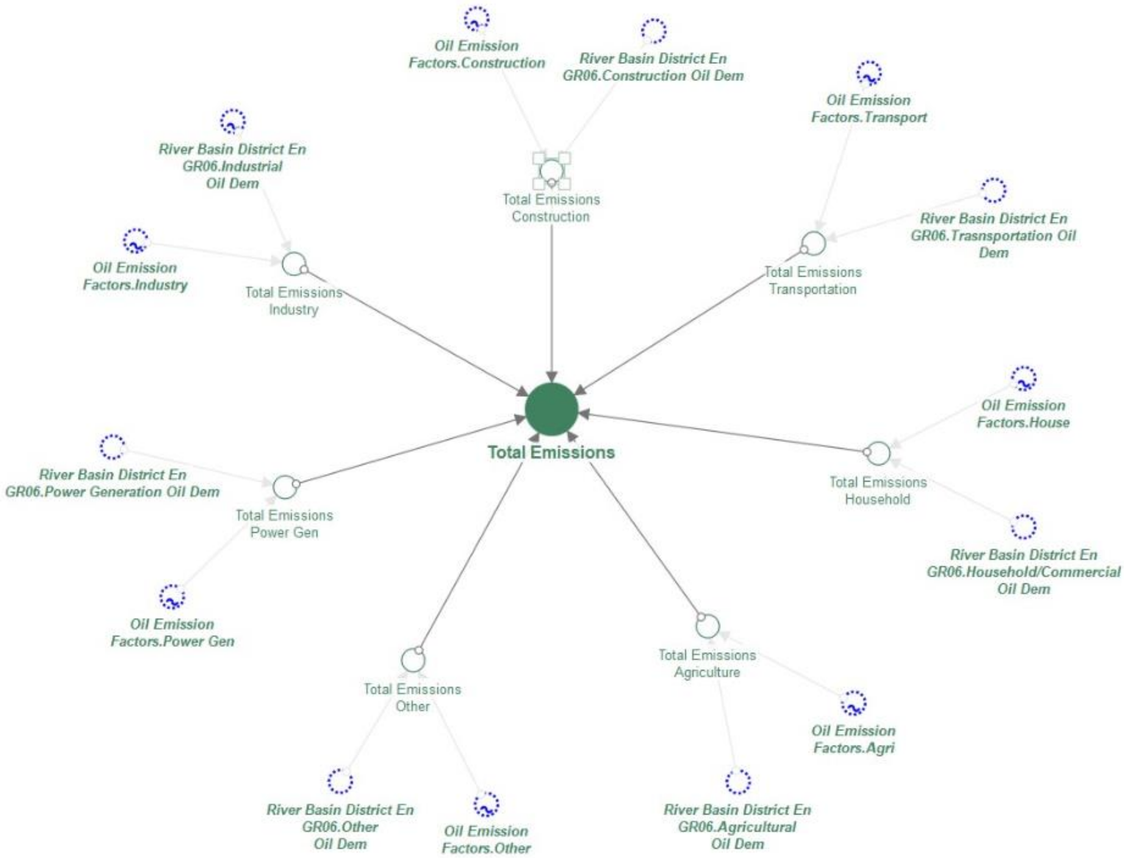
POWER PLANTS



WATER



CLIMATE (OIL)



5.10.3 Policy cards

		Legend: O = Policy Objective; Inst = Policy intervention; W = Water; L = Land; E = Energy; A = Agriculture; F = Food; C = climate.			
		WATER			
Policy objective (O)	***Performance indicator to achieve the O***	***Policy interventions (Ins)***	***Relevant Thematic model?***	***How does this intervention/measure translate into model input?***	***Implementation time***
O1 (PG1-W): Water saving in agricultural sector	**Change of monthly water losses and total irrigation water by changing the irrigation practices (furrow, sprinkle, drip) (m²)** Relevant variables that will reflect the results of the policy: (Agri_WD_GRXX.Total_Irrig_Water) & (Agri_WD_GRXX.Agricultural_Losses)	Adoption of new (alternative) irrigation methods (change of irrigation systems).	No	Change of cropland areas irrigated by different technologies (furrow, sprinkler, drip)	2020-2050
	Change of irrigated crops area (m²) Relevant variable that will reflect the results of the policy: (Agri_WD_GRXX.Total_Irrig_Water)	Diversification of crops or cultivation of crops that are resilient to drought (less water demanding crops).	No	Replace high water consuming crops with other, less water demanding crops OR replace irrigated crops with non-irrigated ones	2014-2020 (CAP) (6 years) 2020-2050
O2 (PG1-W): Water saving in households	**Change of household water consumption (m³)** Relevant variable that will reflect the results of the policy: (Household_DIV_Commercial_WD_GRXX.Total_Household_DIV_Commercial)	Water saving in households by establishing water saving equipment, (e.g. smart taps), changing consumption behaviour, etc.	No	Decrease of water demand by the household/commercial sector.	2020-2050 (30 years)
O3 (PG1-W): Water saving in the industrial sector.	**Change of industrial water demand by adopting water reuse practices (m³)** Relevant variable that will reflect the results of the policy: (Industrial_WD_GRXX.Total_Water)	Reuse of water in the industrial sector (recycled water).	No	Establish water reuse practices or increase water reuse in industry	2020-2050

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		CLIMATE			
Policy objective (O)	***Performance indicator to achieve the O***	***Policy interventions (Ins)***	***Relevant Thematic model?***	***How does this intervention/measure translate into model input?***	***Implementation time***
O1 (PG1-C): Effort sharing decision for Greece / Non-ETS emission reduction target by 2020: -4% compared to 2005.	**Change of GHG emissions derived from all non-ETS sectors (kg of CO_2 equivalents)** Relevant variable that will reflect the results of the policy: (RBD_Cl_GRXX.Total_non-ETS_Emissions_GRXX	Reduction of GHG emissions derived from the non-ETS sectors (agriculture, non-ETS industry, etc.) through the adoption of relative technologies (e.g. technologies that reduceCO_2 emissions).	No	GHG emissions derived from the non-ETS sectors.	2013-2020
	Change of GHG emissions derived from the agricultural sector (kg of CO_2 equivalents) Relevant variable that will reflect the results of the policy: (RBD_Cl_GRXX.Total_Emissions_Agriculture)				
	Change of GHG emissions derived from the non-ETS industrial sector (kg of CO_2 equivalents) Relevant variable that will reflect the results of the policy (the following sum): (OIL_GRXX.Total_non-ETS_Emissions_Industry) + (GAS_GRXX. Total_non-ETS_Emissions_Industry)				
	Change of GHG emissions derived from the non-ETS transportation sector (kg of CO_2 equivalents) Relevant variable that will reflect the results of the policy (the following sum): (OIL_GRXX.Total_non-ETS_Emissions_Transport) + (GAS_GRXX. Total_Emissions_Transportation_(all_non-ETS))				
	Change of GHG emissions derived from the construction sector (non-ETS) (kg of CO_2 equivalents) Relevant variable that will reflect the results of the policy: (OIL_GRXX.Total_Emissions_Construction)				
	Change of GHG emissions derived from the household/commercial sector (non-ETS) (kg of CO_2 equivalents) Relevant variable that will reflect the results of the policy (the following sum): (OIL_GRXX.Total_Emissions_Household) + (GAS_GRXX. Total_Emissions_Household)				

	Change of GHG emissions derived from other non-ETS sectors (kg of CO_2 equivalents) Relevant variable that will reflect the results of the policy (the following sum): (OIL_GRXX.Total_Emissions_Other) + (GAS_GRXX. Total_Emissions_Other)				
O2 (PG1-C): ETS emission reduction target by 2020: 1,74% per year compared to 2005 emissions	**Change of GHG emissions derived from all ETS sectors (kg of CO_2 equivalents)** Relevant variable that will reflect the results of the policy: (RBD_CI_GRXX.Total_ETS_Emissions_GRXX	Reduction of GHG emissions derived from ETS sectors (e.g. power generation sector).	No	GHG emissions derived from ETS sectors.	2013-2020
	Change of GHG emissions derived from the ETS industrial sector (kg of CO_2 equivalents) Relevant variable that will reflect the results of the policy (the following sum): (COAL_GRXX.ETS_Emissions_Industry) + (OIL_GRXX. Total_ETS_Emissions_Industry) + (GAS_GRXX. Total_ETS_Emissions_Industry)				
	Change of GHG emissions derived from the ETS transportation sector (kg of CO_2 equivalents) Relevant variable that will reflect the results of the policy: (OIL_GRXX.Total_ETS_Emissions_Transport)				
	Change of GHG emissions derived from the power generation sector (ETS) (kg of CO_2 equivalents) Relevant variable that will reflect the results of the policy (the following sum): (COAL_GRXX.ETS_Emissions_Power_Gen) + (OIL_GRXX. Total_Emissions_Power_Gen) + (GAS_GRXX. Total_Emissions_Power_Gen) + (BIOMASS_GRXX.Total_Emissions)				
O1 (PG2-C): Effort sharing decision for Greece / Non-ETS emission reduction target by 2030: -16% compared to 2005 emissions	**Same as the previous indicators for non-ETS sectors.**	Reduction of GHG emissions derived from non-ETS sectors (e.g. agriculture, non-ETS industry) through the adoption of relative technologies (e.g. technologies that reduce CO_2 emissions).	No	GHG emissions derived from non-ETS sectors.	2020-2030
O2 (PG2-C): Effort sharing decision for Greece / ETS emission reduction target by 2030: -2.2 % compared to 2005 emissions	**Same as the previous indicators for ETS sectors.**	Reduction of GHG emissions derived from ETS sectors (e.g. power generation sector).	No	GHG emissions derived from ETS sectors.	2020-2030

O1 (PG3-C): Effort sharing decision for Greece / Non-ETS emission reduction target by 2050: -60% compared to 2005 emissions	**Same as the previous indicators for non-ETS sectors.**	Reduction of GHG emissions derived from non-ETS sectors (e.g. agriculture, non-ETS industry) through the adoption of relative technologies (e.g. technologies that reduceCO_2 emissions).	No	GHG emissions derived from non-ETS sectors.	2030-2050
O1 (PG4-C): Emission reduction target for non-ETS sectors: 0 emissions by 2050	**Same as the previous indicators for non-ETS sectors.**	Reduction of GHG emissions derived from non-ETS sectors (e.g. agriculture) in order to achieve 0 emissions through the adoption of relative technologies (e.g. technologies that reduce CO_2 emissions).	No	GHG emissions derived from non-ETS sectors.	2030-2050
O2 (PG4-C): Emission reduction target for ETS sectors: 0 emissions by 2050	**Same as the previous indicators for ETS sectors.**	Reduction of GHG emissions derived from ETS sectors (e.g. power generation sector) in order to achieve 0 emissions.	No	Assumptions about GHG emissions (CO_2) derived from ETS sectors.	2030-2050
O1 (PG5-C): Mitigation of climate change impacts through activities in the LULUCF sector.	**Change of CO_2 sequestration for Cropland (kg of CO_2 equivalents)** Relevant variable that will reflect the results of the policy: (LULUCF_GRXX.Cropland_Emissions) **Change of CO_2 sequestration for Grassland (kg of CO_2 equivalents)** Relevant variable that will reflect the results of the policy: (LULUCF_GRXX.Grassland_Emissions) **Change of GHG emissions for Wetland (kg of CO_2 equivalents)** Relevant variable that will reflect the results of the policy: (LULUCF_GRXX.Wetlandland_Emissions) **Change of CO_2 sequestration for Forest (kg of CO_2 equivalents)** Relevant variable that will reflect the results of the policy: (LULUCF_GRXX.Forest_Emissions)	Protection of forest land, wetland, grassland and crop land (e.g. land use regulations, effective confrontation of forest fires).	No	Assumptions about the area covered by forest land, wetland, grassland and crop land.	2020-2050

ENERGY					
Policy objective (O)	***Performance indicator to achieve the O***	***Policy interventions (Ins)***	***Relevant Thematic model***	***How does this intervention/measure translate into model input?***	***Implementation time***
O1 (PG1-E): Increase RES share in the gross final energy consumption by 20% until 2020.	**Bio-fuels (biomass) used in the transportation sector in relation to other fuels (Joules)** Relevant variable that will reflect the results of the policy (the following fraction): (RBD_En_GRXX.Transportation_BD) / (RBD_En_GRXX.Total_Transportation_Dem_GRXX)	RES share in the transportation sector by 10% until 2020: use of bio-fuels (biomass).	E3ME	Share of bio-fuels in the transportation sector.	2010-2020
	Biomass used in the industrial sector in relation to other fuels (Joules) Relevant variable that will reflect the results of the policy (the following fraction): ((RBD_En_GRXX.Industrial_ETS_BD) + (RBD_En_GRXX.Industrial_non-ETS_BD))/ (RBD_En_GRXX.Total_Industrial_Energy_Demand)	Promotion / Use of biomass in the industrial sector.	E3ME	Share of biomass in the industrial sector.	2010-2020 (same policy card for 2020-2050)
	Biomass used in the household/commercial sector in relation to other fuels (Joules) Relevant variable that will reflect the results of the policy (the following fraction): ((RBD_En_GRXX.Household_DIV_Commercial_BD) / (RBD_En_GRXX.Total_Household_DIV_Commercial_Dem_GRXX)	Promotion / Use of biomass in the household/commercial sector.	E3ME	Share of biomass in the household/commercial sector.	2010-2020 (same policy card for 2020-2050)
	Biomass used in the agricultural sector in relation to other fuels (Joules) Relevant variable that will reflect the results of the policy (the following fraction): ((RBD_En_GRXX.Agricultural_BD) / (RBD_En_GRXX.Total_Agricultural_Dem_GRXX)	Promotion / Use of biomass in the agricultural sector.	E3ME	Share of biomass in the agricultural sector.	2010-2020 (same policy card for 2020-2050)
	Biomass used in other sectors in relation to other fuels (Joules) Relevant variable that will reflect the results of the policy (the following fraction): ((RBD_En_GRXX.Other_BD) / (RBD_En_GRXX.Total_Other_Dem_GRXX)	Promotion / Use of biomass in other sectors.	E3ME	Share of biomass in other sectors.	2010-2020 (same policy card for 2020-2050)
	Share of electricity generated from PVs in the gross final electricity generation (GWh) Relevant variable that will reflect the results of the policy (the following fraction): ((RBD_En_GRXX.Solar) * (National_Factors_Power_Plant.Solar)) / (RBD_En_GRXX.Electricity_Generated_in_GWh_GRXX)	Electricity generation from PVs up to 2500 MW until 2020.	No	Share of PVs in electricity generation.	2010-2020

	Share of electricity generated from wind parks in the gross final electricity generation (GWh) Relevant variable that will reflect the results of the policy (the following fraction): ((RBD_En_GRXX.Wind) * (National_Factors_Power_Plant.Wind)) / (RBD_En_GRXX.Electricity_Generated_in_GWh_GRXX)	Electricity generation from wind up to 7500 MW until 2020.	No	Share of wind parks in electricity generation.	2010-2020
	Share of electricity generated from hydropower plants in the gross final electricity generation (GWh) Relevant variable that will reflect the results of the policy (the following fraction): ((RBD_En_GRXX.Hydropower) * (National_Factors_Power_Plant.Hydro)) / (RBD_En_GRXX.Electricity_Generated_in_GWh_GRXX)	Electricity generation from hydro-power plants up to 3000 MW until 2020.	No	Share of hydro-power plants in electricity generation.	2010-2020
	Share of electricity generated from biomass in the gross final electricity generation (GWh) Relevant variable that will reflect the results of the policy (the following fraction): ((RBD_En_GRXX.Biomass) * (National_Factors_Power_Plant.Biomass)) / (RBD_En_GRXX.Electricity_Generated_in_GWh_GRXX)	Electricity generation from biomass power plants.	No	Share of biomass power plants in electricity generation.	2020-2050
O2 (PG2-E): Increase RES share in the gross final energy consumption by 32% until 2030.	**Is the same with 6, 7, 8, 9 sections of O1**	Further promotion / use of RES for electricity generation.	No	the same with 6, 7, 8, 9 sections of O1	2020-2030
O3 (PG3-E): Use of natural gas for electricity generation.	**Change of natural gas demand by the industrial sector (Joules)** Relevant variable that will reflect the results of the policy: ((RBD_En_GRXX.Industrial_ETS_GD) + (RBD_En_GRXX.Industrial_non-ETS_GD))	Promotion / Use of natural gas in the electricity generation plants, industrial, household/commercial, transportation and other sectors.	No	Demand of natural gas by the electricity generation sector, industrial, household/commercial, transportation and other sectors.	2010-2020 2020-2050
	Change of natural gas demand by the household/commercial sector (Joules) Relevant variable that will reflect the results of the policy: (RBD_En_GRXX.Household_DIV_Commercial_GD)				
	Change of natural gas demand by the power generation sector (Joules) Relevant variable that will reflect the results of the policy: (RBD_En_GRXX.Power_Generation_GD)				
	Change of Natural gas demand by the transportation sector (Joules) Relevant variable that will reflect the results of the policy: (RBD_En_GRXX.Transportation_GD)				

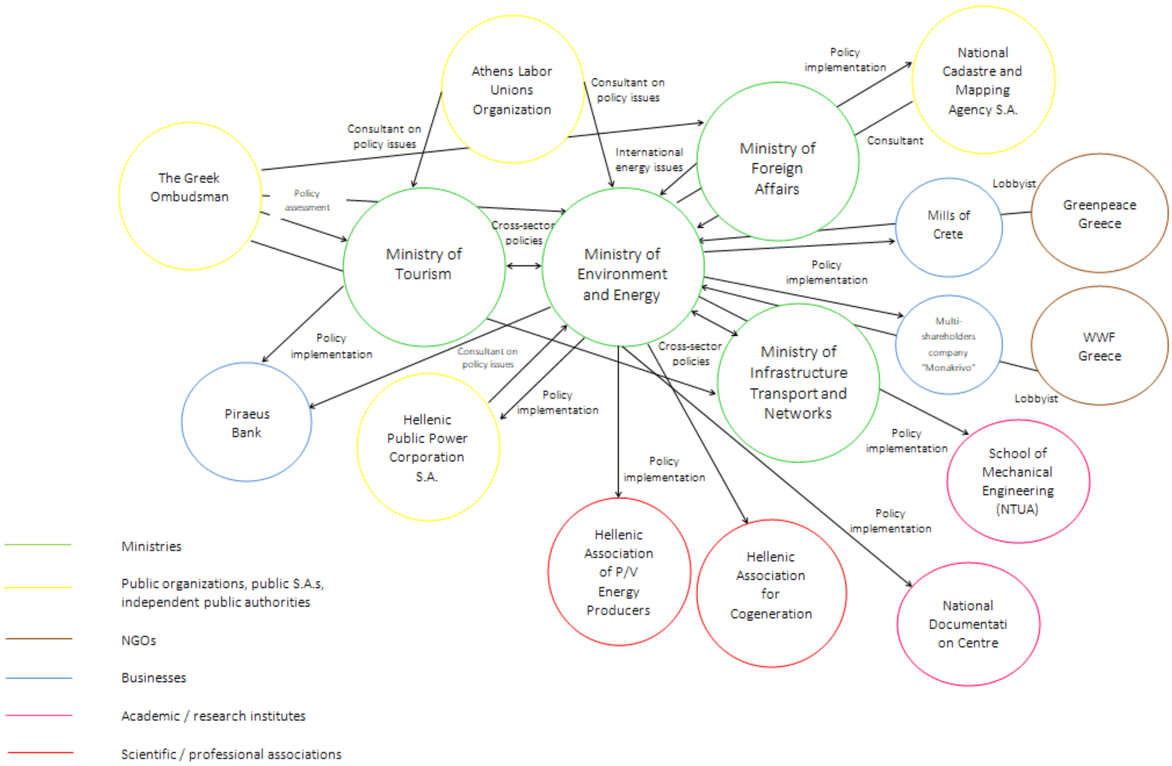
	Change of Natural gas demand by other sectors (Joules) Relevant variable that will reflect the results of the policy: (RBD_En_GRXX.OtherGD)				
	Share of natural gas used for electricity generation (GWh) Relevant variable that will reflect the results of the policy: ((RBD_En_GRXX.Gas) * (National_Factors_Power_Plant.Gas)) / (RBD_En_GRXX.Electricity_Generated_in_GWh_GRXX)				
O4 (PG4-E): Decrease of oil for energy production in the several economic sectors.	**Change of oil demand by the industrial sector (Joules)** Relevant variable that will reflect the results of the policy: ((RBD_En_GRXX.Industrial_ETS_OD) + (RBD_En_GRXX.Industrial_non-ETS_OD))	Reduction of oil and use of other resources (e.g. natural gas) for energy production in the industrial, household/commercial, electricity generation, transportation, construction and other sectors.	No	Demand of oil by the industrial, household/commercial, agricultural, electricity generation, transportation, construction and other sectors.	2010-2050
	Change of oil demand by the household/commercial sector (Joules) Relevant variable that will reflect the results of the policy: (RBD_En_GRXX.Household_DIV_Commercial_OD)				
	Change of oil demand by the agricultural sector (Joules) Relevant variable that will reflect the results of the policy: (RBD_En_GRXX.Agricultural_OD)				
	Change of oil demand by the electricity generation plants sector (power generation) (Joules) Relevant variable that will reflect the results of the policy: (RBD_En_GRXX.Power_Generation_OD)				
	Change of oil demand by the transportation sector (Joules) Relevant variable that will reflect the results of the policy: ((RBD_En_GRXX.Transportation_ETS_OD)) + (RBD_En_GRXX.Transportation_non-ETS_OD))				
	Change of oil demand by the construction sector (Joules) Relevant variable that will reflect the results of the policy: (RBD_En_GRXX.Construction_OD)				
	Change of oil demand by other sectors (Joules) Relevant variable that will reflect the results of the policy: (RBD_En_GRXX.Other_OD)				
	Share of oil used for electricity generation (MW) Relevant variable that will reflect the results of the policy: ((RBD_En_GRXX.Oil) * (National_Factors_Power_Plant.Oil)) / (RBD_En_GRXX.Electricity_Generated_in_GWh_GRXX)				

O5 (PG5-E): Total penetration of RES in gross final energy generation by 2050 at a rate of 60%-70%	**Share of electricity generated from Biomass in the gross final electricity generation (GWh).** Relevant variable that will reflect the results of the policy (the following fraction): ((RBD_En_GRXX.Biomass) * (National_Factors_Power_Plant.Biomass)) / (RBD_En_GRXX.Electricity_Generated_in_GWh_GRXX)	85%-100% electricity generation from RES using all commercially mature technologies.	E3ME	Increase of RES share in electricity generation. Electricity generation plants that exploit RES to produce electricity.	2020-2050
	Share of electricity generated from Hydropower in the gross final electricity generation (GWh). Relevant variable that will reflect the results of the policy (the following fraction): ((RBD_En_GRXX.Hydropower) * (National_Factors_Power_Plant.Hydro)) / (RBD_En_GRXX.Electricity_Generated_in_GWh_GRXX)				
	Share of electricity generated from Wind in the gross final electricity generation (GWh). Relevant variable that will reflect the results of the policy (the following fraction): (RBD_En_GRXX.Wind) * (National_Factors_Power_Plant.Wind) / (RBD_En_GRXX.Electricity_Generated_in_GWh_GRXX)				
	Share of electricity generated from Solar in the gross final electricity generation (GWh). Relevant variable that will reflect the results of the policy (the following fraction): ((RBD_En_GRXX.Solar) * (National_Factors_Power_Plant.Solar)) / (RBD_En_GRXX.Electricity_Generated_in_GWh_GRXX)				
O6 (PG6-E): Decrease of coal for electricity production	**Share of coal used for electricity production (GWh)** ((RBD_En_GRXX.Coal) * (National_Factors_Power_Plant.Coal)) / (RBD_En_GRXX.Electricity_Generated_in_GWh_GRXX)	Reduction of coal and use of other energy sources (e.g. RES) for electricity production	No	Reduction of coal demand by the industrial and electricity generation sectors. Electricity produced from coal.	2020-2050

		FOOD			
Policy objective (O)	***Performance indicator to achieve the O***	***Policy interventions (Ins)***	***Relevant Thematic model***	***How does this intervention/measure translate into model input?***	***Implementation time***
O1 (PG1-F): Cover of food needs, fodder needs and needs related to industrial crops.	1. **Crop food production (kg)** Relevant variable that will reflect the results of the policy: (RBD_F_GRXX.Crop_Food_Production) 2. **Crop feed production (kg)** Relevant variable that will reflect the results of the policy: (RBD_F_GRXX.Crop_Feed_Production) 3. **Crop industrial production (kg)** Relevant variable that will reflect the results of the policy: 1. (RBD_F_GRXX.Crop_Industrial_Production)	Implementation of measures (e.g. subsidies) that reinforce agricultural production in order to cover food and fodder needs as well as needs related to agri-industrial products.	No	Area of cropsproducing food, feed and industrial products.	2020-2050
O2 (PG2-F): Cover of food needs from the sector of livestock (livestock products).	**1. Meat production (kg)** Relevant variable that will reflect the results of the policy: (RBD_F_GRXX.Meat) **2. Milk production (kg)** Relevant variable that will reflect the results of the policy: (RBD_F_GRXX.Milk) **3. Eggs production (number of eggs)** Relevant variable that will reflect the results of the policy: (RBD_F_GRXX.Eggs) **4. Honey production (kg)** Relevant variable that will reflect the results of the policy: (RBD_F_GRXX.Honey)	Implementation of measures (e.g. subsidies) that reinforce livestock production in order to cover food needs.	No	Number of animal heads or beehives	2020-2050

	LAND				
Policy objective (O)	***Performance indicator to achieve the O***	***Policy interventions (Ins)***	***Relevant Thematic model***	***How does this intervention/measure translate into model input?***	***Implementation time***
O1 (PG1-L): Protection of agricultural land and land occupied by livestock	**1. Change of land occupied by agricultural crops (m^2)** Relevant variable that will reflect the results of the policy: (RBD_LU_GRXX.Total_Agri_Area) **2. Change of land occupied by livestock (m^2)** Relevant variable that will reflect the results of the policy: (RBD_LU_GRXX.Livestock_Area)	Land use regulations aiming at the protection of agricultural land and livestock areas – Elimination of land use conflicts.	No	Area occupied by crops and livestock	2014-2020 (CAP) 2020-2050
O2 (PG2-L): Sustainable management of forest land, wetland and grassland	**1. Change of forest land (m^2)** Relevant variable that will reflect the results of the policy: (RBD_LU_GRXX.Forest) **2. Change of wetland (m^2)** Relevant variable that will reflect the results of the policy: (RBD_LU_GRXX.Wetland) **3. Change of grassland (m^2)** Relevant variable that will reflect the results of the policy: (RBD_LU_GRXX.Grassland)	Organization of reforestation actions in the national, regional and municipality level in order to restore biodiversity, forest land wetlands and grasslands (often destroyed by forest fires) – Management of land use conflicts with the agricultural and livestock sectors.	No	Availability of forest land, wetland and grassland.	2015-2025 2025-2050

5.10.4 Stakeholders maps



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6 Latvia

6.1 Introduction

The Latvia case study has been developed at a national level and covers the whole territory of the country. The Republic of Latvia lies in Northern Europe, on the eastern shores of the Baltic Sea. It is bordering with Estonia, Russian Federation, Belarus and Lithuania. The total length of its maritime boundary is 498 km. Latvia covers the area of 64 573 sq.km and about 36% is agricultural land and 47% is covered by forest land. At the beginning of 2019, population of Latvia accounted for 1.9 million people[19].

Figure 42 Map of Latvia

The lead organisation of the Latvian case study is the Association "Baltic Environmental Forum – Latvia" (BEF-Latvia). The key stakeholders of the case study are State authorities (e.g., Ministry of Environmental Protection and Regional Development, Ministry of Agriculture, Ministry of Economics and their subordinated institutions), Universities, Research institutes, State Ltd "Latvian Environment, Geology and Meteorology Centre", Environmental Non-governmental organisations, five Planning Regions coordinating the development at regional level in Latvia.

The Latvia case study is focusing on low-carbon development of the country, considering interlinkages with the Nexus components - climate, water, energy, land use, and food - and identifying potential synergies, trade-offs and possible solutions. Low carbon development calls for reduction of GHG emissions as well as maintaining or even increasing CO_2 sequestration at the same time having positive environmental, economic, and social impacts. The directions of the Latvia case study comprise increasing energy production by RES, reduction of energy demand, decarbonisation of transport, along with sustainable land and water management practices reducing GHG emissions and nitrogen leakage from point and diffuse sources to improve the water quality.

The economic structure of Latvia is based on services, industry, and agriculture. Exports contribute to more than half of GDP. Latvia mostly exports wood and wood products, wood charcoal, electrical machinery, equipment, as well as mineral products. Due to its geographical location, transit services are highly developed, along with timber and wood-processing, agriculture, food products, manufacturing of machinery and electronics industries (IndexMundi, Latvia Economy Profile 2017). Latvia has a high potential for renewable energy but remains largely dependent on imported fossil fuels and electricity. Thus, energy security is of a key concern and ensuring the energy supply, competitiveness, energy efficiency and the use of renewable energy is the target set for 2030. The dependence on imported energy resources is steadily reducing due to the increased gross consumption of renewable energy sources (RES). Wood fuels and hydro energy, along with the oil products and natural gas imported from various countries play the most important role in the energy balance of Latvia. Energy, transport and agriculture are sectors of the highest concern with respect to the greenhouse gas emissions (GHG).

[19] (Central Statistical Bureau of Latvia, 2019).

Having achieved significant reduction of total GHG emissions since 1995, the current level of emissions in Latvia remains high. Thus, relevant policies and measures must be implemented.
The main research question has been : what are the possibilities and implications of a transition to a low carbon economy in Latvia, including which trade-offs would be acceptable and what are the possible solutions to maintain resource sustainability and ensure the economic feasibility.

6.2 Overview of tasks performed

6.2.1 Organisation to carry-out Task 5.2

The Association "Baltic Environmental Forum – Latvia" (BEF-Latvia) is the lead organisation of the Latvia case study of SIM4EXUS project. Four persons from the organisation have been mobilised for the implementation of the case study. MSc. Ingrida Bremere and MChem., MBiol. Daina Indriksone have been responsible for setting the case study goals and objectives, national policy analyses, data collection, communication with project partners, involvement of stakeholders, organisation of stakeholder events, preparation of presentations and reports, contribution to SIM4NEXUS meetings. Dr.Sc.Ing. Gaidis Klāvs has been involved in the development of the conceptual model for the Latvia case study and has participated and contributed to a stakeholder event. Liga Karkle has been responsible for logistics related to the organisation of stakeholder events in Latvia.

The Latvia case study has been implemented in close cooperation with SIM4NEXUS Project partners. The case study leaders from BEF Latvia were in communication through e-mail exchange and Skype sessions with responsible partners on issues related to the implementation of the case study. On certain occasions, the face-to-face meetings were used in combination to stakeholder events organised in Latvia or project partners meetings.

The concept, goals of the case study and implementation approach were communicated with the Project lead organisation Wageningen Economic Research (WEcR) and ACTeon. The activities related to the policy analysis in Latvia, including mapping of stakeholders, policy goals and instruments, assessment of policy coherence, trade-offs and synergies, finding success stories and failures has been implemented in close communication with the PBL Netherlands Environmental Assessment Agency (PBL). Communication with PBL on development of policy recommendations will be continued.

The development of the conceptual model for the Latvia case study highlighting the interlinkages between Water, Energy, Food, Land and Climate sectors was implemented by consulting with experts from the University of Exeter and IHE-Delft. The System dynamics model (SDM) for the Latvia case study has been developed by project partners from the IHE-Delft in close communication with BEF-Latvia team. Three thematic models: E3ME, MAGNET and CAPRI were used for the Latvia case study. The actual model runs were performed by the project partners: for E3ME (Cambridge Econometrics), MAGNET (WEcR), and CAPRI (Technical University of Madrid). BEF-Latvia experts have been communicating the modelling needs and results obtained with the respective project partners. Serious game for the Latvia case is being elaborated by project partners from the University of Exeter and EURECAT. Besides having individual consultations with these partners, BEF-Latvia is participating at regular skype conferences to reflect the progress achieved and to discuss next steps. Regular information exchange has proven to be very helpful to learn from each other's experiences and is highly appreciated.

Several targeted stakeholder events have been organised at national and international level reflecting the case study development. Experts from IHE-Delft have participated and lectured at 2 national stakeholder events held in Riga. The approach and activities planned for stakeholder involvement has been discussed with the project partners from WEcR and ACTeon through regular Skype interviews.

SIM4NEXUS project has unified institutions and organisations from various fields. The transdisciplinary work allows tackling the NEXUS related issues from different perspectives – environmental, political, economic, allowing the achievement of results by considering a variety of aspects.

6.2.2 Schedule of Task 5.2

The following tasks have been performed for implementation of the Latvia case study:

- Setting the playground. The case study goals, and the main research questions were specified as the first step. Critical Nexus interlinkages relevant for the Latvia case study were identified. Desk research and communication with relevant national experts were performed.
- Stakeholder interaction. Public and private actors who may be affected or influence policies in the relevant nexus sectors were identified. Formal and informal practices, stakeholder needs, and interactions were spotlighted based on desk research and communication with stakeholders. Stakeholder interviews, bilateral discussions, small expert meetings and three stakeholder workshops have been organised.
- Policy analyses. Nexus-related policies for the Latvia case study were reviewed. Socio-economic context, trade-offs, synergies, and conflicts between policies in Latvia were identified. Policy success stories and failures were highlighted. Assessment of interactions between nexus critical objectives (policy coherence assessment, including the scoring of interactions) was performed in close communication with national stakeholders. Policy recommendations for a resource efficient and low-carbon Europe are in the development process.
- Development of a Conceptual Complexity Science tool. Reflecting the focus on low carbon development in Latvia, the Conceptual Model for the case study was developed and communicated to stakeholders in Latvia.
- Data collection. Data from national statistics, thematic models (E3ME, CAPRI, MAGNET) and other sources for the baseline scenario modelling and the two-degree scenario were collected to serve as an input for System Dynamics Modelling.
- Contribution to the System dynamics modelling. System dynamics model for the Latvia case study was developed by IHE-Delft incorporating the data collected by BEF-Latvia from the national statistics and the selected thematic models.
- Contribution to the Serious Game development. Identification of policy goals, description of policy interventions, development of use cases was performed. Serious Game for the Latvia case study is under development (March 2020).
- Reporting. Contribution to preparation of the reports e.g., Report on use cases (D1.6), Report on Policy analyses (D2.2), Report on policy Coherence analyses (D2.3.), Report on application of thematic models (D3.5), Learning goals of Latvia case study (D.4.1), Final report on the Case study (D5.5).
- Project meetings. Contribution to the SIM4NEXUS project meetings, reflecting the progress achieved and experience exchange on learnings during implementation of the Latvia case study.
- Other activities. Presenting the SIM4NEXUS project approach, development of the Latvia case study at national and international events organised by other institutions.

6.3 Engagement of stakeholders in the process

6.3.1 Overview of stakeholders' engagement in the case study

Considering the focus of the Latvia case study towards low carbon development, relevant stakeholders have been identified and approached. Stakeholders from national, regional, local authorities; scientific institutions and universities; non-governmental organisations (NGOs); and businesses representing water, energy, land, food and climate sectors have taken part in the Latvia case study development process. Ministries (Ministry of Agriculture, Ministry of Environmental Protection and Regional Development of the Republic of Latvia) have contributed to the goal setting of the case study and for policy coherence assessment. Representatives from scientific institutions and universities (Riga Technical University, University of Latvia, Latvia University of Life Sciences and Technologies, Institute of Agricultural Resources and Economics, Institute of Physical Energetics, Latvian State Forestry Research Institute "Silava") have contributed to the identification of critical Nexus interlinkages and objectives. Test training workshop of the serious game was performed in close cooperation with Vidzeme University of Applied Sciences. Several NGOs (Association "Green Liberty", WWF-Latvia, Foundation "Latvian Fund for Nature", Association "Farmers Parliament") have given their input in the discussions on Nexus interlinkages, policy measures and instruments towards low carbon development in Latvia. Experts from the Latvian Environment, Geology, and Meteorology Centre, Nordic Council of Ministers' Office in Latvia, Zemgale Planning Region have shared information and experience from other related projects expressing their interest for further information exchange and cooperation. Experts from the Central Statistical Bureau have contributed with their knowledge on data availability in Latvia.

Representatives from all stakeholder groups have actively participated in bilateral discussions, small working group meetings, interviews as well as at stakeholder workshops organised within the framework of the project (see also Table 19):

- 1st stakeholders' workshop (15.11.2017, Riga, Latvia) "Potential sustainable solutions and trade-offs in resource use considering climate, water, food, land and energy aspects".
- 2nd stakeholders' workshop (07.03.2018, Riga, Latvia) "Application of System dynamics modelling for evaluation of resource efficiency considering climate, water, food, land and energy aspects".
- 3rd stakeholders' workshop (03.10.2018, Riga, Latvia) "Policy instruments related to climate, water, food, land, forestry and energy sectors towards low carbon development".

Table 19 Interaction with stakeholders for Latvia case study

Interactions with stakeholders	Date Location	Participants number & indicative distribution by nexus sector	Topics discussed	Outcomes / Achievements
Interviews	12.12.2017 Riga, Latvia	5 participants (water, climate)	Water and Climate policy coherence	Obtained knowledge on positive and negative interactions of Water and Climate policy in Latvia
Workshop n°1	15.11.2017 Riga, Latvia	16 participants in total: Water: 4 Energy: 3 Land: 3 Food:1 Climate:5	Nexus interlinkages, data availability	- Identification of critical Nexus interlinkages for the Latvia case study in water, climate, energy, agriculture & food, land &

				forestry, biodiversity sectors - Obtaining an overview on data availability for modelling & assessment of interlinkages
Workshop n°2	07.03.2018 Riga, Latvia	19 participants in total: Water: 6 Energy: 2 Land: 4 Food:1 Climate:6	System dynamics modelling, Conceptual model for the Latvia case study	- Better understanding on SDM application in practice - Verification of the conceptual model
Workshop n°3	03.10.2018 Riga, Latvia	10 participants in total: Water: 3 Energy: 1 Land: 2 Food:2 Climate:2	Discussion on policy goals and instruments	Indication on policy coherence for the Latvia case study

In addition, stakeholder representatives (national authorities, science, business, NGOs) have participated at "SIM4NEXUS Communication and Networking workshop: exploitation of the project products and services in the Baltic Region" (05.07.2019, Riga, Latvia). University and local municipality representatives have participated to the Serious game test training workshop (21.02.2020, Valmiera, Latvia). It is expected that the final stakeholder workshop will be organised in May 2020 to present the project results and outcomes e.g., the Serious game.

In total, approximately 30-35 persons have been already involved in the Latvia case study.

6.3.2 Feedback on stakeholders' engagement in the case study

Stakeholders engagement in the Latvia case study has been going smoothly and was very productive. Already at the beginning of the project, along with stakeholder mapping, BEF Latvia experts were communicating (bilateral meetings, interviews) with the key stakeholders in Latvia. Experts approached expressed interest to receive information about the project activities, participate and contribute during discussions as well as during the stakeholder workshops organised within the frame of the project. All workshops comprised few introductory presentations e.g., on SIM4NEXUS project approach, Nexus interlinkages, Conceptual model, goals and objectives of the Latvia case study, policy measures and instruments, followed by interactive discussions and group work to collect ideas and inputs from stakeholders on defining Nexus questions and pathways, policy analyses, data availability and possibilities for cooperation. A short questionnaire for evaluation of the event and pointing out further discussion needs has been elaborated by BEF-Latvia team and distributed at the event or sent to the participants of stakeholder workshops.

According to the feedback received from the involved stakeholders, the cross-sectoral approach for tackling the NEXUS issues was well appreciated. Participants of the stakeholder workshops highly acknowledged the added value of various Nexus domain representatives participating in the discussions, giving an opportunity to obtain new contacts for networking and to gain information from the perspective of another sector e.g., energy, land, biodiversity, water. However, events targeted just to one Nexus domain would be also valuable. The proposal for sending in advance the materials and documents that serve for the discussions at the event has been pointed out by several stakeholders. Stakeholders have also expressed interest to consider further exploitation of the project results e.g., Serious game.

From the experience gained during stakeholder engagement for the Latvia case study, it can be concluded that well-planned and timely involvement (not too early & not too late) of experts at national, regional and local level is a precondition for successful interaction with stakeholders during the whole project implementation. The approach of starting the stakeholder engagement at bilateral level (small expert meetings), afterwards forming the core group of most interested and engaged stakeholders, and then aiming to reach larger outreach when project results are available, has been followed during the implementation of the Latvia case study. The methods applied for interaction with stakeholders include: providing information, building understanding, obtaining feedback and engaging. In future research more regular contacts with stakeholders, more frequent updates on implementation progress of activities, and request for feedback would be recommendable.

6.4 From conceptual models to System Dynamic Modelling

6.4.1 Case study conceptual model

The Conceptual model for the Latvia case study has been developed by BEF-Latvia experts mainly based on the in-house expertise, literature research, internal discussions and consultations with various experts. Several background materials – scientific articles, assessment reports, and policy documents (e.g., national guidelines, strategies, action plans in energy, transport, agriculture, forestry, climate and environment) reflecting the current situation in the relevant sectors, identifying main policy goals and targets, challenges and measures to be implemented for reaching the policy goals 2030, 2050 have been screened.

Considering the most recent policy developments in Latvia, the focus for the Latvia case study towards low carbon development and resource efficiency by respecting the greenhouse gas emissions and use of renewable energy sources was selected. The Conceptual Model consisting of 5 subsystems: water, energy, food, land and forestry was prepared considering country's specific circumstances in the respective fields (See the Annex 6.10.1,). GHG emissions from energy, land use, food production etc. causing climate change are included in the Conceptual model along with effects of GHG sequestration mainly from forestry.

The Conceptual model has been communicated with stakeholders in Latvia. Already during the 1st national stakeholders' event organised on 15.11.2017, Riga, Latvia, the critical Nexus interlinkages were identified and discussed forming the bases for development of the Conceptual model. During this event, participants were evaluating the potential impacts resulting from transformation of land, food production and consumption, growing of energy plants, agricultural production, forestry, production of biogas and biofuels, use of solid biofuels, production of hydro energy, wind and solar energy towards climate, water, agriculture and food, land use, energy forestry and biodiversity. The potential positive and negative impacts were identified and discussed.

The draft model was further developed receiving inputs and in close communication and consultations with experts from the project partner institutions - University of Exeter and IHE-Delft. BEF-Latvia experts were participating at regular skype conferences organised by the work package leaders and other project partners sharing the drafts and discussing options for improvements.

The draft model has been provided to stakeholders prior to the stakeholders' event; discussed and agreed during the 2nd National Stakeholders workshop organised on 07.03.2018 in Riga, Latvia.

In order to promote Latvia case study development, the Conceptual model has been introduced at national and international events organised in the Baltic Sea Region e.g. in:

- Workshop "Bioeconomy, circular economy and low carbon development – alternative development scenarios for Latvia" on 28.03.2018 in Riga, Latvia (organised by the Association "Green Liberty" and the Nordic Council of Ministers bureau in Latvia);
- Working group meeting of the Interreg Europe project "Water Reuse Policies Advancement for Resource Efficient European Regions" (AQUARES) on 30.11.2018 in Riga, Latvia (organised by the Association "Baltic Coasts");
- "SIM4NEXUS Serious Game Training workshop" on 16.11.2019 in Kaunas, Lithuania (organised in cooperation with Kaunas University of Technology, Institute of Environmental Engineering);
- "SIM4NEXUS Communication and Networking workshop: exploitation of the project products and services in the Baltic Region" on 05.07.2019. in Riga, Latvia (organised in cooperation with SIM4NEXUS project partners).

6.4.2 Modifications introduced to model policy scenarios

6.4.2.1 Development of policy scenarios for the case study

The Latvia case study focus on low carbon development and resource efficiency by respecting the greenhouse gas emissions and use of renewable energy sources. Scenarios were developed to illustrate a possible future development. Scenarios provide a context for the analysis and result from the description of drivers, implications and outcomes. In the SIM4NEXUS approach are used several types of scenarios.

The baseline scenario narrative for Latvia is described in [D1.8]. Latvia is among the fastest growing economies in the European Union. The country joined the Eurozone in 2014 and the OECD in 2016, after a fast recovery from the financial crisis of 2008 - 2010. GDP will continue increasing and double by 2050 in comparison to 2010. GDP per capita is to triple over the same period, improving its difference to the average EU-28 from 50% to 20%. The population is projected to decrease by 20% in 2050, not surpassing 2 million inhabitants. Urbanisation rates will increase moderately, and 8 out of 10 people will be living in urban areas by the mid-century. Demographics dynamics related to migration and ageing population can interfere with the economic growth of the country. Agriculture, chemicals, logistics and woodworking, seconded by the textiles, food processing, machinery production and green technologies are the most prominent sectors in the Latvian economy.

The share of RES in the energy mix is one of the highest in Europe, has increased from 30% in 2010 to 37.2% in 2016. Main renewable energy sources are wood (firewood, wood wastes, wood chips, briquettes and pelleted wood), followed by hydro and (in recent year's) wind. Concerns exist regarding the achievement of the 2020 RES target of 40% in gross final energy consumption. Natural gas and wood biomass are the main energy sources for electricity and heat production. There is no endogenous production of fossil fuels (e.g. oil and natural gas) in the country and although energy dependency has decreased over the last decade (up to 2017), imports still represent 50% of the total energy consumption. Due to the high share of RE, the carbon intensity of the energy sector is 15% lower than the EU-28 average of 2.09 tCO_2/toe in 2010. Hydropower potential in the country makes this an attractive technology to further the decarbonisation of the energy sector, however, at the expense of potential negative impacts on the environment.

About half of the country land area is covered by forests, and nearly 40% is agricultural land, leaving a small share of primary forest (less than 1%). The forestland corresponds mostly to the naturally regenerated forest (around 80%) in the result of forestry sector activities. No major changes are planned over the coming decades. Agriculture and forestry compete for the use of land. Latvia is in a temperate climate region, and its location by the Baltic sea result in mild temperatures. However, as observed in the previous century, the temperature has increased by 1°C, and changes to rainfall patterns were verified, including increased total precipitation. Water quantity and availability is not a challenge in the near future, due to low consumption and water efficiency measures implemented by the government, but there is rather concern for water quality. Eutrophication of marine and inland surface water triggered by higher levels of phosphorus and nitrogen in river systems, caused by local and pollutants diffusion and pollution from the transboundary basins, is a major environmental problem. Pressure from anthropogenic activities on the environment is expected to increase over the coming decades, negatively affecting the Baltic Sea. The food industry is one of the main industries in the country. Top food exports of Latvia include cereals, such as wheat and rapeseed, milk and oil products. Food production and processing are important economic sectors, with revenues in the order of 1.5 billion euros in 2010. The increasing demand for cereals exports, particularly wheat, requires the expansion of cropland area until 2030. Subsequently, the use of fertilisers is expected to rise to secure productivity levels in lower fertility soils, which will exacerbate water quality issues.

Formulation of policy scenario narratives for the case study of Latvia has been in focus at the workshop with stakeholders (03.10.2018) where the discussion was held on policy goals and instruments. Participants have discussed about interaction of various policy instruments in the NEXUS context and gave indications on policy coherence.

In order to define policy interventions to reach the policy objectives and policy goals, the motivating forces and drivers were identified. Focusing on low-carbon development, Latvia is seeking for possibilities to reduce energy dependency from imported fuels, increase sustainable use of renewable energy sources and ensure economic development while reducing greenhouse gas emissions.

In defining the policy scenarios, the case study developers consider the Nexus induced challenges in Latvia:

- Expansion of agricultural activities to support food industry and food exports (e.g., cereals) puts pressure on land use by increasing the use of fertilisers consecutively increasing emissions of nutrients (water quality) and GHG (climate change).
- Intensive exploitation of biomass for energy production puts pressure on forests (forest felling), land (monocultures, fertilisers), consecutively increasing emissions of nutrients (water quality) and reduction of carbon sequestration potential (climate change).

6.4.2.2 Introduction of policy scenarios in the SDM

The SDM for Latvia case study represent the baseline development scenario up to 2050. On top of this, by using the switch function, the policy scenarios can be applied. The case study developers have selected policy scenarios in all five Nexus sectors:

- Water: reduction of nitrogen load in surface water by applying technological solutions for injection of fertilisers and by applying agricultural management practices that result in reduced fertiliser use;
- Energy: reduction of energy demand by increase of energy efficiency; promotion of electricity production from RES; decarbonisation of transport by switch to alternative fuels;
- Land: application of land use practices to balance agricultural land and meadows and pastures; as well application of different agricultural activities on arable land;
- Food: sustainable food production, as well as different consumption and production patterns;

- Climate: application of measures for reduction of GHG emissions and increase of CO2 sequestration.

6.4.3 Modifications introduced to account for data availability

6.4.3.1 Data available from the thematic models

Two thematic models E3ME and CAPRI have been used to feed-in the SDM and to prepare data sets up to 2050. In case of multiple data sets i.e. national predictions and CAPRI results, the case study developers tried to find the compromise that better reflect the national circumstances. Overview on the lists of parameters is provided in sub-sequent sections.

The global macro-econometric **model E3ME** was applied to explore a low-carbon transition through different sets of energy and climate policies in Latvia. E3ME model application to the Latvia case study provided results on energy production by technology, energy consumption by type and sector, GHG emissions. The actual model runs were performed by the project partner at the Cambridge Econometrics and the Latvia case study developers were receiving calculated results.

Parameters covered by the E3ME model:

NEXUS sector	Parameter(s)	Data source
Energy	Energy demand for coal, oil, gas, electricity, heat, biomass and combustible waste – by sector	E3ME baseline, 2000-2050, yearly resolution
	Electricity generation by technology (gas, biomass, hydro, wind)	E3ME baseline, 2000-2050, yearly resolution
Climate	Energy related CO_2 emissions by sector: industry, households, tertiary sector	E3ME baseline, 2000-2050, yearly resolution

The global spatial partial equilibrium model **CAPRI** was applied to explore impacts of agricultural, environmental and trade policies. CAPRI model application to the Latvia case provided results on crop yields, land use patterns and on income from different types of agricultural areas.

Parameters covered by the CAPRI model:

NEXUS sector	Parameter(s)	Data source
Land-use	Utilized agricultural area Arable land Cereals Rape Perennial grasslands Meadows and pastures Pulses	CAPRI baseline, 2010, 2020, 2030, 2040 and 2050
Food	Agricultural production – crop yield Meat output Per capita food consumption	CAPRI baseline, 2010, 2020, 2030, 2040 and 2050

Processing the model results before integration in the SDM :

E3ME and CAPRI model results reflect data for the whole country and therefore **downscaling** to the statistical regions: Pieriga, Vidzeme, Kurzeme, Zemgale and Latgale regions was required. This mainly was implemented by attributing respective shares calculated from national statistical data. **Disaggregation** to a yearly resolution scale was needed for CAPRI model results (presented for 2010, 2020, 2030, 2040 and 2050). Data were further disaggregated by using a linear increment/decrease allocation to calculate the yearly values. **Comparison** of CAPRI model prediction and national prognosis for certain parameters, particularly in land-use sector, was needed to best reflect the national development path and select the data sets accordingly. In case of discrepancies, the priority was assigned to the national prognosis.

6.4.3.2 Local data to be collected

Water

Being rich in fresh water, Latvia does not experience the water scarcity problem – consumption of water by inhabitants, industry, agriculture etc. are far below the water resources available. The main concerns are related to the water quality. The problem of water quality mainly due to eutrophication prevails. This is largely caused by leakage of nutrients (nitrogen and phosphorous) from point and diffuse pollution sources (e.g., agricultural land, forests).

The water quality issue in Latvia is related to the system dynamics of NEXUS: land-use, agriculture/food and water. The case focuses on nitrogen (N) load from a given crop farming area in relation to the mineral fertilizer use, and N load from the forestry activities.

NEXUS sector	Parameter(s)	Data source
Water	Mineral fertilizer use (by statistical regions, 2005-2018), kg/ha Projection up to 2050	Provided by CSB on a special request by BEF LV National prognosis
	Fraction of nitrogen (N) losses (average 1998-2014)	Sudars, et.al., 2016
	Anthropogenic N load from forestry, kg/ha	LEGMC, Analysis of anthropogenic pressures and their impacts, 2015

Data for the crop farming area by statistical regions in Latvia are provided in the land-use sector. Since fertilizer use may differ with intensity of the agricultural production, mineral fertilizer use was also attributed to the statistical regions. For the period 2005 – 2018, these data were requested from the national statistical office to feed-in the SDM. Projections by 2050 for mineral fertilizer use on the national scale were available by the National prognosis. Approach for down-scaling to the statistical regions included multi-step calculation: (i) estimate for multiplier on fertilizer use at national level in future, e.g., 1.53 in 2030 and 1.74 in 2050; (ii) estimate for possible mineral fertilizer use at statistical regions based on the recent average (from 5 year period of 2014-2018) as mineral fertilizer use of 103.2 kg/ha in Pieriga, 85.6 kg/ha in Vidzeme, 117.4 kg/ha in Kurzeme, 149.6 kg/ha in Zemgale and 64.2 kg/ha in Latgale; (iii) calculation for dis-aggregated (yearly) data sets from prognosis by 5-year periods (2015 – 2050). The fraction of 0.175 for N loss from the mineral fertilizers (Sudars, et.al. 2016) was applied to calculate the nitrogen loss emissions to water sources from agricultural activities. Calculated results are compatible with the average N run-off of 18 kg/ha (2000 - 2008) as measured from the diffuse pollution sources (Analysis of anthropogenic pressures and their impacts, 2015).

Another set of data is linked to anthropogenic N load from the forestry activities. Rough estimate of the load of 19.6 kg/ha in Pieriga, 2.8 kg/ha in Vidzeme, 3.6 kg/ha in Kurzeme, 3.9 kg/ha in Zemgale and 19.6 kg/ha in Latgale is calculated from the literature data (Analysis of anthropogenic pressures and their impacts, 2015).

Energy

Latvia is not rich in local energy sources and is dependent on imported energy. Nevertheless, the dependence on imported energy resources is steadily reducing due to the increased gross consumption of renewable energy sources. Renewable energy sources, particularly wood fuels and hydro energy, along with the oil products and natural gas imported from various countries play the most important role in energy balance of Latvia. For SDM calculations, national data on primary energy production, import and export were collected.

NEXUS sector	Parameter(s)	Data source
Energy	Production of primary energy sources, TJ	CSB data base (2000 – 2018)
	Import of energy sources, TJ	CSB data base (2000 – 2018)
	Export of energy sources, TJ	CSB data base (2000 – 2018)

Land-use

For the land-use type, Latvia is rich with forests (ca 50% coverage of the land) and agricultural land (ca 40% coverage of the land). Utilized agricultural area is divided for activities on arable land, e.g., growing of crops, rape, perennial grasslands and other activities, as well as maintenance of meadows and pastures. Activities on forest land are associated with forest felling, forest regeneration and young forest maintenance. Restrictions on forestry activities (final felling, final and improvement felling and clear-cut felling) are imposed on part of the forest area.

Overview on data for land-use collected from local sources is presented in the Table:

NEXUS sector	Parameter(s)	Data source
Land-use	Utilized agricultural area, thsd.ha Arable land, thsd.ha Cereals, thsd.ha Rape, thsd.ha Perennial grasslands, thsd.ha Meadows and pastures, thsd.ha	CSB data base (2000 – 2018) National prognosis
	Area of biological cereals (2010 – 2017), thsd.ha	MoA, Agriculture in Latvia (annual reports)
Forestry	Forest cover, thsd.ha Forest final felling, thsd.ha Forest total felling, thsd.ha Forest area with restrictions on forestry activities, thsd.ha Forest regeneration (cultivated + national), thsd.ha Young forest maintenance, thsd.ha	CSB data base (2000 – 2017) State Forestry Services (2000 – 2017)

Processing of data before integration in the SDM was needed for (i) downscaling to the regions, and (ii) prognosis up to 2050. Data for the land-use in regions (for 2010, 2013 and 2016) were used to calculate the average share for each land-use type and then attributed to other years to disaggregate the total value. Land-use data projections (2019-2050) were based on the National prognosis and CAPRI model predictions. Considering the time span in the model projections, these data were further disaggregated (by a linear increment attribution) to a yearly resolution used by the SDM. Data for the forestry in regions were basically available from CSM (2010-2017) to calculate the average share and then to attribute to other years for disaggregation of the total values. Forestry data projections (2018-2050) were obtained by a trendline (linear function) calculation and extrapolation to the period for projections. In addition, projections for the forest regeneration and young forest maintenance were topped up by combined shares of specific activity.

Food

In Latvia, the key activities in the food production sector comprise growing of crops, dairy farming, meat production, as well as beverages, fish processing and growing of fruits and vegetables. The data for SDM were collected on crop agriculture and livestock related fields.

NEXUS sector	Parameter(s)	Data source
Food	Yield of cereals, ton/ha	CSB data base (2000 – 2017)
	Production of biological cereals (2010 – 2017), thsd.tons	MoA, Agriculture in Latvia (annual reports)
	Import of cereals, thsd.tons Export of cereals, thsd.tons	CSB data base (2000 – 2017)
	Cattle (dairy cows, meat cows), thsd.head Pigs, thsd.head Sheep, thsd.head	CSB data base (2000 – 2017) National prognosis
	Manure production from cattle, kgdm/head/day	Latvian National Inventory
	Meat, milk output, thsd.tons	CSB data base (2000 – 2018) National prognosis
	Food consumption (cereals, meat, milk, other), kg/capita	CSB data base (2000 – 2016)

Processing of data for yield of cereals and cattle before integration in the SDM was needed for downscaling to the regions using their respective shares. Data from CAPRI model predictions and national prognosis were used to estimate values up to 2050. Considering the time span in the model projections, these data were further disaggregated (by a linear increment attribution) to a yearly resolution used by the SDM.

Climate

Reduction of greenhouse gas emissions from various economic sectors e.g. agriculture, energy production and consumption, and transport along with increasing CO2 sequestration e.g., in the forestry sector are few of the key issues for the low-carbon development policy in Latvia. The GHG emission factors for SDM were collected for calculation of emissions in various economic sectors in Latvia.

NEXUS sector	Parameter(s)	Data source
Climate	GHG emission factor for grasslands, tCO2 eq/ha/y	Latvia's national inventory report 1990-2016
	GHG emission factor for forestland (sequestration), tCO2 eq/ha/y	Latvia's national inventory report 1990-2016
	Calculation for N2O emissions from growing of crops	Pilvere I. (2016)
	CH4 emission factor from enteric fermentation, kg CH4/head/y	Latvia's national inventory report 1990-2016
	CH4, N2O emission factors from manure management, kg CH4/head/y, kg N2O/head/y	Latvia's national inventory report 1990-2016
	CO2, CH4, N2O emission factors for energy demand for sectors, kg/TJ, t/TJ	Latvia's national inventory report 1990-2016
	CO2, CH4, N2O emission factors for road and railway transport for different types of fuel consumption, kg/TJ, t/TJ	Latvia's national inventory report 1990-2016
	CO2, CH4, N2O emission factors for energy production, kg/TJ, t/TJ	Latvia's national inventory report 1990-2016

Impact of data availability on the SDM

The Latvia case study developers finds the data availability of pivotal importance to populate the SDM. In general, the national statistical data bases and national prognosis (by 2050) contained a majority of parameters to be incorporated in the calculation. However, downscaling, disaggregation and comparison of data from various sources was necessary and performed by the case study developers. Although, in some data sets the approximation and assumptions were incorporated, the development trends indicated by the SDM results will provide good basis for the further policy recommendations development.

6.4.4 Case Study SDM in Stella/R

The SDM of the Latvia case was developed by IHE-Delft in cooperation with case study developers BEF-Latvia. The development process involved numerous rounds of discussions related to data for population of the SDM and cross-checking the modelling results. As BEF-Latvia was not equipped with Stella license/program, the population of the model was performed by project partners from IHE-Delft. The SDM screenshots provided by IHE-Delft are presented.

The SDM of the Latvia case study consists of 6 subsystems representing five Nexus sectors – water, land, food, energy and climate, as well as the population (see Figure 43).

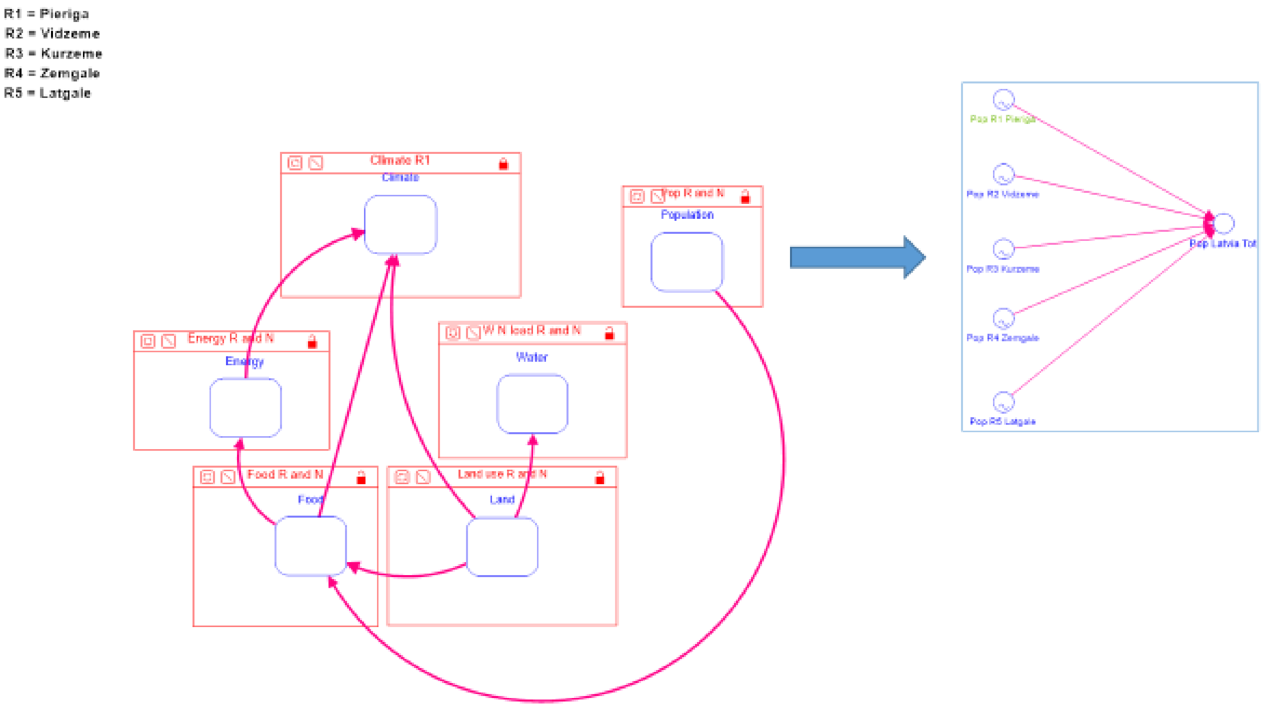

Figure 43 The main structure of the SDM of the Latvia case study

The SDM for the Latvia case study considers the national dimension and disaggregation to 5 administrative regions: Pierīga, Vidzeme, Kurzeme, Zemgale and Latgale (see Figure 44).

Figure 44 Administrative units (regions) covered by the SDM of Latvia case study

Considering the water quality aspects related to the nitrogen pollution, the water subsystem in the Latvia case study is connected to the land subsystem (nitrogen loss from various land use and fertilisation activities).

The land subsystem includes various types of land use in Latvia (e.g., agricultural land, forest). The land subsystem is connected to the water subsystem (nitrogen loss from application of fertilisers), to the climate subsystem (greenhouse gas emissions/CO2 sequestration from different types of land use), and the food subsystem (area used for growing of crops).

The food subsystem includes production of crops, livestock products. The food subsystem is connected to the climate subsystem (greenhouse gas emissions from cattle breeding) and to the energy subsystem (biogas production from manure).

The energy subsystem includes heat and electricity production from fossil and renewable energy sources and demand in various sectors (households, tertiary, industry, transport, agriculture). The energy subsystem is connected to the climate subsystem (greenhouse gas emissions from energy production and consumption).

The population subsystem comprises population data and is connected to the food subsystem (consumption of milk, meat and other products per capita).

6.5 From the System Dynamic Modelling to the Serious Game

6.5.1 Case studies learnings goals

The collected data from thematic models and from national statistics have been used for the baseline scenario in the system dynamic modelling. The serious game (SG) for the Latvia case study is currently under development.

The Latvian case study will quantify the potential of renewable and non-renewable energy sources for energy (electricity and heat) production, and consider interlinkages with the other Nexus components e.g., food and climate in the context of climate change mitigation (reduction of GHG emissions). Latvia has a high potential for renewable energy but remains largely dependent on imported fossil fuels and electricity. Small hydropower plants do not deliver high energy values but are rather harmful for nature. There is a threat of increasing use of nitrogen fertilizers, due to the increased planting of crops, that result in reduction of water quality, water pollution from nitrogen and the related eutrophication of water bodies. The Latvia case study will address trade-offs and evaluate impacts of various water, energy, land, food and climate policies towards the direction of low carbon development and resource efficiency.

Sustainable development goals tackled in the Latvia case study are related to low carbon economy management of conventional energy, diversification of energy sources, renewable energy, surface and ground water quality, economically healthy agricultural sector, sustainable forests, land use management, sustainable/biological food production, food/nutritional quality. The indicators used comprise energy consumption, fossil fuel consumption, renewable and total energy consumption in transport, bioenergy production, wind energy production, GHG emissions, nutrient loads, cropland area, pasture area, area for biomass production, crop production, livestock production, farm income (revenue, cost), trade flows, and the percentage of sustainable/biological food production.

The SG for the Latvia case study will be developed covering the whole country and 5 administrative regions: Pierīga, Vidzeme, Kurzeme, Zemgale and Latgale. The learning goal for the Player of the Serious Game of the Latvia case study is to learn how policies in the domains of agriculture and food, land-use and forestry, production of renewable energy and energy efficiency can affect water quality (nutrient load) and low carbon development (GHG emissions) in the country. The Player will be able to apply policies each 5 years starting from the year 2020 and see the impact on the regional as well as on the country level. From the Player's decisions, we will learn how the players are perceiving evidence of "green solutions" and Nexus interlinkages.

6.5.2 From generic to specific use cases

The use cases developed for the Latvia case study reflect various pathways of interaction between the user and the Serious game. Implementation of the pathways allows the user to select different options to assess the effects and decide if changes (i.e. selection of another pathway) are necessary in order to achieve the desired goal. In line with the policy priorities identified in the Deliverable 2.2, the Latvia case study is tackling the country specific targets related to water quality, energy production and utilisation, GHG emissions, CO2 sequestration, land management, food production and consumption. In this context, the use cases are developed for A) Water, B) Energy, C) Climate, D) Land, and E) Food.

The use cases are targeted at the Ministry of Environmental Protection and Regional Development (Water, Climate), Ministry of Agriculture (Land, Food), Ministry of Economy (Energy), being the national competent authorities responsible for the relevant policy development and playing the major role in setting the playground towards the low carbon economy in the country. The use cases are also relevant for regional level administration (e.g., Planning Regions), responsible for coordinating the implementation of policy measures at the regional level. Certain use cases are relevant also for the private sector (e.g. Farmers unions) being an information source on issues related to agricultural practices and lobbying the farmers interests at the level of policy development. Each use case covers several Nexus sectors. The use cases focus on fertilisation practices, energy efficiency, energy production by RES, decarbonisation of transport, GHG emission reduction in agricultural sector, increasing CO2 sequestration in forestry sector, sustainable land use taking into account farm welfare, food security, sustainable food production and consumption.

The following use cases for different Nexus sectors have been developed:

1. Water

Latvia is not facing a water scarcity problem, while water quality remains an issue. Reduction of Nitrogen leakage from agricultural land is one of the main targets related to improvement of water quality in the country. Application of various measures i.e. precise fertilisation, direct slurry injection, biological farming, green cover can change fertilisation practices. The influence of application of these measures towards the water health will be reflected in the use cases of the SG.

2. Energy
Decreasing energy demand along with increasing energy production from RES and replacement of fossil fuels in transport sector are among the key targets of the energy policy in Latvia. Application of measures e.g., increasing energy efficiency by insulation of buildings in households, tertiary sector and industry, production of electricity from biomass and wind, along with decarbonisation of transport by encouraging the uptake of electric cars and increasing use of biofuels are measures that can support reaching of the policy goals. The influence of application of these measures towards the energy health will be reflected in the use cases of the SG.

3. Climate
Reduction of GHG emissions from various sectors along with increase of CO2 sequestration are the key goals of the Climate policy in Latvia. Application of measures for reduction of GHG emissions from agricultural practices (production of biogas, improvement of feed quality, promotion of fertilization planning) and increase of CO2 sequestration in forestry are included in the use cases. The influence of application of these measures towards the climate health will be reflected in the SG.

4. Land
Sustainable land management is one of the priorities of the Agriculture policy in Latvia. Changing the land use management patterns e.g., arable land, perennial grasslands, growing of energy crops and legumes impacts the farm welfare. Changes in the land-use ratio along with changes in the farm welfare influence the Land health and will be reflected in the SG.

5. Food
Sustainable food production and consumption corresponds to the policy goals of the agricultural sector. Several measures selected for the Latvia case study can be applied to increase production of cereals in conventional and biological farming. Changes in production of cereals influence Food health and will be reflected in the SG. Sustainable food consumption calls for changing the dietary patterns and reduction of meat consumption. Changes in meat consumption and meat production have an impact on Food health to be highlighted in the SG.

6.5.3 Policy cards

Policy cards for the Latvia case study were designed to highlight the key NEXUS issues essential for the low carbon and resource efficient development. The development process was based on the outcomes from the discussions with stakeholders at the events and individual meetings, on the information from the background reports and publications, as well as on the knowledge of the case study developers. The streamlined selection and description of the policy cards was done by the case study developers.

The set of 26 policy cards is created with an aim to back-up the achievement of defined policy goals in the nexus sectors in Latvia.

NEXUS sector	Policy goal	Number of policy cards
Water	Water quality: Reduction of nitrogen load in surface waters	4
Energy	Energy efficiency: Improving the energy efficiency in final energy consumption	3
	Electricity production: Increase the electricity production by RES	2
	Decarbonization of transport: Replacement of fossil fuels	2

Food	Sustainable food: Food security and sustainable food production	3
	Dietary patterns: Sustainable consumption and production patterns	2
Land-use	Sustainable agricultural land use: Sustainable arable land and grassland use considering the farm welfare	3
	Sustainable agricultural activities: Sustainable agricultural activities on arable land considering farm welfare	2
Climate	GHG emissions: Reduction of GHG emissions	3
	CO2 sequestration: Increase CO2 sequestration	2

The policy cards to improve the water quality by reducing the nitrogen load from fields to the surface water bodies, cover technological measures (precise technologies for fertilization, direct injection of organic slurry), and change in agricultural practices (biological farming with no fertilizers application, use of green cover). It is assumed that higher costs would be needed for implementation of technological measures while somewhat higher positive social capital would be generated by application of altered agricultural practices, e.g., organic farming which is actively promoted.

The well-known measures to improve energy efficiency in various sectors, i.e., industry, households and tertiary sector are: allocating subsidies for investments in more efficient technologies and insulation of buildings. Electricity production by RES, namely developing the use of biomass and wind in Latvia, is projected by the E3ME model [D3.5: Final report on the application of thematic models]. These considerations are reflected in the policy cards, although high investment costs would be needed for implementation. Decarbonization of transport by replacement of fossil fuel use is reflected in two policy cards. Increased number of electric vehicles in the country by allocating subsidies for purchasing can be expected in future decades (after 2030). In opposite, the mandate for the use of biofuels in transport is already in effect, however, implementation is rather slow. By supporting the goal to have a share of biofuels at 18% (by 2050), the policy implementation shall be strengthened.

Food security and sustainable food production is in line with the SDG 2. The policy cards reflect production aspects by indicating rural support payments and subsidies to increase production of organic cereals in biological farming and apply more productive cultivars of cereals. In addition, a communication measure refers to increased cereals export at the same time ensuring domestic demand by self-supply. Dietary patterns (in line with SDG 12) are addressed by promotion of reduction of meat consumption and by balance of meat production to self-supply.

Sustainable agricultural land-use and sustainable agricultural activities are directed to maintaining or establishing ratio-based land-use practices to balance the arable land and grasslands, as well as allocation of arable land use for growing of crops and crop rotation.

Several policy cards are developed to reflect aspects in support to reduction of GHG emissions in the agricultural sector. Subsidies for investments to farmers growing cattle (threshold of 80 heads) can promote production of biogas from manure thus reducing emissions from manure management. Fertilization planning and improved feed quality are beneficial for emission reduction as well. Policy cards to increase the CO2 sequestration are limited to the forestry sector by supporting young forest maintenance and increasing afforestation.

6.5.4 Serious Game interface

Currently (March 2020), the Latvia serious game is still under development, thus adding the screenshots is not possible at the moment. The Greek Serious game has served as an example to demonstrate the principal outlook of the game for stakeholders in Latvia, and to organise a test training for students (21.02.2020, Valmiera, Latvia) to obtain their feedback and collect ideas for possible improvements relevant for the Latvia case study. Information about the Serious game was provided to the stakeholders in Latvia at stakeholders' workshop organised within the frame of SIM4NEXUS project, as well as during bilateral meetings, national and international events organised by other projects/institutions in the period from 2017 – 2019 (see Figure 45).

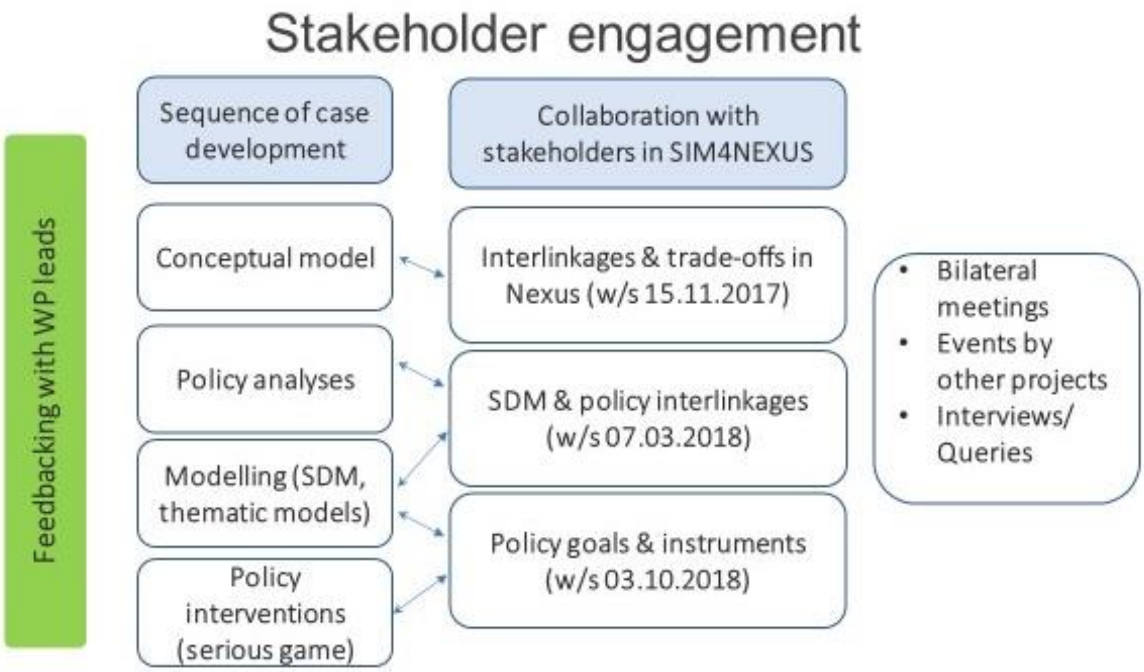

Figure 45 Interaction with stakeholders for the development of the serious game for the Latvia case study.

The main contribution from stakeholders for the development of the SG for the Latvia case study was received during the 3rd stakeholders' event (03.10.2018, in Riga) when participants of the event evaluated the possible policy interventions - impacts of measures to various Nexus sectors relevant for the Latvia case study. Based on input from stakeholders as well as policy analyses performed for the Latvia case study the policy cards for the serious game were developed.

The SG interface for the Latvia case study allows players to apply a set of policy cards for water, energy, land, food and climate sectors and observe the derived changes in Nexus health compared to the baseline scenario. Application of policy cards can be started from the year 2020 (5 years in one turn) up to the year 2050. Policy cards have different periods of activity. The SG allows a player to select playing at a national level, or to select the playing mode by choosing one of 5 regions – administrative units (see Figure 44).

6.6 From the SDM and SG to policy recommendations

6.6.1 Answering main research questions of the case study

The main research question of the Latvia case study concerns exploration of possibilities and implications in a transition to a low-carbon development and resource efficiency in Latvia. The SDM was elaborated to assess cross-sectoral impacts of five Nexus sectors. Policy scenarios (policy cards) covering measures in water, energy, land, food and climate Nexus have been developed to answer the research question. Testing of policy scenarios is in progress.

6.6.2 Supporting policy coherence

In energy sector, several instruments favouring the increase of use of RES sources support the achievement of respective energy and climate objectives. On the other hand, the instrument specifically supporting subsidized energy production from agricultural or forestry biomass reveals constraints in the achievement of water objectives, land objectives and climate adaptation objectives through negative effects from growing energy crops. Energy efficiency instruments have synergies with energy and climate objectives. While market penetration of RES based alternative fuels strongly supports energy, GHG emission reduction and food and agriculture goals, these can hinder the achievement of water and land-use objectives if mono-culture crops are grown for 1st generation biofuel production. In contrast, criteria for sustainability of biofuels may impede the energy objectives while supporting the food and agriculture objectives, water objectives, land objectives, forestry objectives and adaptation to climate change.

Interactions between instruments in food and agriculture sector supports the achievement of objectives in food / agriculture because they enable the efficient use of resources (e.g., agricultural land, protection against flooding of fields) and prevention of pollution (e.g., from manure storage facilities, from application of fertilizers). Also, these instruments contribute to the achievement of water, land, and climate objectives.

In forestry sector, instruments concerning the forest management activities are combined harmonically with climate and land-use objectives while the energy objective on increased share of renewable energy on the one hand is enhanced by incremental volume of forest biomass but on the other hand is hindered by limitations to the forest preservation and biomass harvesting. Limitations to tree cutting have a positive effect on protection of aquatic environment thus also supporting water objectives. The instrument on subsidies to agricultural and forestry enterprises enhances attainment of objectives in energy, food and agriculture, and forestry sectors by promoting innovative technologies, economic activity, and production of high added value products.

6.6.3 Testing policy scenarios

Initial testing of policy scenarios in SDM has been implemented at IHE-Delft by the date of this report (March 2020). Results indicate effect of policy measures compared to the baseline scenario. Further testing will be continued to extend the outcomes to support choice of scenarios and finding beneficial interventions of policies.

6.6.4 Addressing Nexus challenges

Focusing on the development towards low carbon economy and resource efficiency in the country, the Latvia case study addresses Nexus challenges in the water, energy, land, food and climate domains. The Nexus challenges and potential measures that could be applied in SDM and reflected in the SG have been communicated with stakeholders during the 1st stakeholders' workshop (15.11.2017, in Riga) and the 3rd stakeholders' workshop (03.10.2018, in Riga).

Water

Being rich in fresh water, Latvia does not experience the water scarcity problem – consumption of water by inhabitants, industry, agriculture etc. are far below the water resources available.

- The problem of water quality mainly due to eutrophication prevails. This is largely caused by leakage of nutrients (nitrogen and phosphorous) from point and diffuse pollution sources (e.g., agricultural land, forests). More frequent rain events will increase the load of suspended matter and nutrients to lakes and rivers. Moreover, nutrient concentrations in lakes will likely rise, the risk of low-oxygen periods will increase, and CO_2 concentration will increase.

- Water quality is an essential issue for uses e.g., in drinking water and food production, but agro-chemicals (crop protection products), antibiotics and possibly hormones have an impact on water quality.

The SDM and SG is designed to assess the effects from application of measures i.e. precise fertilisation, direct slurry injection, biological farming, green cover with respect to the reduction of nitrogen leakage from reduced amount of Nitrogen fertilisers. The effect in the SG is illustrated by Water health. If the effect on Water health is negligible, alternative measure and/or increase subsidies/ support payment shall be considered.

Energy

Increasing use of different renewable energy sources (RES) to substitute fossil fuels, reduce dependency on energy import from third countries at the same time reducing CO_2 emissions is the key aspect of the case study. Increasing energy efficiency and the use of RES creates several interlinkages with other sectors. Here also the question of many possible trade-offs raises:

- Energy efficiency. Reduction of energy demand by improvement of energy efficiency in various sectors of economy allows decreasing of GHG emissions thus supporting the climate change mitigation goals.
- Hydropower. Having sufficient water supply, the country is utilising its hydro energy potential on inland water bodies through artificial dams constructed on rivers. Use of electricity produced by hydropower prevent GHG emissions, but can cause implications to water quality, land use and biodiversity, flora and fauna. Hydropower installations depend on climate conditions. Increased precipitation and intensification of extreme events (floods & droughts) due to climate change lead to acceleration of the hydrological cycle and impacts hydropower generation.
- Biomass. Use of solid biomass (e.g., wood fuels) for energy production in Latvia helps reaching GHG emission targets, but at the same time is putting pressure on forests, including the impact on biodiversity, CO_2 sequestration, as well as is competing with production of high added value products. Moreover, growing of energy trees (e.g., willows) may compete on arable land to be used for food production. It also requires application of fertilisers and pesticides affecting the water quality in water bodies.
- Biofuels. Biofuels (e.g. 1st generation) can be produced from crops used for energy production (crops/biofuel/biodiesel). Use of biofuels instead of fossil fuels help to reduce GHG emissions from the transport sector, but various processes are needed to make the energy source feasible. Moreover, increase in biofuels production may result in indirect land use change (biofuels take land from food for human consumption), increasing the price of agricultural land which will induce the conversion of non-agricultural land that tends to be carbon-rich into relatively carbon-poor agricultural land. Accordingly, more efforts shall be paid to utilise 2nd generation biofuels.
- Biogas. Agriculture areas use energy as an input to production, but can also provide renewable fuel feedstock (manure, maize, grass, etc.) for the energy sector. There are ca. 60 biogas plants in Latvia. Production and use of biogas can affect energy sector, Anaerobic decomposition of food waste produces methane, which can be converted to electrical power or heat. Use of biogas promotes reduction of GHG, but can cause significant changes to the land use (e.g. growing of energy crops). Another product of anaerobic digestion of food waste is a residual digestate, that can be used as fertilizer and applied e.g., on arable lands.
- Installed technologies for energy production from RES help to reduce GHG emissions, but solar panels, and windmills for power generation, etc. involve direct impacts on land such as removal of vegetation, soil, and alters topography. At the same time, meteorological conditions directly govern the actual output of thermal solar panels, photovoltaics and wind turbines. Currently wind and solar energy does not have an important role in the energy balance of Latvia, although recent developments show a good prospect for penetration of the respective technologies in a broader scale.

- Biodiversity. Growing of energy plants has a negative impact on biodiversity and diminishes areas suitable for protected species. Erection of HPPs creates unfavourable conditions for fish population (e.g., disturbs fish migration).

Focusing on decreasing the energy demand in Latvia, the SDM and SG is designed to assess the effects from application of subsidies for improvement of energy efficiency in industry, households, and the tertiary sector, on reduction of energy (heat) demand. The effect in the SG is illustrated by Energy health. If the effect on Energy health is negligible, alternative measure and/or increase of subsidies shall be considered.

Focusing on increasing energy production by RES, the SDM and SG is designed to assess the effects from application of new more efficient technologies for electricity production from biomass and increase wind energy production by support for broader application of wind energy technologies. The effect can be estimated on the total electricity production from RES and the decision about increasing subsidies for application of the above-mentioned measures can be considered.

Focusing on replacement of fossil fuels in transport, the SDM and SG for the Latvia case is designed to assess the effects from encouraging the uptake of electric cars and increasing the use of biofuels in road transport, thus supporting the goal of decarbonisation of transport. The effect on reduction of oil demand in transport can be estimated. If the reduction of oil demand is negligible, strengthening the application of measures can be considered.

Land

About 47% of the territory of Latvia is covered by forests and ca. 36% of the territory is agricultural land.

- Forests provide the resource for timber production as well as give non-timber products. Forests and semi-natural areas provide resources that can be made available for use in the bioenergy sector to produce both heat and electricity. At the same time forests affect the climate by absorbing CO_2, thus reducing GHG emissions. Moreover, export of forest biomass (e.g., timber, wood and wood-based fuels) plays an important role in national economy at the same time reducing the source available for local use in the country.
- Wetlands act as a retention buffer for water, conserve water, moderate runoff, function as a natural purifier, reduce flood risks at downstream locations, and improve water quality. Wetlands can be source of energy peat and could affect the energy sector by enhancing the use of domestic source, but loss of climate regulation services of converted peatlands and wetlands can have a negative impact on climate.
- Biodiversity. Land use change can cause fragmentation of eco-systems which can lead to extinction of protected biotopes and habitats of species.

Focusing on sustainable land use (arable land and grassland) taking into account farm welfare, the SDM and SG is designed to assess the effects from changing of arable land, changing perennial grasslands, increasing land for energy crops and cultivation of vegetables aiming to support sustainable management of land in the country. The effects of application of measures can be assessed with the help of farm welfare - if the farm welfare decreases by changing the land-use options, the goal is not reached and actions must be taken to alter the rural support and improve land use policies, land use limitations.

Food

Food production plays an important role in the economy of Latvia. At the same time the sector is largely contributing to emissions of GHG and lowering the water quality, mainly because of fertilisation of lands.

- Pastures, cropland, wetlands have a food production role. Agriculture also contributes to CO_2 sequestration, by absorbing CO_2. The growing demand for food, as well as non-food biomass, can lead to an expansion of croplands and deforestation creating consequences on the microclimate.

- Cropland areas are assessed to be expanded rapidly, particularly for wheat due to increasing market demand. Availability of high-quality arable land is considered as a limiting factor. Increasing yield may require application of higher amount of (nitrogen) fertilizers thus causing additional pressure on water quality due to leakages from fields.
- Food waste: a large amount of energy put into food production is wasted, since the food is not consumed. On the other side, food processing waste that has high contents of oil and grease can produce biofuels and food processing waste that has high contents of hydrocarbon can produce ethanol.
- Biodiversity. Expanding of arable lands on territories covered by natural/ semi-natural grasslands abolishes valuable natural biotopes. On the other hand, extensive approach to agricultural practices, e.g., grazing, allows maintenance of biologically valuable grasslands.

Focusing on sustainable food production, the SDM and SG of the Latvia case study is designed to assess the effects from support to biological cereals in food production, promotion of export of cereals, promotion of more productive cultivars of cereals by rural support payments in line with the goal of food security and sustainable food production. The effect on production of cereals in conventional and biological farming can be assessed. If the produced organic cereals increase and the produced conventional cereals increase is negligible, the increase of rural support payments can be considered.

Focusing on sustainable consumption and production patterns, the SDM and SG is designed to assess the impacts of changing dietary patterns by promotion of reduction of meat consumption and by balancing the meat production to self-supply. The effect on meat production can be assessed. If the produced meat is lower than the self-supply, increase of rural support payments can be considered.

Climate

Reduction of GHG emissions in various sectors of the economy as well as increasing carbon capture (CO2 sequestration) have become an important target for Latvia. Emission reduction shall be achieved by increasing energy efficiency, increasing use of RES, improving agricultural practices, introducing "green" alternatives for transport and fuels.

- Climate change will lead to more air-conditioning in summer and less heating in winter; as heating is usually provided by fuel burning and while air conditioning is operated by electricity, the demand would shift towards electrical energy.
- Extreme temperatures lead to increased usage of heating and cooling systems thus require higher energy production and possibly lead to increase of GHG emissions (in case fossil fuels are used).

Focusing on GHG emission reduction in the agricultural sector, the SDM and SG is designed to assess the impacts of increase production of biogas from manure, improvement of feed quality and promotion of fertilization planning through subsidies or rural support payments. As the result, if the GHG emission decrease from agriculture is negligible, alternative measures and/or increase subsidies/support payments shall be considered.

Focusing on increasing CO2 sequestration in forestry, the SDM and SG is designed to assess the impacts of increasing the support to young forest maintenance and afforestation by application of subsidies. The impacts can be assessed by calculation of the total CO2 sequestration by forests. For policy decisions, if the CO2 sequestration increase is negligible, alternative measure and/or increase subsidies for application of measure can be considered.

6.7 Short-term and long-term policy recommendations

6.7.1 Summary of the Nexus issues in the case study

Initial considerations for implementation of the Latvia case study were mainly focused on energy and climate Nexus by linking energy production and self-supply, use of biomass and GHG emissions. On a course of implementation, the case study developers realised the importance of cross-sectoral Nexus interlinkages going beyond the energy and climate Nexus. It can be highlighted that land use is important and is calling for specific policy measures to food production in Latvia.

Biomass is a prominent local resource. Its production and use are projected to increase considerably including power generation sector. Thus, the sustainability aspects become of pivotal importance, covering local conditions for production and use, import and export of the resource.

Taking water quality as the main aspect in the water Nexus, land management practices related to application of fertilisers play a key role in this context.

6.7.2 Description of the policies targeted for recommendations

Policies targeted for recommendations in Latvia are mapped in the Deliverable D2.2 (see Table below). The policy agenda in Latvia is continuously focusing on low-carbon economy, sustainability in development and efficient use of resources.

Energy	
Heading (short description)	**Detailed description (including specification of context)**
Increase use of renewable energy sources (RES)	Refers to the increased share of renewable energy (40%) from total gross final energy consumption by 2020
Increase use of RES in transport energy	Refers to the increased share of renewable energy in the transport sector to at least 10% of gross final energy consumption for transport by 2020
Increase the efficiency of use of energy sources	Refers to all sectors where efficiency can be improved (buildings, cars, industry, agriculture, housing, etc.)
Food and agriculture	
Heading (short description)	**Detailed description (including specification of context)**
Increase the efficiency of use of resources	Refers to prudent use of resources, supporting climate resilient and low carbon economy in agriculture and food sectors, application of innovative technologies
Prevent deterioration of ecosystems from agriculture and food production	Refers to prevention and reduction of pollution (air, water, land) and waste minimisation from agriculture and food sector
FA3 Increase of economic development of rural areas	Refers to reduction of poverty, social integration, and entrepreneurship
Water	
Heading (short description)	**Detailed description (including specification of context)**
Sustainable and rational use of water resources	Refers to sustainable and rational use of water resources and sufficient supply to inhabitants with good quality surface water and groundwater

Protection of the aquatic environment	Refers to protection of the aquatic environment, gradually reducing emission and discharge of priority substances, phasing out emission and discharge of substances, which are especially hazardous to the aquatic environment
Prevention of pollution of the sea	Refers to reduction of eutrophication of inland water bodies and the Baltic Sea (HELCOM Convention)
Land	
Efficient use of land	Refers to prevention to fragmentation, reduction of abandoned areas of usable arable land, efficient use of built up areas and re-cultivation of degraded territories
Quality of soil and biodiversity	Refers to soil protection (including prevention of erosion) and increase of soil quality
Forestry	
Sustainable forest management	Refers to maintenance of forest areas, increase of forest productivity (including amelioration) and afforested areas
Production of high added value forestry products	Refers to increased competitiveness of forestry sector, higher productivity, application of innovative technologies
Climate	
Climate change mitigation	Refers to the reduction of GHG emissions by setting GHG emission targets for the EU ETS and non-ETS sectors
Climate change adaptation	Refers to selection and application of measures for adaptation to climate change in various sectors

6.7.3 Policy recommendations

6.7.3.1 Changes in policy outputs

Organic farming is on EU political agenda. Biological products are getting an increasing attention by consumers. Organic farming has a positive impact on water, land and climate Nexus health. Setting more ambitious target for organic farming is a future development.

In short	Recommendation name: Promote organic farming
Target group	Policy developers (ministries and subordinated institutions)
Target policy goal	Sustainable agriculture
Target policy instrument	Rural support programs
Target policy process phase	Implementation of farming practices
Administrative level	community, region, country, EU
Time scale	long-term till 2100
Cost-effectivity	
Social implications	

6.7.3.2 Changes in policy contents

Model predictions for Latvia indicate increased growing of cereals along with expansion of cereals export. In order to balance economic (farm welfare) and sustainability considerations, policy content shall ensure sustainable production of cereals. This would imply good land use practice (avoiding large areas of monocultures), keeping balance of agricultural and other land use types (e.g. maintaining areas for pastures and meadows). Sustainable cereals production includes balanced use of fertilisers, growing of more productive cultivars.

In short	Recommendation name: Sustainable cereals production
Target group	Policy developers (ministries and subordinated institutions)
Target policy goal	Sustainable agriculture
Target policy instrument	Performance-based regulation (rural support programs)
Target policy process phase	Implementation of farming practices
Administrative level	community, region, country
Time scale	middle-term till 2050,
Cost-effectivity	
Social implications	

6.7.3.3 Innovations

Biomass resource is projected to be widely used for energy production. However, substantial amount of energy production installations are old and out-dated with low energy production efficiency. Considering the goal on resource efficiency, application of new and more efficient technologies is needed for the coming decades. New technologies for electricity production from biomass e.g., gasification, pyrolysis are known, but have to be introduced in the energy sector. Replacement of old technologies for use of biomass in combustion plants installed in district heating and local heating is required as well.

In short	Recommendation name: Switch to new technologies to efficient use of biomass for energy
Target group	Energy production companies
Target policy goal	Resource efficiency
Target policy instrument	Subsidies
Target policy process phase	Implementation
Administrative level	community, region, country
Time scale	short term till 2030
Cost-effectivity	High investments
Social implications	

6.7.3.4 Changes in the policy process

The forest sector is one of the key cornerstones in the national economy and has a high export capacity. The industry still operates in the frame of long developed under market economy conditions with low added value per employee generated (Ozolins, Nipers (2016)) and the policy arrangement thus focus on stimulation of deeper wood processing in a long-term development. Cutting of trees in forests and exporting the wood for renewable energy production abroad creates income to the forestry sector and helps to reach RES targets in the countries importing the wood fuels but has a negative impact on meeting the GHG emission reduction and CO_2 sequestration targets in Latvia. Export of wood biomass creates a conflict between Energy Nexus critical objectives (NCOs) and Climate NCOs.

Based on analyses presented in Deliverable 2.2., unsuccessful policy arrangement is in the nexus area of forestry for promotion of competitiveness and production of high added value forestry, wood processing and furniture products. By the opinion of Latvian Wood Industry Federation there are key preconditions to the success - for small and medium enterprises (SMEs) on availability of raw material, support to research and development (R&D) activities, access to qualified work force and sufficient local market for products; and for large companies important are access to raw material in the local market, infrastructure, qualified work force and cost competitiveness as compared to other regions. Despite the availability of financial instruments in support of innovations and business in Latvia, the response from SMEs is reserved due to rather high load of bureaucratic procedures and high effort to prepare for use of support instruments.

In short	Recommendation name: Promotion of competitive local use of biomass
Target group	Policy developers (ministries)
Target policy goal	Climate change mitigation
Target policy instrument	Market based instruments (e.g. subsidies)
Target policy process phase	Policy implementation (translation to practical level) – simplification of bureaucratic procedures for higher uptake of market-based instruments
Administrative level	country, EU (?)
Time scale	middle-term till 2050
Cost-effectivity	
Social implications	

6.7.3.5 Changes in the science-policy interface

Biomass is an important resource in the country. Local biomass production is heavily debated in Latvia e.g., criteria for forest cutting, cultivation of monocultures. These discussions are silos-based presenting strong opinion of sector specific stakeholders (industry representatives, forest owners, farmers, nature experts) rather than sound arguments based on research results. Integration of science-based Nexus approach in such debate and back-up on research results will fill the gaps of missing knowledge to develop cross-sectoral compliant policy. Integration aspects shall be adequately communicated to wide range of stakeholders.

In short	Recommendation name: Integration of Nexus approach in stakeholder dialog.
Target group	Researchers, policy developers, multipliers (facilitators)
Target policy goal	Sustainable use of resource
Target policy instrument	Communication
Target policy process phase	Policy drafting (formation) phase
Administrative level	Community, region, country
Time scale	short term till 2030, middle-term till 2050
Cost-effectivity	
Social implications	Social awareness and acceptance raising

6.7.3.6 Conclusion on coherent, Nexus-compliant policies

Recommendations for Nexus compliant policies in Latvia focus mainly on policy implementation phase. Cross-sectoral approach towards sustainability and resource efficiency covers performance-based and market-based instruments. Policy developers from ministries and their sub-ordinated institutions are seen as key players for taking the initiative. Short and middle-term time line is suggested for actions and range of administrative levels to be involved.

6.8 Conclusion

- The success of the Latvia case study implementation is based on close cooperation with partners from the consortium providing support to address specific components of the work to complement and enhance the in-house knowledge of the case developers.
- Stakeholders in Latvia were addressed at an early stage of the case study development by initiating the engagement at bilateral level (small expert meetings), afterwards forming the core group of most interested and engaged stakeholders, and then aiming to reach larger outreach when the project results become available. Interaction with stakeholders at national, regional and local level included providing information, building understanding; obtaining feedback and engaging to participate in testing the project outputs. This approach proved to be efficient as stakeholders showed an interest to participate in further project activities. Regular contacts with stakeholders were essential to keep them updated on project progress.
- The SIM4NEXUS approach was acknowledged by stakeholders as appropriate to tackle the complex issues and to promote cross-sectoral thinking going beyond the silos dimension. As a project added value stakeholders appreciated meeting of national experts from different sectors and project partners bringing external expertise.
- Various models were used in the Latvia case study implementation, from development of the Conceptual model to further application of thematic models to creation of the SDM. The case study developers see the proceeding from simple schemes of interlinkages to more complex interactions in the SDM as suitable approach to reflect the complexity of Nexus.
- Data availability is of pivotal importance to populate the SDM, create the SG and to develop policy recommendations. Available data sets requested additional operations to downscale, disaggregate and compare data from various sources, making approximation and assumptions. The case study developers find the assembled data sufficient to reflect the development trends in Latvia for coming decades.
- The set of 26 Policy cards is created with an aim to back-up the achievement of defined policy goals in the nexus sectors in Latvia. Policy cards for the Latvia case study were designed to highlight the key NEXUS issues essential for the low carbon and resource efficient development. Implementation of the pathways allows the user to select different options to assess the effects and decide if changes (i.e. selection of another pathway) are necessary in order to achieve the desired goal.
- The main research question of the Latvia case study concerns exploration of possibilities and implications in a transition to a low-carbon development and resource efficiency in Latvia. Suggestions for policy recommendations highlight the policy implementation phase and cross-sectoral approach towards sustainability and resource efficiency.

6.9 References

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6.10 Annexes

6.10.1 Conceptual model

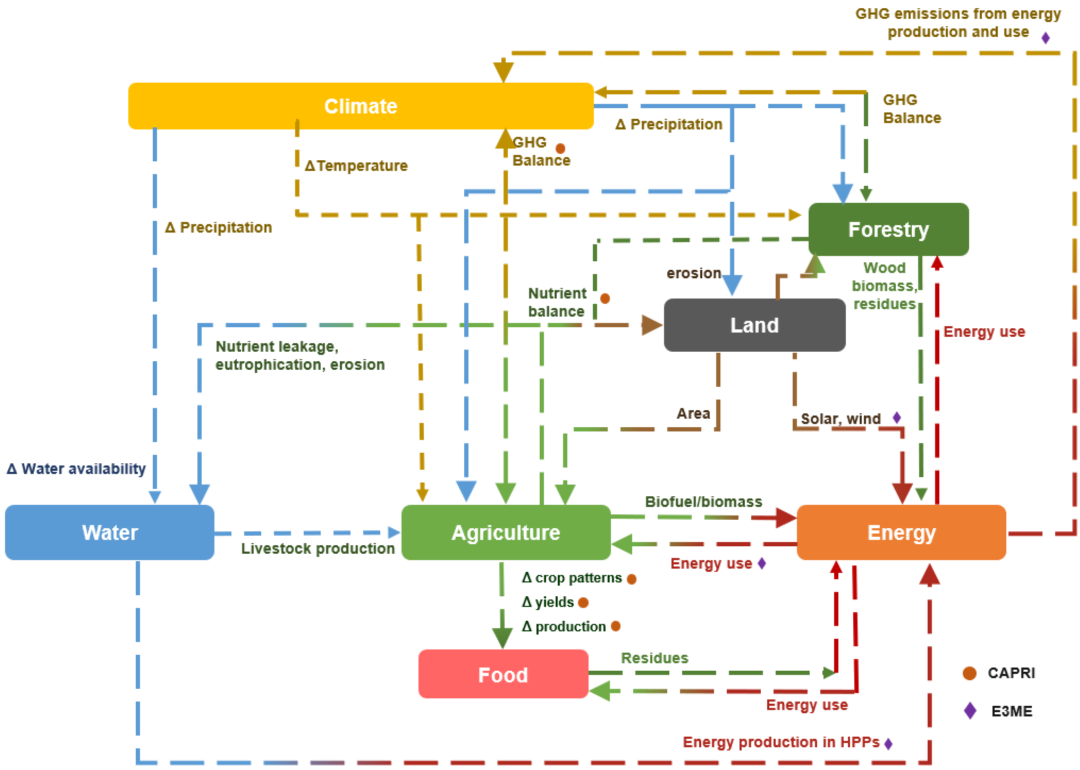

Figure 46 The Conceptual model of the Latvia case study reflecting all Nexus domains and the respective interlinkages

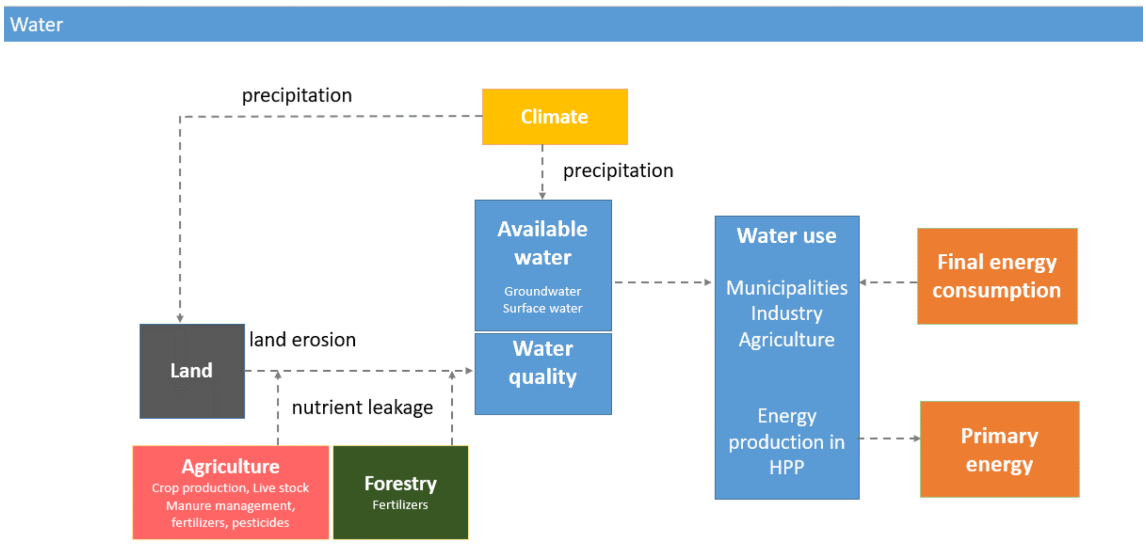

Figure 47 The Conceptual model of the Latvia case study focusing on the Water domain

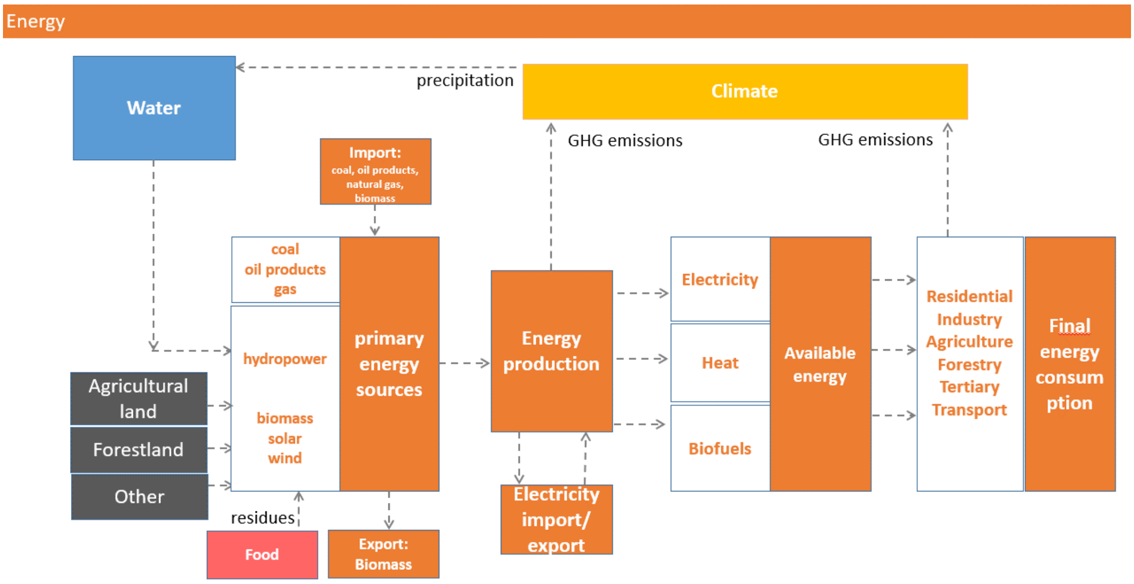

Figure 48 The Conceptual model of the Latvia case study focusing on the Energy domain

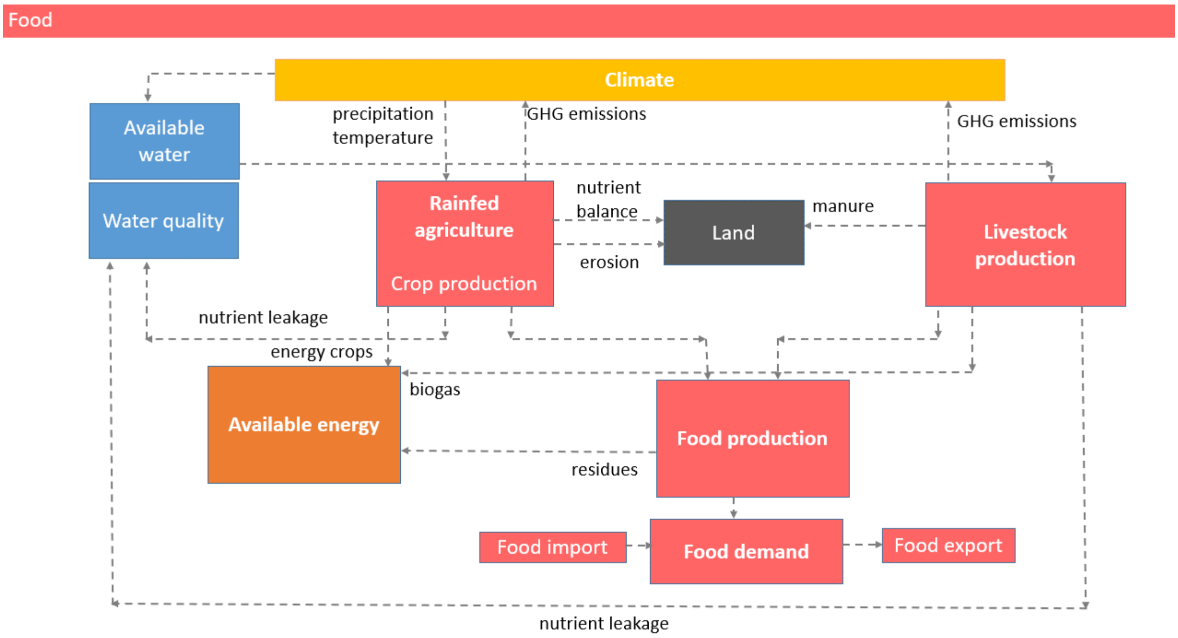

Figure 49 The Conceptual model of the Latvia case study focusing on the Food domain

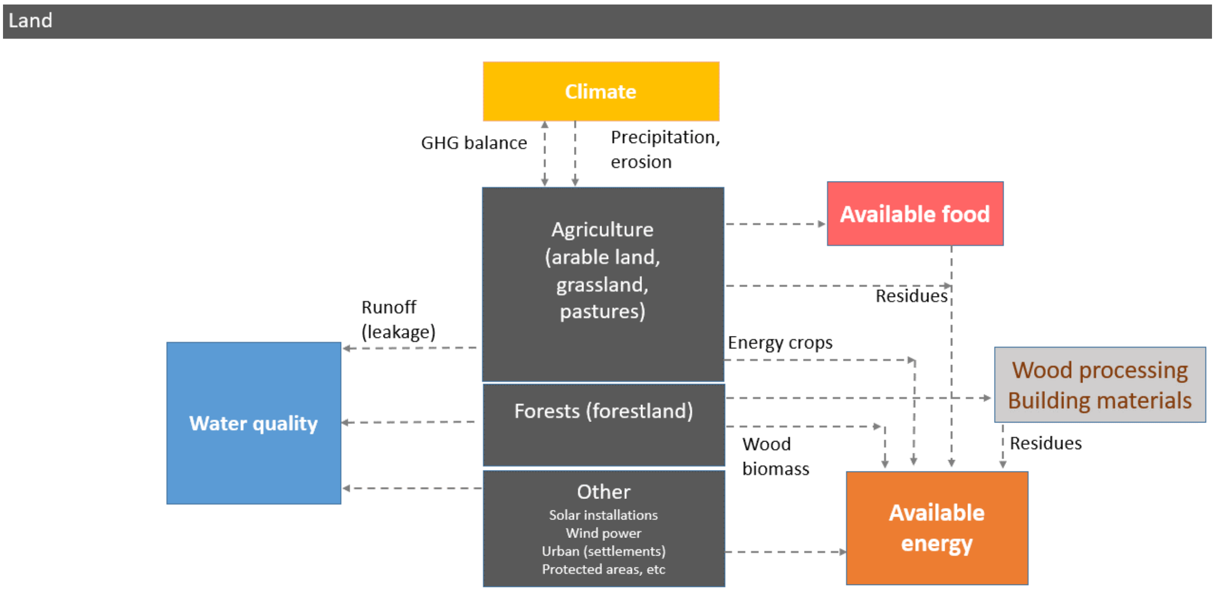

Figure 50 The Conceptual model of the Latvia case study focusing on the Land domain

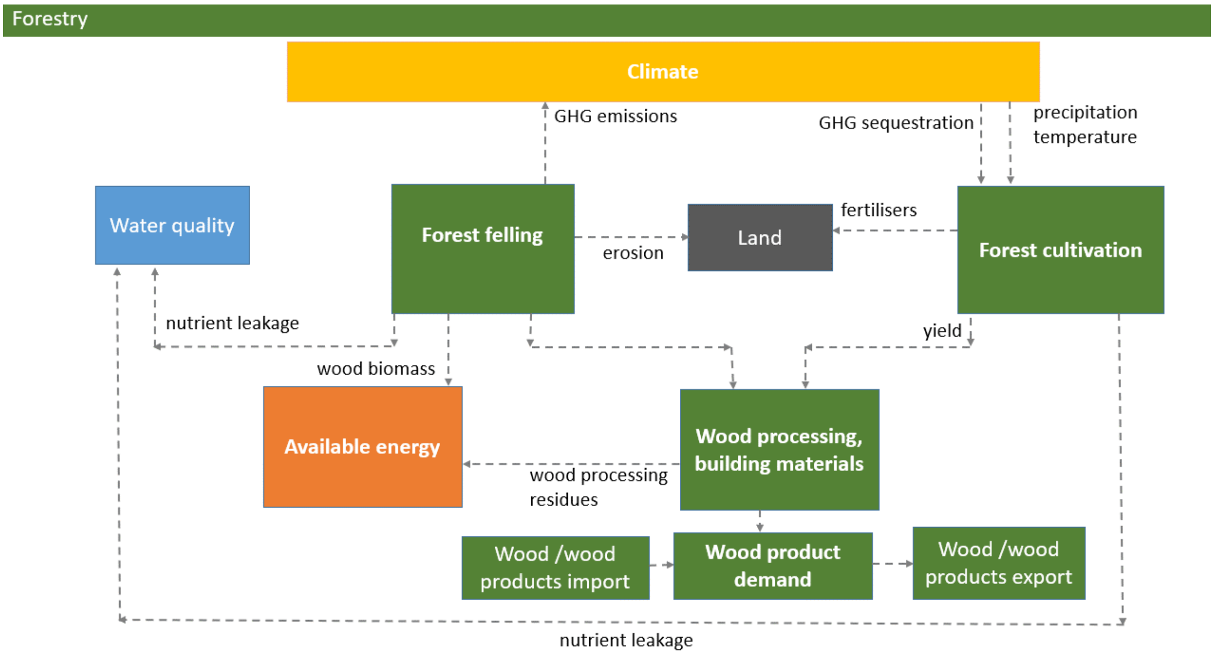

Figure 51 The Conceptual model of the Latvia case study focusing on the Forestry domain

6.10.2 SDM screenshots

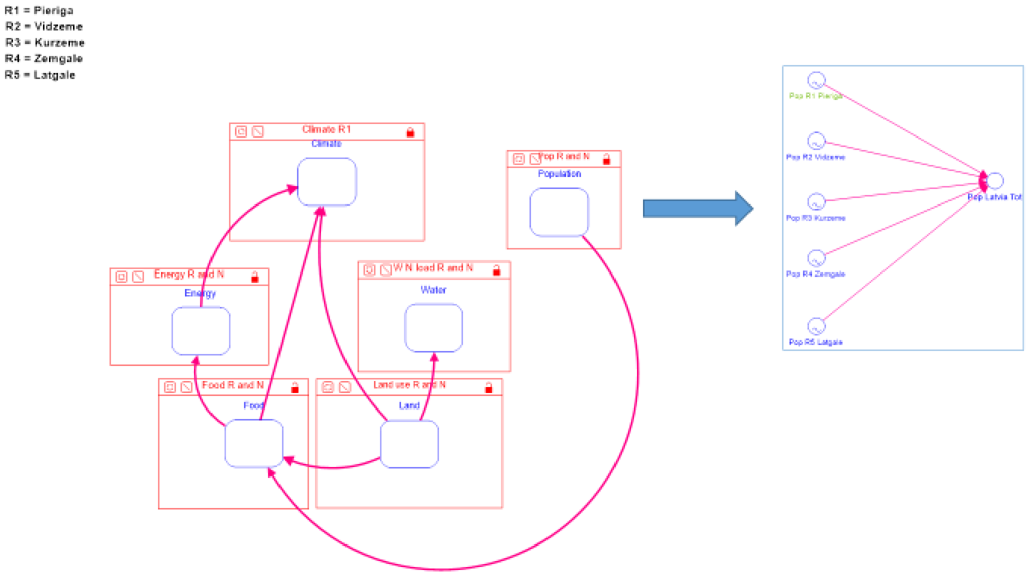

Figure 52 The overall outlook of the SDM of Latvia case study

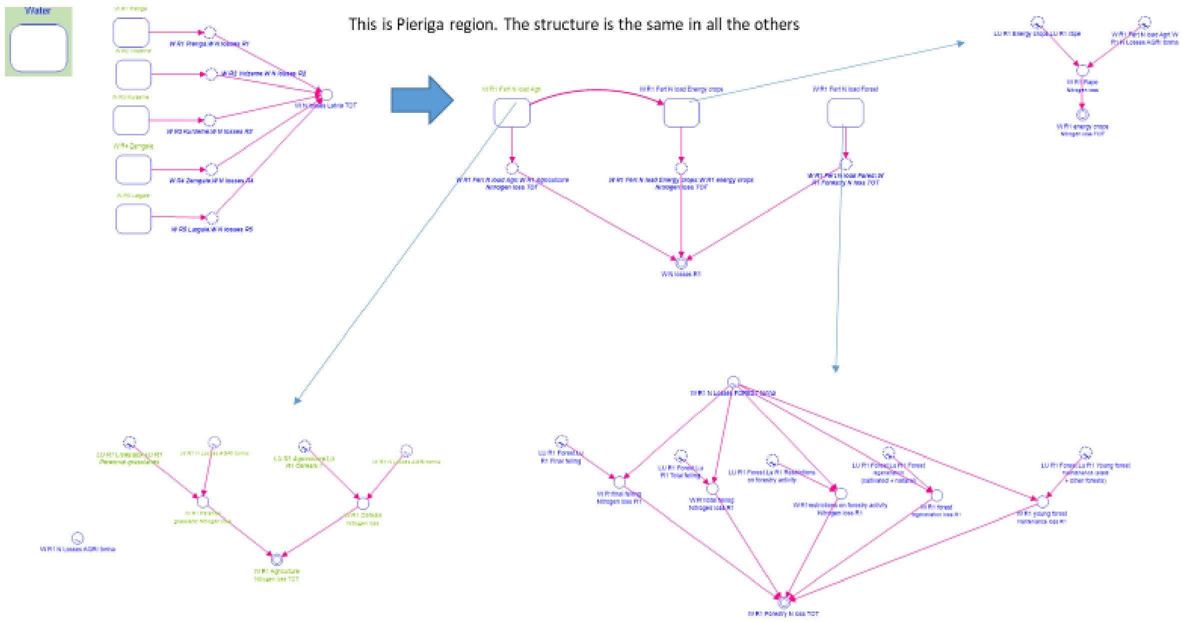

Figure 53 The Water subsystem of SDM of Latvia case study

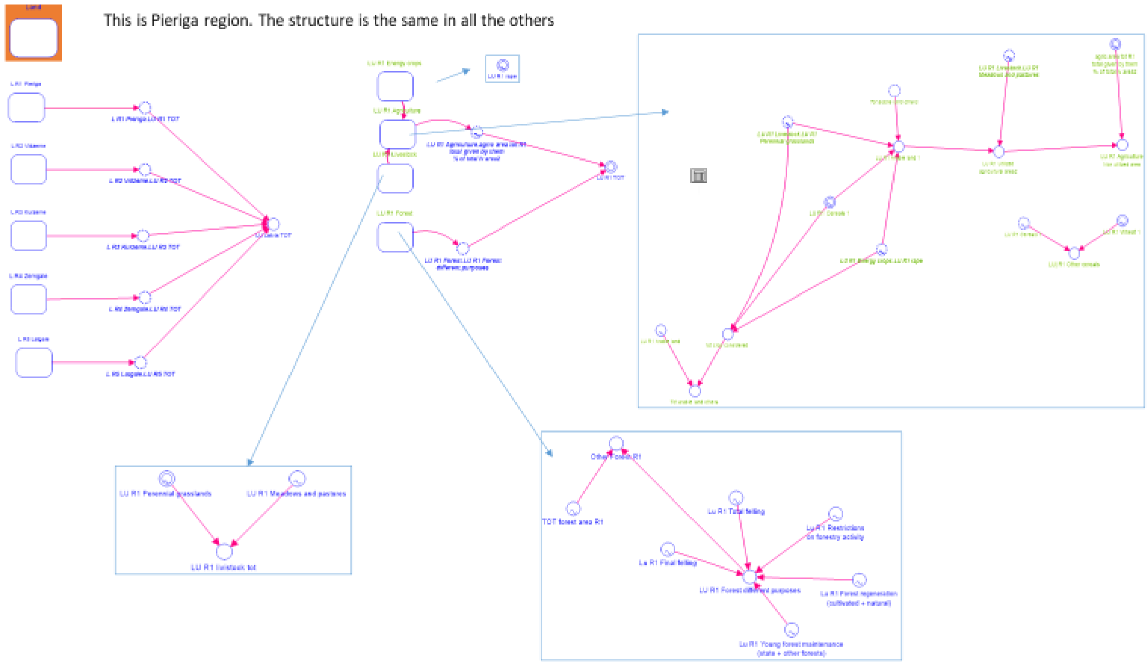

Figure 54 The Land subsystem of SDM of Latvia case study

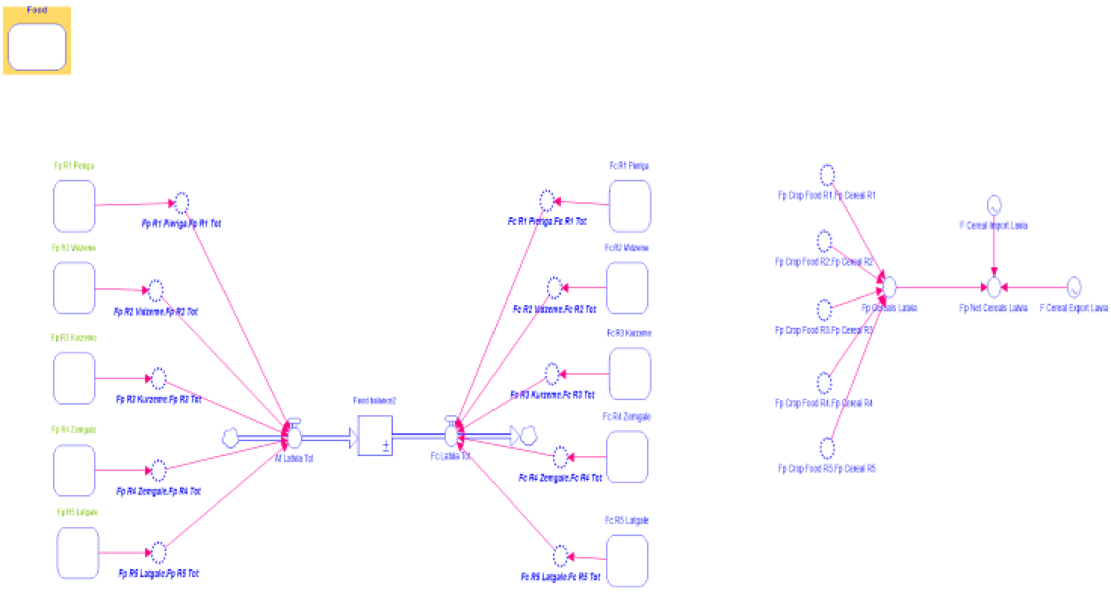

Figure 55 The Food subsystem of SDM of Latvia case study

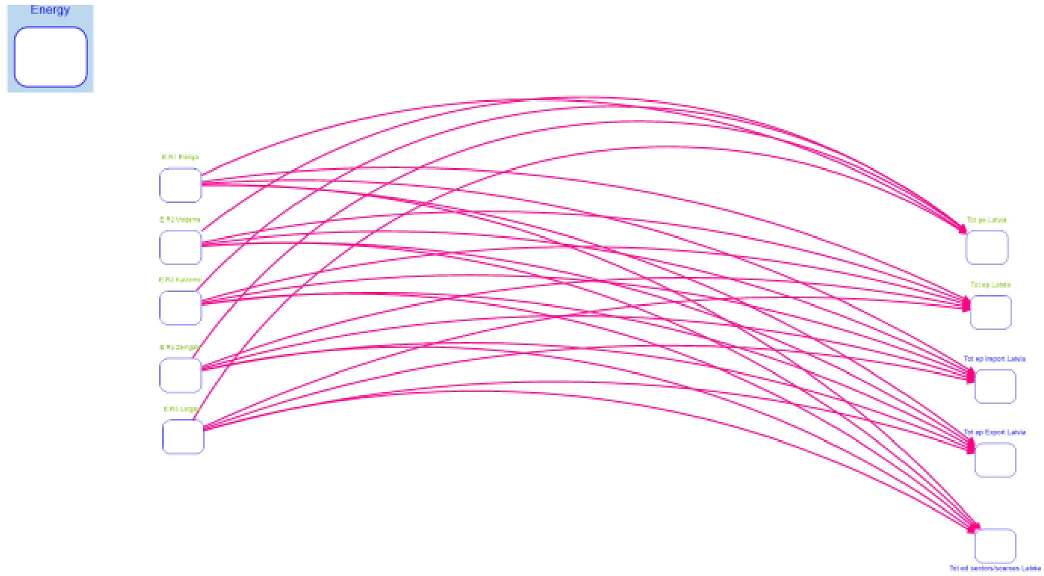

Figure 56 The Energy subsystem of SDM of Latvia case study

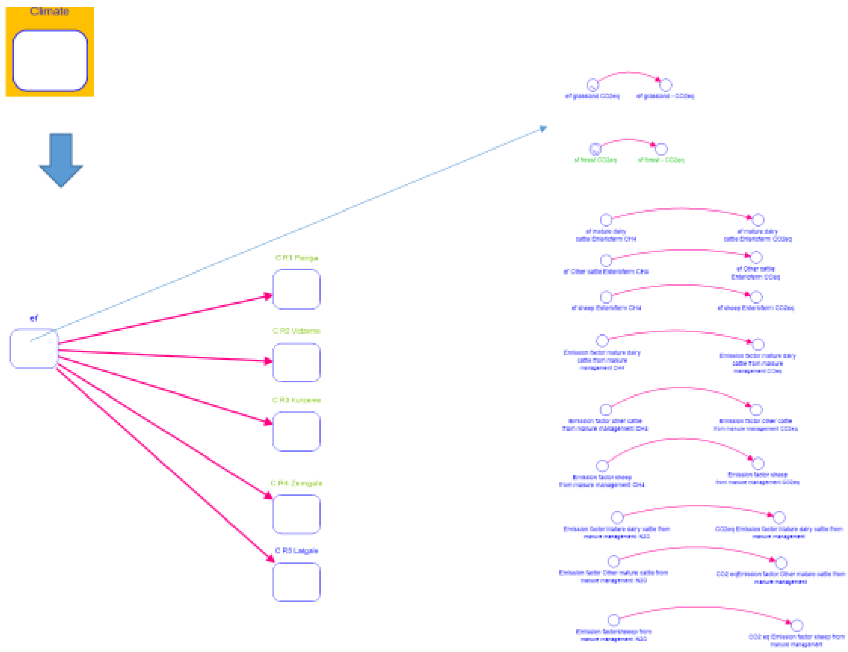

Figure 57 The Climate subsystem of SDM of Latvia case study

6.10.3 Policy cards

Policy Id	Nexus Sector	Name	Very short policy card name	Description of intervention as captured by the policy card	Period of activity
1	Water/Climate	Application of precise technologies for fertilisation	Precise fertilisation	Precise technologies for application of fertilisers (reduction of N consumption 8%), subsidies for purchase of technology [reduction share of 0.08 of mineral N fertilisers]	Active until 2030
2	Water/Climate	Increase application of modern slurry application technologies	Direct slurry injection	Direct injection of organic slurry into the soil, subsidies for purchase of technologies [reduction of nitrogen fertilisers by 12.3 kg N per ha].	Active until 2030
3	Water	Increase of biological farming	Biological farming	Application of mineral fertilisers is not allowed in biological farming; rural support payments for growing of cereals by biological farming [reduction share of 1 for mineral fertiliser on share of land for biological cereals]	Active until 2050
4	Water	Application of green cover before next spring crops	Green cover	Establishment of green cover before next spring crops, mandatory for receiving rural support payments [reduction share of 0.1 of mineral N fertilisers]	Active until 2050
5	Energy	Increase energy efficiency in industry	Energy efficiency in industry	Improvements to energy efficiency in industry, subsidies for investments in new more efficient technologies in production processes as well as for insulation of industrial buildings, [reduction of energy consumption in industry]	Active until 2030

Policy Id	Nexus Sector	Name	Very short policy card name	Description of intervention as captured by the policy card	Period of activity
6	Energy	Increase energy efficiency in households	Energy efficiency in households	Improvements to energy efficiency in households (subsidies for investments in insulation of buildings) [reduction of heat energy consumption in households]	Active until 2030
7	Energy	Increase energy efficiency in tertiary sector	Energy efficiency in tertiary sector	Improvements to energy efficiency in tertiary sector (subsidies for investments in insulation of public buildings) [reduction of heat energy consumption in tertiary sector]	Active until 2030
8	Energy	Application of new technologies for electricity production from biomass	New RE technologies	Application of new and more efficient technologies for electricity production from biomass e.g., gasification, pyrolysis, subsidies for production units [replacement of natural gas]	Implemented after 2030 till 2050
9	Energy	Increase wind energy production	Wind energy	Support for broader application of wind energy technologies (feed in tariffs and subsidies)	Active until 2025
10	Energy	Increase number of electric vehicles	Electric vehicles	Encouraging uptake of electric cars (subsidies for purchasing of ELVs) [reduction of consumption of fossil fuels in transport]	Implemented after 2030 till 2050
11	Energy	Increase share of biofuels in transport	Use of biofuels	Mandate for the use of biofuels in transport (mandatory requirement). [Biofuels shall reach 18% of the total fuel consumption by 2050]	Active until 2050

Policy Id	Nexus Sector	Name	Very short policy card name	Description of intervention as captured by the policy card	Period of activity
12	Food	Increase production of organic cereals in biological farming	Organic cereals	Support to biological cereals in food production (thsd.tons), rural support payments to organic farmers [share of cereals 3% of total production in 2017]	Active until 2050
13	Food	Increase export of cereals - wheat	Cereals export	Promotion of export of cereals (mainly wheat) at the same time ensuring domestic demand by self-supply, communication measure [increased share of export]	Active until 2050
14	Food	Productive cultivars of cereals	Productive cereals	Promotion of more productive cultivars of cereals, subsidies to farmers [increased yields, not increased use of fertilizers]	Implemented after 2025 till 2050
15	Food	Reduction of meat consumption	Reduced meat consumption	Promotion of reduction of meat consumption (kg/capita), communication measure [meat consumption reduces for 1/2, share of population implementing this; meat calories are replaced by cereals], [calculation from kcal intake from meat and cereals]	Active until 2050
16	Food	Balance meat production to self-supply	Meat production	Increased share of meat cattle (decrease of milk cattle), rural support payments to farmers [share of meat to dairy cattle, total number of cattle remains]	Active until 2050
17	Land	Increase arable land	Increase arable land	Increase of arable land (max. up to 70% of used agricultural land), rural support payments, [resulting in reduction of grasslands]	Active until 2050

Policy Id	Nexus Sector	Name	Very short policy card name	Description of intervention as captured by the policy card	Period of activity
18	Land	Ratio-based perennial grasslands on agricultural area	Grasslands on agricultural area	Maintaining/establishing the share of perennial grasslands on arable land (up to 70% of used agricultural land), rural support payments for grasslands [reduction of sown area, reduction of total amount of mineral fertilisers applied]	Active until 2050
19	Land	Balanced perennial grasslands and arable land	Balanced grasslands and arable land	Maintaining/establishing the share of perennial grasslands (50%) and arable land (50%), rural support payments for grasslands	Active until 2050
20	Land	Increase growing of energy crop - rape	Growing of energy crop - rape	Increase of land for energy crops - rape up to 25% arable area - rural support payments [baseline data show 13-15% from total arable land] [resulting in reduction of area for cereals]	Active until 2050
21	Land	Legumes in crop rotation	Legumes in crop rotation	Cultivation of legumes in crop rotation, rural support payment, (result in reduction of area for cereals, increase in nitrogen sequestration and carbon accumulation) [Up to 25% of arable land for cereals][Reduction of GHG (N20) emissions from reducing the use of nitrogen fertilisers (-62.4 kg N t/ha), increase of carbon accumulation in soil by7t/ha)]	Active until 2050

Policy Id	Nexus Sector	Name	Very short policy card name	Description of intervention as captured by the policy card	Period of activity
22	Climate	Increase production of biogas from manure	Production of biogas	Promotion of production of biogas from manure (subsidies for investments); resulting in reduction of CH4 and N2O emissions from the manure management [lowest threshold for support is 80 heads of cattle; 50% from dairy cattle qualifies for receiving of subsidies]	Active until 2050
23	Climate	Improvement of feed quality	Feed quality	Subsidies for improvement of feed quality (resulting in reduction of CH4 emissions from enteric fermentation because of food digestibility improvements from 66 to 67%) [Applied to 50% of dairy cows; reduction of CH4 emissions for 14%]	Active until 2050
24	Climate	Support to fertilization planning	Fertilization planning	Fertilization planning to reduction of GHG emissions, rural support payments [apply to 27% from 46.2% of utilized agricultural area, reduction of N2O emissions, reducing the use of nitrogen fertilizers by 27%]	Active until 2050
25	Climate	Support to young forest maintenance	Young forest maintenance	Support to young forest maintenance [share of managed forest], subsidies for forest maintenance, increased carbon sequestration 21 tCO2/ha in 10 years]	Active until 2050

Policy Id	Nexus Sector	Name	Very short policy card name	Description of intervention as captured by the policy card	Period of activity
26	Climate	Increase afforestation	Increase afforestation	Support to forest cultivation (afforestation, resulted in increase of forest area, increased carbon accumulation in afforested lands), subsidies for afforestation activities [share of forest area, increase on land for meadows and pastures] [a total of 10 000 ha increased by 2030]	Active until 2030

6.10.4 Stakeholders maps

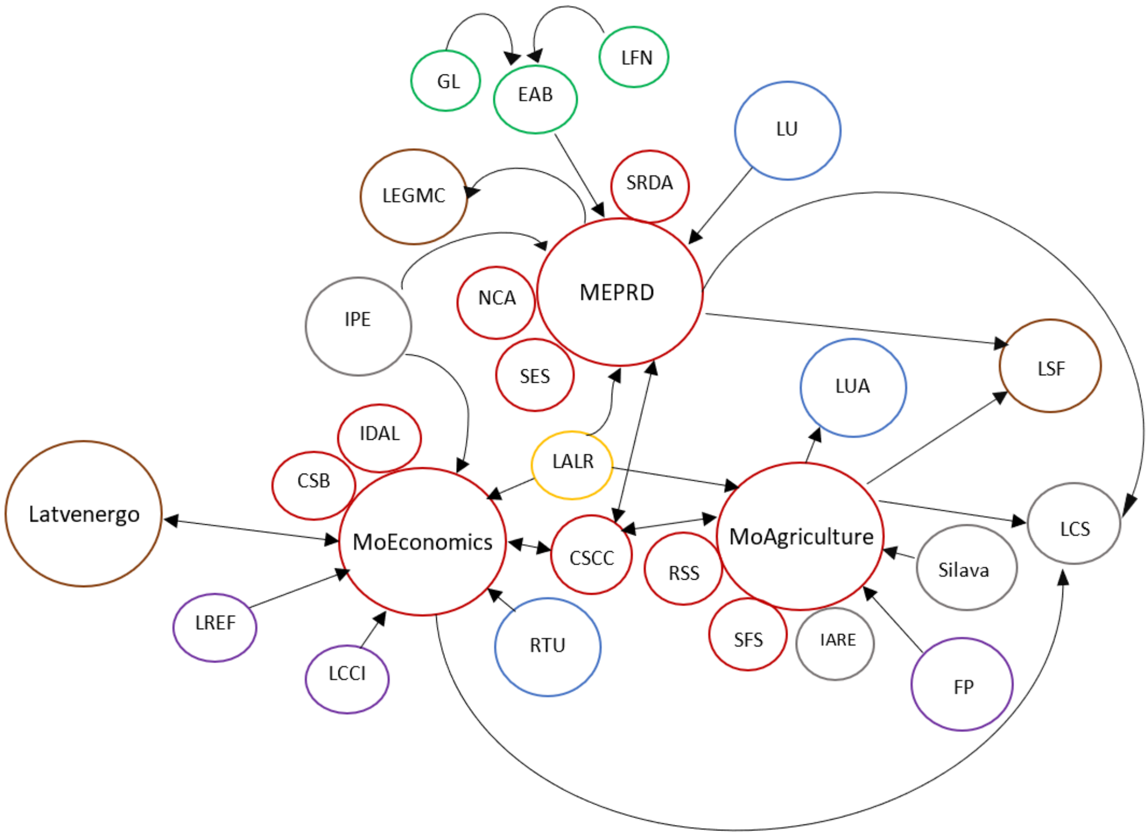

Figure 58 Map of relevant stakeholders and relationships

Legend:

NATIONAL COMPETENT AUTHORITY	RESEARCH
BUSINESS	MUNICIPALITIES
EDUCATION	TRADE UNION
	NGO

Abbreviations:

MEPRD	Ministry of Environmental Protection and Regional Development	IARE	Institute of Agricultural Resources and Economics
MoAgriculture	Ministry of Agriculture	Silava	Latvian State Forestry Research Institute “Silava”
MoEconomics	Ministry of Economics	LCS	Latvian Council of Science
IDAL	Investment and Development Agency of Latvia	IPE	Institute of Physical Energetics
CSB	Central Statistical Bureau	LALRG	Latvian Association of Local and Regional Government
CSCC	Cross-Sectoral Coordination Centre	LCCI	Latvian Chamber of Commerce and Industry
SES	State Environmental Service	FP	Association “Farmers Parliament”
NCA	Nature Conservation Agency	LREF	Latvian Renewable Energy Federation

SRDA	State Regional Development Agency	EAB	Environmental Advisory Board
SFS	State Forest Service	GL	Association “Green Liberty”
RSS	Rural Support Service	LFN	Foundation “Latvian Fund for Nature”
LEGMC	Latvian Environment, Geology, and Meteorology Centre		
Latvenergo	JSC “Latvenergo”		
LSF	JSC “Latvia’s State Forests”		
LU	University of Latvia		
LUA	**Latvia University of Life Sciences and Technologies**		
RTU	Riga Technical University		

6.10.5 Use cases

A. Water

Step in the SG:

1. Identify cereals area which is fertilised.
2. Identify the measure to be applied (precise fertilisation, direct slurry injection, biological farming, green cover)
3. Specify the area where the change of fertilisation will take place.
4. Calculate reduction of N leakage from reduced amount of fertilisers.

If the effect on Water health is negligible, check an alternative measure and/or increase subsidies/ support payment.

If the effect on Water health is pronounced, no need for immediate action.

B. Energy

USE CASE E.1	Energy
Related Learning Goals	Decreasing energy demand
Goal	Increasing energy efficiency
User	Public Sector: Ministry of Economy
Actions	➢ Improvement of energy efficiency in industry by available subsidies for investments in more efficient technologies and insulation of industrial buildings ➢ Improvement of energy efficiency in households by available subsidies for insulation of buildings ➢ Improvement of energy efficiency in tertiary sector by available subsidies for insulation of public buildings
Indicator	➢ Energy (heat) demand by industry ➢ Energy (heat) demand by households ➢ Energy (heat) demand by tertiary sector

Step in the SG:

1. Identify current total heat demand.
2. Identify the measure to be applied to reduce heat demand in sectors (industry, households, tertiary sector)
3. Calculate the reduction of heat demand.

If the effect on Energy health is negligible, check an alternative measure and/or increase subsidies.

If the effect on Energy health is pronounced, no need for immediate action.

USE CASE E.2	Energy
Related Learning Goals	Increasing electricity production by RES
Goal	Increasing electricity production by RES
User	Public Sector: Ministry of Economy
Actions	➢ Application of new more efficient technologies for electricity production from biomass ➢ Increase wind energy production by support for broader application of wind energy technologies (feed-in tariffs and subsidies)
Indicator	➢ Electricity production from biomass ➢ Electricity production by wind ➢ Total electricity production by RES

Step in the SG:

1. Identify the electricity produced from RES.
2. Identify the measure to be applied to increase electricity production (biomass efficient technologies, increased wind energy)
3. Calculate the total electricity production by RES.

If the electricity produced by RES is lower than 100%, increase subsidies for application of measures

If the electricity produced by RES is 100%, no need for immediate action.

USE CASE E.3	Energy
Related Learning Goals	Replacement of fossil fuels in transport
Goal	Decarbonisation of transport
User	Public Sector: Ministry of Economy
Actions	➢ Encouraging uptake of electric cars (subsidies for purchasing of electric vehicles) ➢ Increasing use of biofuels in road transport (subsidies)
Indicator	➢ Reduction of oil consumption in transport

Step in the SG:

1. Identify the oil consumption in transport.
2. Identify the measure to be applied.
3. Calculate the total reduction of oil consumption in transport.

If the reduction of oil demand is less than 18%, increase subsidies for application of measures

If the reduction of oil demand is equal or more than 18%, no need for immediate action.

C. Climate

USE CASE C.1	Climate
Related Learning Goals	Reduction of GHG emissions
Goal	Emission reduction in the agricultural sector
User	Public sector: Ministry of Agriculture Private: Farmers unions

Actions	➢ Increase production of biogas from manure (subsidies for investments) ➢ Improvement of feed quality (subsidies) ➢ Promote fertilization planning (rural support payments)
Indicator	➢ Change of GHG emissions derived from agriculture

Step in the SG:
1. Identify current GHG emissions from agriculture.
2. Identify the measure to be applied (production of biogas, improvement of feed quality, promotion of fertilization planning).
3. Calculate the GHG emissions from agriculture.

If the GHG emission decrease from agriculture is negligible, check an alternative measure and/or increase subsidies/support payments.

If the GHG emission decrease from agriculture is pronounced, no need for immediate action.

USE CASE C.2	Climate
Related Learning Goals	Increase CO_2 sequestration
Goal	Increase CO_2 sequestration in forestry
User	Public sector: Ministry of Agriculture, Ministry of Environmental Protection and Regional Development
Actions	➢ Increase support to young forest maintenance (subsidies) ➢ Increase afforestation (subsidies)
Indicator	➢ Change in CO_2 sequestration derived from forestry

Step in the SG:
1. Identify current CO_2 sequestration from forests.
2. Identify the measure to be applied (young forest maintenance, afforestation).
3. Calculate the CO_2 sequestration from forests.

If the CO_2 sequestration increase is negligible, check an alternative measure and/or increase subsidies for application of measure.

If the CO_2 sequestration increase is pronounced, no need for immediate action.

D. Land

USE CASE L.1	Land and Forest
Related Learning Goals	Sustainable management of land
Goal	Sustainable land use (arable land and grassland) taking into account farm welfare
User	Public Sector: Ministry of Agriculture Private: Farmers unions
Actions	➢ Increase of arable land (rural support payments) ➢ Maintaining the share of perennial grasslands on arable land (rural support payments) ➢ Increase land for energy crops (rape) (rural support payments) ➢ Cultivation of legumes in crop rotation (rural support payment)
Indicator	➢ Change of arable land ➢ Change of perennial grasslands ➢ Change of land for energy crops (rape)

Step in the SG:
1. Identify current share of arable land, perennial grasslands, and energy crops and the farm welfare.
2. Select the land management measures.
3. Calculate the change in land-use ratio and farm welfare

If the farm welfare decreases by changing the land-use options, the goal is not reached and actions must be taken to alter the rural support and improve land use policies, land use limitations.

E. Food

USE CASE A&F.1	Agriculture and Food
Related Learning Goals	Sustainable food production
Goal	Food security and sustainable food production (SDG2)
User	Public Sector: Ministry of Agriculture
Actions	➢ Support to biological cereals in food production (rural support payments) ➢ Promotion of export of cereals (rural support payments) ➢ Promotion of more productive cultivars of cereals (rural support payments)
Indicator	➢ Production of organic cereals ➢ Share of cereals export ➢ Total production of cereals

Step in the SG:
1. Identify amount of cereals produced.
2. Identify the measures to increase production of cereals in conventional and biological farming.
3. Calculate the production of cereals in conventional and biological farming.

If the produced organic cereals increase is pronounced, no need for immediate action.
If the produced conventional cereals increase is pronounced, no need for immediate action.
If the produced organic cereals increase is negligible, increase rural support payments.
If the produced conventional cereals increase is negligible, increase rural support payments.

USE CASE A&F.2	Agriculture and Food
Related Learning Goals	Changing dietary patterns
Goal	Sustainable consumption and production patterns
User	Public Sector: Ministry of Agriculture
Actions	➢ Promotion of reduction of meat consumption (communication measure) ➢ Balance meat production to self-supply (rural support payments)
Indicator	➢ Consumption of meat ➢ Share of meat cattle

Step in the SG:
1. Identify amount of meat consumed.
2. Identify the measures to balance meat production to self-supply.
3. Calculate the meat production.

If the produced meat meets the self-supply, no need for immediate action.
If the produced meat is lower than the self-supply, increase rural support payments.

7 Sweden

7.1 Introduction

Sweden is a country in northern Europe (Figure 59) bordered by Norway in the west, the North Sea in the southwest, the Baltic Sea in the east and Finland in the northeast. Two thirds of Sweden are currently covered by forests, of which the majority is subject to forestry. Despite a large per capita energy consumption, Sweden's economy is today one of the least dependent on fossil fuels and has one of the lowest carbon emission rates. Sweden is limited in production by climatic conditions and most food production happens on the South. While Sweden is relatively rich in water resources, in southern Sweden, water shortages during summer increasingly affect the drinking water supply, both in terms of quality and quantity (Eklund et al. 2015).

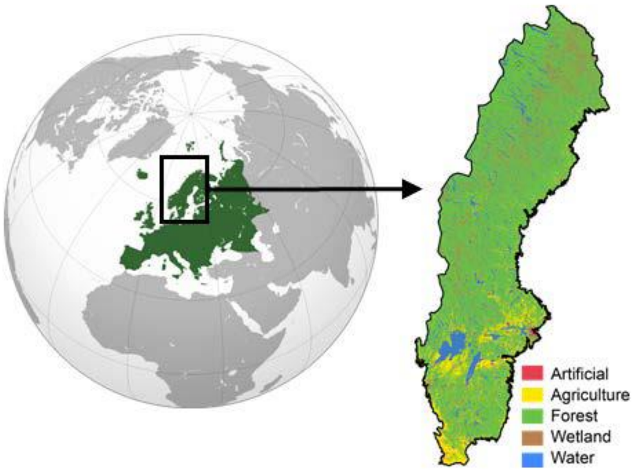

Figure 59 Map of the Sweden SIM4NEXUS case study

Main nexus challenges are linked to forestry, water, energy and climate sectors. In Sweden, the forestry sector is subject to alterations in the light of developments in energy, governance and land use systems, climate politics, and taking account of an increasing competition between economic, environmental and recreational functions (Sandström et al., 2011). The growing demand for bioenergy has led to an intensification of the forest industry (Helmisaari et al., 2014), in particular through extensions of managed forest land and introduction of fast-growing tree species.

As the market for biofuels further grows, the question arises as to whether the supply of forest biomass for energy can further be increased. The competition between forests, water and energy resources and their impacts on biodiversity is further intensified by changing climate conditions. Key research questions in the water sector relate to how future climate change, streamflow shifts and changing forestry practices might affect (drinking) water availability and quality.

Knowledge gaps and considerable uncertainties on how environmental systems will change and on their impacts are major challenges. Swedish law prohibits hydropower constructions in four of the biggest streams and a number of smaller rivers, and, thus, limits further expansion of hydropower. Large uncertainties remain in terms of the effect of future seasonal shifts in water availability (e.g., more streamflow during winter, but expected longer drought period during summer) on hydropower.

The research within the case study concentrates on the impacts of introducing mechanisms for decreasing emissions, alternative uses of the additional biomass potential (carbon sequestration in standing forests versus increased bioenergy or agricultural production) and the consequences for the available water supply and quality, and for biodiversity and potential impact on other water goods and services. The goals of the case study are to increase the understanding of forest-water interlinkages in the context of climate change, as well as to bring research and stakeholders together and communicate the results.

Case study lead organisation is Uppsala University. Main stakeholders involved in the case study are representatives of forestry agency, food agency, municipalities, water related NGO and a consultancy company.

7.2 Overview of tasks performed

7.2.1 Organisation to carry-out Task 5.2

Task 5.2. has been carried out by researchers from Uppsala University (two people), in collaboration with other SIM4NEXUS partners as listed below:

1. WUR-LEI to provide thematic modelling results from MAGNET
2. UPM to provide thematic modelling results from CAPRI
3. PBL to provide thematic modelling results from IMAGE-GLOBIO
4. IHE-DELFT to develop the conceptual case study model
5. IHE-DELFT to create the System Dynamics Model (SDM)
6. UNEXE to create the SG

Key responsibility in launching the stakeholder involvement process, performing the policy coherence analysis, development of conceptual model, data gathering and scenarios development was on the Uppsala University researchers, while the modelling was conducted by the respective modellers at WUR-LEI, UPM, PBL and IHE-DELFT, and Serious Game was created by the game developers at UNEXE, in discussion with and using inputs from the Uppsala University researchers.

Collaboration between partners took place in numerous ways. First, project meetings were used as discussion venue for planning of project activities. Second, a 2-days meeting with SDM modellers from IHE-DELFT was organised in Uppsala to discuss the conceptual model and its application in the System Dynamic Modelling, as well as data needs (January 2019). Finally, frequent skype meetings and mail exchange were used.

The transdisciplinary work both provides benefits and represents challenges. A transdisciplinary approach is necessary to address most of today's environmental problems, as they involve a broad range of aspects and issues that cannot be tackled by representatives of one discipline and without involvement of actual stakeholders – users of the solutions that are being developed. Transdisciplinary approach allows for transcending the borders between different societal sectors and adopting broader perspective that "connects the dots" of the whole system. This allows for seeing the problem in question from different angles, and understanding the, seemingly conflicting, perspectives of other actors involved. This may allow for finding a common ground and mutual priorities that can led to solutions that benefit different sectors. However, there are also downsides. Most of all, transdisciplinary collaboration is very time demanding – it requires long term involvement, as initially representatives of different disciplines, as well as practitioners speak different "languages" and may have problem with communication and it takes time to learn each other's understandings and terms used. Another challenge is to encourage stakeholders to participate in the research project. Stakeholders are usually very busy and even if they are interested in the project as such they may not find time to participate in its activities, such as whole-day workshops. This was the case in the Swedish case study, where many of the invited stakeholder, while interested in general, had no possibility to come to the workshops.

7.2.2 Schedule of Task 5.2

- June – July 2016: Launching the case study processes
- August 2016-September 2016: initial stakeholder mapping
- October 2016 – November 2016:
    - preparation of outreach material
    - preparations for initial survey among stakeholders
- November 2016:
    - final list of stakeholders
    - initial survey sent to stakeholders
- December 2016 - February 2017: analysis of survey results
- January 2017 – December 2017:
    - review of policy documents EU and Sweden
    - policy coherence analysis in Sweden, part 1
- December 2017 – June 2018: Policy coherency analysis, part 2
- March 2018: Second survey of stakeholders from whole Sweden to identify synergies and conflicts
- February – April 2018 – Development of the first conceptual model draft
- 18th April 2018 – First stakeholder workshop
- May 2018 – Refining policy coherency analysis based on stakeholders' feedback
- May-June 2018 – Refining the conceptual model based on stakeholders' feedback and in discussion with the System Dynamics modellers
- September – December 2018 – Data gathering
- 23 - 24 January 2019 – Two-days meeting with System Dynamics modellers
- February – June 2019 – Data gathering, based on needs identified with System Dynamics modellers
- January – March 2019 – Development of scenarios
- 13th March 2019 – Second stakeholder workshop
- April 2019 – refining the scenarios based on stakeholders' feedback
- May - July 2019 – Creation of the policy cards
- June – October 2019 – more data gathering, based on needs identified with System Dynamics modellers
- December 2019 – Checking the results of the System Dynamics Model
- January – February 2020 – Implementation of the scenarios in the System Dynamics Model
- February – March 2020 – Application of the policy cards in the SG (and development of the Game)
- April/May 2020 – Testing the SG in Sweden (depending on the game's availability).

7.3 Engagement of stakeholders in the process

7.3.1 Overview of stakeholders' engagement in the case study

All five nexus sectors were represented by at least one stakeholder. While we had a large number of passive stakeholders (e.g., Swedish municipalities), our main stakeholders (12 unique people) involved in the case study were representatives of forestry agency, food agency, two local municipalities, water related, a consultancy company and researchers. Consequently, stakeholders in the project had different roles. For instance, a large number of municipalities were consulted to give input through online surveys, but were not included in a two-way dialogue. On the other hand, the main stakeholders (representatives of forestry agency, food agency, municipalities, water related, a consultancy company and researchers) were actively involved in the workshops. They helped to refine the results obtained by the policy coherence analysis and validated the conceptual model. They also had a chance to comment on results from the thematic models. An overview of stakeholder activities can be found in Table 20.

Table 20 Interactions with stakeholders from 2016-2020

Interactions with stakeholders	Date Location	Number of participants and indicative distribution by nexus sector	Topics discussed	Outcomes / Achievements
survey	November – December 2016	59 responses All sectors	Interest in the project and knowledge about the nexus approach, willingness to collaborate	General overview of stakeholders' interests and list of stakeholders to contact with workshop invitation
survey	March 2018	101 responses All sectors	Policy coherency	Stakeholders' views on the conflicts and synergies between particular policy goals of different sectors, as input used to refine the policy coherency analysis
workshop n°1	18 April 2018	10 All sectors	Conceptual model and policy coherency analysis	Stakeholders' views on the conflicts and synergies between particular policy goals of different sectors, as input used to refine the policy coherency analysis
conference	22 November 2018	Ca. 30 Mostly forestry and water sectors	Discussion forest and water challenges in relation to EU project GRIP on LIFE	Discussions with stakeholders on nexus challenges and new useful contacts
workshop n°2	13 March 2019	6 Forestry, water and climate	Presenting results of policy coherency analysis and presentation of the final conceptual model. Discussion on policy scenario, based on existing data trends	Inputs to refine initial scenarios
conference	7-12 April 2019	Ca. 20 direct interactions	Discussion of trade-offs and synergies between	Discussions with stakeholders on nexus

		during poster presentation	ecosystem services within the Water-Energy-Food-Land-Climate Nexus in Sweden	challenges and new useful contacts
workshop	April-May 2020	Ca. 15-20, all sectors	SG play session	Feedback on SG
conference	3-8 May 2020	Ca. 20 direct interactions during poster presentation	Discussion of dynamics in the Swedish water-energy-land-food-climate nexus	Discussions with stakeholders on lessons from combining policy analysis and system dynamics modelling

7.3.2 Feedback on stakeholders' engagement in the case study

In general, it was not easy to involve stakeholders on a long-term basis. There were two main reasons for that: First, everyone is very busy and it is difficult to commit time for a whole day workshop. Second, Sweden is a large country, so travelling time is added to the actual engagement time. Because of that, most of the stakeholders came from the region around Uppsala and Stockholm, where the workshops took place. The distance could also lead to unexpected changes in plan – on the second stakeholder workshop, one of the stakeholders that travelled from North of Sweden could not come as her plane was cancelled in the last minute. In this situation, we provided the possibility to participate remotely via skype and it worked well, however prevented this stakeholder from discussions in groups. Still, she could participate in the general discussions and take part in reflection on important issues.

On the other hand, the stakeholders that participated in the workshops were very interested and engaged. They took part in in-depth discussions and provided many important inputs to the SIM4NEXUS work. To make the workshops interesting for stakeholders, many interactive exercises were planned. These were in the form of group work where stakeholders could reflect on pre-prepared questions/issues to discuss. This was very appreciated. In the workshops evaluations most of the stakeholders that took part suggested that what they liked most was possibility to discuss about different issues with people from other sectors. Care was also taken to make the workshops simply nice – with good lunch and attractive catering for coffee break, to make stakeholders feel comfortable and satisfied. It seemed to be important to keep the stakeholders happy during the process.

It seems that if the stakeholders have common interest to the project, they are more motivated to join. It was evident in the case of the forestry sector stakeholders, who were around the time of SIM4NEXUS project starting a large EU project on forestry, water and energy, that was well aligned with SIM4NEXUS thinking. The stakeholders shared information about their project with the Uppsala University researchers and invited them for the conference they organized about this project, which also improved the collaboration.

Regarding the surveys conducted, the response rate was reasonable. To the first survey it was 59 out of 339 contacted stakeholders that responded (17%), and to the second survey 101 out of 354 contacted stakeholders responded (29%). Particularly the second survey was beneficial for the project as it contributed to refining the policy coherency analysis. While policy coherency analysis was a very complex task, care was taken to provide a survey that was relatively simple, to facilitate high response rate.

Unfortunately, Swedish stakeholders did not express high interest in the SG, but they believed that it would mostly be useful for educational purposes, e.g. for students at universities. There are two key reasons for that. Firstly, Swedish stakeholders have their own approaches and ways of working that are relatively advanced and well-established, and they do not feel they need a new tool. Second, the stakeholders did not think that the complexity of the nexus can be properly treated in a simplified model and a cut-down and streamlined game (see more on that in Section 2.6.1). While the approaches and routines used in Sweden are of sectoral nature, the stakeholders still thought they are more efficient to use (especially when underlying knowledge of the complexity in the nexus is available) than trying to connect all sectors in one decision tool in such a limited and simplified way. This issue highlights the necessity of discussing the final outcome/decision tool that is to be produced by such a huge research project as SIM4NEXUS a priori together with affected stakeholders.

7.4 From conceptual models to System Dynamic Modelling

7.4.1 Case study conceptual model

The conceptual model was developed based on 1) comprehensive review of relevant literature; 2) expert judgement; and 3) stakeholders' inputs at the first stakeholder workshop.

First, a review of relevant scientific studies and grey literature reports from Sweden was conducted. It covered different aspects of the nexus sectors to derive information about most important connections. Simultaneously, there were numerous discussions within the expert group that included three researchers from Uppsala University with expertise in water, energy, climate and forestry (key sectors in the focus of the Swedish case study). The conceptual model was then discussed with a group of stakeholders on the first stakeholder workshop. The stakeholders got the initial draft of the model printed out and had a task to discuss it in groups and add comments and relevant links, as well as suggest removing some links if necessary. This was then discussed in the plenary.

After the stakeholder workshop, the conceptual model was refined and improved. Finally, it was discussed with the System Dynamics Modelling people, particularly in relation to the data needs and possibilities to obtain them. A two days meeting with Uppsala University researchers and the modellers was organised in January 2019 to discuss that in detail and, based on that, the conceptual model was refined further. The Conceptual Complexity Science Graphs are included in the Annex in section 7.10.1.

7.4.2 Modifications introduced to model policy scenarios

7.4.2.1 Development of policy scenarios for the case study

The policy scenarios were developed based on 1) policy coherency analysis; 2) ongoing political initiatives and government agenda; 3) expert judgement; and 4) discussions with stakeholders on the second stakeholder workshop. In addition, insights form the development of the conceptual model helped in the scenario development as it revealed key areas of interest in the Swedish context.

First, the policy coherency analysis constituted a base for the development of the scenarios. It provided knowledge on the key focus areas in the decision making in Sweden, main objectives of different sectors, as well as conflicts and synergies between them. By combining these results with information gathered from the ongoing government agenda and with their own expert knowledge, Uppsala University researchers developed a set of initial scenarios to cover the key challenges identified, as well as potential approaches to tackling them. The focus was on the different instruments, which could be applied to achieve particular objectives for Sweden. These scenarios were then discussed with the stakeholders on the second stakeholder workshop. The scenarios were given to stakeholders and they were supposed to respond to a set of questions about each of the scenarios, ranking: 1) how realistic introduction of

particular instrument is; 2) how much it could contribute to particular policy objective; 3) what the costs would be; and 4) what would social acceptability be. This exercise led to in-depth discussions on the feasibility of the presented scenarios and the further potential scenarios that could be used.
After the workshop, the scenarios were refined by the Uppsala University researchers to reflect the inputs from the stakeholders. The focus of the final scenarios is on all nexus sectors, however with particular focus on the climate and energy sectors.
Compared to the baseline described in D1.8 (Figure 60), these final scenarios are in line with the policy objectives of the ongoing government agenda, but represent innovative political instruments/measures (see section 7.4.2.1) that are not presently being implemented in this form, for example subsidies for environmentally friendly trucks or re-wetting the wetlands (SEPA 2019).

Sweden

Sweden follows a path with no major changes in recent trends at social, economic and technological levels. The forestry sector and the increase use of renewable energy sources continue to dominate the national agenda. The population is expected to increase by 33% in 2050. Although most of the population lived in cities in 2010 (85%), the urbanization rate will continue to increase reaching 92% by the mid-century. GDP will more than double by 2050 and average per capita income will also increase but at a smaller rate. Nonetheless, income is expected to reach 59 thousand US$2005 by 2050, more than 25% above the average European income. Hydropower and nuclear power are the backbone of the electricity system, providing reliable and relatively low energy costs in comparison to other countries in Europe and low carbon intensity (low emissions from electricity generation). Excluding taxes and levies, household electricity prices for electricity are lower than the EU-28 average. The long lifetime of hydropower plants secures partly electricity supply. On the other hand, expansion of this renewable technology is limited by law, as already ⅔ of the rivers in the country host this type of infrastructure. The fragmentation of river system has impacts to ecosystems, and because of that recently introduced legislation protects the only five major rivers not hosting hydropower dams thus no new large hydro dams can be constructed. Already now forestry by-products and waste are used for energy production, particularly for heating, and this will continue in the future. The increasing demand for bioenergy, in particular from the intensification of the forestry industry, may increase the share of managed forest land in forestry sector, and the area of energy forest of fast-growing tree species and use of fertilizers in agricultural sector. All these activities impact ecosystems and biodiversity, and also affect water quality. Wood and black liquor (a by-product of pulp processing) represent over 80% of the biofuel demand in Sweden, followed by densified wood and waste). Two thirds of the country's land is covered by forests and 55% by productive forest (i.e. producing at least 1 cubic meter wood per ha per year). The forestry sector continues to play an important role in the economy, although increased mechanization in the large-scale forestry leads to lessen the employment opportunities in the sector. Water is an abundant resource in the country, however vulnerable to changes in the climate. Precipitation and temperature are likely to increase in the future as is the risk of flooding and drought events. Drinking water supply in the south is likely to be affected more often by reduced water availability. As climate is a limiting factor in the agricultural production, most food production occurs in the South. There are 63,000 farms in Sweden, with average side of farm of 41 hectares. Swedish exports of food and agri-cultural products currently amount to EUR 5 billion, and is steadily increasing. Sweden has very ambitious targets when it comes to sustainability and values in food production and Swedish organic production is increasing and has more than doubled in the last ten years. The farmed land (arable land, pastures and meadows) used for organic production is currently 18 percent. In 2017, the Swedish Government set a target that certified organic production shall increase to at least 30 percent of the cultivated area by 2030.

Figure 60 Baseline narrative as described in SIM4NEXUS deliverable D1.8

The final scenarios are listed below, in relation to particular sectors.

7.4.2.1.1 CLIMATE SECTOR

Objective: Reduction of climate impacts

Subsidies on environmentally friendly trucks: in this scenario, subsidies for environmentally friendly trucks are introduced that lead to more such trucks and less conventional trucks and thus less emissions. This has consequences for energy and climate sectors. In the scenario, different levels of subsidies can be used leading to different level of effects.

Re-wetting of peatlands: in this scenario, previously ditched forest land will be re-wetted, through government support (compensation schemes), leading to less CO^2 emissions. In the scenario different number of hectares of the forest will be re-wetted leading to different decreases in emissions.

7.4.2.1.2 ENERGY SECTORS

Objective: Increase share of renewable energy

Subsidies on solar panels: in this scenario, subsidies for solar panels are introduced that lead to more panels, i.e. less energy production from fossil fuels, and thus less emissions. This has consequences for energy and climate sectors. In the scenario, different levels of subsidies can be used leading to different level of effects.

Start-up grants for Salix (willow) plantations and tax reliefs on forest biomass: in this scenario, bioenergy is promoted (through start-up grants and tax relief) to produce more biomass for energy production; also, more biomass is used from the forest, leading to shorter rotation ages and focus on coniferous species and fast-growing broadleaves. More use of land for energy production leads to less land for food production. Changes in the forestry lead to lower average age of Swedish forests and less area of valuable broadleaved species, with negative consequences for biodiversity.

7.4.2.1.3 WATER SECTOR

Objectives: Improving water quality and decreasing water use

Tax on fertilizer: in this scenario a tax on fertilizer is introduced, leading to less fertilizer use and thus positive effects on water quality. At the same time, less fertiliser means and less food production, potentially leading to food security issues. In the scenario, different levels of the tax can be used leading to different level of effects

Increase water fees for property owners: in this scenario water fees are introduced, leading to less water use and thus positive effects on water quantity. In the scenario, different levels of the fee can be used leading to different level of effects.

7.4.2.1.4 FOOD SECTOR

Objectives: increasing food production and thus food security

Subsidy on fertilizer: in this scenario, subsidy on fertilizer is introduced, leading to more fertilizer use and more food production. At the same time, more fertiliser means negative effects on water quality. In the scenario, different levels of the subsidy can be used leading to different level of effects.

Subsidy on arable land: in this scenario subsidy on fertilizers is introduced, leading to more fertilizer use and more food production). At the same time, more food production may mean negative effects on water quality (through fertiliser use). In the scenario, different levels of the subsidy can be used leading to different level of effects.

7.4.2.1.5 LAND SECTOR

Objective: Improved conditions for forest biodiversity

Compensation for forest protection: in this scenario financial compensation is given to forest owners for lost production to protect more forest areas. This improves conditions for forest biodiversity but leads to lower area of productive forest. The compensation can be set at different levels leading to different level of effects.

7.4.2.2 Introduction of policy scenarios in the SDM

Once the set of policies to be analysed is defined, the next step was to 'map' the policies to the SDM. This implied identifying those policies that could be easily converted into a simulation variable (which might have needed a bit of adjustment and/or additional data to be able to be implemented) and those policies which could not be modelled using the data and knowledge available. With the case study leads, each policy was further refined to be able to identify specific targets and the means to achieve those targets (i.e. policy measures).

Based on this information, the identified policies, target, and measures were cross referenced with SDM parameters to identify which, if any, parameter could be adjusted in the SDM in order to accurately represent the policy measure. Once a suitable parameter was identified, the next step was to identify which values were affected as a result of implementing the policy, and how to implement the changes.

Once this was done, a new variable was inserted to the SDM to represent the policy, and essential acts as a switch. If the policy switch is off, the parameter to change is not altered. However, if the switch is on, then the parameter is altered in order to represent the applied policy. The parameter to affect as a result of implementing the policy is targeted, and the equation in the affected parameter is re-written to represent the impact of implementing the policy and the outcome. In essence, each policy is 'recoded' in terms of SDM variable and suitable logic to quantitatively represent the identified policy in the model. As such, there are some minor adjustments in the model (SDM) to incorporate the policy variable. The exact parameters to trigger, and the magnitude of the change, differs by each different policy. When policy switches are off, the model runs as in the baseline, with no changes. It is noted that because of the interlinked nature of each sector in the SDM, there may be (unanticipated) indirect side-effects resulting from the implementation of a single policy. However, this is exactly the idea of SIM4NEXUS: to learn about interdisciplinary connections, trade-offs and synergies across the nexus. Consequently, this will support an in-depth analysis of how implementing a given policy in a given sector may have impacts, positive or negative, across the whole nexus.

7.4.3 Modifications introduced to account for data availability

7.4.3.1 Data available from the thematic models

In the Swedish case study, three main models were selected initially based on review report, the model factsheet and the presentations during the project meeting in Barcelona: CAPRI, MAGNET and GLOBIO. All provided results for the baseline scenario.

The Common Agricultural Policy Regionalised Impact modelling system (CAPRI) is a global agro-economic model designed for the ex-ante impact assessment of agricultural, environmental and trade policies with a focus on the European Union. It is a global spatial partial equilibrium model, solved by sequential iteration between supply and market modules. The unique combination of regional supply-side models with a global market model for agricultural products provides simulated results for the EU at subnational level, whilst, at the same time, simulating global agricultural markets. CAPRI provides a large number of economic, yield and environmental (e.g. fertilizer and CO2 emissions) indicators of the agricultural sector. In the Swedish case study, we were mainly interested in the environmental indicators related to the use of fertilizer, nutrient balances and total emissions.

MAGNET (Modular Agricultural GeNeral Equilibrium Tool) is a general computable equilibrium model, with an additional focus on agriculture, designed for economic impact assessment. MAGNET builds on the global general equilibrium Global Trade Analysis Project (GTAP) model. MAGNET is a tool for analysis of trade, agricultural, climate and bioenergy policies. For the Swedish case study, MAGNET provided mainly a number of economic variables (e.g., GDP), consumption behaviour, imports/exports of food, energy and other resources, as well as emissions.

The GLOBIO (Global Biodiversity) model is used to assess the consequences of global environmental change on biodiversity (terrestrial and aquatic), and ecosystem services (GLOBIO-ES). For the Swedish case study, the GLOBIO model delivered mainly parameters for surface water quality and biodiversity. It included the total nitrogen and total phosphorus concentrations in surface water as well as the following indicators for biodiversity intactness: (1) percentage of lakes with high concentrations of blue-green algae in summer, (2) biodiversity intactness in lakes, (3) biodiversity intactness in rivers, (4) biodiversity intactness in wetlands, (5) average freshwater biodiversity intactness, (6) biodiversity loss in rivers due to flow disturbance, (7) terrestrial biodiversity intactness, and (8) fraction of urban + agricultural land.

The data of the three thematic models was presented to the stakeholders during a stakeholder workshop held in March 2019 at Uppsala University. In an interactive exercise, stakeholders were presented with historic trends of a number of variables and were asked to continue drawing the curves into the future based on their expert judgement. These judgements were subsequently compared to the actual projections made by the thematic models and other data sources. Thereafter, the thematic model results and future trends were extensively discussed with the stakeholders with the aim of identifying gaps and selecting suitable future scenarios. These discussions resulted in the insight that the chosen thematic models are not able to simulate a large number of water- and forest-related variables that would be needed for Sweden, given the scope of this particular case study.

7.4.3.2 Local data to be collected

The Swedish case study leads had to find a large amount of additional potential data sources for the analysis of the nexus. The majority of the data used for the system dynamics modelling and the subsequent analysis of the nexus was gathered from publicly available databases provided by Swedish authorities. For instance, the majority of population dynamics, emissions, land-use data, water demand, as well as food production/consumption was available through Statistics Sweden (SCB). Most of the energy data was provided by the Swedish Energy Agency. Agricultural data was gathered from a database hosted by the Swedish Board of Agriculture. Swedish forest data was obtained from the Swedish National Forest Inventory, while the data on available water was provided by the Swedish Meteorological and Hydrological Institute (SMHI), to mention only a few.

As Sweden is the third largest country in the EU by size, a division into sub-regions was deemed to be useful to obtain more detailed regional results. Therefore, Sweden was divided into three subregions (Figure 61), that each represented different climate zones, combined a range of country administrative boards, as well as different water districts. The spatial resolution of the data varied largely, ranging from municipal and county level to national level. When data was available on municipal or county level, we aggregated the data into the three regions under consideration (i.e., southeast, southwest, north). If data was only available at national level, we scaled the data accordingly.

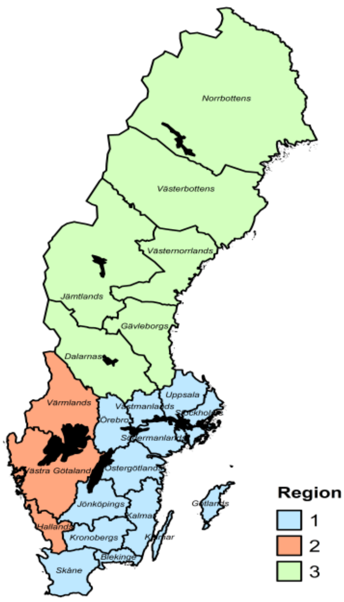

Figure 61 Overview of subdivisions into 3 regions: North (green), Southwest (orange) and Southeast (blue)

7.4.4 Case Study SDM in Stella/R

The SDM for the Sweden case study dynamically connects all five nexus sectors, and uses population to drive the demand of water, land, and food resources (see Appendix). Each nexus sector is represented by its own sub-module in which all relevant factors regarding a given sector (e.g. water sources, or sectoral water demand in the water sector) are accounted for, quantified and, where necessary, linked to other nexus sectors, forming the dynamic connections. As such, change in one parameter in one sector can have nexus-wide impacts, determined by the model interconnections.

In the water sector (see Appendix), the total freshwater available is accounted for. On the demand side, domestic demand, from both public and private supplies, industrial and agricultural water demands are quantified. In addition, the amount of treated water that is reused is accounted, as is an estimate for the amount of hydropower generated and the runoff of nitrogen (N) and phosphorous (P) to water bodies. Agricultural water demand is modulated by the area of a given crop and the water demand per-area of that crop.

The land sector (see Appendix) is split into two main types: land for forests and land for agriculture. Forest land is split into unproductive/protected land and productive land. The productive land sector is extremely detailed, quantifying details for five species of tree (lodgepole pine, spruce, birch, pine and others). The area of each species is broken down into two distinct metrics, offering an indicator of biodiversity: species age and species standing volume. The areas of felling are also accounted. In agriculture, the areas of 17 crop types are distinguished along with a measure of the fertiliser used. In addition, the numbers of different livestock animals (cattle, sheep, chickens) are also quantified and used in the food sector to estimate food production from different sources.

In the food sector (see Appendix), both production and demand are accounted for. On the production side, food crops, livestock, and other production is quantified. Crop production comes from the area of each crop (from the land sector) and a value for the yield produced (ton/ha) of each crop: 17 sources are therefore quantified. Livestock production accounts for meat from 10 different sources, while in other food types, the production of eggs and other dairy products are distinguished. The demand side accounts for direct food consumption, food imports and food exports, giving a net demand. The direct local consumption of food is modulated by statistics on the per-capita consumption of different products and the population. Similarly, the amount of import and export is based on values per-capita and subsequently scaled by the population.

The energy sector (see Appendix) is very detailed in Sweden's SIM4NEXUS SDM. Primary energy is converted to secondary energy which is available for use. Energy demand is broken into that for households and services, industry, and transport. In primary energy fuels, four fossil fuels, four renewable fuels, and nuclear energy are accounted for. In terms of electricity. For heat, again there are four fossil fuel sources, three renewable sources and nuclear fuels are replaced with biomass sources. In terms of the production of secondary energy for consumption, electricity derives from three renewable sources, nuclear fuels, biomass sources, and four fossil fuel sources. For heat energy, there are four fossil fuel sources, biomass, heat pumps, waste heat and electric boilers. Distribution losses are quantified. The total of secondary energy is represented as available energy. Household demand, like food demand, is modulated by statistics on the per-capita demand for different fuel types and the population. Industrial and transport energy demand for different fuels are similarly calculated. The balance between supply and demand is estimated.

The climate sector (see Appendix) accounts for greenhouse gas (GHG) emissions and sequestration, expressed in units of CO_2-equivilent rather than quantifying the emission of each GHG source individually. Sequestration is accounted for only by forest land. The volumes of different tree species are multiplied by a sequestration coefficient, yielding a total value for sequestration. On the emissions side, GHG emissions from agriculture, the food sector and the energy sector are accounted for. In agriculture, emissions coefficients are used to estimate the GHG emissions from livestock and from the total arable land used. In the food sector, emissions corresponding to the production of 12 food types are accounted for. In the energy sector, the emissions from electricity and heat production, transport energy consumption, service and household energy consumption, and industrial sector energy consumption are quantified and summed up. The balance between emissions and sequestration is estimated. It is noted that both emissions and sequestration will be underestimated as in both parts some sectors are not accounted for. For example, is sequestration, on forest land is counted, while on the emissions side, not all energy sources are covered, and energy used in the water sector, or in the production of fertilisers, is not included due to a lack of data.

The Sweden case study is divided into three regions for better spatial representation. As a result, all the data required were collected for each of these regions. Likewise, the SDM as described above was developed for each region. For example, in the water sector, each region has its own sub-module, within which the detailed calculations are carried out. Regions can either be summed to give national totals, or can be kept disaggregated, giving finer resolution detail within Sweden as to nexus performance. The disaggregation does give extra detail for this case study, but also led to a significant increase in data collection and data harmonisation efforts. In addition, there was additional effort required on the SDM model development and data population. Model run times are not adversely affected, still being less than five seconds. The biggest challenges were therefore: data collection and harmonisation for nearly 300 variables, converting the conceptual diagram into a coherent representation of the case study in SDM and, populating the SDM with the data delivered.

7.5 From the System Dynamic Modelling to the Serious Game

7.5.1 Case studies learnings goals

Serious Game for the Swedish case study is still under development at the time of writing this case study report and the outcomes will be reported in WP4.

7.5.2 From generic to specific use cases

A Use Case defines the different paths of interaction between the user and the SG. It captures possible ways the user may follow to achieve a specified goal, as well as alternative paths and/or results if feasible.

The design of Use Cases needs to take into consideration the interlinkages existing among the nexus components. This is due to the fact that the implementation of a Use Case that focuses on one nexus component may entail impacts to other nexus components managed by other Use Cases. Therefore, in the process of structuring Use Cases, one needs to pay attention not only to the management and future perspectives of the principle component that a specific Use Case deals with, but also to possible impacts on other nexus components.

Among the elements of each Use Case developed for the SG are:

a) the goal to be achieved by the SG user,
b) the available actions/interventions to be taken on each game session context,
c) the indicators to assess the implementation level of each action/intervention.

Before and after an intervention, the performance of each nexus component varies. The proposed Use Cases will support the assessment of such variations with respective indicators.

For the Swedish case study, three use cases were defined. An overview and more detailed description of these use cases is included in the Annex section 7.10.3.

The three Swedish use cases relate to the main nexus sectors of interest in Sweden, namely water, land (forest) and climate, with the following learning goals:

7. Water: sustainable use and management of water resources
8. Land (forest): Importance of a rich diversity of plant and animal life
9. Climate: Effects of reducing greenhouse gas emissions and climate impacts

Deliverable D1.2 provided a list of generic use cases that served as inspiration for developing the use cases in Sweden. However, the provided generic use cases had to be adapted to other sectors, user groups and possible actions and indicators. This adaptation was accomplished based on expert judgement by involved researchers with expertise in all nexus sectors as well as feedback/suggestions from stakeholders provided at the second stakeholder workshop.

All three use cases aim at students as the target user group, simply because Swedish stakeholders did not express high interest in the SG, but they believed that it would mostly be useful for educational purposes, e.g. for the students at universities.

7.5.3 Policy cards

The policy cards were developed based on the policy scenarios. For each policy scenario, four different levels of implementation (i.e., different levels of taxes, subsidies or other instruments) were assumed and translated into policy cards. Thus, the 11 different policy scenarios resulted in 44 policy cards that can be played in the SG.

The interventions and targets of the policy cards were originally developed based on 1) policy coherency analysis, 2) ongoing political initiatives and government agenda and 3) expert judgement from involved researchers. These interventions were then discussed with the stakeholders on the second stakeholder workshop. The stakeholders were given the set of scenarios, each representing one specific instrument to be implemented and they were asked to respond to a set of questions about each of the cards. The questions were the following: 1) how realistic introduction of particular instrument is; 2) how much it could contribute to particular policy objective; 3) what the costs would be; and 4) what would social acceptability be. For each of the question, the stakeholders could rank their responses from 0 to 100 %. This exercise led to in-depth discussions on the feasibility of the presented policy cards. One interesting insight from the ranking was that the stakeholders had problem to rank the different instruments separately, and instead were ranking them in relation to each other. For example, some of the instruments could be more realistic to introduce than others or they could contribute more to reaching a certain objective than others. Likewise, the instruments came with different costs and different degrees of social acceptance that had to be ranked in relation to each other. This shows the interlinked nature of different objectives and instruments coming from various sectors of human activity. In addition to ranking of the given instruments/scenarios, the stakeholders came up with ideas for additional instruments and/or changes needed in the Swedish decision-making system. However, not all of them could be introduced in the modelling or SG, due to either complexity or lack of possibility to translate the planned intervention into quantitative measures.

An overview of the final Swedish policy cards can be found in the Annex in section 7.10.4.

7.5.4 Serious Game interface

The Serious Game Interface for the Swedish case study is still under development at the time of writing this case study report and the outcomes will be reported in WP4.

7.6 From the SDM and SG to policy recommendations

7.6.1 Answering main research questions of the case study

The main nexus challenges in Sweden are linked to forestry, water, energy and climate sectors. All of these four sectors were included in the policy analysis, development of the conceptual model, implementation of the SDM and the final version of the SG. Consequently, the policy cards that can be played in the game also cover the main sectors of interest.

In Sweden, the forestry sector is subject to alterations in the light of developments in energy, governance and land use systems, climate politics, and taking account of an increasing competition between economic, environmental and recreational functions (Sandström et al., 2011). The growing demand for bioenergy has led to an intensification of the forest industry (Helmisaari et al., 2014), in particular through extensions of managed forest land and introduction of fast-growing tree species.

As the market for biofuels further grows, the question arises as to whether the supply of forest biomass for energy can further be increased. The competition between forests, water and energy resources and their impacts on biodiversity is further intensified by changing climate conditions. Key research questions in the water sector relate to how future climate change, streamflow shifts and changing forestry practices might affect (drinking) water availability and quality.

Knowledge gaps and considerable uncertainties on how environmental systems will change and on their impacts are major challenges. For example, large uncertainties remain in terms of the effect of future seasonal shifts in water availability (e.g., more streamflow during winter, but expected longer drought period during summer) on hydropower. Swedish law prohibits hydropower constructions in four of the biggest streams and a number of smaller rivers, and, thus, limits further expansion of hydropower, and in relation to that it is crucial to know how the water availability may impact the existing hydropower capacity.

The research within the case study concentrates on the impacts of introducing mechanisms for decreasing emissions, alternative uses of the additional biomass potential (carbon sequestration in standing forests versus increased bioenergy or agricultural production) and the consequences for the available water supply and quality, and for biodiversity and potential impact on other water goods and services. The goals of the case study are to increase the understanding of forest-water interlinkages in the context of climate change, as well as to bring research and stakeholders together and communicate the results.

The SDM (and to some extend the SG) can potentially help to answer some of these questions, because we directly target the policy interventions towards these research questions. However, it should be noted that one has to be cautious when trying to draw profound conclusions or decide on serious matters based on the final game. The game is based on a conceptual model and represents therefore a highly simplified model of the real-world nexus interactions. Although all simulation models are simplifications of the real world, the degree of simplification in this particular project is disproportionately high, because a manageable and simulatable model of a hugely complex system with thousands (or even millions) of possible interactions between sectors had to be developed in a limited amount of time and with limited financial resources.

In addition, it is important to emphasize that the final results are based on a long and intertwined chain of different thematic models, various data sources and simplified assumptions/representations in the system dynamics model, all of which introduce a large amount of uncertainties. Swedish stakeholders have rightfully questioned the use of the SG for decision-making and suggested the SG rather for educational purposes and awareness raising. The key rationale for that was that the SDM and SG can only be a very simple version of reality that does not reflect the real complexity of the nexus. While this is enough for educational purposes, in form of showing students basic links between different sectors and increasing their awareness of these interdependencies (as a way of investing in future generations and capacity building), it is not sufficient for real-life decision making.

7.6.2 Supporting policy coherence

The key analysis of policy coherency took place at a relatively early stage of the case study development, during which the SDM and SG were not developed yet. Thus, the results of coherency analysis, coming from literature review, expert judgement, survey of stakeholders and stakeholder workshops, were instrumental in informing development of the conceptual model of the Swedish nexus and, in turn, the Swedish SDM. The analysis also helped to develop the scenarios to be run in the SDM.

The general insights from the stakeholders involved in the process of policy analysis confirm that a Nexus approach is necessary to solve the current challenges in different sectors. Most of the sectoral issues that the stakeholders discussed led to conclusion that other sectors need to be involved as well in designing solutions. It was highlighted that we cannot address the most important challenges if we only have a sectoral perspective. For example, a recurrent issue mentioned by stakeholders highlighted the danger of implementing ambitious climate mitigation policy goals, without considering other sectors. For example, while using biomass may seem a very good approach to decrease the level of emissions, there are limits to using land for biomass production, which can have consequences for both biodiversity conservation, wood production for other purposes, and food production.

The results of the policy coherency analysis and the insights from the stakeholder workshops were to a large extend confirmed by the SDM runs. Especially the applied policies in the energy and climate sector have purely synergetic effects, as they foster the reduction of energy use and facilitate the transition towards renewable energy use, which inevitably supports the reduction of GHG emissions and the mitigation of climate change effects. However, the SDM runs also confirmed previously identified conflicts and trade-offs, especially the ones highlighted between the agricultural sector (i.e. food production) and the environmental quality objectives (e.g., nutrient pollution of surface waters).

The SDM results shed more light on the relations between different sectors and helped highlight key conflicts and synergies, while the SG serves as an educational tool for raising awareness about the nexus complexity and issues involved. Our case has shown that the SG can be particularly useful for students in learning about the nexus and the trade-offs that decisions in one sector may impose on another sector. Moreover, the stakeholders in the case study highlighted very much the importance of communication and coming together to discuss with people from other sectors. Because the nexus system is very complex and incorporating this complexity in a model has its limits, it is crucial to still apply sectoral approaches to modelling, but such sectoral modelling should be conducted by people with in-depth insights into connections with other sectors.

7.6.3 Testing policy scenarios

To assure low carbon economy and resource efficiency, different combinations of policy interventions can be used. For example, increasing amount of environmentally friendly trucks (through implementing subsidies) leads to decrease in emissions from transport by 3 to 12 % (depending on the level of subsidies offered and thus amount of trucks changed in the system. At the same time a re-wetting of wetlands initiative can be introduced, adding to emission reduction. In water sector, water use fees can be introduced to assure decreased use of water – depending on the level of the fee the decrease in the use can be slight or large.

The suggested policy interventions to be used in SDM and the SG were derived from policy coherence analysis including desk study and expert judgements and were then refined with stakeholders on the second stakeholder workshop. As such, all the intervention came from particular sectors, which is logical, as specific policy instruments are normally implemented within one particular sector. While in case of energy and climate sectors' interventions this was not a problem, as mostly synergies were observed in the results (which is in line with the policy analysis indicating that these sectors contribute positively to each other), there were conflicts in relation to other sectors, for example agricultural sector production and water quality.

If particular interventions come from specific sectors, introducing them at the same time may lead to large clashes and, as a result, not very efficient outcomes. For example, two interventions that were proposed were about the use of fertilizer: one came from water sector and involved introduction of fertiliser tax to reduce leakage of nitrogen and phosphorus from agricultural land, while the other came from the land sector and involved increasing use of fertilizer by 10% and thereby the food production by introducing a fertilizer subsidy (to support food security). One can easily imagine that both instruments are implemented simultaneously – but independently by each of the sectors. If the sectors do not communicate, this may have very negative consequences, as the policies basically cancel each other's effects.

This example shows clear need for nexus considerations when introducing particular policies in individual sectors. The use of the two policy cards from the example above in the SG will help the game layers learn about such trade-offs that exist in real life – it would be ridiculous for the player to choose both policy cards at the same time, as their effects contradict each other.

7.6.4 Addressing Nexus challenges

Challenges within the nexus can be related to four sectors: Climate, Land, Water and Energy, that are further explained below.

7.6.4.1 Climate

Temperature and precipitation are projected to increase more in high-latitude regions such as Sweden than in the rest of Europe (IPCC, 2014; Jacob et al., 2014). Based on the two Representative Concentration Pathways RCP4.5 and RCP8.5 (representing intermediate and high emissions, respectively), the annual average temperature is projected to be 2-6°C higher by the end of this century than for the period 1961-1990, while the average annual precipitation is projected to increase by 10-40% (Sjökvist et al., 2015). Extreme short-term precipitation events (in particular short torrential showers) are projected to become more intensive (Sjökvist et al., 2015). Due to the fact that high-latitude ecosystems have adapted to low natural energy flows, they are relatively more sensitive to a given shift in climate, physical and biogeochemical conditions, which could intensify regional and seasonal environmental responses (Roots, 1989). To enhance the preparedness and capacity to respond to such climate change impacts, the EU Adaptation Strategy (European Commission, 2013) aims to make Europe more climate resilient. The strategy stresses that many economic sectors, including forestry, are directly dependent on climatic conditions and are already facing the consequences of a changing climate. Challenges are related to both physical climate impacts and mutual dependencies across environmental systems, as well as to policy failures and knowledge gaps. Adaptation strategies are seen as the most effective instrument when assessing impacts, vulnerability and adaptation options and thus to face the projected impacts of climate change across sectors.

In the SDM and SG, a changing climate is considered in the future modeling. In addition, different policy scenarios and cards are introduced to reduce the greenhouse emissions and limit the effect of climate change. One of the proposed interventions is the introduction of subsidies on environmentally friendly trucks to encourage increase in such trucks, thus leading to decreased emissions. The other intervention is re-wetting peatlands that also leads to decreased emissions.

7.6.4.2 Land

Within the boreal region, Fennoscandia represents an extreme in terms of the degree and extent to which landscape dynamics are influenced by land management (Gauthier et al., 2015). For example, more than two thirds of Sweden are currently covered by forests, of which the majority is subject to forestry (SLU, 2015). The country has a long history of using its natural forest resources, while also protecting and developing them (Andersson, 2012). Total forest industry output was approximately 23 billion Euros in 2011 (Skogsstyrelsen, 2014), while the export value of forestry and the forest products industry was 13 billion Euros. The total number of employees in large-scale forestry has declined significantly in recent years, while, at the same time, the role of forest entrepreneurs (and their employees) has become increasingly important (Skogsstyrelsen, 2014).

Forests play an important role in terms of diverse and multifunctional benefits to people in Sweden. In addition to the economic output that is generated by the forestry sector, forests also deliver social and environmental functions. For instance, forests support biodiversity, provide opportunities for recreational activities ('freedom to roam', which is a general public right codified in law), allow for mushroom and berry picking, sequester atmospheric carbon, improve air quality, and regulate water quantity and quality.

Forestry in Sweden is currently regulated by the 1993 Forestry Act (Swedish Government, 1993), which states that "the forest is a national resource", which "shall be managed in such a way as to provide a valuable yield and at the same time preserve biodiversity".

The forestry sector is subject to alterations in the light of developments in energy, governance and land use systems, climate politics, and taking account of an increasing competition between economic, environmental and recreational functions (Sandström et al., 2011). The growing demand for bioenergy has led to an intensification of the forest industry (Helmisaari et al., 2014), in particular through extensions of managed forest land, introduction of fast-growing tree species and increasing use of fertilization (Rytter et al., 2013). In the future, more intense forestry practices will require technological and logistical improvements to render an economically sustainable production and to reduce the negative effects on the environment (de Jong et al., 2014). In addition, the extended growing season that arises from warmer temperatures in the future, in particular in the North, means that some areas will become increasingly available and attractive to forestry. This warming might also imply a shift in vegetation types and a shortening of the presently rather long rotation periods of typical boreal forests. Consequently, one of the key questions is whether the extraction of forest biomass can be further increased in the future without negative consequences for other forest functions and for water availability/quality. Typical forestry practices have an impact on soil, water, climate and biodiversity (de Jong et al., 2014) and, thus, a main challenge is to manage trade-offs between economic, environmental and recreational functions (Sandström et al., 2011).

The Swedish case study planned to introduce policies related to forest to addressed these questions, particularly a tax relief on forest biomass, which aims at increasing the amount of biomass produced by forests and fosters the production of biofuels from biomass or wood pellets. However, it occurred to be not possible to link the forestry production to energy sector in the system dynamics model, due to incompatibility of data. See discussion on this issue in the Section 3.7. As a result, only one policy intervention was planned: i.e. introducing new instruments for forest protection, which should somewhat reduce forest production and create more protected forest areas. Initially we had also planned to include a third intervention that would introduce legal regulation that forces forest managers to increase the rotation age of spruce and pine in Swedish forests, which will likely improve the conditions for forest biodiversity. However, this idea was abandoned as no data were available to quantitatively link forest age with biodiversity in the model.

7.6.4.3 Water Sector

Swedish hydrological regimes are generally characterized by rather low winter streamflow with a dominating snowmelt-driven spring flood peak (mainly in central and northern Sweden), followed by low summer flows and/or a somewhat lower precipitation-induced flood peak in the fall (mainly in southern Sweden). In a future climate, however, streamflow is projected to change to a more even regime with dominating large winter streamflow and no spring flood peak at all (Arheimer and Lindström, 2015; Donnelly et al., 2013; Teutschbein et al., 2011, 2015). Annual water availability in general is expected to increase as a result of increasing precipitation. There are, however, large seasonal variations: especially during summer months, water availability is likely to decline as a results of increasing evaporation rates in large parts of the country (Eklund et al., 2015).

In southern Sweden, water shortages during summer increasingly affect the drinking water supply, both in terms of quality and quantity. Increasing temperatures, shifts in seasonality and more streamflow (especially during winter) are likely to cause higher nutrient loads in Swedish boreal (Teutschbein et al., 2017). In addition, a continued intensification of the forest industry (Helmisaari et al., 2014), in particular extensions of managed forest land and increasing use of fertilization (Rytter et al., 2013), may increase the risk of nutrients leaching from watersheds (Sponseller et al., 2016). Consequently, key research questions in the water sector relate to how future climate change, streamflow shifts and changing forestry practices might affect (drinking) water availability and quality.

In the SDM and the SG both water quality and quantity are addressed. In particular, instruments are introduced to (1) reduce the leakage of nitrogen and phosphorus from agricultural land to water bodies (i.e., a tax on fertilizer) and (2) reduce water consumption (i.e., through higher drinking and waste water fees).

7.6.4.4 Energy Sector

Sweden's total energy supply in 2015 was 557 GWh. The most important energy sources are nuclear fuel (33 %), crude oil and petroleum products (24%), biofuels (23%) and hydropower (12%). For the past decades, Sweden has invested heavily in alternative energy sources and is now in the front line of renewable energy use. The interaction between abundant natural resources, high oil prices, public concern for the environment, broad policy support, and strong incentives led to a transformation of Sweden's oil-dependent energy system (Andersson, 2012). Despite a large per capita energy consumption, Sweden's economy is today one of the least dependent on fossil fuels and has one of the lowest carbon emission rates. Thus, Sweden has set a model in terms of a resource-efficient and low-carbon economy that much of the world could emulate.

Biofuels play a major role in industry, district heating, and to an increasing degree also in electricity production and transport. Biofuel is a collective term for several different types of fuels, including densified and undensified wood fuels, black liquor, biofuels from agriculture, combustible waster, bioethanol, biodiesel and biogas. The biofuel market in Sweden is presently growing at a rate of 3 TWh per year, which equals $1.5\text{x}10^6$ m3 of wood (de Jong et al., 2014). At present, the two leading biofuel sources are undensified wood (41%) and black liquor (33%), followed by densified wood (8%) and municipal waste-bio (7%). The increasing use of biofuels for electricity and heat production has caused a rising demand for wood fuels (Energimyndigheten, 2016), which has been satisfied through increased extraction of forest biofuels (de Jong et al., 2014). The market is expected to grow further in the near future (Energimyndigheten, 2013) and the supply of forest biomass for energy could potentially increase by 70% (Andersson, 2012). As the market for biofuels further grows, the question arises as to whether the supply of forest biomass for energy can further be increased. The competition between forests, water and energy resources is further intensified by changing climate conditions. Knowledge gaps and considerable uncertainties on how environmental systems will change and on their impacts are major challenges.

Sweden is the largest hydropower producer in the EU and the tenth biggest in the world, generating on average 67 TWh of electricity per year. Most hydropower is produced in northern Sweden. The annual hydropower output varies depending on seasonal precipitation: during the past 15 years, hydroelectric output varied from 53 TWh in 2003 (European summer drought) to 79 TWh in 2000 (particularly wet year). Swedish hydropower provides a valuable source of renewable energy and is able to balance the national electricity grid (Rudberg, 2013). However, about three quarters of the largest river systems are affected by fragmentation from water regulation (Rudberg, 2013), causing negative ecological consequences. Swedish law prohibits hydropower constructions in four of the biggest streams and a number of smaller rivers, and, thus, limits further expansion of hydropower. Large uncertainties remain in terms of the effect of future seasonal shifts in water availability (e.g., more streamflow during winter, but expected longer drought period during summer) on hydropower, which highlights the need for further research.

To further promote the production of renewable energy, three different policy interventions are considered in the SDM and SG:

(1) Subsidies on solar panels
(2) Start-up grants for Salix (willow) plantations that are used for biofuel production
(3) Tax reliefs for forest biomass products that can be used for biofuel production

7.6.4.5 Addressing Nexus challenges in the SDM and Serious Game

Using a combination of the policy interventions from different sectors (see descriptions above) in the SDM led to results that show the effects of particular measures on different sectors. For example, in the water sector, application of these types of policy interventions at different levels of intensity in the SDM enables insights into the effects of different levels of taxes and water fees on water quality and quantity in the future and can thereby contribute to design solutions, providing information on which of the interventions would be best to introduce by the policy makers. Similarly, in the energy sector, a combination of three different interventions introduced at different levels of intensity is applied in the SDM to provide information about the relative effects of the different measures on the promotion of renewable energy sources. This can help to find new solutions by supporting decisions on the investment into the particular types of intervention that uses empirical data to prioritise among the different energy sources. In the climate sector, introduction of different policy options into the SDM provided results that can be useful for decision makers, as they show the level of emission decrease linked to each level of planned intervention (number of trucks purchased with a help of subsidy or number of re-wetted hectares). Such numbers support decision makers in providing arguments behind particular interventions, and also how much investment should be made into reducing emissions (what level of intervention).

The SG uses policy cards based on the proposed interventions in the different sectors and linking the nexus in one holistic approach. The game supports the player in understanding interactions between the sectors and allows for a better planning of the different interventions, considering inter-sectoral impacts.

Both the SDM results and the SG can facilitate strategies towards future low-carbon and resource efficiency in Sweden. SDM provides modelling results showing the impacts of different interventions, which enables to select the ones that are most efficient from both low-carbon and resources use point of view. Particularly, the climate and energy sectors interventions are important in relation to low carbon economy, and water sector intervention in relation to resources efficiency (water quantity supported by water use fees, and water quality improved by introducing fertiliser tax). SG constitutes a novel educational tool that can help informing future managers and decision makers about the nexus challenges and, by doing that, increase the capacity of the Swedish society do deal with them better.

7.7 Short-term and long-term policy recommendations

7.7.1 Summary of the Nexus issues in the case study

In the Swedish case there are clear connections between all of the nexus sectors. As the market for biofuels further grows, the question arises as to whether the supply of forest biomass for energy can further be increased. The competition between forests, water and energy resources and their impacts on biodiversity is further intensified by changing climate conditions. Also, there is increasing question of food security needs, particularly in relation on the climate change and extreme weather events related to it (droughts and floods). Key research questions are about how to deal with the ongoing climate change, what instruments can be used to mitigate that, whether the extraction of forest biomass can be further increased in the future without negative consequences for other forest functions biodiversity and for water availability/quality and how to ensure food security.

The recommendations presented below are relevant to all these challenges and focus particularly on the goal of becoming climate-neutral (by 2050 at the latest), i.e. an economy with net-zero greenhouse gas emissions and resource efficiency, by supporting the regulation of resources use, increased awareness and capacity of the society and facilitation of social and governance innovation. They also cover how policy processes should change to transform thinking of decision makers towards nexus -focused one.

However, when providing such recommendations, it is important to consider the interactions between the different nexus sectors. In the Swedish case study, the sectors are interlinked through a variety of processes. For example, the climate sector is influenced by other sectors mainly through the negative impacts of greenhouse gas emissions (e.g. in the production/use of energy or through land-use and land-use change) and through positive effects of sequestration in forests. On the other hand, the climate sector (i.e., the climate itself) affects other sectors through direct changes in the climate system, e.g., changes in wind (important for production of wind energy), water and temperature (both important for crop production and forest growth in land sector and for water availability in the water sector). The energy sector connects to the land, food and water sector through the direct use of resources (such as forest biomass, water for hydropower or crop/waste biomass) to produce renewable energy. In turn, large amounts of energy are used in other sectors for processing and distribution of goods, for treatment and pumping of water or for soil preparation, planting, fertilizing, harvesting and transport. Water is also an important sector as it provides the source for hydropower production (energy), irrigation (land) and for livestock and crop production (food). However, water quantity it is sensitive to changes in the climate (precipitation and temperature) and water quality is affected by fertilizer use in the land sector. The land sector plays a vital role for forestry and agriculture. It emits and sequesters large amounts of greenhouse gases, leaches fertilizer and pesticides, and provides the basis for livestock and crop production. It should be noted that activities in the land sector largely affect biodiversity indicators related to forest species and forest age distributions.

For a more detailed overview of interlinkages, please refer to section 7.4 and the conceptual model shown in Annex 7.10.1.

7.7.2 Description of the policies targeted for recommendations

Key stakeholders relevant for the Swedish case study were mapped at the beginning of the project (see Appendix 7.10.5). These include: national agencies (Swedish Forest Agency, the Swedish Board of Agriculture and Swedish Energy Agency, Swedish Environmental Protection Agency), research institutes (universities), municipalities, County Administrative Boards, environmental consultancy companies and NGOs.

Key policy objectives of interest in the case study come from all five nexus sectors and are presented in Table 21.

Table 21 Key policy objectives of interest

Sector	Goal	Description
Water	Environmental goal: Flourishing Lakes and Streams	Natural productive capacity, biological diversity, cultural heritage assets and the ecological and water-conserving function of lakes and watercourses must be preserved in an ecologically sustainable way (SEPA 2011a).
	Environmental goal: Good-Quality Groundwater	Groundwater must provide a safe and sustainable supply of drinking water and contribute to viable habitats for flora and fauna in lakes and watercourses (SEPA 2011a).
	Environmental goal: Thriving Wetlands	The ecological and water-conserving function of wetlands in the landscape must be maintained and valuable wetlands preserved for the future (SEPA 2011a).
	Reduce the harmful consequences of floods	Harmful consequences of floods should be reduced (SFS 2009)
	Environmental goal: Zero Eutrophication	Nutrient levels in soil and water must not be such that they adversely affect human health, the conditions for biological diversity or the possibility of varied use of land and water (SEPA 2011a).
	Environmental goal: Natural Acidification Only	The acidifying effects of deposition and land use must not exceed the limits that can be tolerated by soil and water (SEPA 2011a).
Energy	Sustainable and environmentally friendly energy supply	The production of renewable energy should be promoted to increase their share, which supports a transition towards a • 50 percent share of renewable energy in gross final energy consumption by 2020 • 100% renewable electricity production by 2040 and • no net emissions of GHG by 2045 (MEE 2018)
	Increase energy efficiency	Sweden's energy use is to be 50 percent more efficient in 2030 than in 2005
Land	Forestry production goal: Ensure a long-term sustained yield of timber	The forest and forest land must be utilized efficiently and responsibly so that it yields a sustainable good return (SFS 1979)
	Forestry environmental goal: Sustainable forests	The value of forests and forest land for biological production must be protected, at the same time as biological diversity and cultural heritage and recreational assets are safeguarded (SEPA 2011a).
	Agriculture environmental goal: A varied agricultural landscape	The value of the farmed landscape and agricultural land for biological production and food production must be protected, at the same time as biological diversity and cultural heritage assets are preserved and strengthened (SEPA 2011a).
Food	Food production goal: A market-oriented agricultural sector and a competitive food supply chain	National food strategy's objectives: • Food on the market must be safe and labelled correctly • Increase organic production and consumption of food • Strengthen the competitiveness of the sector on market terms • Greater production for both domestic and foreign markets • Higher growth and employment in the affected industries • Increase exports, innovation power and profitability (Swedish Government 2016)
Climate	Environmental goal: Reduce Climate Impacts	Concentrations of greenhouse gases in the atmosphere must be stabilised at a level that will prevent dangerous anthropogenic interference with the climate system (SEPA 2011a).

	Emission Reduction Targets	Sweden aims to achieve: • no net emissions of GHG by 2045 and negative emissions thereafter • reduction of -70% of emissions from domestic transport by 2030 • reduction of -75% of emissions from sectors outside the EU ETC by 2040 • reduction of -63% of emissions from sectors outside the EU ETS by 2030 • reduction of -40% of emissions from sectors outside the EU ETS by 2020 (MEE 2018)

Main nexus challenges in the Swedish case study are linked to forestry, water, energy and climate sectors. In Sweden, the forestry sector is subject to alterations in the light of developments in energy, governance and land use systems, climate politics, and taking account of an increasing competition between economic, environmental and recreational functions (Sandström et al., 2011). The growing demand for bioenergy has led to an intensification of the forest industry (Helmisaari et al., 2014), in particular through extensions of managed forest land and introduction of fast-growing tree species.
As the market for biofuels further grows, the question arises as to whether the supply of forest biomass for energy can further be increased. The competition between forests, water and energy resources and their impacts on biodiversity is further intensified by changing climate conditions. Key research questions in the water sector relate to how future climate change, streamflow shifts and changing forestry practices might affect (drinking) water availability and quality.

Knowledge gaps and considerable uncertainties on how environmental systems will change and on their impacts are major challenges. Swedish law prohibits hydropower constructions in four of the biggest streams and a number of smaller rivers, and, thus, limits further expansion of hydropower. Large uncertainties remain in terms of the effect of future seasonal shifts in water availability (e.g., more streamflow during winter, but expected longer drought period during summer) on hydropower.

The Swedish case study concentrated on the impacts of introducing mechanisms for decreasing emissions, alternative uses of the additional biomass potential (carbon sequestration in standing forests versus increased bioenergy or agricultural production) and the consequences for the available water supply and quality, and for biodiversity and potential impact on other water goods and services. The goals of the case study are to increase the understanding of forest-water interlinkages in the context of climate change, as well as to bring research and stakeholders together and communicate the results.

In general, the SIM4NEXUS work in the Swedish case study and interactions with stakeholders made us aware that it is challenging to directly influence policy processes as they to a large extend depend on politicians' priorities, which we cannot directly regulate. However, what we, as researchers can do is to facilitate thinking and discussions across sectors and provide knowledge that can motivate policy actors to introduce changes. The recommendations below have been developed with this in mind.

7.7.3 Policy recommendations

7.7.3.1 Changes in policy outputs

In general, it was suggested that there should be more focus on biodiversity and strengthening resilience of ecosystems, as tool to improve climate adaptation and food security. Policies and policy instruments should be strengthened in relation to that. In addition, support from the state is needed for the multifunctional agriculture that at the same time produces food and energy, supports biodiversity and is good for the climate resilience. With regard to that Sweden could better promote and utilize its image of "environmentally friendly" food producer and built its market competitiveness on it – this would lead to better alignment of the agricultural goal with other goals (particularly environmental objectives). There is also need for investment in food crops that are more resilient to effects of climate change.

7.7.3.2 Changes in policy contents

The case study stakeholders mentioned during the workshops that Sweden has a large number of voluntary instruments (e.g., recommendations provided by the Forestry Agency to the private forest owners in the forestry sector or possibility to create voluntary local water councils in the water sector), but highlighted the need for stronger legal instruments, particularly with regard to use of resources in Sweden. For example, it was suggested by the stakeholders on the workshop that more legal support is needed to protect agricultural land against development and make forest management more biodiversity friendly, not only production-oriented. Strengthened legal requirements were also suggested in relation to water management. Currently, there is not legal demand for stakeholders from different sectors (e.g. municipalities, forestry managers) to collaborate on water issues, so if there is collaboration depends mostly on engaged and interested individuals. Legal requirements as well as legal frameworks for such (obligatory) collaborations could be introduced to facilitate more integrated water planning that considers multiple sectors.

To be able to introduce stronger national regulations, there is a need for support from the EU legal framework that could also be strengthened in this way. Particularly, the environmental aspects, such as biodiversity conservation or development of green infrastructure for increased resilience need to be strengthened. This could, e.g. be incorporated in the new revised CAP, that presents an opportunity to mainstreaming nexus thinking, as it is relevant for all nexus sectors (agricultural food production, bioenergy production, biodiversity conservation, adaptation to climate change and improving climate resilience, as well as water management). Of course, the more obligatory instruments would mean higher costs, as their implementation needs to be coordinated and monitored. In relation to that recent Swedish Governmental Inquiry about SDGs suggested the need to invest more into environmental and sustainability issues, as costs of inaction can be higher (Regeringskansliet 2018).

7.7.3.3 Innovations

It was suggested on one of the stakeholder workshops that it is very important to introduce nexus related environmental aspects early on in education systems to create a society that is aware of and can deal with environmental problems. Increasing capacity of the general society with regard to nexus challenges can then lead to social innovations that will improve our chances for dealing with these challenges. Most of all, including nexus thinking form the early stages of education will support development of the new generation of experts for whom the nexus interaction will be an obvious thing and who will only be able to work in integrated manner.

In addition, the stakeholders in the case study highlighted very much the importance of communication and coming together to discuss with people from other sectors. If the sectors improve their cross-sectoral communication, policies with synergetic effects can be introduced and negative effects from potentially conflicting policies can be avoided. This could, in long term, lead to governance innovations where the silo-approach of sectoral thinking could change to a more integrated system of governance where nexus issues are treated simultaneously.

7.7.3.4 Changes in the policy process

Policy formulation and re-formulation is often based on scientific data. Particularly, decision makers like numbers to inform decision. However, when it comes to nexus thinking there can be a danger in using numbers, as it usually implies many simplifications, where the number lose the deeper sense and context information. Also, many potential solutions are not about "hard" innovations, but about "softer" changes in the system. For example, during the SIM4NEXUS case study work, stakeholders provided many good suggestions for the changes in the nexus system that were not possible to translate into hard data that could be used in modelling. These were for example about improving water planning through information, collaboration and capacity building, or introduction of elements of green infrastructure in agriculture and forestry that would improve biodiversity and as a result landscape resilience.

Because many potential changes in the nexus system can build on aspects that cannot be easily modelled in a quantitative way, it is recommended that the process of policy making for the nexus should be based not only on scientific modelling of numbers, but also on learning of good practices and from success stories and through communication between sectors. The authorities of particular sectors should strive for developing routines for such learning and collaboration, in addition to their established, very sectoral routines of work. This is necessary to create a better culture of communication between sectors and increase country's capacity to deal with nexus challenges.

Moreover, the stakeholders in the case study highlighted very much the importance of communication and coming together to discuss with people from other sectors. Because the nexus system is very complex and incorporating this complexity in a model has its limits, it is crucial to still apply sectoral approaches to modelling, but such sectoral modelling should be conducted by people with in-depth insights into connections with other sectors.

7.7.3.5 Changes in the science-policy interface

Swedish stakeholders did not express high interest in the SG. They have questioned the use of the SG for decision-making and suggested the SG rather for educational purposes and awareness raising. The key rationale for that was that the SDM and SG can only be a very simple version of reality that does not reflect the real complexity of the nexus. While this is enough for educational purposes, in form of showing students basic links between different sectors and increasing their awareness of these interdependencies (as a way of investing in future generations and capacity building), it is not sufficient for real-life decision making. This emphasizes the need for discussing with decision makers a priori how to reach policy recommendations. In SIM4NEXUS it was decided already at the time of the proposal to use an SDM and to develop a SG for decisions making. However, while this approach worked well in some of the case studies, it did not fit well with the practices and expectations of Swedish stakeholders, which themselves might have needed another tool for decision making. Therefore, we recommend that decision makers should work in close collaboration with researchers and clearly communicate their expectations, beliefs and needs to guarantee a successful policy-making process that leads to an integrated system of governance. Collaboration between researchers and stakeholders/decision makers from start to end of the policy process has been proven to be beneficial to bridge the gap between the evidence produced by researchers and the advice received by the decision makers. Stakeholders noted the role of a small number of influential research groups and individuals in promoting political change. Therefore, we encourage to actively cross the boundaries between academia, policy making and practice, and suggest to work with boundary organisations and influencers as part of the policy-making process. A better link between academic and national and local decisions on what to choose, fund and implement is needed.

7.7.3.6 Changes in register-based national data

In case of Sweden, a huge amount of data from different sectors are freely available in national open data portals, which is potentially very beneficial for the decision making with regards to the nexus and for research that can support such decision making. For example, the Swedish Forest Agency, the Swedish Board of Agriculture and Swedish Energy Agency, all have large comprehensive databases covering many dimensions of their particular sectors. Much of this data has been used in the Swedish case study.

However, a problem arises when data are to be used in analysis that should inform decisions that may have implications across sectors. Not all data are compatible in between sectors, e.g. different categories can be included in different classifications of resources, energy use; or data can be grouped in different categories (e.g. sectors of energy use). In addition, it is difficult to find information on how changes in one sector may impact other sectors. For example, in the Swedish SDM we planned to use an intervention of increasing forest biomass use (applying tax reliefs), but we were not able to connect that in the model to the energy sector – what would increasing biomass mean for the use of fossil fuels. While there was general information of how much of different categories of biomass is being used in the energy sector, it was not clear what type of biomass it is, where it comes from (forest, agriculture) and in which societal areas it is being used (transport, heating, households, services), etc. Thus, it was difficult to understand how changes in the forest sector's production of biomass can impact use of fossil fuels in Sweden and, as a result, this policy intervention was disregarded in the SDM and the SG.

This points to the need of streamlining the data produced and gathered and of trying, at national scale, to collect a more coherent data that can work with each other. In Sweden, much progress has been made to collect/synthesize such regional and national data by Statistics Sweden, a government agency that produces official statistics, and the National Archives in Sweden. However, such an open data portal is not available in many other countries. Thus, to collect such data, a new framework must be created that represents the key connections in the nexus and highlights key priorities linked to the intersectoral relations. The conceptual model developed in SIM4NEXUS could be a starting point for such discussion among Swedish authorities responsible for data gathering in different sectors.

7.7.3.7 Conclusion on coherent, Nexus-compliant policies

The recommendations provided above, if used, may facilitate improvement across the nexus and lead to the development of more coherent policies. Particularly, increased communication between different sectors and improved compatibility of data across them will be very beneficial and improve possibilities towards a more resource efficient and low carbon economy, as they will enable: 1) better cross-sectoral understanding and thus improved sectoral decision making that can benefit multiple sectors simultaneously; 2) better analysis of data that can show the impacts on relevant sectors linked to changes in other sectors derived from the decisions taken. In addition, better collaboration and communication between academia, policy and practice as well as working with boundary organisations and influencers as part of the policy-making process are likely to be beneficial to achieve a resource-efficient Europe.

The Swedish case study has demonstrated added value of adopting the nexus approach, particularly in increasing the awareness of stakeholders about the challenges going beyond their individual sectors, and thus strengthening their capacity to deal with them in a more coherent manner. However, the work within the case also highlighted that the use of nexus approach is not easy and may lead to many difficulties, such as the ones with combability of data between sectors. The adoption of the nexus thinking can also be time consuming as it requires going beyond own sector, specific expertise and comfort zone. With regard to that, both availability of time and resources and open mind of the stakeholders are necessary pre-conditions to succeed. This suggests that, while nexus compliance is possible, it requires comprehensive long-term concerted actions and systemic changes in different policy areas and at many different levels (see the proposed recommendations above).

7.8 Conclusion

Main nexus challenges in the Swedish case study are linked to forestry, water, energy and climate sectors. In Sweden, the forestry sector is subject to alterations in the light of developments in energy, governance and land use systems, climate politics, and taking account of an increasing competition between economic, environmental and recreational functions (Sandström et al., 2011). The growing demand for bioenergy has led to an intensification of the forest industry (Helmisaari et al., 2014), in particular through extensions of managed forest land and introduction of fast-growing tree species.

As the market for biofuels further grows, the question arises as to whether the supply of forest biomass for energy can further be increased. The competition between forests, water and energy resources and their impacts on biodiversity is further intensified by changing climate conditions. Key research questions in the water sector relate to how future climate change, streamflow shifts and changing forestry practices might affect (drinking) water availability and quality.

Knowledge gaps and considerable uncertainties on how environmental systems will change and on their impacts are major challenges. Swedish law prohibits hydropower constructions in four of the biggest streams and a number of smaller rivers, and, thus, limits further expansion of hydropower. Large uncertainties remain in terms of the effect of future seasonal shifts in water availability (e.g., more streamflow during winter, but expected longer drought period during summer) on hydropower.

The work within the Swedish case study has led to two key conclusions: 1) that nexus approach is necessary to handle current challenges societies are facing, particularly with regard to addressing climate change and efficient resources use; and 2) that adopting such approach is a complex endeavour that requires comprehensive changes in the current policy making and decision-making systems. The recommendations above provide an overview of the activities and changes that could be used by policy makers to facilitate these changes and to handle current and future societal challenges.

Moreover, the work within the case study clearly showed that interaction with stakeholders from different sectors, including face-to-face cross-sectoral meetings (workshops), are necessary to increase awareness of nexus issues and build capacity of the different sectors for future improvements. On the other hand, the work in the project also showed that organising a long-term meaningful stakeholder engagement is very difficult, mainly due the necessary time commitments and financial resources limitations.

The SDM an SG proved to be important tools for reaching the project's outcomes and for the learning purposes. Nevertheless, due to data limitations and the related complexity of the nexus system, such tools were suggested to be better utilised for educational purposes than the real-life decision making.

The key policy recommendations that came out of the Swedish case study are about changes in policy outputs (increased focus on biodiversity), policy contents (strengthening the existing policies and instruments), and policy processes (changes in decision making systems that are not always about "hard" data and innovations, but are focusing on "softer" aspects). In addition, changes in the science-policy interface are suggested, i.e. increased effort to cross boundaries between academia, policy and practice and improvement in data compatibility across sectors. Finally, social innovation is suggested in the form of early stage nexus education to support capacity building of the whole society with regard to nexus challenges.

The nexus approach as a whole may facilitate better outcomes than sectoral approaches, as it provides a more comprehensive picture of the nexus "reality", particularly interactions between different sectors, their resource and energy use, and cross-sectoral impacts. However, introduction of nexus thinking in the societies is difficult and requires long-term commitment to this transition.

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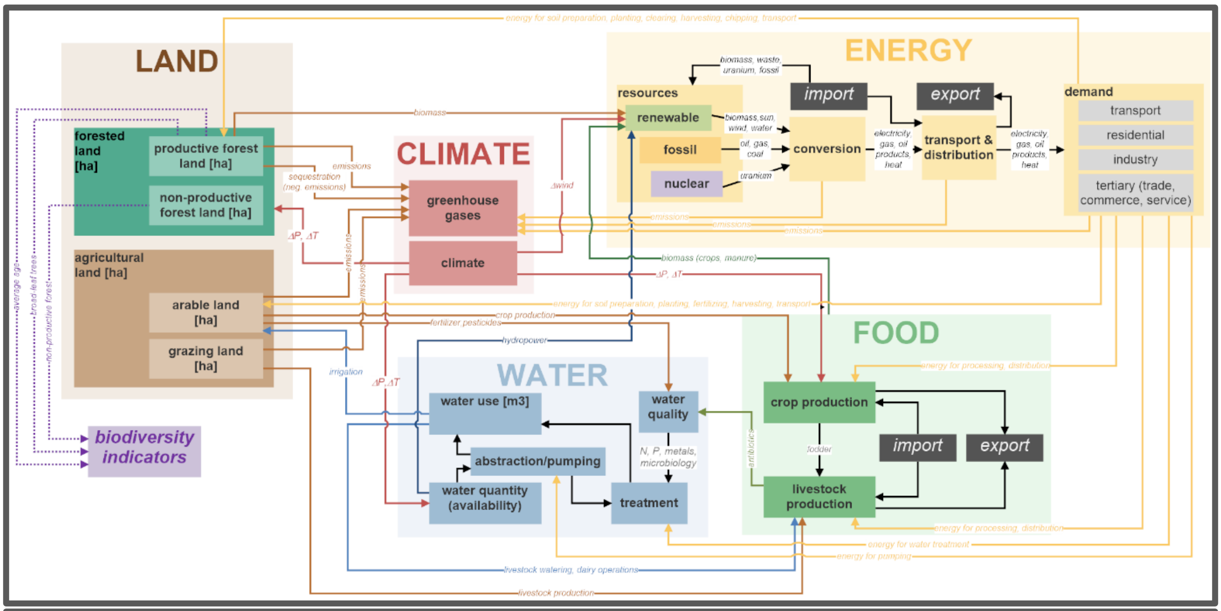
7.10 Annexes

7.10.1 Conceptual model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greenhouse gases
climate
ENERGY
resources
renewable
fossil
nuclear
import
export
conversion
transport & distribution
demand
transport
residential
industry
tertiary (trade, commerce, service)
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import
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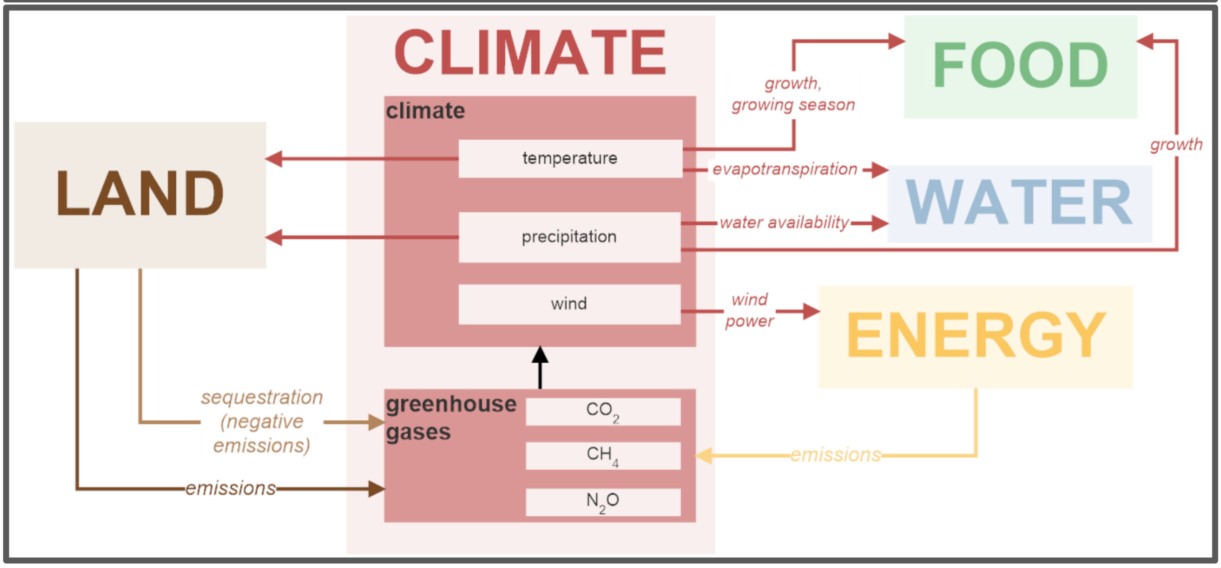
livestock production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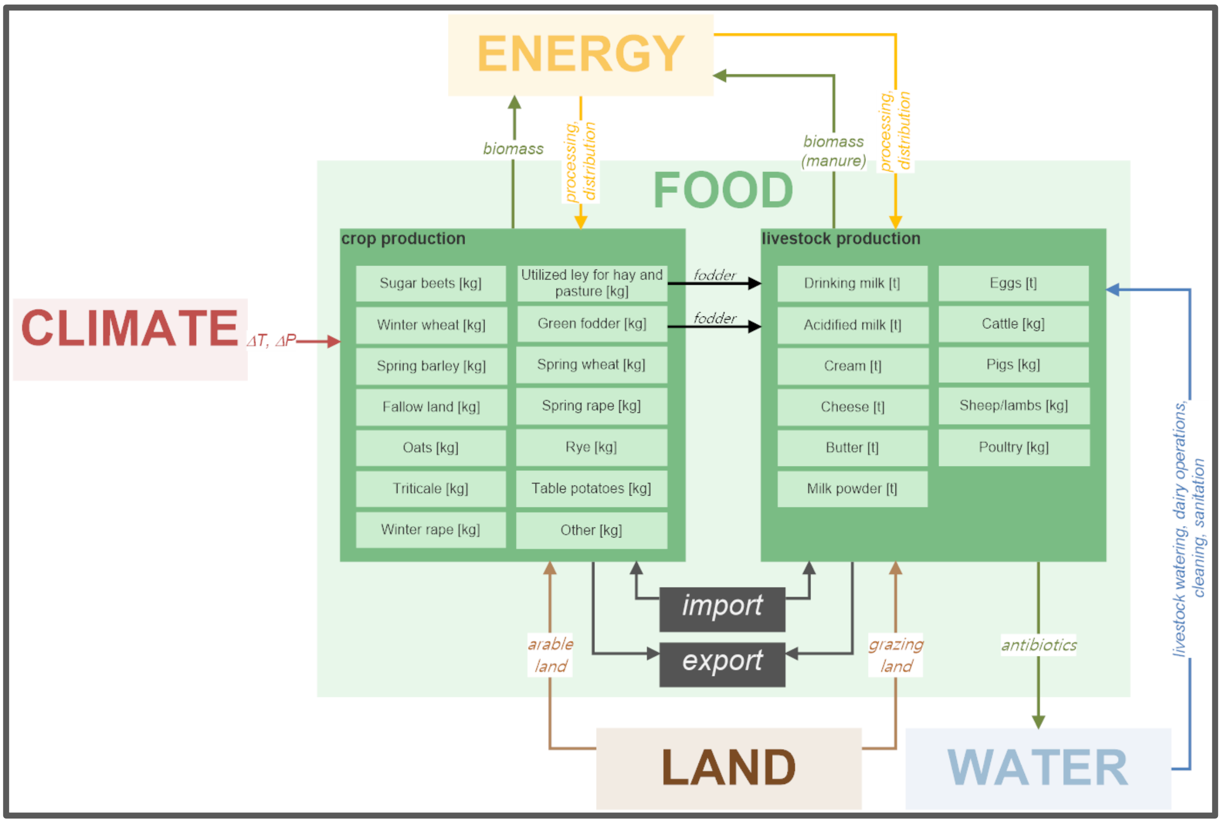
evapotranspiration
water availability
wind power
sequestration (negative emissions)
emissions
emissions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processing, distribution
biomass (manure)
processing, distribution
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Utilized ley for hay and pasture [kg]
Winter wheat [kg]
Green fodder [kg]
Spring barley [kg]
Spring wheat [kg]
Fallow land [kg]
Spring rape [kg]
Oats [kg]
Rye [kg]
Triticale [kg]
Table potatoes [kg]
Winter rape [kg]
Other [kg]
fodder
fodder
livestock production
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Eggs [t]
Acidified milk [t]
Cattle [kg]
Cream [t]
Pigs [kg]
Cheese [t]
Sheep/lambs [kg]
Butter [t]
Poultry [kg]
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export
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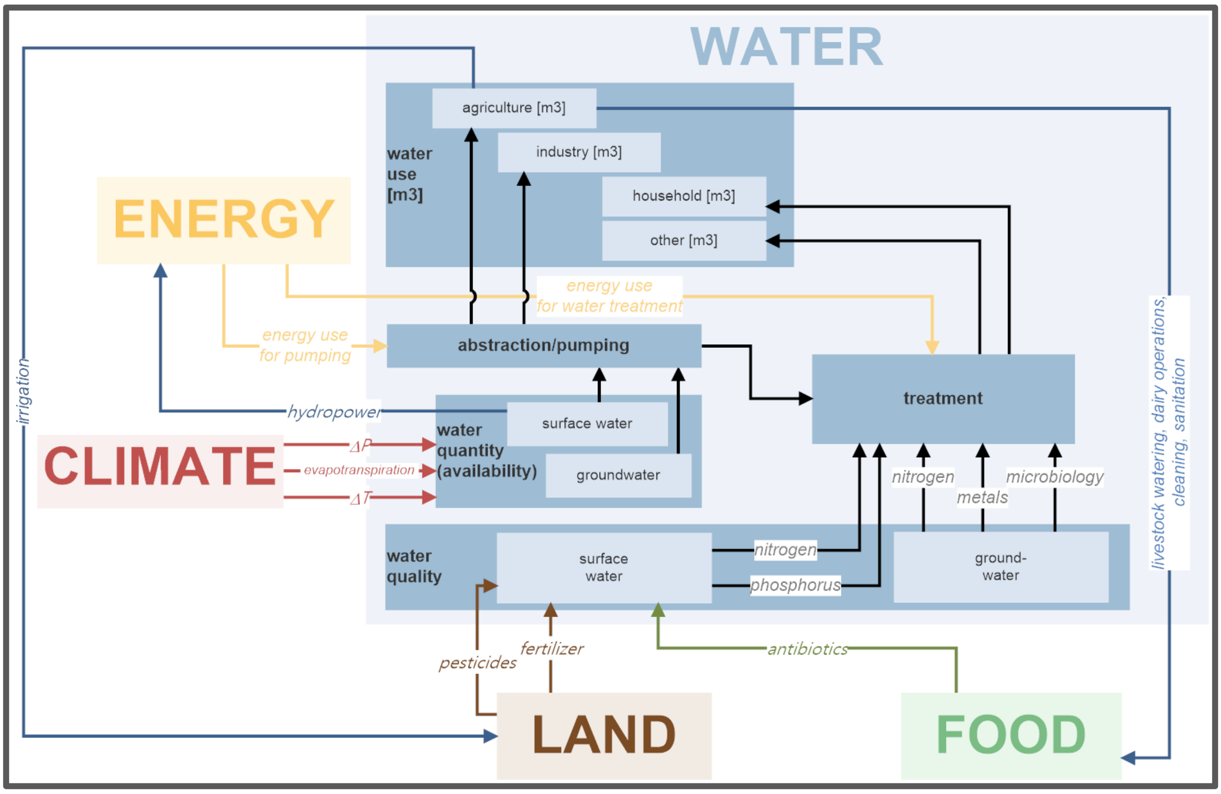
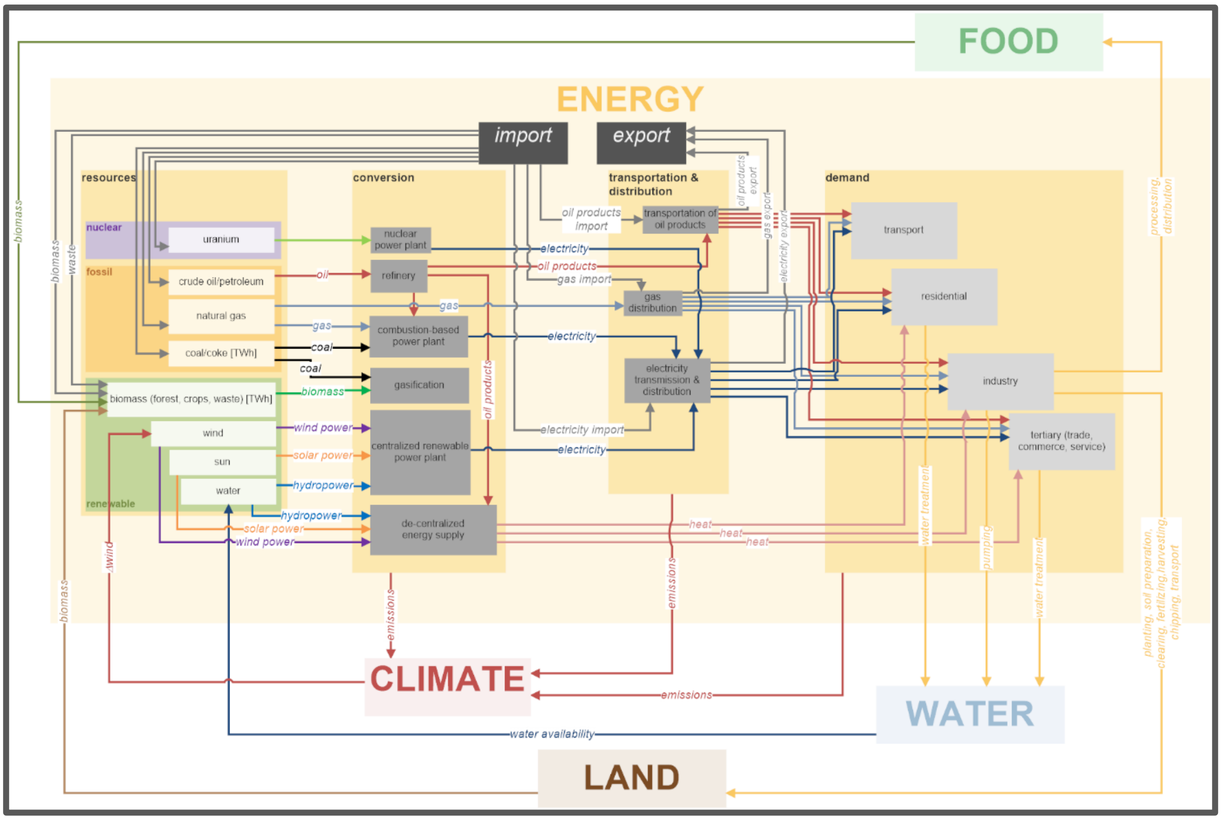
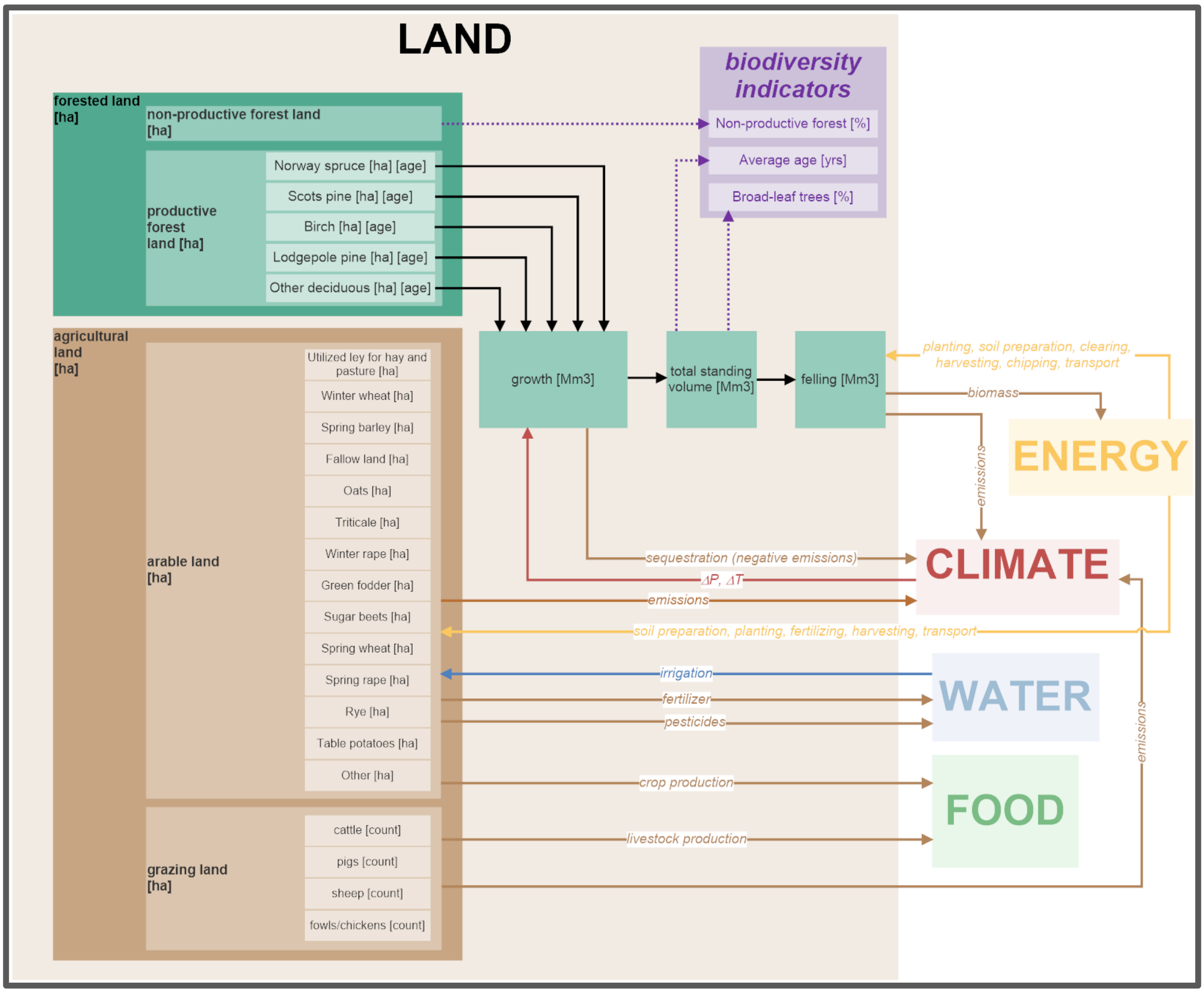
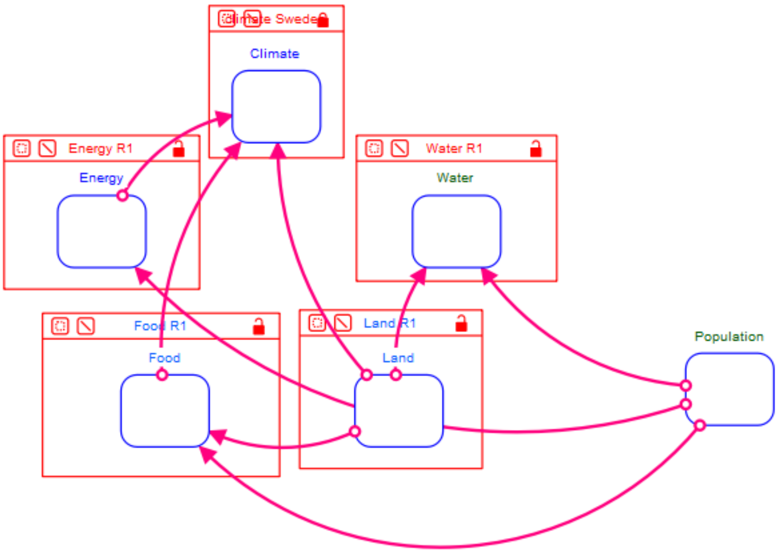
antibiotics
livestock watering, dairy operations, cleaning, sanitation
LAND
WATER


WATER
agriculture [m3]
industry [m3]
household [m3]
other [m3]
water use [m3]
ENERGY
energy use for water treatment
energy use for pumping
abstraction/pumping
treatment
irrigation
hydropower
CLIMATE
ΔP
evapotranspiration
ΔT
water quantity (availability)
surface water
groundwater
nitrogen
metals
microbiology
water quality
surface water
nitrogen
phosphorus
ground-water
livestock watering, dairy operations, cleaning, sanitation
fertilizer
pesticides
antibiotics
LAND
FOOD

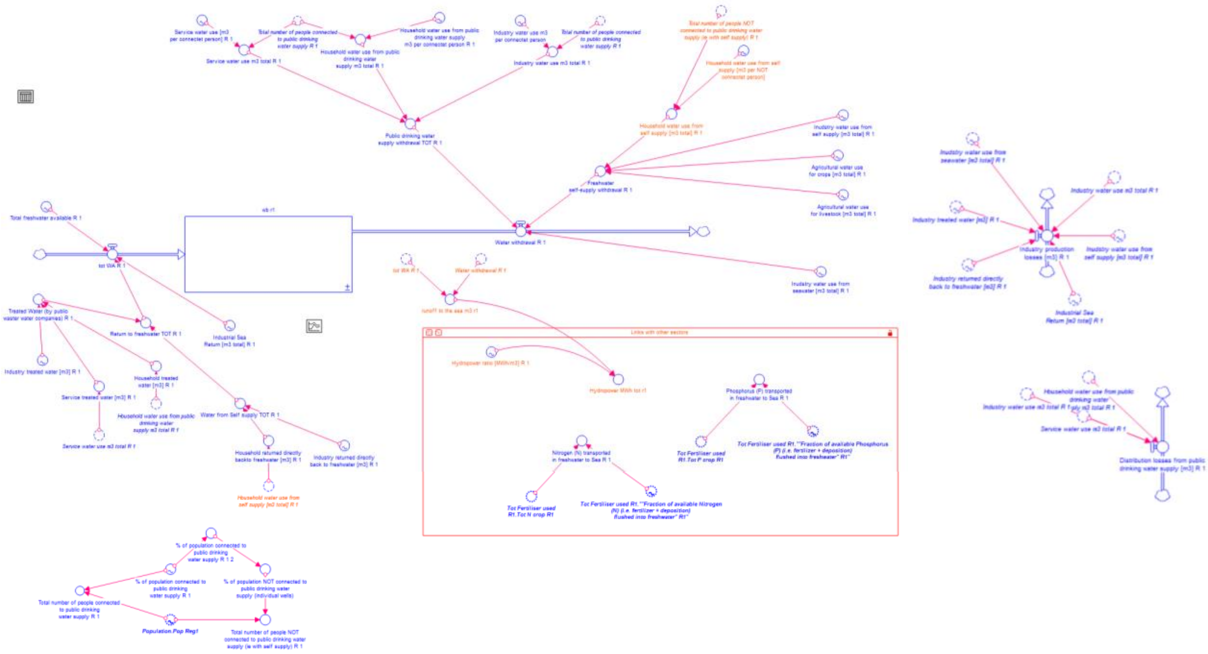

FOOD
ENERGY
import
export
resources
nuclear
uranium
fossil
crude oil/petroleum
natural gas
coal/coke [TWh]
biomass (forest, crops, waste) [TWh]
wind
sun
water
renewable
conversion
nuclear power plant
refinery
combustion-based power plant
gasification
centralized renewable power plant
de-centralized energy supply
transportation & distribution
transportation of oil products
gas distribution
electricity transmission & distribution
demand
transport
residential
industry
tertiary (trade, commerce, service)
oil
gas
coal
biomass
wind power
solar power
hydropower
electricity
oil products
oil products import
gas import
electricity import
oil products export
gas export
electricity export
heat
emissions
water treatment
pumping
water availability
processing, distribution
planting, soil preparation, clearing, harvesting, chipping, transport
waste
CLIMATE
WATER
LAND


LAND
biodiversity indicators
Non-productive forest [%]
Average age [yrs]
Broad-leaf trees [%]
forested land [ha]
non-productive forest land [ha]
productive forest land [ha]
Norway spruce [ha] [age]
Scots pine [ha] [age]
Birch [ha] [age]
Lodgepole pine [ha] [age]
Other deciduous [ha] [age]
growth [Mm3]
total standing volume [Mm3]
felling [Mm3]
planting, soil preparation, clearing, harvesting, chipping, transport
biomass
ENERGY
emissions
CLIMATE
sequestration (negative emissions)
ΔP, ΔT
agricultural land [ha]
arable land [ha]
Utilized ley for hay and pasture [ha]
Winter wheat [ha]
Spring barley [ha]
Fallow land [ha]
Oats [ha]
Triticale [ha]
Winter rape [ha]
Green fodder [ha]
Sugar beets [ha]
Spring wheat [ha]
Spring rape [ha]
Rye [ha]
Table potatoes [ha]
Other [ha]
soil preparation, planting, fertilizing, harvesting, transport
irrigation
fertilizer
pesticides
WATER
crop production
livestock production
FOOD
grazing land [ha]
cattle [count]
pigs [count]
sheep [count]
fowls/chickens [count]

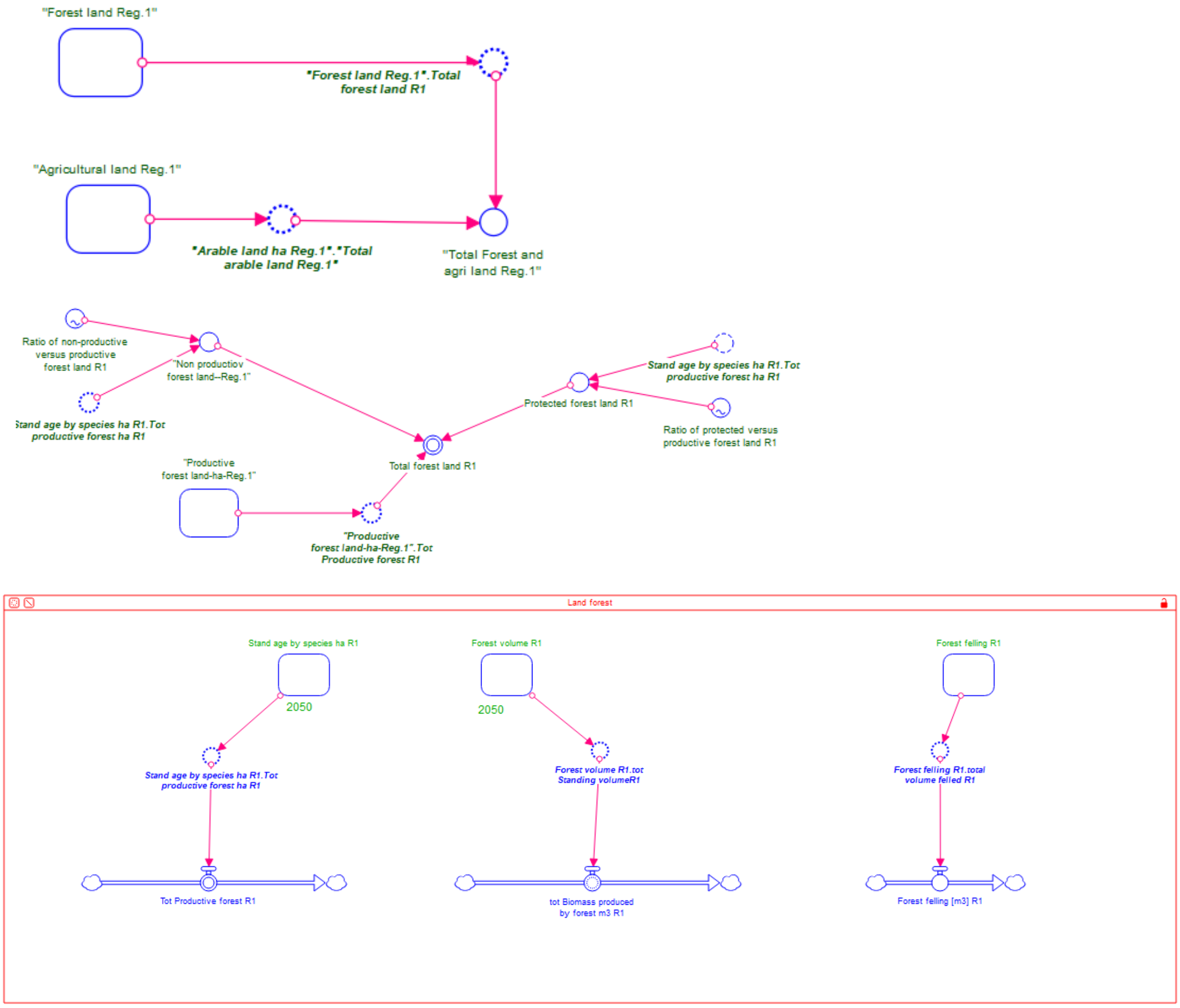
7.10.2 SDM screenshots



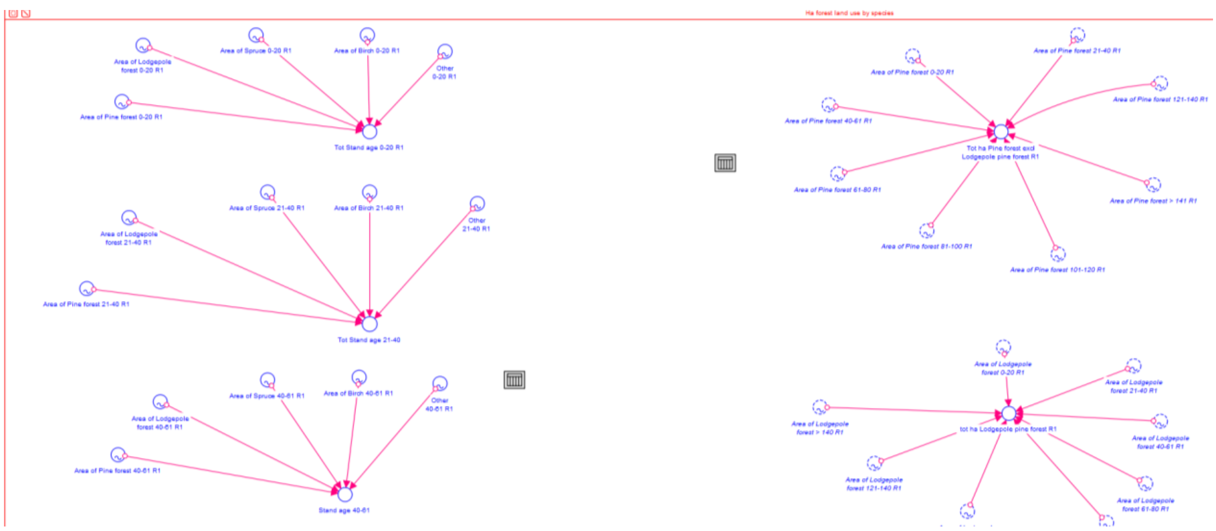
Top level of the SDM



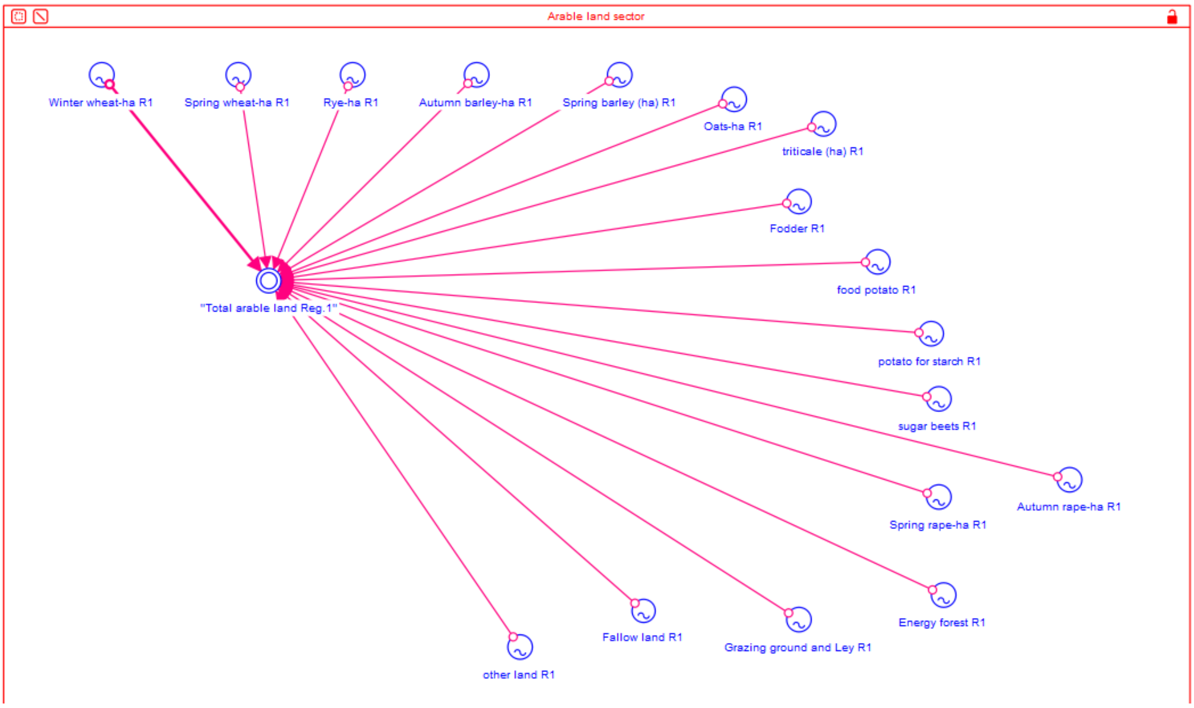
Water module

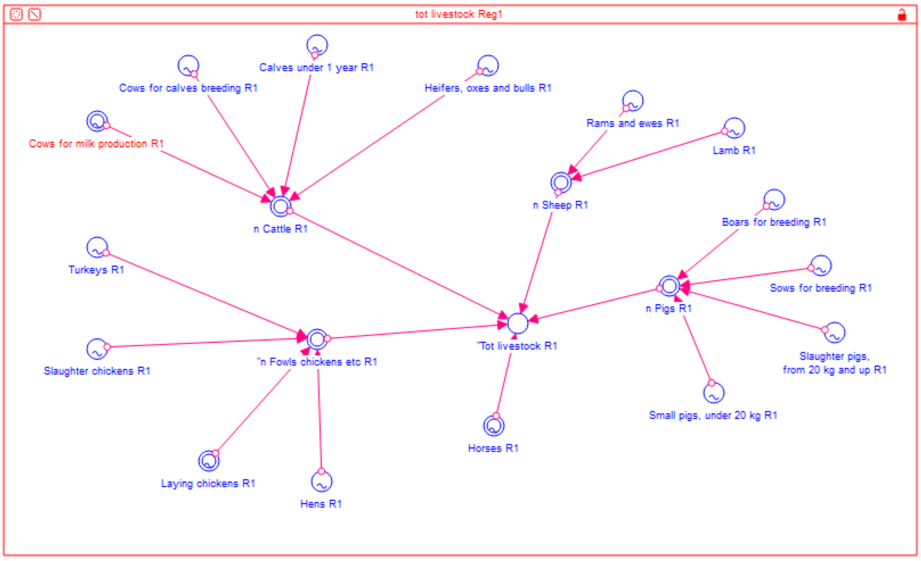


Detail showing top level of the land module (top), forestry sub-module (middle) and productive forestry land module (bottom)

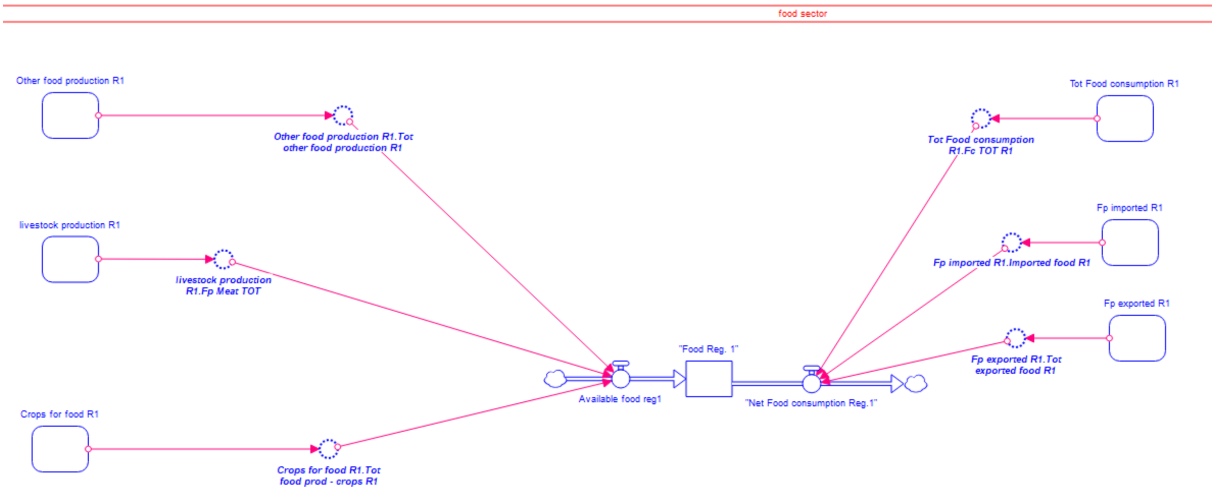


Detail showing part of the module calculating the area covered by different tree species in different age classes

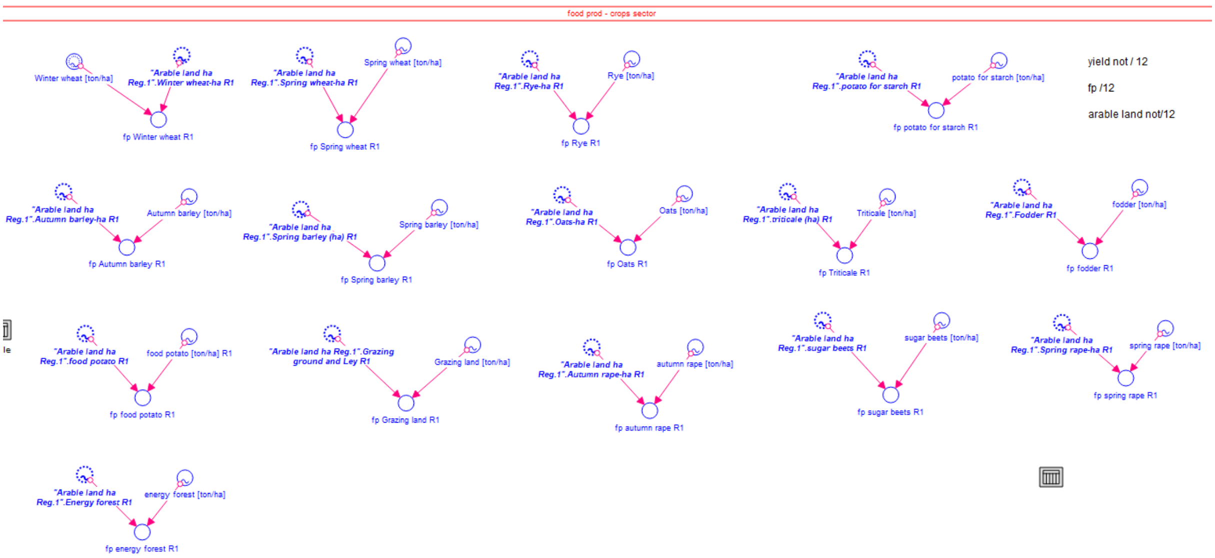




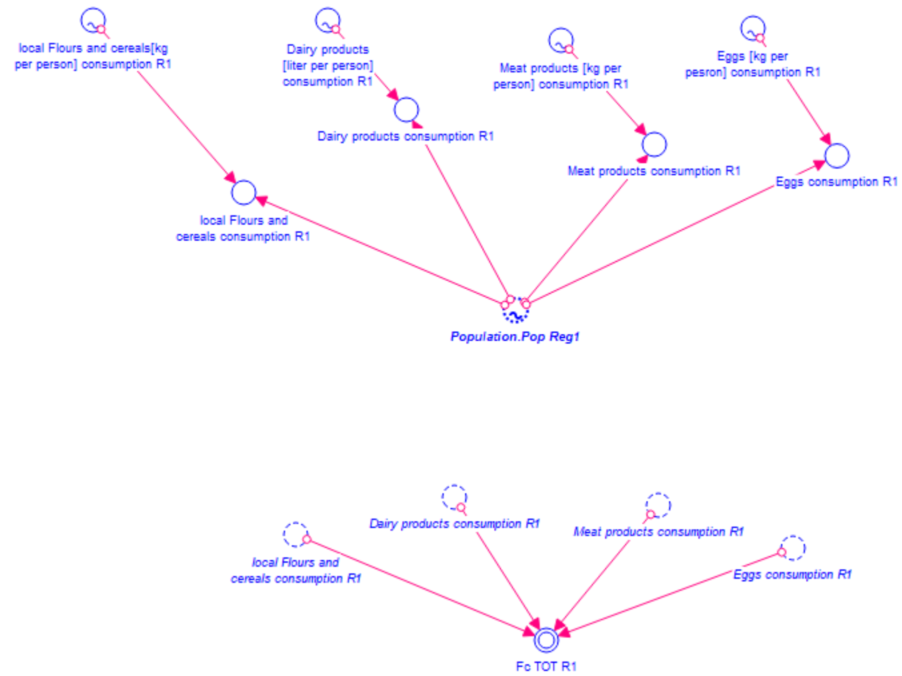
Detail showing the land modules for arable land (top) and livestock land (bottom)



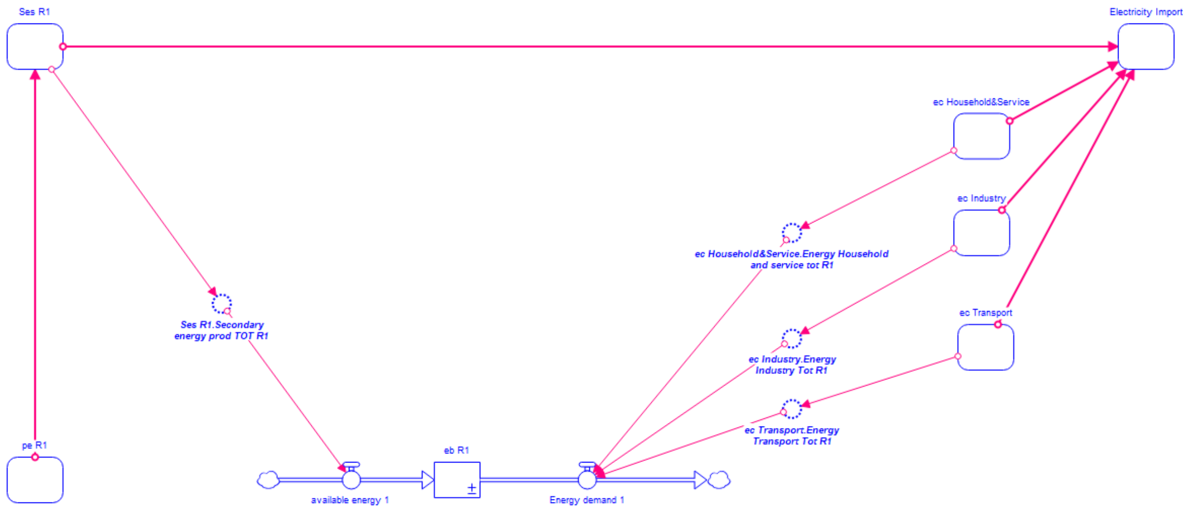
The top level of the food production and consumption module.



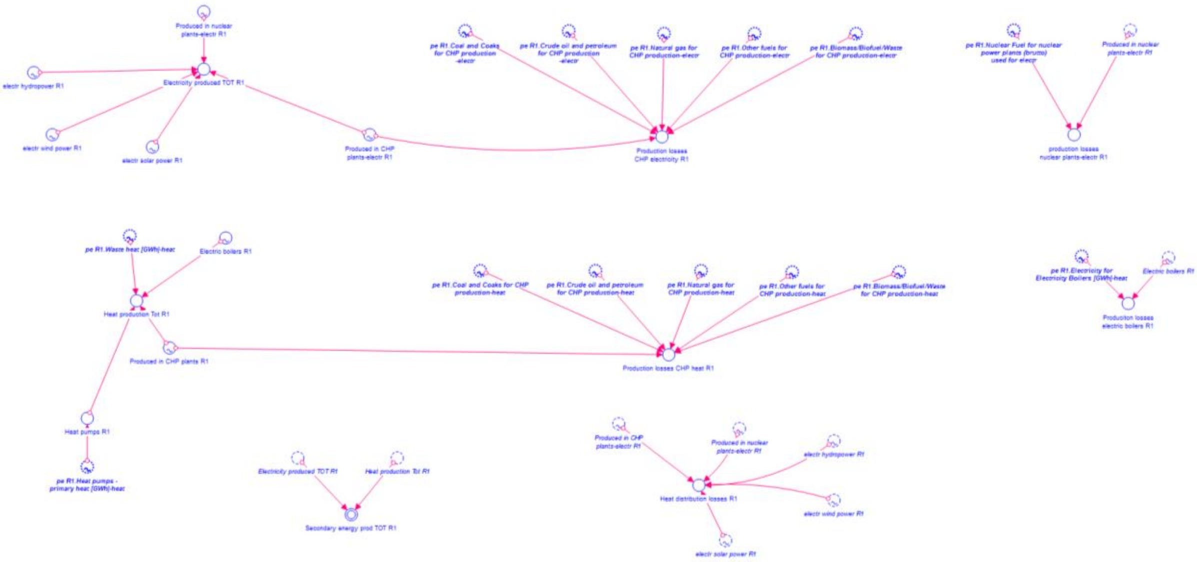
Detail of the crop food production sub-module



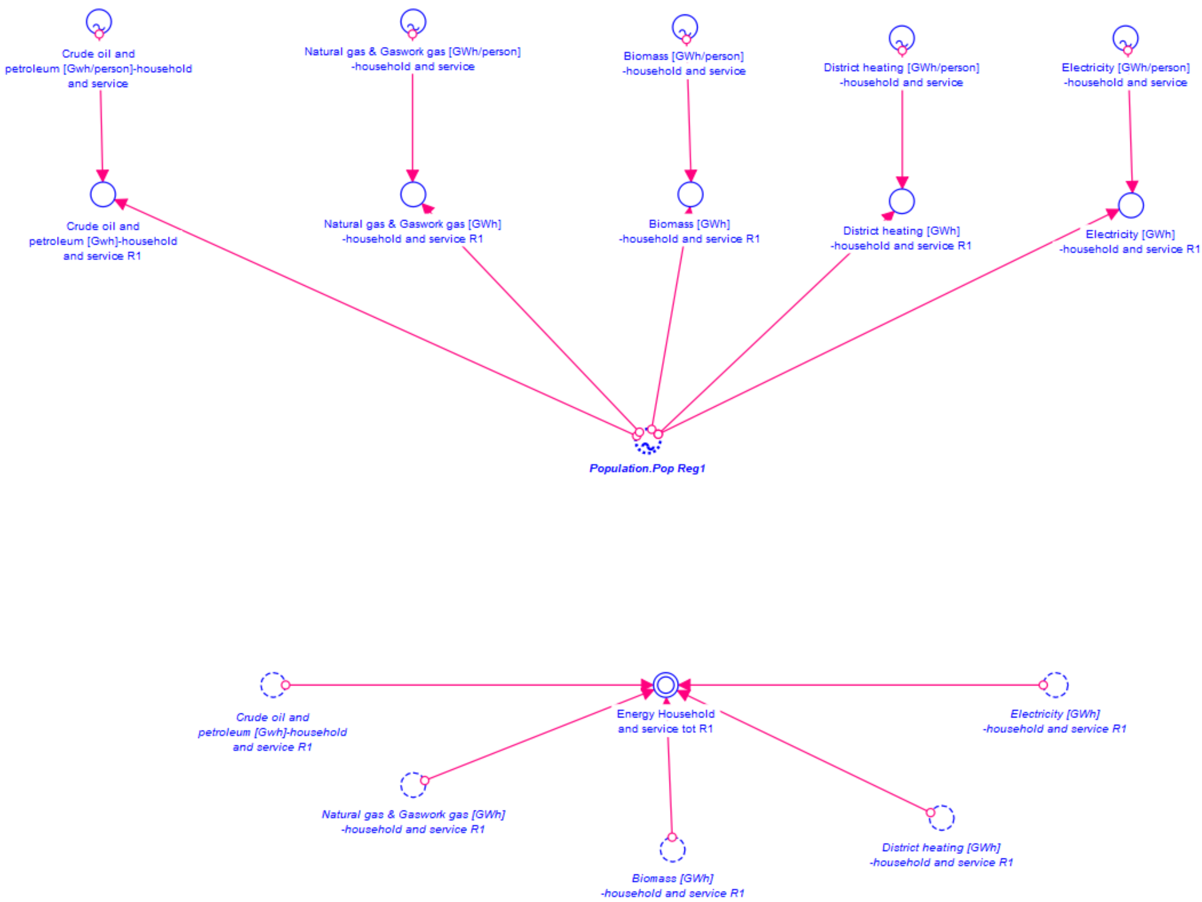
Detail of the food consumption sub-module.



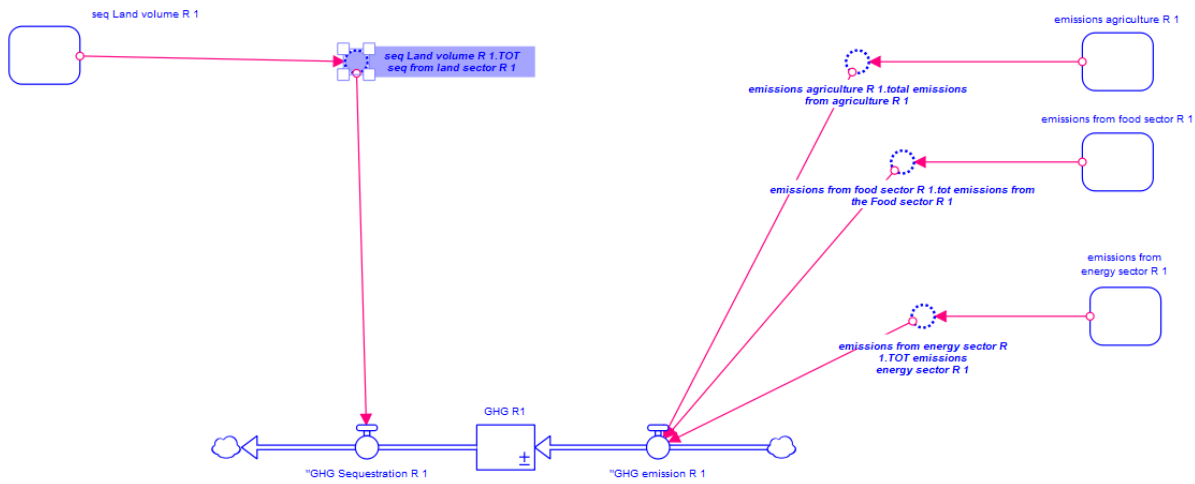
Top level of the energy module.



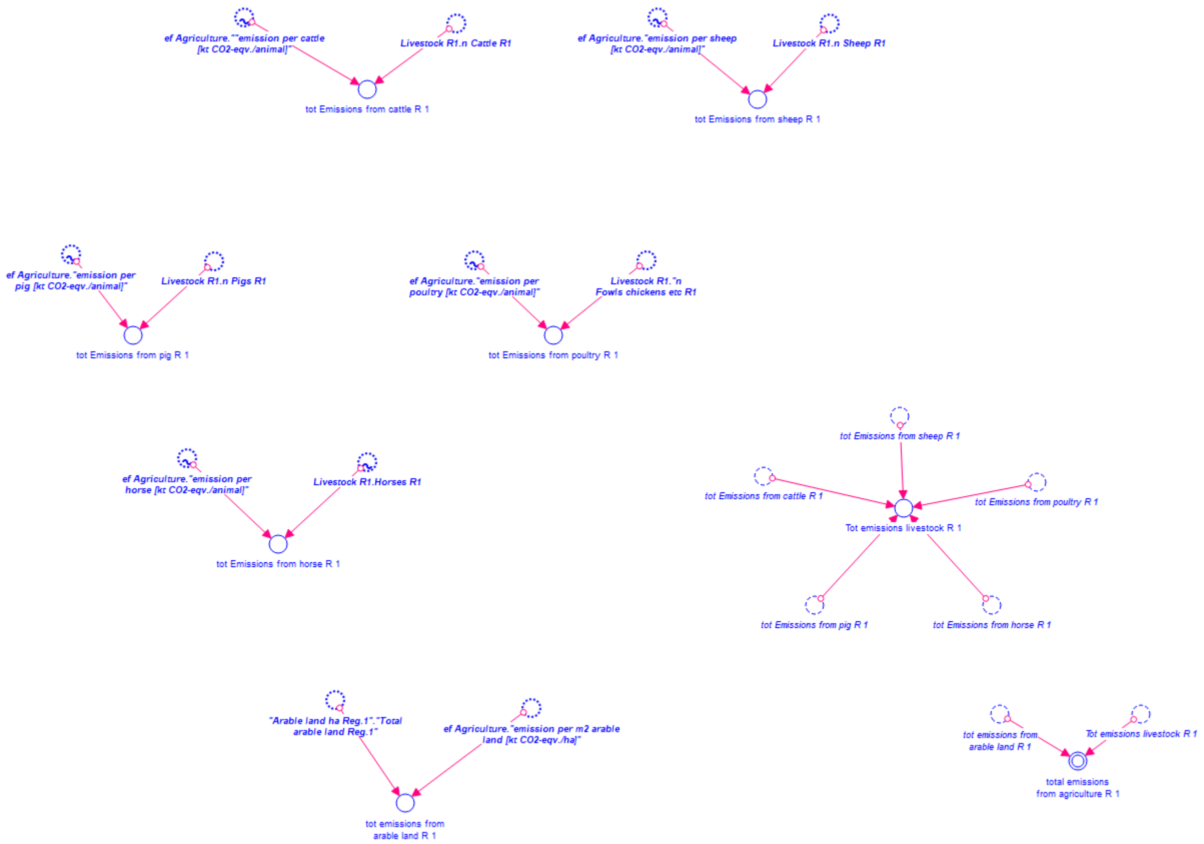
Detail of the secondary energy production sub-module.



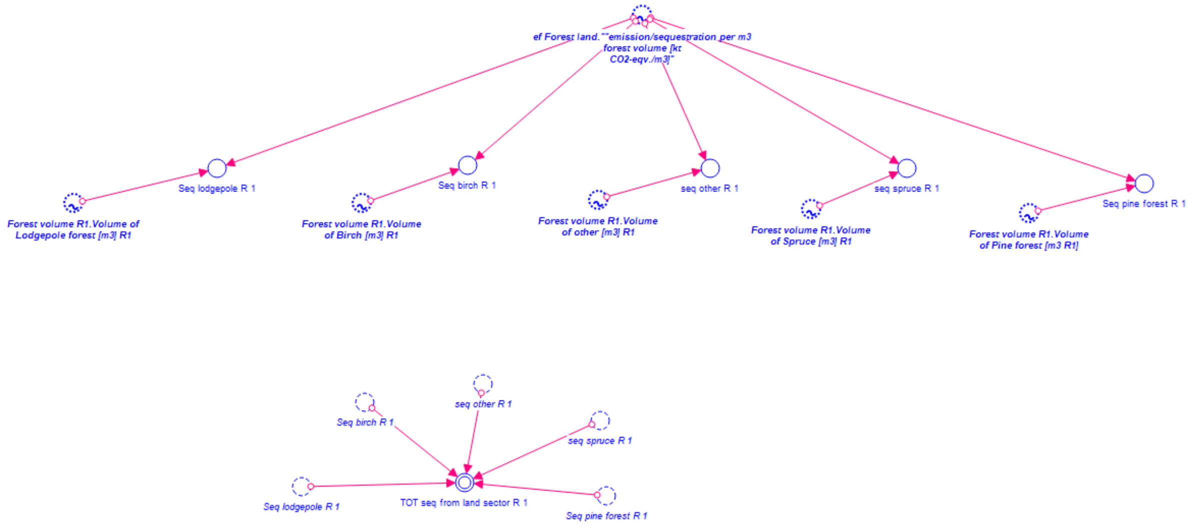
Detail showing the domestic energy consumption sub-module. Industrial and transport consumptive sectors are similarly structured.



Top-level of the climate emissions module.



Detail showing the emissions from land-use – in particular animal production. Emissions from other sectors are similarly calculated.



Detail of the sub-module calculating sequestration of carbon from land types.

7.10.3 Use Cases

USE CASE C.1	CLIMATE
Related Learning Goals	Effects of reducing greenhouse gas emissions and climate impacts
Goal	Limiting the rise in the global average temperature by reducing emissions
User	Students
Actions	10. Increase the share of environmentally friendly heavy trucks (>3.5 ton) on the road through providing subsidies 11. Re-wetting 10% (i.e. 154,580 ha) of drained peatland (formerly ditched and drained to create productive land) to reduce GHG emissions
Indicator	12. CO_2,eq emissions from transport sector 13. Total CO_2,eq emissions

STEP in the SG

1. Identify number of trucks (>3.5 ton) on the road and CO2 equ emissions per truck
2. Identify area of drained peatland (in ha) and estimate CO2 equ emissions per hectare
3. Calculate rate of change in emissions
    a. With different levels of subsidies on environmentally friendly trucks
    b. With different amounts of drained peatland area rewetted

USE CASE W.1	WATER
Related Learning Goals	Sustainable use and management of water resources
Goal	Improving management of water resources to increase water quality and decrease water use
User	Students
Actions	14. Reduce the use of fertilizer (through a fertilizer tax) and thereby the leakage of nitrogen and phosphorus from agricultural land 15. Reduce the domestic water use through water fees
Indicator	16. Nitrogen and phosphorus concentrations in water (lakes/rivers) 17. amount of water used in domestic and service sector

STEP in the SG

1. Identify level of fertilizer use and nitrogen/phosphorus concentrations
2. Identify water used in domestic and service sector
3. Calculate rate of change in
    a. Water use in domestic and service sector
    b. Water quality

USE CASE W.1	LAND (FOREST)
Related Learning Goals	Importance of a rich diversity of plant and animal life
Goal	Improvements in land use to foster higher biodiversity
User	Students

Actions	18. Increase the average stand age of spruce and pine through legislation regulating the rotation age 19. Increase the area of non-productive (protected) forest through financial compensation for protecting forests
Indicator	20. Average forest stand age 21. Amount of non-productive forest land in hectares

STEP in the SG

1. Identify the average stand age of spruce and pine
2. Identify the area of non-productive (protected) forest
3. Calculate rate of change in
    a. Average forest stand age
    b. Amount of non-productive forest land in hectares

7.10.4 Policy cards

Poliy Goal ID	PolicyId (Objective)	Nexus Sector	Name	Very short policy card name	Description of intervention as captured by the policy card	Level: National(0), Regional(1)	Permanent?	Can this policy be applied only once, or can it be applied multiple time (Once/Multiple)	If the policy can be applied multiple time, does it always effects the same changes each new run	Is this policy applied pre-game from 2010 to 2015 (as a % of policy efficiency)?	Is this policy applied pre-game from 2015 to 2020 (as a % of policy efficiency)?	Building/ implementation time (years, multiple of 5)	Active time (years, multiple of 5)	Costs associated to the intervention/ measure per turn (5 years): Order of Magnitude High, Medium, Low	Economic Value generated by the intervention/measure per playround: Order of Magnitude High, Medium, Low	Social capital required to implement the policy intervention: Order of Magnitude High, Medium, Low	Social Capital generated by the intervention/measure per turn: High, medium, low, positive or negative	Is the intervention/measure included in any of the thematic models?	How does this intervention/measure translate into model input?
PG1-C	O1	Climate	Increase the share of environmentally friendly heavy trucks (>3.5 ton) on the road to 20% though subsidies (low level)	Subsidies on environmentally friendly trucks (low level)	Subsidies for environmentally friendly trucks are introduced to foster their market share to 20%. This low support leads to slightly more biofuel used in transport sector and to 3% less emissions from domestic transport.	0	No	Multiple	0	no	no	10	10	Low	0	Low	Positive	no	decrease of emissions in
PG1-C	O1	Climate	Increase the share of environmentally friendly heavy trucks (>3.5 ton) on the road to 40% though subsidies (medium level)	Subsidies on environmentally friendly trucks (medium level)	Subsidies for environmentally friendly trucks are introduced to foster their market share to 40%. This medium support leads to slightly more biofuel used in transport sector and to 6% reduced emissions from domestic transport.	0	No	Multiple	0	no	no	10	10	Medium	0	Low	Positive	no	decrease of emissions in
PG1-C	O1	Climate	Increase the share of environmentally friendly heavy trucks (>3.5 ton) on the road to 60% though subsidies (high level)	Subsidies on environmentally friendly trucks (high level)	Subsidies for environmentally friendly trucks are introduced to foster their market share to 60%. This relatively high support for sun panels leads to 8.5% less emissions from fossil fuel use and therefore to reduced climate impacts.	0	No	Multiple	0	no	no	10	10	High	0	Low	Positive	no	decrease of emissions in
PG1-C	O1	Climate	Increase the share of environmentally friendly heavy trucks (>3.5 ton) on the road to 80% though subsidies (very high level)	Subsidies on environmentally friendly trucks (very high level)	Subsidies for environmentally friendly trucks are introduced to foster their market share to 80%. This very high support for sun panels leads to 11% less emissions from fossil fuel use and therefore to largely reduced climate impacts.	0	No	Multiple	0	no	no	10	10	Very high	0	Low	Positive	no	decrease of emissions in

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement NO 689150 SIM4NEXUS

PG1-C	O2	Climate	Re-wetting 10% (i.e. 154,580 ha) of drained peatland (formerly ditched and drained to create productive land) to reduce GHG emissions	Re-wetting of peatlands (low level)	18% of all peatland in Sweden have been ditched long ago (to create productive land) and now these areas release a lot of GHG. Through government support (compensation schemes), 154,580 ha of forest land will be re-wetted, which leads to 309,160 kg less CO2 emissions (-0.7%).	0	Yes	Multiple	0	no	no	10	20	Low	0	Low	Positive	no	decrease in total emissions
PG1-C	O2	Climate	Re-wetting 20% (i.e. 309,160 ha) of drained peatland (formerly ditched and drained to create productive land) to reduce GHG emissions	Re-wetting of peatlands (medium level)	18% of all peatland in Sweden have been ditched long ago (to create productive land) and now these areas release a lot of GHG. Through government support (compensation schemes), 309,160 ha of forest land will be re-wetted, which leads to 618,320 kg less CO2 emissions (-1.4%).	0	Yes	Multiple	0	no	no	10	20	Medium	0	Low	Positive	no	decrease in total emissions
PG1-C	O2	Climate	Re-wetting 30% (i.e. 463,740 ha) of drained peatland (formerly ditched and drained to create productive land) to reduce GHG emissions	Re-wetting of peatlands (high level)	18% of all peatland in Sweden have been ditched long ago (to create productive land) and now these areas release a lot of GHG. Through government support (compensation schemes), 463,740 ha of forest land will be re-wetted, which leads to 972,480 kg less CO2 emissions (-2.1%).	0	Yes	Multiple	0	no	no	15	20	High	0	Low	Positive	no	decrease in total emissions
PG1-C	O2	Climate	Re-wetting 40% (i.e. 618,320 ha) of drained peatland (formerly ditched and drained to create productive land) to reduce GHG emissions	Re-wetting of peatlands (very high level)	18% of all peatland in Sweden have been ditched long ago (to create productive land) and now these areas release a lot of GHG. Through government support (compensation schemes), 618,320 ha of forest land will be re-wetted, which leads to 1,236,640 kg less CO2 emissions (-2.8%).	0	Yes	Multiple	0	no	no	15	20	Very high	0	Low	Positive	no	decrease in total emissions
PG2-E	O3	Energy	Increase the share of solar electricity poduction to 2.5% (of total electriCity porduction) through subsidies (low level: 10% of installation costs) for solar panels	Subsidies on solar panels (low level)	Subsidies for solar panels are introduced to foster their installation and the production of solar energy. This low support for sun panels leads to slightly reduced emissions from fossil fuel use and therefore to reduced climate impacts.	0	Yes	Multiple	0	no	no	5	5	Low	0	Low	Positive	no	increase of solar electricity
PG2-E	O3	Energy	Increase the share of solar electricity poduction to 5% (of total electricity porduction) through subsidies (medium level: 30% of installation costs) for solar panels	Subsidies on solar panels (medium level)	Subsidies for solar panels are introduced to foster their installation and the production of solar energy. This medium support for sun panels leads to somewhat reduced emissions from fossil fuel use and therefore to reduced climate impacts.	0	Yes	Multiple	0	no	no	5	5	Medium	0	Low	Positive	no	increase of solar electricity
PG2-E	O3	Energy	Increase the share of solar electricity poduction to 7.5% (of total electricity porduction) through subsidies (high level: 50% of installation costs) for solar panels	Subsidies on solar panels (high level)	Subsidies for solar panels are introduced to foster their installation and the production of solar energy. This relatively high support for sun panels leads to reduced emissions from fossil fuel use and therefore to reduced climate impacts.	0	Yes	Multiple	0	no	no	5	5	High	0	Low	Positive	no	increase of solar electricity

PG2-E	O3	Energy	Increase the share of solar electricity poduction to 10% (of total electricity porduction) through subsidies (very high level: 70% of installation costs) for solar panels	Subsidies on solar panels (very high level)	Subsidies for solar panels are introduced to foster their installation and the production of solar energy. This very high support for sun panels leads to reduced emissions from fossil fuel use and therefore to reduced climate impacts.	0	Yes	Multiple	0	no	no	5	5	Very high	0	Low	Positive	no	increase of solar electricity
PG2-E	O4	Energy	Increase the amount of arable land used for growing energy crops ("energy forest") by 5% through start-up grants (low level) for Salix plantations	Start-up grants for Salix (willow) plantations (low level)	Energy crops (more specifically Salix/willow) are slightly promoted to produce more biomass for energy production	0	No	Multiple	0	no	no	5	10	Low	?	Low	Positive	no	increase in energy crops
PG2-E	O4	Energy	Increase the amount of arable land used for growing energy crops ("energy forest") by 10% through start-up grants (medium level) for Salix plantations	Start-up grants for Salix (willow) plantations (medium level)	Energy crops (more specifically Salix/willow) are somewhat promoted to produce more biomass for energy production	0	No	Multiple	0	no	no	5	10	Medium	?	Low	Positive	no	increase in energy crops
PG2-E	O4	Energy	Increase the amount of arable land used for growing energy crops ("energy forest") by 15% through start-up grants (high level) for Salix plantations	Start-up grants for Salix (willow) plantations (high level)	Energy crops (more specifically Salix/willow) are largely promoted to produce more biomass for energy production	0	No	Multiple	0	no	no	5	10	High	?	Low	Positive	no	increase in energy crops
PG2-E	O4	Energy	Increase the amount of arable land used for growing energy crops ("energy forest") by 20% through start-up grants (very high level) for Salix plantations	Start-up grants for Salix (willow) plantations (very high level)	Energy crops (more specifically Salix/willow) are very strongly promoted to produce more biomass for energy production	0	No	Multiple	0	no	no	5	10	Very high	?	Low	Positive	no	increase in energy crops
PG3-W	O6	Water	Reduce the use of fertilizer by 10% and thereby the leakage of nitrogen and phosphorus from agricultural land by introducing a fertilizer tax (low level).	Tax on fertilizer (low level)	A tax on fertilizer (low level) leads to slightly less fertilizer use in land sector and thus less leakage of nitrogen and phosphorus into water resources. This in turn will increase water quality. It also is positive for ecological production, but has a negative effect on food security.	0	No	Multiple	0	no	no	10	10	Low	?	Medium	Neutral	no	Reduction of fertiliser and P concentrations
PG3-W	O6	Water	Reduce the use of fertilizer by 20% and thereby the leakage of nitrogen and phosphorus from agricultural land by introducing a fertilizer tax (medium level).	Tax on fertilizer (medium level)	A tax on fertilizer (medium level) leads to somewhat less fertilizer use in land sector and thus less leakage of nitrogen and phosphorus into water resources. This in turn will increase water quality. It also is positive for ecological production, but has a negative effect on food security.	0	No	Multiple	0	no	no	10	10	Low	?	Medium	Neutral	no	Reduction of fertiliser and P concentrations

PG3-W	O6	Water	Reduce the use of fertilizer by 30% and thereby the leakage of nitrogen and phosphorus from agricultural land by introducing a fertilizer tax (high level).	Tax on fertilizer (high level)	A tax on fertilizer (high level) leads to significantly less fertilizer use in land sector and thus less leakage of nitrogen and phosphorus into water resources. This in turn will increase water quality. It also is positive for ecological production, but has a negative effect on food security.	0	No	Multiple	0	no	no	10	10	Low	?	Medium	Neutral	no	Reduction of fertiliser and P concentrations
PG3-W	O6	Water	Reduce the use of fertilizer by 40% and thereby the leakage of nitrogen and phosphorus from agricultural land by introducing a fertilizer tax (very high level).	Tax on fertilizer (very high level)	A tax on fertilizer (very high level) leads to significantly less fertilizer use in land sector and thus less leakage of nitrogen and phosphorus into water resources. This in turn will increase water quality. It also is positive for ecological production, but has a negative effect on food security.	0	No	Multiple	0	no	no	10	10	Low	?	Medium	Neutral	no	Reduction of fertiliser and P concentrations
PG3-W	O7	Water	Reduce the domestic water use by 5% through the increase of higher water fees (low level)	Increase water fees for property owners (low level)	Water fees (low level) to be paid by property owners for public drinking water supply and the removal of waste water will be increased to slightly promote water saving.	0	Yes	Multiple	0	no	no	5	10	Low	?	Medium	Neutral	no	Reduction of water use in
PG3-W	O7	Water	Reduce the domestic water use by 10% through the increase of higher water fees (medium level)	Increase water fees for property owners (medium level)	Water fees (medium level) to be paid by property owners for public drinking water supply and the removal of waste water will be increased to somewhat promote water saving.	0	Yes	Multiple	0	no	no	5	10	Low	?	Medium	Neutral	no	Reduction of water use in
PG3-W	O7	Water	Reduce the domestic water use by 15% through the increase of higher water fees (high level)	Increase water fees for property owners (high level)	Water fees (high level) to be paid by property owners for public drinking water supply and the removal of waste water will be increased to strongly promote water saving.	0	Yes	Multiple	0	no	no	5	10	Low	?	High	Neutral	no	Reduction of water use in
PG3-W	O7	Water	Reduce the domestic water use by 20% through the increase of higher water fees (very high level)	Increase water fees for property owners (very high level)	Water fees (very high level) to be paid by property owners for public drinking water supply and the removal of waste water will be increased to heavily promote water saving.	0	Yes	Multiple	0	no	no	5	10	Low	?	High	Neutral	no	Reduction of water use in
PG4-F	O8	Food	Increase the use of fertilizer by 10% and thereby the food production by introducing a fertilizer subsidy (low level).	Subsidy on fertilizer (low level)	Subsidies on fertilizer (low level) lead to slightly more fertilizer use in land sector and thus more production of food and consequently food security. But the use of fertlizer causes more leakage of nitrogen and phosphorus into water resources. This in turn will decrease water quality.	0	No	Multiple	0	no	no	5	10	Low	0	Low	Positive	no	Increase in fertiliser, decrease in water

PG4-F	O8	Food	Increase the use of fertilizer by 20% and thereby the food production by introducing a fertilizer subsidy (medium level).	Subsidy on fertilizer (medium level)	Subsidies on fertilizer (medium level) lead to somewhat more fertilizer use in land sector and thus more production of food and consequently food security. But the use of fertlizer causes more leakage of nitrogen and phosphorus into water resources. This in turn will decrease water quality.	0	No	Multiple	0	no	no	5	10	Medium	0	Low	Positiv e	no	Increase in fertiliser, decrease in water
PG4-F	O8	Food	Increase the use of fertilizer by 30% and thereby the food production by introducing a fertilizer subsidy (high level).	Subsidy on fertilizer (high level)	Subsidies on fertilizer (high level) lead to much more fertilizer use in land sector and thus more production of food and consequently food security. But the use of fertlizer causes more leakage of nitrogen and phosphorus into water resources. This in turn will decrease water quality.	0	No	Multiple	0	no	no	5	10	High	0	Low	Positiv e	no	Increase in fertiliser, decrease in water
PG4-F	O8	Food	Increase the use of fertilizer by 40% and thereby the food production by introducing a fertilizer subsidy (veryhigh level).	Subsidy on fertilizer (very high level)	Subsidies on fertilizer (very high level) lead to significantly more fertilizer use in land sector and thus more production of food and consequently food security. But the use of fertlizer causes more leakage of nitrogen and phosphorus into water resources. This in turn will decrease water quality.	0	No	Multiple	0	no	no	5	10	Very high	0	Low	Positiv e	no	Increase in fertiliser, decrease in water
PG4-F	O9	Food	Increase the total arable land by 2.5% through subsidies (low level) on agricultural area	Subsidy on arable land (low level)	Subsidy on arable land (low level) will lead to a slight increase in agricultural area where crops are produced, which will lead to slightly more food production and security.	0	No	Multiple	0	no	no	5	10	Low	0	Low	Positiv e	no	Increase in arable land,
PG4-F	O9	Food	Increase the total arable land by 5% through subsidies (medium level) on agricultural area	Subsidy on arable land (medium level)	Subsidy on arable land (medium level) will lead to a an increase in agricultural area where crops are produced, which will lead to more food production and security.	0	No	Multiple	0	no	no	5	10	Medium	0	Low	Positiv e	no	Increase in arable
PG4-F	O9	Food	Increase the total arable land by 7.5% through subsidies (high level) on agricultural area	Subsidy on arable land (high level)	Subsidy on arable land (high level) will lead to a strong increase in agricultural area where crops are produced, which will lead to much more food production and security.	0	No	Multiple	0	no	no	5	10	High	0	Low	Positiv e	no	Increase in arable
PG4-F	O9	Food	Increase the total arable land by 10% through subsidies (very high level) on agricultural area	Subsidy on arable land (very high level)	Subsidy on arable land (very high level) will lead to a heavy increase in agricultural area where crops are produced, which will lead to much more food production and security.	0	No	Multiple	0	no	no	5	10	Very high	0	Low	Positiv e	no	Increase in arable

PG5-L	O11	Land	Increase the area of non-productive (protected) forest by 25 % through financial compensation (low level) for protecting forests	Compensation (low level) for forest protection	Financial compensation (low level) given to forest owners for lost production will lead to slightly more protected forest areas and thus less productive forest.	0	No	Multiple	0	no	no	5	20	Low	0	Low	Positiv e	no	Increase in non-productive
PG5-L	O11	Land	Increase the area of non-productive (protected) forest by 50 % through financial compensation (medium level) for protecting forests	Compensation (medium level) for forest protection	Financial compensation (medium level) given to forest owners for lost production will lead to more protected forest areas and thus less productive forest.	0	No	Multiple	0	no	no	10	20	Medium	0	Low	Positiv e	no	Increase in non-productive
PG5-L	O11	Land	Increase the area of non-productive (protected) forest by 75 % through financial compensation (high level) for protecting forests	Compensation (high level) for forest protection	Financial compensation (high level) given to forest owners for lost production will lead to much more protected forest areas and thus less productive forest.	0	No	Multiple	0	no	no	15	20	High	0	Low	Positiv e	no	Increase in non-productive
PGL	O11	Land	Increase the area of non-productive (protected) forest by 100 % through financial compensation (very high level) for protecting forests	Compensation (very high level) for forest protection	Financial compensation (very high level) given to forest owners for lost production will lead to much more protected forest areas and thus less productive forest.	0	No	Multiple	0	no	no	20	20	Very high	0	Low	Positiv e	no	Increase in non-productive

7.10.5 Stakeholders maps

A list of organizations relevant for the sectors under consideration in the Swedish case study was created based on expert judgement. To identify the most relevant stakeholders and their influence in the policy process, they were clustered into actor groups (i.e., types of organizations) that have similar roles in the policy arrangement (Table 22): (1) businesses, (2) common interest associations, (3) local federations, (4) local governmental organizations, (5) regional governmental organizations, (6), national governmental organizations, (7) non-governmental organizations (NGOs), (8) research organizations and (9) trade associations.

Table 22 List of potential stakeholders grouped by the type of organization

ID	TYPE OF ORGANIZATION	ORGANIZATION
1	business	Bergvik Skog AB
2	business	Boxholms Skogar AB
3	business	E.ON vattenkraft
4	business	Fortum
5	business	Holmen Energi
6	business	Holmen Skog AB
7	business	Persson Invest Skog AB
8	business	Rebio
9	business	SCA Skog AB
10	business	SeKab
11	business	Skellefteå Kraft
12	business	Skogssällskapet förvaltning AB
13	business	Statkraft
14	business	Stockholm Vatten
15	business	Sveaskog AB
16	business	Uppsala University Foundations Management of Estates and Funds (Uppsala Akademiförvaltning)
17	business	Uppsala Vatten
18	business	Vattenfall
19	common-interest association	Agroforestry
20	local governmental organization	Sweden's 290 municipalities
21	local federation	Norrvatten
22	local federation	VA Syd
23	national governmental organization	Ministry of the Environment and Energy
24	national governmental organization	Swedish Environmental Protection Agency (Naturvårdsverket)
25	national governmental organization	The National Food Agency (Livsmedelsverket)
26	national governmental organization	The National Property Board of Sweden (Statens fastighetsverk)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement NO 689150 SIM4NEXUS

ID	TYPE OF ORGANIZATION	ORGANIZATION
27	national governmental organization	The Swedish Agency for Marine and Water Management (Hav och Vatten)
28	national governmental organization	The Swedish Energy Agency (Energimyndigheten)
29	national governmental organization	The Swedish Forest Agency (Skogsstyrelsen)
30	national governmental organization	The Swedish Fortifications Agency (Fortifikationsverket)
31	national governmental organization	The Swedish Geological Survey (Sveriges Geologiska Undersökning)
32	NGO	Forest Stewardship Council (FSC)
33	NGO	Swedish Programme for the Endorsement of Forest Certification (PEFC)
34	NGO	Swedish Society for Nature Conservation
35	NGO	The Royal Swedish Academy of Agriculture and Forestry (Kunglig Skogs- och Lantbruksakademin)
36	NGO	The Swedish Forest Society Foundation (Skogssällskapet)
37	NGO	The Swedish Forestry Association (Föreningen Skogen)
38	regional governmental organization	Water authority Bothnian Bay (Vattenmyndigheten i Bottenvikens vattendistrikt)
39	regional governmental organization	Water authority Bothnian Sea (Vattenmyndigheten i Bottenhavets vattendistrikt)
40	regional governmental organization	Water authority Northern Baltic Sea (Vattenmyndigheten i Norra Östersjöns vattendistrikt)
41	regional governmental organization	Water authority Skagerack and Kattegat (Vattenmyndigheten i Västerhavets vattendistrikt)
42	regional governmental organization	Water authority Southern Baltic Sea (Vattenmyndigheten i Södra Östersjöns vattendistrikt)
43	research	Nordic Association for Hydrology (NHF)
44	research	Stockholm International Water Institute (SIWI)
45	research	Swedish Energy Research Centre (Energiforsk)
46	research	Swedish Hydrological Council (Svenska hydrologiska rådet)
47	research	The Forestry Research Institute of Sweden (Skogforsk)
48	trade association	Lantmännen Agroetanol
49	trade association	Mellanskog
50	trade association	Norrskog
51	trade association	Swedish Forest Industries Federation (Skogsindustrierna)
52	trade association	Swedish Hydropower Association (Svensk Vattenkraftförening)
53	trade association	Swedish Petroleum and Biofuel Institute (SPBI)
54	trade association	The Federation of Swedish Family Forest Owners (LRF Skogsägarna)
55	trade association	The Swedish Bioenergy Association (Svebio)
56	trade association	Water Regulation Enterprises (Vattenregleringsföretagen)

The stakeholder list (Table 22) contains eighteen ***businesses***, comprising a number of different hydropower, biofuel and forest-owing companies. One ***common interest association***, i.e., a group of individuals who voluntarily formed an organization to promote agroforestry, was identified. The list further includes two ***local federations*** formed by municipalities to manage local drinking water concerns, 290 municipalities belonging in the group of ***local governmental organizations***, five ***regional governmental organizations*** coordinating the work within the Swedish water districts, and nine ***national governmental organizations*** mainly consisting of Swedish government agencies that act independently to carry out policies. Furthermore, six ***NGOs*** dealing with forest issues and nature conservation, five

research organizations in the forest, water and energy sectors, as well as nine ***trade associations*** were identified.

The division of resources between these actors naturally leads to differences in power and influence. As a starting point for looking at the relative position of the stakeholder and their power relations, actor groups were mapped to visualize their sizes, influence, roles and relationships (Figure 62). In addition, a power-interest grid per sector was generated (Figure 63) to visualize which stakeholders are key players that should preferably be fully engaged and which stakeholders only play a minor role.

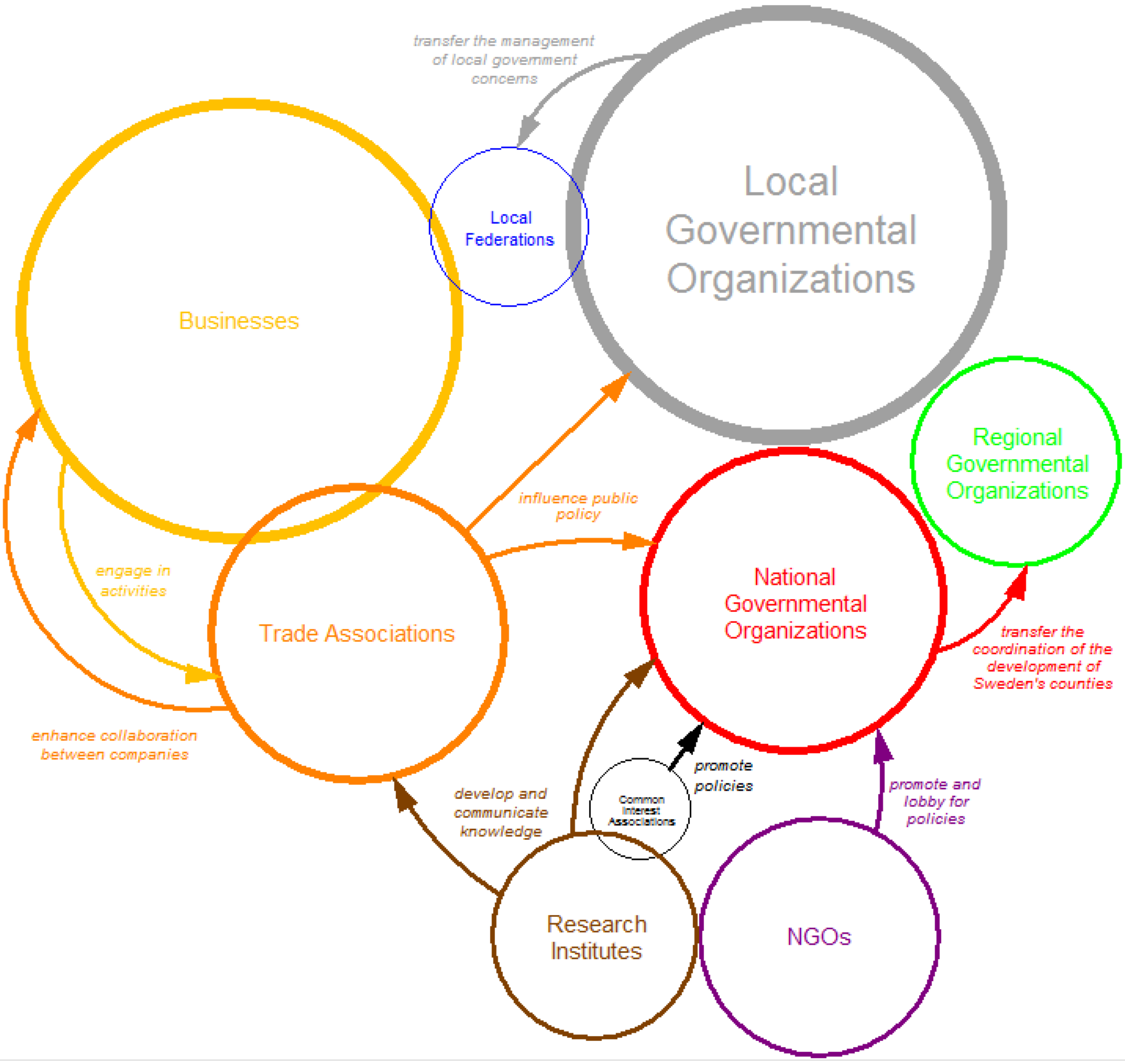


Figure 62 Map of relevant stakeholder groups and their relations. The size of the circles indicates the size of stakeholder groups, different colors represent different groups, the distance/overlap between circles indicates the relationship between the groups. Arrows indicate the main direction of the relationship.

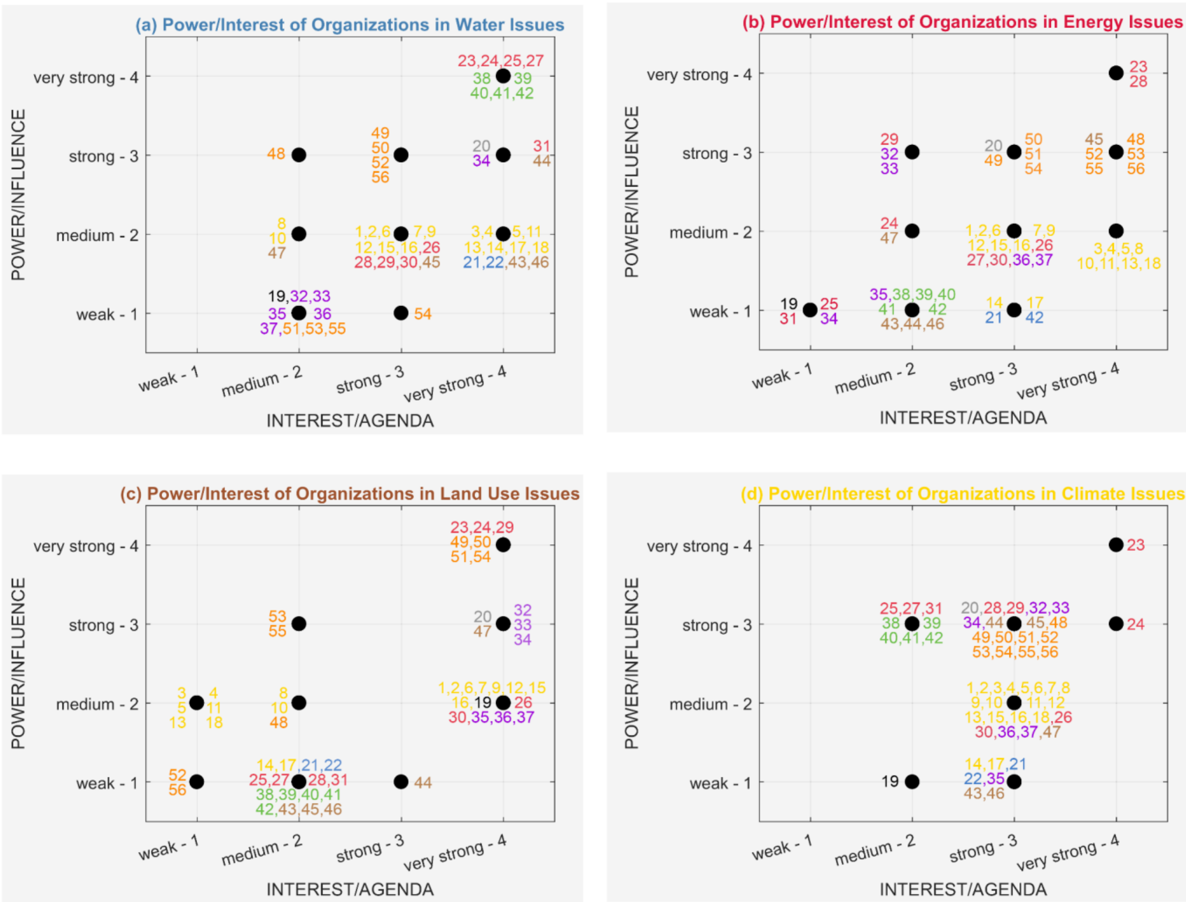


Figure 63 Power-interest grid of potential stakeholders in (a) the water sector, (b) the energy sector, (c) the land use sector, and (d) the climate sector

Key stakeholders with high power (strong to very strong) and high interest (strong to very strong) were identified for each sector separately based on the power-interest grid (Figure 63). Ten stakeholders, which play a major role in more than two sectors, emerged (Table 23).

Table 23 Key stakeholders with high power and interest in more than 2 sectors (F = forest/land use, W = water, E = energy, C = climate)

ID	ORGANIZATION	F	W	E	C
Key actors in all 4 sectors					
20	Sweden's 290 municipalities	x	x	x	x
23	Ministry of the Environment and Energy	x	x	x	x
24	Swedish Environmental Protection Agency (Naturvårdsverket)	x	x	x	x
49	Mellanskog	x	x	x	x
50	Norrskog	x	x	x	x
Key actors in 3 sectors					
34	Swedish Society for Nature Conservation	x	x		x
51	Swedish Forest Industries Federation (Skogsindustrierna)	x		x	x
52	Swedish Hydropower Association (Svensk Vattenkraftförening)		x	x	x
54	The Federation of Swedish Family Forest Owners (LRF Skogsägarna)	x		x	x
56	Water Regulation Enterprises (Vattenregleringsföretagen)		x	x	x

8 Netherlands

8.1 Introduction

The Netherlands comprises of a land area of 37,354 km^2 and is partly sub-sea level. It borders to Germany to the east, Belgium to the south, and the North Sea to the northwest. It has a population of 17 million inhabitants and a population density of about 450 inhabitants per km^2. There is a strong pressure on land that is scarce and expensive. Further, agriculture, energy, water, nature, and climate are strongly interconnected. The Netherlands has also an open economy (83% of GDP is export) and many natural resources come from abroad. The demand for biomass is expected to increase the coming years. This is due to an increasing focus on climate issues and more opportunities for applying biomass in the chain from production to re-usage of waste.

Figure 64 shows the land use in the Netherlands in 2012. Despite the high population density, agriculture covers more than 60 % of the land area in the Netherlands. Approximately 700 thousand ha is used for built-up area and infrastructure (referred to as red space in Figure 64). Woodland and nature cover about 600 thousand ha.

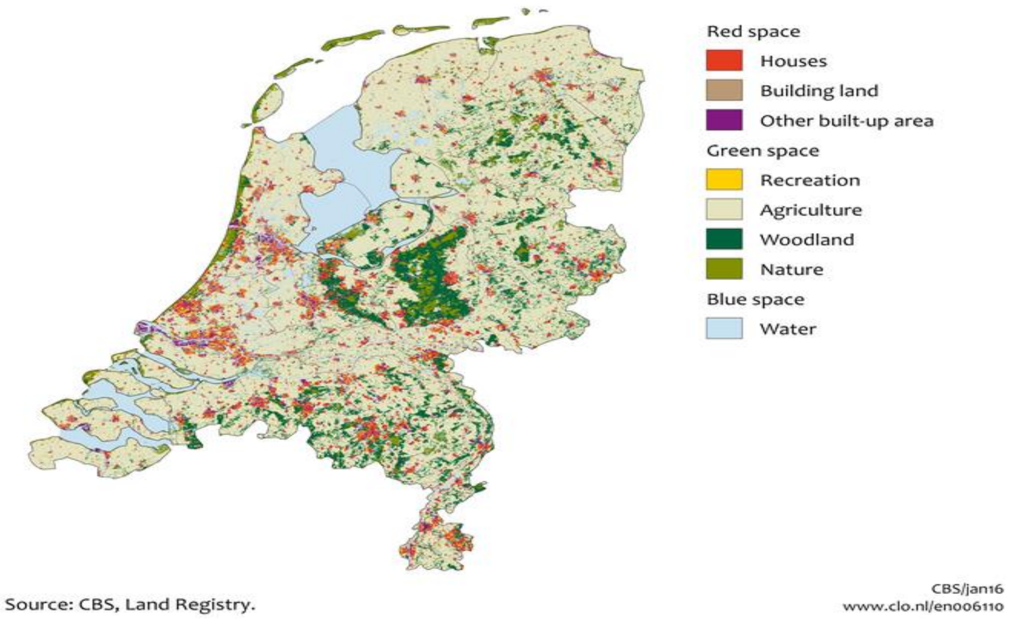


Figure 64 Land use in the Netherlands 2012

Name of case study lead organisation
Wageningen Economic Research

Main stakeholders involved
Of the main stakeholders involved we had public servants from the most relevant ministries; The Ministry of Economic Affairs and Climate (energy, climate, circular and bio-based economy); the Ministry of Agriculture, Nature and Food Quality; the Ministry of Infrastructure and Water Management. From the 12 provinces we had four involved; North Holland, South Holland, Overijssel and Gelderland. Involved is also the Dutch Water Authorities (Unie van Waterschappen, UvW), a national association for the 21 water boards. Public agencies are also central, as the Netherlands Enterprise Agency (RVO),

which is a part of the Ministry of Economic Affairs and Climate Policy). The Netherlands Environmental Assessment Agency (PBL) is part of the Ministry of Infrastructure and Water. Several private businesses, branch associations and NGOs are involved, such as the Dutch Bioenergy Association (PBE; covering the entire biomass chain); the Biomass Alliance ("smart" collaboration, new business cases), the WWR-group (waste), RWE (waste), JIN Climate & Sustainability.

Nexus domains addressed

Biomass relates to all Nexus domains climate, energy, food, land and water. The link to corresponding policies is strong: energy, agriculture and food, waste, nature, spatial planning and water.

Main Nexus challenges

The main problem addressed in this report is the ambiguity between on the one hand biomass as an essential source of renewable energy to reach the goal of a low-carbon economy in 2050, and on the other hand the potential trade-offs on water, land and food, and the potential discrepancy with the goals of a circular and bio-based economy

Main research questions

The main research question in the SIM4NEXUS case study of the Netherlands is:

What is the role of biomass in the realization of a low-carbon and resource-efficient economy in the Netherlands in 2050?

Sub-questions:

- To what extent is the intensification of biomass production for energy in The Netherlands feasible from a biophysical, socioeconomic and policy perspective? How will resource efficiency in terms of nutrient emissions to water be affected?
- How much sustainably produced biomass will be available in 2050 for energy generation in The Netherlands, produced in the Netherlands or abroad and imported? Depending on definitions and the point of views on sustainability, this will be a range and not a fixed amount.
- Which users will share the available biomass in The Netherlands in 2050, and who will get priority? Priority will be flexible and depend on point of view. Biomass for energy has a low value, and it releases direct carbon emissions to air when not captured or compensated.
- What will be the impact on water, land, agriculture, food and GHG emissions of biomass production and use in The Netherlands in 2050?

8.2 Overview of tasks performed

8.2.1 Organisation to carry-out Task 5.2

Wageningen Economic Research was the lead of the Dutch case study of SIM4NEXUS. There were 3 main researchers who conducted most of the work in the Dutch case study, see Table 24.

Table 24 People from Wageningen Economic Research involved in the Dutch case study

NAME	RESPONSIBILITIES
VINCENT LINDERHOF	CASE STUDY LEAD, CONCEPTUAL MODEL, SDM, POLICY ANALYSIS, POLICY CARDS PREPARATION, STAKEHOLDER INTERACTION, CONDUCTING WORKSHOPS/EXPERT MEETINGS, CONTRIBUTION TO SIM4NEXUS MEETINGS

NICO POLMAN	CONCEPTUAL MODEL, SDM, POLICY CARDS PREPARATION, SG INSTRUCTIONS, CONDUCTING WORKSHOPS/EXPERT MEETINGS, WP3/WP4 SKYPE MEETINGS, CONTRIBUTION TO SIM4NEXUS MEETINGS
TROND SELNES	CONCEPTUAL MODEL, POLICY ANALYSIS, COHERENCY ANALYSIS, STAKEHOLDER INTERACTION, REVIEWING POLICY CARDS, CONDUCTING WORKSHOPS/EXPERT MEETINGS, CONTRIBUTION TO SIM4NEXUS MEETINGS
KRISTIE DEKKERS	PREPARING SDM (FIRST VERSION), DATA COLLECTION OTHER SOURCES
JAMAL ROSKAM	DATA COLLECTION OTHER SOURCES

Kristie Dekkers wrote a master thesis “Policy instruments on mitigation options for a low-carbon economy in 2050: Using a System Dynamics modelling approach” for the master Management, Economics and Consumer Studies at the Wageningen University and Research. She was supervised by Vincent Linderhof and Nico Polman. She prepared a SDM in Stella with which she analysed a number of economic interventions to reduce GHG emissions, (Dekkers 2017). It was the start of the SDM work for the Dutch case study.

For the Dutch case study, WEcR collaborated closely with Maria Witmer (PBL) and Janez Susnik and Sara Masia (IHE Delft), see Table 25. With Maria Witmer, Janez Susnik and Sara Masia, we have had regular meetings to identify the conceptual model of the Dutch case study and the interaction with stakeholders.

Maria Witmer, Stefania Munaretto and Roos Marinissen (PBL) collaborated with Trond Selnes and Vincent Linderhof on the stakeholder analyses, and the policy coherence analyses for the Dutch case study. The modelling activities for the SDM of the Dutch case study have been done by Vincent Linderhof and Nico Polman under supervision of Janez Susnik and Sara Masia (IHE Delft).

Table 25: People from partners involved in the Dutch case study

ORGANIZATION	NAME	RESPONSIBILITIES
NETHERLANDS ENVIRONMENTAL ASSESSMENT AGENVCY (PBL)	MARIA WITMER	CONCEPTUAL MODEL, POLICY ANALYSIS, POLICY CARDS PREPARATION, STAKEHOLDER INTERACTION, REVIEWING POLICY CARDS, CONDUCTING WORKSHOPS/EXPERT MEETINGS
	STEFANIA MUNARETTO	POLICY COHERENCE ANALYSIS
	ROOS MARINNISEN	POLICY ANALYSIS, COHERENCY ANALYSIS
IHE DELFT	JANEZ SUSNIK	CONCEPTUAL MODEL, SUPERVISION SDM CONSTRUCTION, CONTRIBUTING TO WORKSHOPS/EXPERT MEETINGS
	SARA MASIA	CONCEPTUAL MODEL, SUPERVISION SDM CONSTRUCTION, CONTRIBUTING TO WORKSHOPS/EXPERT MEETINGS

For the master Environment and Resource Management (ERM) at the Vrije Universiteit in Amsterdam (The Netherlands), Roos Marinissen wrote a master thesis “Sufficient support or too many trade-offs? Biomass production in The Netherlands from a policy perspective” under the supervision of Stefania Munaretto and Maria Witmer. Roos analysed the biomass production as a source of energy in the existing policies related to energy, climate, water, land and food, see (Marinissen 2017).

For the necessary data for the case study, we have had irregular contact with Eva Alexandri (Cambridge Econometrics) for the E3ME data, Maria Blanco (University of Madrid) for the CAPRI data and Jason Levin-Koopman (WEcR) for the MAGNET data.

8.2.2 Schedule of Task 5.2

Table 26 presents the list of tasks/activities conducted by the Dutch case study team. The tasks/activities include the modelling, data collection, policy analysis, stakeholder interaction, reporting and project meetings. In addition, additional activities have been undertaken such as contributions to conferences, papers and other projects.

Table 26 Overview of tasks performed in the Dutch case study

TASKS	DESCRIPTION
MODELLING	
CONCEPTUAL MODEL	PREPARATION OF THE CONCEPTUAL MODEL IN PPT
SDM	PREPARATION OF THE SDM
POLICY CARDS	PREPARATION OF POLICY CARDS TO BE INCLUDED IN THE SDM/SG
SERIOUS GAME	PREPARATION OF THE SDM
DATA	
BASELINE DATA COLLECTION	DATA COLLECTION FROM THEMATIC MODELS
BASELINE DATA COLLECTION	DATA COLLECTION FROM OTHER SOURCES
SCENARIO DATA COLLECTION	DATA COLLECTION FROM THEMATIC MODELS
SCENARIO DATA COLLECTION	DATA COLLECTION FROM OTHER SOURCES
POLICY	
POLICY ANALYSIS	POLICY ANALYSIS OF THE NEXUS-RELATED POLICIES IN THE NETHERLANDS
POLICY COHERENCE ANALYSIS	ANALYSIS OF COHERENCY IN POLICY IN THE NETHERLANDS
STAKEHOLDER INTERACTION	
STAKEHOLDER INTERVIEWS	INTERVIEWS FOR STAKEHOLDER MAPPING, CONCEPTUAL MODEL, AND POLICY ANALYSES
WORKSHOP	FIRST STAKEOLDER WORKSHOP ON 26-10-2017 AT PBL
MEETING	UNIE VAN WATERSCHAPPEN 21-1-2018
WORKSHOP	SECOND STAKEOLDER WORKSHOP ON 24-4-2018 AT PBL
EXPERT MEETING	THIRD STAKEHOLDER MEETING ON 21-5-2019 AT WECR
EXPERT MEETING	THIRD STAKEHOLDER MEETING ON 24-10-2019 AT WECR
REPORTING	
D1.6	USE CASES
D2.2	REPORT ON POLICY ANALYSIS
D2.3	REPORT ON POLICY COHERENCE ANALYSIS
D4.1	LEARNING GOALS OF DUTCH CASE STUDY
D4.8	UPDATE ON LEARNING GOALS OF DUTCH CASE STUDY
D5.2	INTERMEDIATE REPORT ON THE CASE STUDY PROGRESS
D5.5	FINAL REPORT ON THE CASE STUDY
MS18	
PROJECT MEETINGS	

JULY 11-12, 2016	SIM4NEXUS PROJECT MEETING IN SCHEVENINGEN
NOVEMBER 16-18, 2016	SIM4NEXUS PROJECT MEETING IN BARCELONA
JUNE 1-2, 2017	TREBON
MARCH 12-14, 2018	SIM4NEXUS PROJECT MEETING IN ATHENS
JULY 3-5, 2019	SIM4NEXUS PROJECT MEETING IN RIGA
MARCH 25-27, 2020	SIM4NEXUS PROJECT MEETING IN VIENNA
OTHER ACTIVITIES	
DEEDS PROJECT MEETING	CONTRIBUTION TO THE DEEDS STAKEHOLDER CONSULTANCY MEETING IN MONTPELLIER ON NOVEMBER 17, 2019
MAGIC-SIM4NEXUS MEETING	FEBRUARY 19, 2018: WITH TEAM MEMBERS OF THE NEXUS PROJECT "MAGIC" WE EXPLORE THE SYNERGIES AND DIFFERENCES BETWEEN THE TWO NEXUS PROJECTS
CONFERENCE CONTRIBUTION	POSTER PRESENTATION AT THE DNC2020 CONFERENCE IN DRESDEN, JUNE 3-5, 2020
CONFERENCE CONTRIBUTION	PRESENTATION AT THE ENERGY RESEARCH AND SOCIAL SCIENCE 2019 CONFERENCE IN PHOENIX, MAY 28-31, 2019
CONFERENCE CONTRIBUTION	POSTER PRESENTATION AT THE BLUE ECONOMY CONFERENCE IN WATERLOO, SEPTEMBER 9-11, 2017
ARTICLE	"THE NEXUS CONCEPT INTEGRATING ENERGY AND RESOURCE EFFICIENCY FOR POLICY ASSESSMENTS: A COMPARATIVE APPROACH FROM THREE CASES" IN SUSTAINABILITY (BROUWER ET AL. 2018)

Data collection from thematic models. The process of data collection was not clear. The results of the baseline models and the policy scenarios were available in a late stage of the project. Data on other scenarios were provided through the Power BI tool which is not easily accessible.

Another challenge was the continuation of the interaction with the stakeholders. The first two stakeholder workshops were successful in terms of participation (15-20 people), while the third and fourth workshop were held with a few stakeholders. The third and fourth workshop were primarily focused on the System Dynamics modelling of the case study and on the incorporation of possible interventions. Stakeholders who were not able to participate did show their interests in the Serious Game application.

One of the other activities was the meeting with the team of the other H2020 Nexus project "MAGIC" on February 19, 2018. The team of MAGIC consisted of representatives of the University Twente, Wageningen Livestock Research and the Universitat Autònoma de Barcelona. In this meeting, we explored the synergies and differences in the projects with respect to the case studies of both projects in the Netherlands. The MAGIC project emphasized the (water) foot print approach which involved a lot of conceptualizing data and data collection. The Dutch case study of MAGIC focused attention on the technologies to generate biofuels form manure. The teams of both projects agreed on the intention to write a joint article on the results of the Dutch case studies of both projects.

8.3 Engagement of stakeholders in the process

8.3.1 Overview of stakeholders' engagement in the case study

Based on the central issue of the case 'the role of biomass in reaching a low-carbon economy', we have identified organisations which are involved in this field and which would be potential users of the results of this case-study and the SG. Many public-private covenants have been concluded such as the Dutch

Energy Agreement for Sustainable Growth (SER 2013; 2015). Within these covenants public and private parties collaborate on sustainable growth/low-carbon economy.

Table 27 present the list of stakeholders and their interest in the Nexus challenges. The main categories of stakeholders throughout the activities were: national government, regional government, research, consultancy, public-private coalitions, business sector and NGOs. Despite the broad range of stakeholders involved in the project, the bio-waste companies and environmental NGOs were underrepresented at the workshop.

Table 27 List of stakeholders involved in the project Sim4NEXUS in the Netherlands

Type of organization	Name of organization	**Description**	**Core Nexus Interest W-F-E-C-L**
National government	Ministry of Infrastructure and Water	Main policy-maker for Infrastructure, water, spatial planning	W-L-C
	Ministry of Economic Affairs and Climate	Main policy-maker for energy and climate policy	E-C
	Ministry of Agriculture, Nature and Food Quality	Main policy-maker for agriculture and nature policy	F-L
	Staatsbosbeheer (National Forestry Agency)	Commissioned to strengthen the position of nature. Land owner and manager	L
	Rijkswaterstaat: Public Agency Infrastructure	Implementing agency for the Dutch infrastructure.	W-L
	RVO (Netherlands Enterprise Agency)	improve opportunities/conditions for entrepreneurs in sustainable, agrarian, innovative and international	W-F-E-C-L
	UvW - Dutch Water Authorities[A]	Cooperation of the Dutch water boards	W
Regional government	Provinces (4 in S4N: Overijssel, Gelderland, North Holland, South Holland)	Implementation and coordination of policy at the regional level	W-F-L
Research	PBL – Netherlands Environmental Assessment Agency	National institute for independent policy research	W-F-E-C-L
	WUR – Wageningen University and Research	University research, many aspects of biomass, such as production technologies research	W-F-E-C-L
	ECN - Energy research Centre of the Netherlands[B]	ECN/part of TNO energy research, technology and market analysis.	E
	University of Twente	University research, many aspects of biomass, focus on production technologies research	W-F-E-C-L
Consultancy	BTG Biomass Technology Group	private group of companies, specialized in the process of conversion of biomass into useful fuels and energy: consultancy, project development, research	E
	Probos	non-profit institute for forestry, forest products and services Advisor on wood and timber use,	E-L

		biomass production and procurement	
Public-private collaboration	Topsectors Energy, Agri. & food and Horticulture and Materials	A network initiated by the government to combine knowledge and stakeholders inclusive the policy-makers	F-E
	Biomassa Alliantie	Biomass alliance for regional governments, public agencies, private business association, knowledge institutes	E-L
Business	ENECO	Energy company	E
	Bio Energie Centrale Cuijk	Bio-energy producer	E
	WWR group	Biomass trader, recycling	F-E-L
	Energon B.V	Biomass, bio-energy (part of the WWR group)	E
	RWE	Energy supplier	E
Business association	Stichting Biomassa	Biomass processing innovation for the region Achterhoek	F-E-L
	Stichting Groen Gas	Green gas (biogas) representing 125 businesses and organizations	E
	VVNH	Employer organization for wood products/imports	L
	VNCI	The Association of the Dutch Chemical Industry (VNCI) promotes the collective interests of the chemical industry	F-E
	Platform Bioenergie (PBE)	Biomass chain, advise, lobby, representation	Energy
Branche organization	LTO-Noord	Business and employers' organisation (50.000 farmers)	F-L
NGO	BEON[B]	Bioenergy Cluster Eastern Netherlands including provinces Overijssel and Gelderland, PBE, Probos, SNM, National Forestry Agency, Probos, LTO, Stichting Biomassa	E-L
	SNM Stichting Natuur en Milieu[B]	Interest organisation for nature and environment	F-E-C-L
	Natuurmonumenten[B]	Nature organisation (700.000 members)	F-E-C-L

[A] The team of the Dutch case study gave a presentation of the Dutch case study of SIM4NEXUS during the meeting with UvW on 21-1-2018.
[B] The team interviewed representatives of these organizations.

When it comes to the process of engagement, we distinguish between four stages. (1) policy analysis, (2) preparation of the conceptual framework, (3) preparation of the system dynamics model and (4) preparing and playing the Serious Game, see Figure 2.

Stakeholders interaction is foreseen in all stages of the case study. First, we engage the stakeholders to discuss policy matters (targets, coherence). Second, we discussed input for the conceptual framework with relevant relationships and trade-offs as well as priorities and policy strategies. Third, we involved stakeholders in the building of the System Dynamics Model and finally the Serious Game.

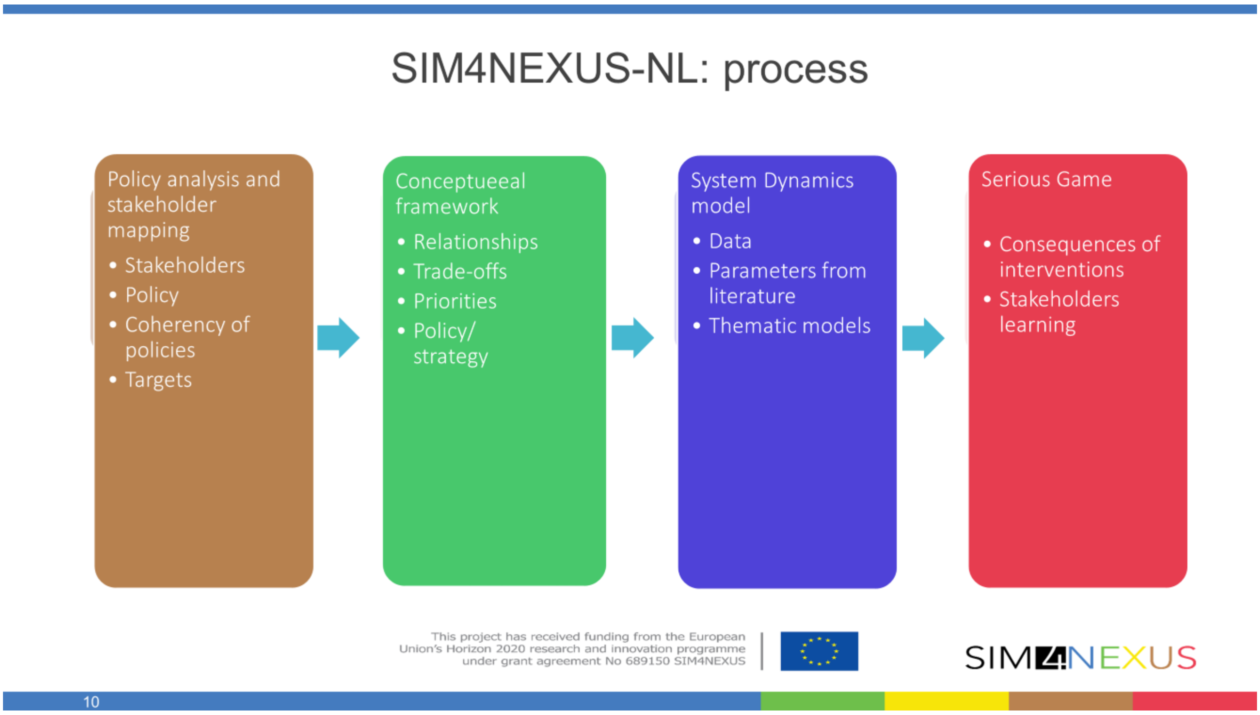


Figure 65 Four phases of the SIM4NEXUS project and the Netherlands case study

Stakeholder interaction was useful to be useful for several reasons:

- Dialogue among actors with various views & interests & disciplines
- Joint elaboration of opportunities & barriers
- Experience the advantages of the Serious Game for decision making processes
- Explore joint interests & deal with tension: make difficult choices
- Establish priorities from integrated assessments.

In total we had four workshops where we presented and discussed opportunities and challenges regarding the application of biomass as a renewable energy source and usage as material for the bio-based economy; and how to improve the Conceptual Framework and the System Dynamics model to make the game as useful as possible. In the last workshop (April/May 2020) we play (the prototype of) the Serious Game, see Table 28.

Table 28 Activities with stakeholders involved in the Dutch case study

Interactions with stakeholders	Date Location	Number of participants and indicative distribution by Nexus sector	Main topics discussed	Outcomes / Achievements
interviews	Spring 2017	17 (all sectors)	Biomass policy and practice	A broad picture of strengths and weaknesses of both policy and practice
Workshop n°1	26-10-2017	21 (15 outside project) a spread of biomass-chain stakeholders from energy and bio-waste-business, knowledge institutes, government, public agencies: often attached	Policy and practice: challenges	A broad picture of strengths and weaknesses of both policy and practice

		to more than one single Nexus-domain.		
Workshop n°2	24-4-2018	20 (11 outside the project). More researchers, governmental and agency people than at the first workshop, but also business and NGOs present.	Models, SG and policy interventions	Improved insights into policy versus practice: motivations and behaviour of markets and government
Workshop n°3	21-5-2019	8 (4 outside the project)	From model to practice; link SG and policy cards	Better view to the links between models and practice.
Workshop n°4	24-10-2019	10 (5 outside the project). A smaller workshop with experts that could be allowed more time to elaborate	The more explicit link between the SG and policy cards	Better insights into the usage and usefulness of policy cards for the SG
workshop n°5	Expectation: May 2020	To come	On the SG	Improve SG

In the Dutch case study approximately 60 different people have participated.

8.3.2 Feedback on stakeholders' engagement in the case study

The stakeholders appreciated the transdisciplinary and multi-sector approach, which highlighted relevant challenges and offered the stakeholders opportunities to meet and talk open on the matters of biomass. It was however harder to keep their attention over time as it was quite a time-lap between the workshops. In particular, it is difficult to discuss a Serious Game two to three year before its realization. Solutions to overcome such challenges are not obvious as the project goes on for four years. But demonstrating progress and linking up to relevant current policy processes are useful ways to keep the relationship going. In addition, playing the Greek game helped to discuss the potential of a Serious Game for the Dutch case.

8.4 From conceptual models to System Dynamic Modelling

8.4.1 Case study conceptual model

The conceptual model was built based upon a short review of the policy debate in the Netherlands, expertise of the project team members and interaction with stakeholders.

Based on Ros et al. (2016), and after discussions with experts in the field of Dutch energy and climate policy, it was decided to focus on the role of biomass in the energy transition to a low-carbon economy in 2050. Reasons for this choice were the connections between biomass, land, water, energy, food and climate, and the scarcity of land and high importance of agriculture in The Netherlands. Ros and Daniëls (2017) concluded that a 95 percent reduction of GHG emissions in 2050 compared to 1990 will only be feasible in The Netherlands if biomass and CCS will be applied. But the supply of sustainably produced biomass is limited and there are numerous demands for biomass. EU and Dutch biomass policy developed the cascade principle that sets out the priority for high-quality use of biomass and puts biomass for energy generation at the lowest cascade level. The main research question is: 'What can be the role of biomass in the Dutch transition to a low-carbon economy by 2050, considering the interaction with water, land, energy, food and climate?'

In the policy debate, it was suggested to use available options to reduce GHG emissions for reaching a 95 percent reduction of GHG emissions in 2050 (Ros et al. 2016). The reduction potential of the options was identified, and the study concluded that a mix of the technological option should be implemented to achieve a low-carbon economy in the Netherlands in 2050.

During the process of the project, there was a new government installed on 26th of October 2017. Climate policy was one of the key elements of the coalition agreement. It set a target of a 49-55 percent reduction of GHG emission in 2030 in the Netherlands as compared to 1990 and aims for a maximum temperature rise below 2 degrees Celsius in 2050 which corresponds with the Paris agreement (VVD, CDA, D66 & Christen Unie, 2017). However, there are no targets for the share of renewable energy in the energy mix, reduction in energy use and increase of energy efficiency in 2030 or 2050, nor is there a distribution of the reduction targets among the different economic sectors. This means that there is a large degree of freedom in choosing different pathways to reach a low-carbon economy in 2050, although Ros et al. (2016) state that all available options to reduce GHG emissions need to be used to reach a 95 percent reduction of GHG emissions in 2050.

At the first workshop on 24th of October 2017, stakeholders pointed out the bad image of biomass for energy use in Dutch politics and public opinion as the main challenge for increasing the share of biomass in the energy mix. Image is however seen as key to success by the stakeholders at the workshop. The current negative image is made up by a blend of opinions: it is associated with for instance co-firing with coal, (local) pollution and Not-In-My-Backyard (NIMBY) attitudes, a fear of importing highly unsustainable biomass from for instance nature (forests) abroad. The sources of and usage of biomass are also viewed to be very diverse and unclear, with a fragmented and unclear policy. One of the important sources of uncertainty, lack of trust and dispute is the current lack of sustainability criteria, an issue that the PBL is working on now (March 2020). The general result pointed out by the stakeholders during the four workshops, see Table 28, is a lack of trust in how to use biomass wisely. Between scientists and professionals, biomass is heavily disputed in The Netherlands, because the reduction of GHG emissions reached by using biomass as compared to fossil energy depends on definitions and time horizon, and because biomass production has potentially negative effects on water, land and food. The discussion is highly polarised. The Serious Game might become a tool to facilitate the discussion, if assumptions and methods used in the game are transparent (and accepted) and if the game is considered as 'neutral'. This means that outcomes of the Serious Game may be presented as possible developments, depending on definitions and visions. This is the consequence of using disputed knowledge.

Biomass is a catch-all term, according to the stakeholders. It was suggested to divide the diverse types of biomass by origin, source and uses in the conceptual model and Serious Game. Also, the ambiguity of model outcomes, depending on definitions and viewpoints, needs to be integrated in the model and game.

The Serious Game could have an educational function, as the bad image of biomass is partly based on incorrect information. Two main streams of biomass are distinguished:

1. small-scale (non-woody) biomass which reflects different types of biomass from different sources, such as energy crops, crop residues, manure, wastewater, organic waste;
2. large-scale woody biomass from forestry in the Netherlands or from imports.

The functional requirements for the conceptual framework, complexity model and Serious Game were formulated in cooperation with the stakeholders. Within the limits of feasibility with respect to system dynamics modelling and complexity, these requirements were translated into the conceptual model. As biomass is the central element in the Dutch case study and not water scarcity as in the pilots, the conceptual model was adjusted, based on the functional requirements of the Dutch case and on the input from the stakeholders. Biomass is part of or affects the Nexus elements (subsystems) water, land, agriculture, food and energy, as well as part of flows between these elements. The tension between biomass production for energy generation on the one hand and the pursuit of resource efficiency and circular economy on the other hand was included after discussion with stakeholders, as well as the competition between several users for sustainable biomass as a scarce resource. Energy, land and food are represented in detail distinguishing different types of energy including multiple biomass-related types, different types of land use and different types of food production.

8.4.2 Modifications introduced to model policy scenarios

8.4.2.1 Development of policy scenarios for the case study

The two overarching policy goals of SIM4NEXUS as well as the Dutch case study are 1) a low carbon economy and 2) resource efficiency.

Low carbon economy is a common policy goal for all case studies and easily translated numerically, as it can be equated to the global and EU GHG emission goals and the related national goals for 2020, 2030 and 2050. The low carbon economy in 2050 implies a 95% reduction of GHG emissions compared to the GHG emission level in 1990. For 2030, the Dutch government has formulated a 49% GHG emission reduction (Dutch Government 2019).

Resource efficiency is a broad concept and can be operationalised in many ways. In the SDM of the Dutch case, there are three elements that to resource efficiency in three different Nexus sectors namely water, energy and land, see Table 29. Note however that the SDM does not cover all aspects of resource efficiency. First, there is the policy objective of reducing nitrogen and phosphate emissions to surface water to achieve the good water quality status required by the Water Frame Directive. In the Dutch case, the policy objective is related to the pollution of diffuse source in agriculture. Secondly, there is an objective to ensure sustainable use of (woody) biomass. Energy from biomass and particularly from wood (residues) is debated heavily from a sustainability perspective. Therefore, more sustainable use of woody biomass is advocated. Thirdly, there was a policy for less intensive use of the soil to use the soil as a source for carbon sequestration.

The objectives of the climate Nexus sector are obviously connected to the low-carbon economy objective. However, lower levels of greenhouse gas emissions can also be linked to an improvement of resource efficiency. In the Dutch case, we considered two sub-objectives namely agricultural and non-agricultural GHG emissions. The reason to do so is that agricultural emissions are not so much related to energy use and capture mainly methane (CH_4) and nitrous dioxide (N_2O) emissions. In addition, the policy cards to reduce emissions are also different from the policy cards reducing non-agricultural GHG emissions. In this way, we can put more emphasis on (or weight to) the reduction of agriculture-related GHG emissions.

Table 29 Policy objectives of the Nexus sectors in the Dutch case study

NEXUS SECTOR	POLICY OBJECTIVE	POLICY OBJECTIVE: DESCRIPTION	OCERARCHING OBJECTIVES
WATER	SUSTAINABLE USE OF WATER RESOURCES: GOOD WATER QUAILTY OF SURFACE AND GROUND WATER	LESS NUTRIENT EMISSIONS FROM AGRICULTURE TO WATER	RESOURCE EFFICIENCY
		REDUCTION OF WATER DEMAND BY AGRICULTURE	
ENERGY		SHARE OF RENEWABLES TO 100%	

	OPTIMAL USE OF RENEWABLES FOR ENERGY AND APPLYING CASCADE PRINCIPLE FOR BIOMASS	TO INCREASE NON-ENERGY USE OF BIOMASS (INDUSTRY)	RESOURCE EFFICIENCY
FOOD	VIABLE AGRICULTURE SECTOR AND HEALTHY POPULATION	IMPROVING AREA WITH HIGH VALUE CROPS	
		TO INCREASE PLANT PROTEINS IN DIETS	
LAND	SUSTAINABLE LAND USE	KEEP OR INCREASE PROTECTED AREA (NATURA 2000)	
		PROMOTE NATURE INCLUSIVE FARMING: CROP ROTATION WITH LESS INTENSIVE CROPS	RESOURCE EFFICIENCY
CLIMATE	CLIMATE POLICY	95% REDUCTION OF TOTAL NON-AGRICULTURE GHG EMISSIONS IN 2050	LOW-CARBON ECONOMY
		95% REDUCTION OF TOTAL AGRICULTURE GHG EMISSIONS IN 2050	LOW-CARBON ECONOMY

In the Dutch case study, there are two scenarios used: the Baseline scenario and the 2°C Climate scenario, see (Munaretto and Witmer 2018).

The general Baseline scenario in SIM4NEXUS is defined as the SSP2 with policies implemented and under implementation up to but not including the UNFCCC Paris agreement that was agreed in December 2015. This date also sets the limit to the policies for the other Nexus sectors. All policies in the Baseline are accepted, instrumented and financed up to December 2015, but no later policies. E.g. the CAP 2014-2020 is included in the Baseline, as it was agreed in 2014. The EU energy/climate package for 2020 is included in the Baseline, as it was accepted policy before the Paris agreement. The EU energy/climate package released in 2016 with goals for 2030 is not included in the Baseline.

Policy scenarios: The 2°C Climate scenario is a climate goal 'back casting' scenario that assumes that the goal of the Paris agreement will be reached, under certain assumptions about socio-economic trends and policies till 2050. The scenario e.g. assumes high CO_2 prices. The meaning of this scenario is to assess the possible changes in e.g. economy, trade and land use in Europe and the world if the 2°C goal for all countries will be reached by 2050 according to the RCP 2.6 pathway (van Vuuren et al. 2011).

The Baseline scenario was used as the reference for the SDM of the Dutch case study. Players will be able to choose policy cards to achieve the policy objectives. The policy cards are constructed in such a way that the 2 degrees scenario can be reached when playing the game.

The cases can compare the assumptions about policies included in these general scenarios with the national and regional policies defined in their own cases and decide which of their own policies match with a general goal scenario. E.g. national and regional energy/climate policies based on the EU 2020 climate package and national and regional agriculture policies based on the CAP 2014-2020 are part of the Baseline. Stricter policies and policies for 2030 and 2050 are part of goal scenarios, either general or case-specific (Munaretto and Witmer 2018).

8.4.2.2 Introduction of policy scenarios in the SDM

The SDM includes information from two scenarios. The reference scenario is the baseline scenario, see previous section. The results of the baseline scenario of the thematic models were included in the base model of the SDM. In addition, policy cards are formulated, so that players can build their own scenarios without any prior information of possible climate scenarios. However, the policy cards are formulated in such a way that the 2°C Climate scenario can be met. In this way, multiple pathways for the climate scenarios could result from the SDM and SG for the Netherlands.

In the SDM, combinations of parameters of indicators are triggered by the individual policy cards. None of the policy cards affect the same set of parameters/indicators in the SDM. Many policy cards are no single period interventions.

The full version of the SDM includes the policy cards, which are separate indicators in the model. Most policy cards affect at least two indicators at the same time.

8.4.3 Modifications introduced to account for data availability

8.4.3.1 Data available from the thematic models

The thematic models mainly enabled the construction of databases used for the SDM consistent with the SIM4NEXUS scenarios. The data from these models offered opportunities to analyse the different domains of the Nexus in much more detail in a more consistent way as compared to a situation in which everything would have been constructed from scratch. The models include the impact of dynamics that go beyond the Netherlands (European and Global). The models offer opportunities to include time series on flows of resources, environmental impacts (GHG emissions, nitrogen and phosphate emissions, etc.) but also economic data.

The thematic models needed to be supplemented with (sometimes more detailed) data from other sources as for the parts on energy and non-agricultural land use (e.g. nature areas). The data were often discussed with stakeholders and experts in specific fields of the Nexus. In addition, the results of the thematic models were also used to calibrate the policy cards to develop consistent policy cards taking into the assumptions and mechanisms build in into the thematic models. Policy cards were discussed in several rounds with different stakeholders (policy, business and research). These sessions were meant to go into more depth. These sessions allowed to fill data gaps and to incorporate additional knowledge.

For the SDM, there were inputs from 3 thematic models: CAPRI, E3ME and MAGNET.

From CAPRI, there are 21 indicators for the Dutch SDM, see Table 30. The indicators used were on twelve land use indicators (ha), six yield coefficients on the crops grown (ton/ha) and three herd size indicators for the main animal categories (millions).

Table 30 Indicators derived from CAPRI on land use (1-12), crop yields (13-18) and herd size indicators for the main animal categories (9-21)

	INDICATOR	DESCRIPTION	UNITS
1	LU_AGR_EC_TOT	LAND USED TO CULTIVATE ALL CROPS TO PRODUCE BIOMASS	HA
2	LU_AGR_FOOD_CEREALS	LAND USED TO CULTIVATE CEREALS FOR FOOD & FIBRE	HA
3	LU_AGR_FOOD_SUGARBEET	LAND USED TO CULTIVATE SUGAR BEET FOR FOOD & FIBRE	HA
4	LU_AGR_FOOD_POTATOES	LAND USED TO CULTIVATE POTATOES FOR FOOD & FIBRE	HA
5	LU_AGR_FOOD_VEG	LAND USED TO CULTIVATE VEGETABLES AND PERMANENT CROPS FOR FOOD & FIBRE	HA
6	LU_AGR_FOOD_OTHER	LAND USED TO CULTIVATE OTHER CROPS FOR FOOD & FIBRE	HA
7	LU_AGR_FOOD_HVCROPSBASE	LAND USED TO CULTIVATE HIGH VALUE CROPS) BASELINE)	HA
8	LU_AGR_FOOD_VEGBASE	LAND USED TO CULTIVATE VEGETABLES AND PERMANENT CROPS FOR FOOD & FIBRE (BASELINE)	HA
9	LU_AGR_FOOD_OTHERBASE	LAND USED TO CULTIVATE OTHER CROPS FOR FOOD & FIBRE (BASELINE)	HA
10	LU_AGR_FODDER_GRASSTOT*	TOTAL GRASSLAND (PEAT, CLAY AND SANDY SOILS)	HA
11	LU_AGR_FODDER_MAIZE	LAND USED TO CULTIVATE MAIZE FOR FODDER	HA
12	LU_AGR_FODDER_OTHER	LAND USED TO CULTIVATE OTHER CROPS FOR FODDER	HA

13	YC_FODDER_MAIZE	PRODUCTION PER HA OF FODDER MAIZE	TON/HA
14	YC_FODDER_OTHER	PRODUCTION PER HA OF OTHER FODDER CROPS	TON/HA
15	YC_FODDER_GRASSSAND	PRODUCTION PER HA OF GRASS	TON/HA
16	YC_SUGARBEET	YIELD COEFFICIENT SUGAR BEET (TON/HA)	TON/HA
17	YC_CEREALS	YIELD COEFFICIENT CEREALS (TON/HA)	TON/HA
18	YC_POTATOES	YIELD COEFFICIENT POTATOES (TON/HA)	TON/HA
19	N_PIGS	NUMBER OF HEADS (PIGS)	MILLION
20	N_POULTRY	NUMBER OF HEADS (POULTRY)	MILLION
21	N_CATTLE	NUMBER OF HEADS (CATTLE)	MILLION

For grassland (lu_AGR_Fodder_grassTOT, number 10), we distinguished three soil types: peat soil, clay soil and sandy soil because soil type is important for the potential of carbon sequestration and emissions. This distribution of the soil types was collected from Statistics Netherlands.

From E3ME, there were 30 indicators derived for the SDM for the Dutch case, see Table 31. There are 10 indicators on energy demand for economic sectors (domestic sector, DOM; agriculture, AGR; Manufacturing industry, IND; Transport sector, TRA; and Services sector, OTH), four on energy production, six on GHG emissions, and six economic indicators on value added and GDP.

Table 31 Indicators derived from E3ME on energy intensity for economic sectors (1-11), energy production (12-14), GHG emissions (15-20), value added (21-24), GDP (25-26) and GHG per PJ (27-30)

	INDICATOR	DESCRIPTION	UNITS
1	EI_AGR_NRE_BASE	NON-RENEWABLE ENERGY INTENSITY IN THE AGRICULTURAL SECTOR (BASE)	GJ/EUR
2	EI_AGR_RE_BASE	RENEWABLE ENERGY INTENSITY OF THE AGRICULTURE SECTOR (BASE)	GJ/EUR
3	EI_IND_NRE_BASE	NON-RENEWABLE ENERGY INTENSITY IN THE INDUSTRY SECTOR (BASE)	GJ/EUR
4	EI_IND_RE_BASE	RENEWABLE ENERGY INTENSITY IN THE INDUSTRY SECTOR (BASE)	GJ/EUR
5	EI_TRA_NRE_BASE	NON-RENEWABLE ENERGY INTENSITY IN THE TRANSPORT SECTOR (BASE)	GJ/EUR
6	EI_TRA_RE_BASE	RENEWABLE ENERGY INTENSITY IN THE TRANSPORT SECTOR (BASE)	GJ/EUR
7	EI_OTH_NRE_BASE	NON-RENEWABLE ENERGY INTENSITY IN THE SERVICES SECTOR (BASE)	GJ/EUR
8	EI_OTH_RE_BASE	RENEWABLE ENERGY INTENSITY IN THE SERVICES SECTOR (BASE)	GJ/EUR
9	EI_DOM_NRE_BASE	NON-RENEWABLE ENERGY INTENSITY IN THE DOMESTIC SECTOR (BASE)	GJ/EUR
10	EI_DOM_RE_BASE	RENEWABLE ENERGY INTENSITY IN THE DOMESTIC SECTOR (BASE)	GJ/EUR
11	AV_RE	DEMAND FOR BIOMASS OF RE PRODUCTION	MTON
12	PE_COAL_BASE	PRIMARY ENERGY FROM COAL (BASELINE)	PJ
13	PE_OIL_BASE	PRIMARY ENERGY FROM OIL (BASELINE)	PJ
14	PE_GAS_BASE	PRIMARY ENERGY FROM GAS (BASELINE)	PJ
15	E_GHG_TRA	GHG EMISSIONS FOR TRANSPORTATION	MTON CO2
16	E_GHG_IND	GHG EMISSIONS FOR INDUSTRY	MTON CO2
17	E_GHG_DOM	GHG EMISSIONS FOR DOMESTIC SECTOR	MTON CO2
18	E_GHG_OTH	GHG EMISSIONS PER PJ FOR OTHER SECTORS	MTON CO2
19	E_GHG_NONAGR_BASE	NON-AGRICULTURAL GHG EMISSIONS	MTON CO2
20	E_GHG_AGR_BASE	AGRICULTURAL GHG EMISSIONS	MTON CO2
21	VA_AGR	VALUE ADDED AGRICULTURE	EUR BN
22	VA_IND	VALUE ADDED INDUSTRY	EUR BN
23	VA_TRA	VALUE ADDED TRANSPORTATION	EUR BN
24	VA_OTH	VALUE ADDED OTHER SECTORS	EUR BN
25	GDP_TOT	GROSS DOMESTIC PRODUCT	EUR BN
26	GDP_REST	DIFFERENCE GDP AND SUM OF VA	EUR BN
27	EF_GHG_NRE_COAL	GHG EMISSIONS PER PJ FOR COAL	MTON CO2/PJ

28	EF_GHG_NRE_OIL	GHG EMISSIONS PER PJ FOR OILL	MTON CO2/PJ
29	EF_GHG_NRE_GAS	GHG EMISSIONS PER PJ FOR GAS	MTON CO2/PJ
30	EF_GHG_NRE_NUCLEAR	GHG EMISSIONS PER PJ FOR NUCLEAR	MTON CO2/PJ

The energy demand indicator is derived from E3ME results. E3ME has output on energy use for 23 economic sectors and the 6 energy carriers (coal, oil, gas, electricity, heat and biomass). The 23 economic sectors were aggregated to 5 economic sectors in the Dutch SDM, see Table 32.

Table 32 SDM sectors derived from the economic sectors in E3ME

SDM SECTOR	E3ME SECTOR	
MANUFACTURING INDUSTRIES	1 POWER OWN USE & TRANS.	8 ORE-EXTRA (NON-ENERGY)
	2 ENERGY OWN USE & TRA	9 FOOD, DRINK & TOB.
	3 HYDROGEN PRODUCTION	10 TEX., CLOTH. & FOOTW.
	4 IRON & STEEL	11 PAPER & PULP
	5 NON-FERROUS METALS	12 ENGINEERING ETC
	6 CHEMICALS	13 OTHER INDUSTRY
	7 NON-METALLICS NES	14 CONSTRUCTION
TRANSPORT SECTOR	15 RAIL TRANSPORT	17 AIR TRANSPORT
	16 ROAD TRANSPORT	18 OTHER TRANSP. SERV.
DOMESTIC SECTOR	19 HOUSEHOLDS	
AGRICULTURE AND FORESTRY	20 AGRICULTURE, FORESTRY	21 FISHING
SERVICE SECTOR	22 OTHER FINAL USE	23 NON-ENERGY USE

The six energy carriers do not correspond uniquely to renewable and non-renewable energy use. The energy carrier biomass is renewable energy. The energy carrier electricity is partially renewable (from solar power, wind power, and biomass) and partially non-renewable such as nuclear energy. Based on supplementary data sources from Statistics Netherlands and policy documents, the renewable electricity share was estimated. Energy based on coal, oil, gas and heat are assumed to be non-renewables. Note that we considered heat as an integral part of non-renewable energy carriers. Thus, renewable energy use includes the energy carriers biomass and the renewable electricity (solar, wind and biomass). The non-renewable energy includes the energy carriers coal, oil, gas, heat and the non-renewable part of electricity.

The E3ME data on energy production and consumption were not available in the detail as required for the Dutch SDM. Additional data had to be collected on different types of biomass as this data was only available in an aggregated way. For the different types of biomass for energy additional data was collected from Statistics Netherlands. Information from solar power fields as an alternative way of "cultivating" agricultural area and off-shore wind park wind were collected from a combination of Statistics Netherlands and Environmental Data Compendium (Statistics Netherlands, PBL, RIVM and WUR). In addition to these data sources, policy plans until 2030 for these renewables were included the baseline.

8.4.3.2 Local data to be collected

In addition to the indicators with data from the thematic models, we have collected a list of additional indicators, Table 33. The main data sources are Statistics Netherlands and the Environmental Data Compendium Statistics Netherlands, PBL, RIVM and WUR).

Table 33 SDM sectors derived from the economic sectors in E3ME

Variable	Description	Unit
lu_RE_windOn-shore	Land for on-shore wind power	ha
lu_RE_solarRural	Land use for solar power fields in rural areas	ha
luc_URB_pop	urban land per person	ha/person
lu_NAT_non-forest	Land for protected area (non-forests)	ha
lu_NAT_forestN	Land for natural forests	ha
lu_NAT_forestB	Land for forests for biomass	ha

Variable	Description	Unit
pol_NAT_TOT_target	Policy objective for land for nature (target)	ha
pei_***_NRE	Price elasticity of non-renewable energy intensity in the agricultural sector	Unit
cpei_***_RE-NRE	Cross-price elasticitity of non-renewable energy intensity in the agricultural sector	Unit
cpei_***_NRE-RE	Cross-price elasticitity of renewable energy intensity in the agricultural sector	Unit
pei_***_RE	Price elasticity of renewable energy intensity in the agricultural sector	Unit
av_biomass_import	Total importsDemand for biomass per unit of VA of the industry	Mton
se_RE_other	available energy from other renewable sources	PJ
caf_CR	capacity factor energy from crop residues	PJ/Mton
caf_EC	capacity factor energy from energy crops	PJ/Mton
caf_forest	capacity factor energy from forest residues	PJ/Mton
caf_manure	capacity factor energy from manure	PJ/Mton
caf_organic_private	capacity factor energy from organic waste (collected)	PJ/Mton
caf_organic_public	capacity factor energy from organic waste (public)	PJ/Mton
caf_WasteWater	capacity factor energy from waste water	PJ/Mton
dm_EC_import	import of EC biomass	Mton DM
eec_CR	energy efficiency coefficient of crop residues	%
eec_EC	energy efficiency coefficient of energy crop	%
eec_forest	energy efficiency coefficient forest residues	%
eec_manure	energy efficiency coefficient of manure	%
eec_organic_private	energy efficiency coefficient of organic waste (collected)	%
eec_organic_public	energy efficiency coefficient of organic waste (road sides etc.)	%
eec_WasteWater	energy efficiency coefficient of waste water	%
eec_coal	energy efficiency coefficient of coal	%
eec_oil	energy efficiency coefficient of oil	%
eec_gas	energy efficiency coefficient of gas	%
eec_nuclear	energy efficiency coefficient of nuclear	%
pe_nuclear	primary energy from nuclear	PJ
av_import_RE	Dry matter of biomass for energy production	%
bd_IND_energy	Demand for dry matter of biomass for chemical industry	Mton
caf_import_RE	Capacity factor of imported biomass for energy production	PJ/Mton
caf_Wind_off-shore	Capacity factor of off-shore wind	PJ/ha
caf_Wind_on-shore	Capacity factor of on-shore wind	PJ/ha
eec_Wind_off-shore	energy efficiency coefficient of on-shore wind power	%
eec_Wind_on-shore	energy efficiency coefficient of on-shore wind power	%
caf_Solar	Capacity factor of energy per unit of land	PJ/ha
caf_Solar_urban	Share of urban land used for solar power roofs	%
pe_Solar_rural	installed capacity of rural solar power	PJ
pe_Solar_urban	installed capacity of urban solar power	PJ
eec_Solar	energy efficiency of solar power	%
dmf_livestock_cattle	Fraction of dry matter of cattle manure	%
dmf_livestock_pigs	Fraction of dry matter of pigs manure	%
dmf_livestock_poultry	Fraction of dry matter of poultry manure	%
d_fodder_cattle	demand for fodder from cattle	Mton
d_fodder_pigs	demand for fodder from pigs	Mton
d_fodder_poultry	demand for fodder from poultry	Mton
d_protein_plant_base	Demand for food - protein plant-based	kg/cap/day
d_protein_plant	Demand for food - protein plant-based	kg/cap/day
d_protein_animal_base	Demand for food - protein animal-based	kg/cap/day
d_protein_animal	Demand for food - protein animal-based	kg/cap/day
d_cal	Demand for food - calories	kcal/cap/day
yc_EC_maize	Yield coefficient of maize	ton/ha
yc_EC_hemp	Yield coefficient of hemp	ton/ha
yc_EC_misc	Yield coefficient of misc	ton/ha
yc_EC_raps	Yield coefficient of rape seed	ton/ha
yc_EC_oth	Yield coefficient of oth	ton/ha
share_energy_maize	Share of maize yield for energy	%
share_energy_hemp	Share of hemp yield for energy	%
share_energy_misc	Share of misc yield for energy	%
share_energy_raps	Share of raps yield for energy	%
share_energy_oth	Share of other energy crops yield for energy	%
yc_biomass_Forest	Yield coefficient of biomass from forest	m3/ha
res_Potatoes	Residues of potatoes	%
cf_Sugarbeet_cal	coefficient of calories in sugar beet	kg kcal/kg
cf_Cereals_cal	coefficient of calories in cereals	kg kcal/kg

Variable	Description	Unit
cf_Potatoes_cal	coefficient of calories in potatoes	kg kcal/kg
cf_Sugarbeet_protein	coefficient of proteins in sugar beet	kg protein/kg
cf_Cereals_protein	coefficient of proteins in cereals	kg protein/kg
cf_Potatoes_protein	coefficient of proteins in potatoes	kg protein/kg
cf_Vegetables_cal	coefficient of calories in vegetables	kg kcal/kg
cf_Other_cal	coefficient of calories in other arable crops	kg kcal/kg
cf_Vegetables_protein	coefficient of proteins in vegetables	kg protein/kg
cf_Other_protein	coefficient of proteins in other	kg protein/kg
crs_Sugarbeet	Share of crop residues of sugar beet	%
crs_Cereals	Share of crop residues of cereals	%
dmf_Sugarbeet	share of dry matter of sugar beet	%
dmf_Cereals	share of dry matter of cereals	%
dmf_Potatoes	share of dry matter of potatoes	%
dm_organic_Public	Dry matter capacity of waste from public places	%
dm_organic_Private	Dry matter capacity of waste from private places	%
waf_organic_Private	Organic waste (private) per month per mln people (dry matter)	ton/person
waf_organic_Public	Organic waste (private) per month per ha	ton/person
dm_WasteWater	Dry matter capacity of waste from waste water	Mton
waf_WasteWater	Organic waste per month per mln persons (dry matter)	Mton/bn EUR
ef_N_grassSand	Emission factor of N per ha grassland on sandy soils	kg/ha
ef_P_grassSand	Emission factor of P per ha grassland on sandy soils	kg/ha
ef_N_grassPeat	Emission factor of N per ha grassland on peatlands	kg/ha
ef_P_grassPeat	Emission factor of P per ha grassland on peatlands	kg/ha
ef_N_grassClay	Emission factor of N per ha grassland on clay soils	kg/ha
ef_P_grassClay	Emission factor of P per ha grassland on clay soils	kg/ha
ef_N_Maize	Emission factor of N per ha maize	kg/ha
ef_P_Maize	Emission factor of P per ha maize	kg/ha
ef_N_OtherFodder	Emission factor of N per ha other fodder crops	kg/ha
ef_P_OtherFodder	Emission factor of P per ha other fodder crops	kg/ha
ef_N_SugarBeet	Emission factor of N per ha sugar beet	kg/ha
ef_P_SugarBeet	Emission factor of P per ha sugar beet	kg/ha
ef_N_Ceareals	Emission factor of N per ha grassland on peatlands	kg/ha
ef_P_Ceareals	Emission factor of P per ha grassland on peatlands	kg/ha
ef_N_Potatoes	Emission factor of N per ha potatoes	kg/ha
ef_P_Potatoes	Emission factor of P per ha potatoes	kg/ha
ef_N_veg	Emission factor of N per ha vegetables	kg/ha
ef_P_veg	Emission factor of P per ha vegetables	kg/ha
ef_N_OtherFood	Emission factor of N per ha other fodder crops	kg/ha
ef_P_OtherFood	Emission factor of P per ha other fodder crops	kg/ha
wf_crops_arable	water demand per ha of arable land	m3/ha
wf_crops_fodder_maize	water demand per ha of fodder maize land	m3/ha
wf_crops_EC	water demand per ha of energy crop land	m3/ha
wf_forest	water demand per ha of forest land	m3/ha
wf_livestock_cattle	water demand per head for cattle	m3/head
wf_livestock_pigs	water demand per head for pigs	m3/head
wf_livestock_poultry	water demand per head for poultry	m3/head
pol_AGR_wd_target	water demand agriculture (target)	km3
ef_GHG_Forest	GHG emissions factor for forests	ton CO2/ha
ef_GHG_Peatland_base	GHG emissions factor per ha from peatlands (base)	Mton/Mha
ef_GHG_livestock_cattleBase	GHG emissions factor per head from cattle (baseline)	Mton/mln animals
ef_GHG_livestock_pigsBase	GHG emissions factor per head from pigs (baseline)	Mton/mln animals
ef_GHG_livestock_poultryBase	GHG emissions factor per head from poultry (baseline)	Mton/mln animals
pol_GHG_NonAGR_target	Non-agricultural GHG emission target	Mton CO2
pol_GHG_AGR_target	agricultural GHG emission target	Mton CO2
POP_	Population	millions

8.4.4 Case Study SDM in Stella/R

The SDM of the Dutch case consists of 6 subsystems, which are the five Nexus sectors and a socio-economic sector, see Figure 66. The socioeconomic system includes population and economic developments of the four production sectors distinguished. The socioeconomic subsystem is connected to the Land subsystem (demand for build-up areas for housing and infrastructure), energy (energy demand per sector) and Food subsystem(demand for food).

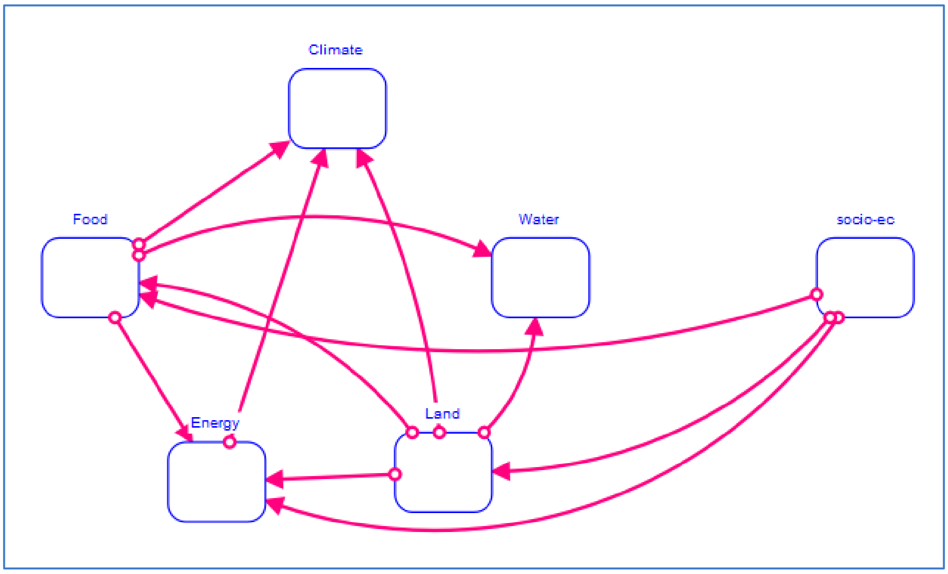


Figure 66 The main structure of the SDM of the Dutch conceptual model

The land subsystem includes different types of land use such as the build-up area, cultivated area for agricultural activities, nature and renewable energy technologies, such as solar power fields and on-shore wind power turbines. The land subsystem is connected to the energy subsystem (available land for renewable energy), food subsystem (available land for agricultural production), climate subsystem (emissions from peat land amongst others) and the water subsystem (water demand of agricultural activities and emissions from agricultural activities).

The food subsystem includes the production of food crops, fodder crops, energy crops and livestock. Moreover, the food crops also determine the availability of crop residues, and the livestock determines the amount of manure. For convenience, other biomass production is included as well in the food system, such as forestry residues, wastewater, and organic waste from households and public places. The food subsystem connects to the energy subsystem (supply of different types of biomass), the water system (water demand for agricultural production) and climate (non-energy related GHG emissions).

The energy subsystem includes the demand for energy and the supply of energy. The energy subsystem is connected to climate due to the GHG emissions from energy production. In addition, the energy subsystem also includes the biomass demand of the Manufacturing industry as resources for production.

The SDM for the Netherlands considers one geographical unit: the Netherlands. It distinguishes different economic sectors as mentioned above. The land subsystem, the agricultural subsystem and the energy subsystem were more sophistically developed.

8.5 From the System Dynamic Modelling to the Serious Game

8.5.1 Case studies learnings goals

The goal of the Dutch case study is to explore the role of biomass in the identification of low-carbon and resource-efficient pathways for the Nexus under the condition of climate change. It focused on biomass in climate mitigation and adaptation strategies and relations with land use, water, agriculture and food production. For example, the shift towards a low-carbon economy influences energy, land-use and the nutrient cycle, but it has consequences for the water demand as well. The case study assessed the socioeconomic, environmental (water, land, climate) and technological consequences of and conditions for pathways to a low-carbon and resource-efficient economy in the Netherlands including import and export. The pathways to a low-carbon economy should be identified in close cooperation with stakeholders such as private sector, policy makers at different levels and from different sectors, governmental and research organizations. The case study investigates mid-term and long-term trends and policy options. The research results raise awareness among policy-makers and other stakeholders about connections between the sectors in the Nexus, sector policy goals and instruments, synergies, conflicts and trade-offs.

The Dutch case has three main learning goals:
1. You will learn how policies aiming for a low-carbon and resource-efficient economy in the Netherlands with reduced energy demand, more renewable energy production from biomass and other sources and reduced greenhouse gas emissions, can affect land and water use in the Netherlands and abroad by import and export, agricultural production, and risks of flooding and droughts under different climate change scenarios.

2. You will learn to make choices and balance interests between policies by experiencing how changes with policy cards (or policy interventions) will affect the other Nexus sectors over time.

3. You will learn how the need for biomass as a renewable energy source may conflict or have synergies with the creation of a bio-based and circular economy. For example it will give insight in the debate on small-scale biomass (from energy crops, crop residues, manure, wastewater and organic waste) versus large scale woody biomass from imports or grown in the Netherlands which are sometimes considered to be unsustainable (imports) or take up a large share of the land use in the Netherlands and would take a long period of time to become productive.

8.5.2 From generic to specific use cases

In general, "a use case defines which the different paths of interaction between the user and the SG are. It captures possible ways the user may follow to achieve a specified goal, as well as alternative paths and/or results if feasible, such as things that can go wrong in the process" (see D1.2). The Dutch use cases are in line with this general definition but have been made more specific to the Dutch context, e.g. related to specific types of land use in the Netherlands (peat) or the ongoing Dutch policy debate. In general, the Dutch government has been engaged in a lengthy multi-stakeholder approach (governments, business sector and NGOs) to tackle many of the problems associated with biomass (Selnes, Linderhof, and Marinissen 2017). However, plenty work remains and many stakeholders view the policy still to be fragmented with too much administrative red-tape.

In this context, we developed use cases with learning goals for A) energy, B) climate, C) land, and D) food. The use cases focus on the ministry of Economic Affairs and Climate Policy (Energy and Climate) Staatsbosbeheer - a public land management authority - and the ministry of Agriculture, Nature and Food Quality (Food). In practice, the different ministries cooperate in the Netherlands and we only mentioned the main responsible ministry. The use cases are also relevant for lower governance levels like provinces and regions. The use case will depend on the regional context of the lower governance levels. The use cases cover different actions involving more than 1 sector of the Nexus. The cases focus on the share of renewable energy, capturing carbon, land use changes, and food production and consumptions. Representative use cases are described in more detail below for illustrative purposes. There is no specific use case for water although interlinkages are covered. Several policy cards are included on other Nexus elements that strongly deal with water related issues (e.g. switch from coal power to biomass generation and land use changes related to nitrogen emissions).

We adapted the use cases for the different Nexus elements as follows:

1. Energy

Energy is central to the Dutch case study. The main goal is reduction of GHG emissions. The Dutch case is in line with the use cases on Renewable Energy Targets (RET) and focusses on increasing the share of renewable energy and mainly focusses at the government. Currently, renewable energy is debated in the Netherlands and is expected to attract players of the game. Several actions and indicators specific to the Dutch context are distinguished. It needs to be stressed that the SDM is for learning purposes as compared to studies in the Netherlands which are in much more detail for purpose of policy advices.

2. Climate

Climate related use cases are important within the current debate in the Netherlands. The main goal of the use case is to reduce GHG emissions. The use case will be beneficial to support the learning experiences. Change of GHG emissions is of central interest for discussions.

3. Land

The use Cases for land depict from the point of view of a governmental player two different goals: sustainable management of land and reduce emissions from peatland. The modelling of the actions is dependent on the Dutch context (e.g. peat) A land use related case study is formulated in the context of a decreasing agricultural area in the Netherlands. Different indicators are available to show the effects of the actions and to give a meaningful experience in the Serious Game. The user is Staatsbosbeheer, which is a forest/land management organisation commissioned by the Dutch government to strengthen the position of nature in the Netherlands. As a leading national public body and as land owner and manager of a sizeable amount of nature reserves Staatsbosbeheer works to conserve and develop the Netherlands' characteristic green heritage. Together with society, Staatsbosbeheer is committed to ensuring that current and future generations can experience the many essential values of nature, balanced with sustainable use of our protected areas.

4. Food

The primary goal of the use case is sustainable food production and consumption. The actions deal with influencing the demand for plant-based proteins and crop production. This use case is linked to the use case on healthy diets and sustainable food systems in deliverable 1.2. The Dutch food use cases are developed to support the debate on sustainable food production. Plant based diets are of interest to different stakeholders.

8.5.3 Policy cards

The policy scenarios tables have been transformed into the format of policy cards (Munaretto and Witmer 2018). A policy scenario is defined as a package of policy interventions. In the Serious Game, these policy cards can be placed in a timeline, to reach policy objectives and policy goals. Policy interventions may be policy instruments, e.g. a law, subsidy, tax, communication campaign, or measures, e.g. repair leaking water infrastructure, insulate a house, reforestation. In SIM4NEXUS, both policy instruments and measures are referred to as interventions. The Baseline scenario was used as a reference for all other policy cards. In the Dutch case, both policy cards that are favourable for the whole Nexus and for specific sectors were included. The policy cards were turned into model terms in an interactive way which implied that we went back to the SDM several times and adjusted the SDM in several rounds.

In the 4th workshop with stakeholders in October 2019 with a focus on policy cards and the game itself, the policy cards have been discussed extensively. The use of general labels for policy instruments was considered too confusing. It was argued that instruments like subsidies or standardisation could lead to normative judgements about the type of instruments. It was not immediately clear what constitutes a policy instrument and what does not. The player will not consider the instruments to be neutral as he or she could just dislike subsidies, taxes or communication campaigns. It was suggested to focus more on technical issues and/or neutral formulations. Combining policy instruments with (several) technical measures was considered not to be a good idea because it could be confusing as well.

As a result, we applied the following principles in describing policy cards:

- To focus on interventions (techniques, practices and innovations) without general policy related labels
- To avoid a normative story
- To be aware of for the intervention logic in the policy cads

By applying these principles, the Dutch policy cards have become more concrete. Table 34 gives an overview of the Dutch policy cards for Nexus sectors and economic sectors. The water dimension of the Nexus is not explicitly included in table 11. Interlinkages to the water sector and the impact are part of the SDM.

Table 34 Policy cards for the Dutch case for different Nexus and economic sectors

	AGRICULTURE	DOMESTIC	INDUSTRY *	SERVICE SECTOR	TRAN-SPORT	ALL SECTORS	TOTAL
CLIMATE	1	2	2	0	0	2	7
ENERGY	3	4	7	2	3	0	19
FOOD	1	1	0	0	0	0	2
LAND	4	0	2	0	0	0	6
TOTAL	9	7	11	2	3	2	34

Remark: the sector ”Industry” includes the energy production sector.

Most policy cards are in the agricultural sector, domestic and industry. These policy cards focus to a large extent on energy related measures, followed by climate and land. The Dutch policy cards are not classified as water related issues. However, some policy cards could have been classified under the sector water, like a peat land related policy card or to stimulate high value crop production (leading to a higher water demand). Policy goals deal with all Nexus elements: water, energy, food, land and climate.

The next step was to determine if the policy was permanent and whether it could be applied several times or not. This followed from the type of intervention. Most policies were not applied in a pre-game setting. The costs of the intervention and economic value generated have been estimated in a rough way where the Netherlands as whole was leading. The order of magnitude (high, medium or low) have been chosen in relation to the importance of the economic sector for the Dutch economy and the impact on the measure within a sector. Social capital required and generated has been roughly estimated on basis of the impact it would have on different people depending also on the visibility of a measure. 7 policy cards were also included in the thematic models (E3ME, CAPRI and MAGNET) and 27 were not.

8.5.4 Serious Game interface

At the end of March 2020, the Dutch Serious Game was still under development. Therefore, it is not yet possible to add screen shots this Section. The Greek example of the Serious Game has been used as a showcase for what the Dutch game could look like. This was very helpful to have a good discussion about the future potential of the game. The Dutch stakeholders were informed about (the design of) the Serious Game throughout the project (2017 – 2019) at several occasions, see Figure 67.

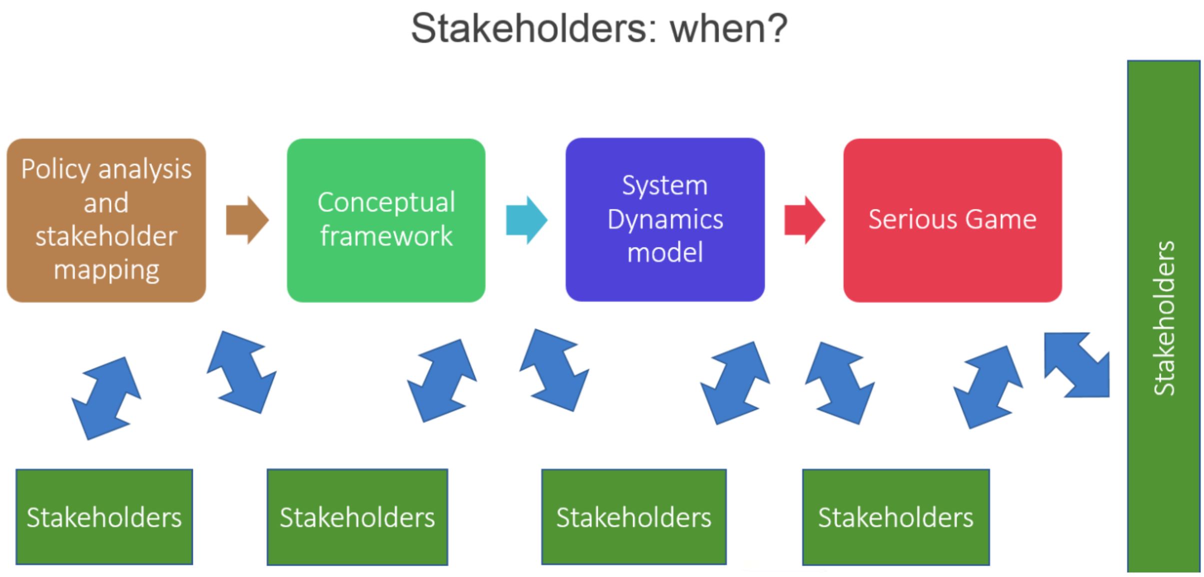


Figure 67 Different stages in stakeholder interaction towards developing Dutch Serious Game

In 2017, it was indicated to the stakeholders that the results of the workshops will partly determine the content and focus of the Serious Game to be developed. The game can be used to explore the role of biomass from different angles. Among other things, the Serious Game will indicate what the various options mean for the use of energy, land and water, food production and the emission of greenhouse gases. The field of tension between biomass for energy generation on the one hand and the economical use of raw materials on the other is an important point of attention for building the game. In 2017 it was also indicated that the advantage of the Serious Game approach is that the consequences of policy alternatives for the future can be visualized. Stakeholders can experience for themselves how their own actions help determine the future.

In 2018, it has been illustrated that the SDM and the Serious Game are linked. It has also been discussed that a spatial allocation by regions or a region as the starting point of the model was not yet possible at that time. The production of biomass is linked to regions and locations, which means that local and regional decision-making and instruments are also important. The project team indicates that the model is focused on the national scale of the Netherlands and has not been further spatially subdivided into regions, provinces, municipalities, river basins or otherwise. This option has not been further explored in 2019. There is only a rough division by soil types for grassland, but this division is not explicitly spatial.

The Greek case has been used to illustrate the way you play the game. For instance, it has been discussed that for the Serious Game to be developed on a national scale, local and regional interventions must add up to be relevant on a national scale. This also applies to policies on a local and regional scale, urban policies or policies of private entrepreneurs.

It was argued in 2018 that there is a lot of ignorance and fear about biomass. It was expected that the Serious Game could therefore play a role in education and information. The biomass sector is poorly organized compared to the compost sector in the past. However, the question is whether you can talk about one branch with all those different types of biomass and uses. In the Serious Game it is important to tot consider communication aspects about biomass.

In 2019, it was indicated that it is important to prevent policy cards from becoming normative in the game. This means that just too many contested terms such as prohibitions or commandments should not be used. Attention was also drawn to the logic behind the policy cards when a player would play the Serious Game. Can logical combinations of cards be played in the Serious Game (also in perspective of the time horizon in the Serious Game)? The time dimension is here of great importance. For a player playing the game sense making, including the time frames should play a role. It makes for instance sense to first build an infrastructure before you can deploy CCS. Forests also grow and sequester carbon over decades. Cutting trees, planting new ones and by that making the carbon release neutral takes a long time. The Serious Game should try to facilitate this time dimension. It was also argued that attention needs to be paid to the "soft part" of playing the game. It is therefore important to be able to include "quick wins" which are important for the psychology of motivation for continuing to play the game. For instance, policy cards that lead to quick wins in achieving the aim of the game lead to positive stimuli to (further) play the game. For this reason, quick wins have also been included in the policy cards. The current policy in the Netherlands has the time-frame as a crucial element. It is more and more about road mapping, which refers to changing needs as time goes by.

8.6 From the SDM and SG to policy recommendations

8.6.1 Answering main research questions of the case study

The main research question of the Dutch case was:

What is the role of biomass in the realization of a low-carbon and resource-efficient economy in the Netherlands in 2050?

There is a substantial policy role for biomass in the realization of a low-carbon and resource-efficient economy in the Netherlands in the future. Biomass is an essential part of the renewable energy mix because of its potential for significant CO_2 reductions against moderate costs. The use of biomass is very likely to increase over time (after 2030) with the target of 49% CO_2 reduction. Also, the role of biomass in terms of importance will then increase as the use of biomass is important in both the energy sector and the higher end of the circular economy (cascading). Many of the high-end applications are likely to come from this growing bio-based economy. The Dutch government acknowledges the opportunities and importance of the bio-based economy for the Netherlands and it has a special bio-based policy programme. An increase in productivity in agriculture and forestry alone is not enough to increase the biomass supply. Conversion technologies, innovation, and acceptance of the public are important subjects that need attention as well. Although electricity can be made from wind and solar power, transport and industry (process industry) need biomass as well. Import of biomass will play a major role, but also domestic rest streams, solid bio-waste and new developments as seaweed from the North Sea. The role of biomass now is mainly substantial where other renewables are less suitable, as industrial heating, high value resources (chemical industry), the transport sector (shipping, aviation, trucks) and as back-up for the regular electricity production.

Biomass could be useful as energy for reducing CO_2 emissions (Ros et al. 2016; Ros and Daniëls 2017). It does not require major changes to the energy system, it is not complex, short term effects are achievable and the technology is relatively inexpensive. However, the future supply of biomass is uncertain, and it is unclear whether there will be biomass for other purposes than those that are a priority, which is essentially where there are no sustainable alternatives. This means that biomass will not be available for cities, electricity, transportation of persons. The problem is that there is no international biomass market that comply with the Dutch sustainability criteria from the recent Energy Agreement. Strategies to enhance the domestic supply of biomass could then now become interesting.

What sectors and policy domains are important for the use of biomass in the Dutch transition towards a low-carbon and resource-efficient economy in 2050?

Biomass represents a very diverse 'sector' that involves many parts of the economy (and policy), such as waste, energy, food, feed, agriculture, land use, spatial planning, nature and water. Even other parts of the economy and policy are also important. The present framing of biomass as a part of the bio-based economy means that biomass is part of large portions of the economy. The energy sector and the chemical (high-end) sector are of key interest in this development. For the future, there are considerable uncertainties involved as it is not clear how much biomass will contribute to the greening of fuel, on land, water and air.

What are the main policy goals and policy instruments for these policy domains, and how coherent are these? How are they connected to EU and global policies?

The waste policy and biomass policy are very synergistic. When it comes to nature and agriculture, the policies seem coherent on the level of objectives, but the nature policy does not have any means to increase sustainable agricultural productivity and the agricultural policies' means to protect nature are not very effective. A nature inclusive agriculture is in the best interest of both sectors. To reduce the conflict between nature and agriculture it is good to focus on the synergies between the two of them and explore the possibilities for better integrated policies. Sustainable biomass production could play a role in such a process.

Coherence often at the level of policy-making – not policy practice

The results show a lot of synergies in comparison to only a few trade-offs. This is in line with what (International Council for Science 2016; McCormick and Kaberger 2007) found in their studies on policy interactions in the EU: policies are often coherent at the level of objectives and less at the implementation phase. This picture has been confirmed in this research. Being willing and able to tackle key barriers is pivotal to coherence between biomass/bio-energy, waste, agriculture, nature, food and spatial planning.

Biomass is seen as an important means for substituting carbon from fossil materials and it can be used for several non-food purposes. A challenge for the policy coherence is that biomass is used for both generating energy from biomass and for higher value usage in the (chemical) industry. The concept of cascading is here the key concept. Bio-energy is one of the lowest value applications of biomass. Higher value applications of biomass are still in an early stadium of development, but they are gaining interest with the focus on a bio-based economy. With more innovation this is likely to change over time. From an environmental point of view, the process of cascading is important and beneficial. But looking at the division of biomass sources in 2015 the category household and industrial waste forms more than one third of the total biomass production used for energy. Reducing waste means less waste that can be burned to get energy. Still, a relatively ambitious renewable energy target needs to be fulfilled soon of which bio-energy forms a substantial part.

Synergy between food and biomass

The objectives of food and biomass are mostly synergistic. This is because the government focuses on generating biomass from rest streams and not on the cultivation of energy crops. Regarding the Dutch biomass production, there are no biomass sources that can provide an oily basis for making fuels except pyrolysis. By importing these sources, problems of competition with food and indirect land use change are shifted to other countries. To prevent negative environmental impacts, the EU has imposed sustainability criteria on biofuel production in the Renewable Energy Directive in 2009. Critics pointed out that a potential policy failure lies in applying sustainability regulation to a single sector in a single region (Frank et al. 2013). The European Commission proposed in November 2016 a revised Renewable Energy Directive that includes updated sustainability criteria for solid and gaseous biomass and for biofuels used in transport and bioliquids. And the Dutch government states in Biomassa 2030 that the possibilities for one overarching sustainability framework for all resources (including biomass) is explored. In addition to that, efforts are made to create a European harmonized sustainability system for biomass. But most stakeholders argue that the sustainability criteria are not yet clear and not-binding.

Agriculture, nature and biomass: more synergy potential

The agricultural policy does not focus much on biomass as its core business is producing food and not rest streams. The focus is however increasing, as illustrated by the stimulation of area coalitions between farmers, provinces and other regional partners to establish or make use of synergy between water management, agriculture, sustainable production of energy and nature. Both policy-makers and others are increasingly aware of potential synergies between different sectors. Many industrial and environmental actors argue that CAP could be used more actively to stimulate such synergy instead of focussing on hectares and production. This discussion is however very sensitive in a political way, as it might result in a CAP that is open for more actors than just farmers.

The objective of a sustainable increase in agricultural productivity in the nature policy is interesting as agriculture and nature often are conflicting with each other. At present, much attention is paid to the linkages between nature and agriculture. Using an economic language is becoming common with the language of natural capital, a nature inclusive economy and green entrepreneurship in the nature policy. But this is also rather a dilemma for policy, as it aims for both using the economic potential of nature as well as conserving nature, and many legal issues play a role (Broekmeyer, Bastmeijer, and Kamphorst 2017). The potential conflicts between nature and agriculture is as such acknowledged in policy but incorporating objectives of one sector in the other does not mean these conflicts are solved. For example the measures of the CAP, created to achieve the greening objectives, are not effective according to several studies (Solazzo et al. 2016; Westhoek et al. 2012). 'Biomassa 2030' states that 'there is a need for a focused policy to realize an increase in productivity of agriculture and forestry' (Ministry of Economic Affairs and Ministry of Infrastructure and the Environment 2015). Without a focused policy on increasing biomass supply, the supply is likely to remain on the lowest side of the range in available potential. In the policy documents about nature, there are clear objectives on increasing forestry productivity and exact numbers and ambitions on this are captured in “Action Plan Forest and Wood”. In the agricultural policy documents, the objective to increase agricultural production sustainably is there, but no concrete measures for increasing productivity are present. In short, there are more opportunities for synergies between agriculture, nature, biomass and also water, a finding that is acknowledged both in policy (Biomass 2030) and research (Popp et al. 2014; Boosten et al. 2016).

Which stakeholders are involved and what are their positions, roles, power and relationships?

The Dutch way of policy-making is featured by extensive consultations among public actors and between public and private actors. Since 2011, a series of arrangements have been set up to address coherence, synergies, trade-offs in the biomass practice. One of the success factors in the Netherlands has been the (inter)active and ongoing dialogue between public and private stakeholders. Another success factor is the willingness to stimulate investments through public programmes for research, investments and business development for the short and long term. We should also mention the partnerships on cross-sector innovations carried forward by enthusiasm as a success factor. We have mentioned an example as the Cluster Bio Energy East Netherlands.

With the strategy plan Biomass 2030 the government bundles much of the public aims, opportunities and stakeholder interaction into a joint framework regarding the biomass supply and/or production (Ministry of Economic Affairs and Ministry of Infrastructure and the Environment 2015). The term 'optimizing' captures much of the approach of the government for an increase in biomass supply: objectives such as optimizing generation of biomass from rest streams and optimizing closed resource loops form important parts of the policy on increasing biomass production. Furthermore, the objectives about increasing agricultural productivity, increasing forestry productivity, development of aquatic biomass and use of degraded soils were not specifically focused on implementation on national scale, but also on implementation on European and global scale. The concrete success stories in chapter 5 are mostly about partnerships working on joint management for (using) new technologies or developing new business models.

When it comes to failure, stakeholders argue that the negative image of bio-energy is hampering the development of bio-energy projects. Although a strategy document such as Biomassa 2030 clearly explains why it is worth investing and stimulating bio-energy, with all its positive and negative impacts (Ministry of Economic Affairs and Ministry of Infrastructure and the Environment 2015). However, such a document has a limited reach and it is not enough to change the image of biomass. The sector is very diverse if not fragmented, and partly because of that, many stakeholders also finds the policy to be fragmented. They also report too much administrative red tape as a problem. In addition, they tend to view the ambitions for a national supply of biomass for energy as not clearly expressed in the Dutch policies. An underlying factor is also the inability to establish a level playing field. A lack of clear sustainability criteria is often seen as a major factor.

8.6.2 Supporting policy coherence

Central to the Dutch case study is the role of biomass in transition to a low-carbon economy as described in D2.2 (Selnes, Linderhof, and Marinissen 2017). An important condition is sustainable production and use of biomass, also of imported biomass, effects on GHG emissions, land and water outside the Netherlands. The coherence assessment was conducted between biomass objectives and objectives for water, land use (spatial planning), climate (GHG emissions), food and agriculture, nature and waste. In the Netherlands, objectives for agriculture, water, soil and waste are integrated in policies for biomass, however, there is also competition for scarce water and land.

The Dutch way of policy-making is featured by extensive consultations among public actors and between public and private actors. Since 2011, a series of arrangements have been set up to address coherence, synergies, trade-offs in the biomass practice. In general, the Dutch government has been engaged in a lengthy multi-stakeholder approach to tackle many of the Nexus-issues we cover here. One of the success factors in the Netherlands has been the (inter)active and ongoing dialogue between public and private stakeholders. Innovation is seen as a key factor, and both public and private parties aim to invest both at the national and international level. Another success factor is the willingness to stimulate investments through public programmes for research, investments and business development for the short and long term. During the meetings with stakeholders several successful examples were mentioned.

In the background report on Nexus-relevant policies, D2.2, it was concluded that the waste policy and biomass policy are very synergistic (Selnes, Linderhof, and Marinissen 2017). When it comes to nature and agriculture, the policies seem coherent on the level of objectives, but the nature policy does not have any means to increase sustainable agricultural productivity and the agricultural policies' means to protect nature are not very effective. Stimulating “nature inclusive agriculture” as could be in the best interest of both sectors (Ministry of Agriculture, Nature and Food Quality 2018). To reduce the conflict between nature and agriculture it is good to focus on the synergies between the two of them and explore the possibilities for better integrated policies. Sustainable biomass production could play a role in such a process. Coherence is often at the level of policy-making – not policy practice. In the Netherlands, the results show a lot of synergies in comparison to only a few trade-offs. Biomass is seen as an important means for both substituting carbon from fossil materials and for several non-food purposes.

In the policy analysis we saw that the framing of the biomass image is essential but also negative, see D2.2 (Selnes, Linderhof, and Marinissen 2017) and workshop report 2017 and workshop report 2018). In the 2018 workshop, the alternative uses of biomass were stressed (e.g. raw material for building). Currently, biomass as a source of energy is still heavily debated in the Netherlands Bio-energy is sometimes seen as polluting (negative impact on health due to particulate emissions). By importing biomass, problems of competition with food and indirect land use change are shifted to other countries. Several articles in national and regional newspapers and Dutch television illustrate the ongoing debate on biomass: e.g. “Biomass is under attack. Is that right?” (Markus 2019); “Director of the Ede heating company: discussion about biomass no long has any nuance” (Van Gils 2019); and “In order to meet our climate targets, the US is 'completely destroying the landscape’” (Tukker 2020). In D2.2, similar questions were raised on the sustainability of global biomass (Selnes, Linderhof, and Marinissen 2017). The debate on biomass has been translated to policy cards via social costs of policies.

The Dutch polices on biomass are fragmented (Selnes, Linderhof, and Marinissen 2017). The agricultural policy does not focus much on biomass as its core business is producing food and not rest streams. The focus is however increasing, as illustrated by the stimulation of area coalitions between farmers, provinces and other regional partners to establish or make use of synergy between water management, agriculture, sustainable production and nature. Both policy-makers and others are increasingly aware of potential synergies and trade-offs between different sectors. In D2.2 we discussed that biomass in the Netherlands is a 'container-concept' covering many types of biomass and activities (Selnes, Linderhof, and Marinissen 2017). This container characteristic has been reflected in the SDM through distinguishing different types of biomass (e.g. manure, energy crops, etc.).

The political and societal unrest over nitrogen deposition has been considerable since the Council of State stopped granting permits based on the Nitrogen Programme in May 2019. It may then be advisable to choose measures on nitrogen that also contribute to energy transition or climate policy, for example (Vink and Hinsberg 2019). Furthermore, they argue that several types of measures that reduce nitrogen emissions also may lead to gains in terms of climate and energy (e.g. making transport electric). The objectives of the SDM show the effect on nitrogen emissions, although, it is not possible to include the whole range of options to deal with deposition.

8.6.3 Testing policy scenarios

The reference scenario is the baseline scenario, see Section 8.4.2.2. This scenario is mainly based on the thematic models (including additional data where needed). In addition, policy cards are available, so that players can build their own policy scenarios, even without any prior information of possible climate scenarios. The policy cards are formulated in such a way that the 2^{o}C Climate scenario can potentially be met. In this way, multiple pathways could result from the SDM and Serious Game for the Netherlands. In the SDM, combinations of parameters of indicators are triggered by single policy cards of combinations of policy cards. None of the policy cards affect the same set of parameters/indicators in the SDM. Many policy cards run for more than 1-year period. The full version of the SDM includes the policy cards, which are separate indicators in the model. Most policy cards affect at least two indicators at the same time. The policy cards have been tested in the sense that they have been checked with stakeholders during the workshops and with experts of Wageningen Economic Research (face validity). In this procedure policy cards have been adapted, deleted or new cards were introduced.

8.6.4 Addressing Nexus challenges

The main problem addressed in the Dutch case is the ambiguity between on the one hand the need to use biomass as an essential source of renewable energy to reach the goal of a low-carbon economy in 2050, and on the other hand the potential trade-offs on water, land and food, and the discrepancy with the goals of a circular and bio-based economy. In Table 27 we presented a list of stakeholders and their interest in the Dutch Nexus challenges. The main Nexus challenges are formulated towards biomass and are discussed in Section 8.7.1. Policies relevant for recommendations for the Nexus challenge are presented in Table 36 List of policies relevant for recommendations in in the Dutch case study Table 36.

8.7 Short-term and long-term policy recommendations

8.7.1 Summary of the Nexus issues in the case study

Note: the final workshop with the SG has not taken place yet!

What are the Nexus challenges you want to recommend about? How are these Nexus issues related to the climate goals in 2050 and resource efficiency goals (i.e. the two main SIM4NEXUS goals)?

The overall objective of the Dutch case study in SIM4NEXUS is to identify low-carbon and resource-efficient pathways for the water-land-food-energy Nexus in 2050. In particular, what can be the role of biomass in the transition to a low-carbon economy in 2050 considering the interaction with water, land, energy, food and climate. Biomass will be needed to achieve the 95 percent GHG emission reduction to develop a low-carbon economy in 2050. However, the application of biomass needs to be sustainable and therefore has requirements and limitations. The main Nexus challenges are:

- Biomass should be produced and collected in a sustainable way. The domestic supply of sustainable biomass is limited and will be insufficient for the various demands in The Netherlands, so imports are needed. Sustainably produced biomass is a scarce resource;
- Application of biomass for energy production at a large scale either being energy crops for biofuels, or production forests for woody biomass will affect the availability and quality of land, water, food and energy and will affect climate;
- It is debated whether the use of imported large-scale woody biomass for energy generation contributes to a net reduction of GHG emissions or not. The sustainability criteria for woody biomass are still under debate.
- In addition, biomass has a negative image because it is often associated with the use of coal for energy production (co-firing) which means more imports of woody biomass for co-generation implies more coal use. Moreover, woody biomass for energy is associated with large scale deforestation. It is also associated with land grabbing and competition with local food production;
- In addition, there are knowledge gaps by politician and the public about the diversity of biomass and the best application of these different types.

Table 35 Connection of the different Nexus sectors through changing and affected component in the Dutch case study adjusted from D4.8 (Robbemond et al. 2018)

	Affected component				
Changing component	climate	water	food	land	energy
Climate					
Water	Reduce GHG emissions from peat lands			Land is production factor for food. Changes in diets (protein) and renewable energy	Water is a production factor for energy production (biomass)
Food		Water demand for food production in the NL Agriculture impact on water quality			Energy used for food production; food crops for renewable energy
Land	More forest to store carbon	Land for agriculture is related to water demand	Availability of land for food crops		Availability of land for food crops and fibre.
Energy	Impact of energy transition on climate (GHG emissions)	Water demand for energy crop production in the NL	Energy is a production factor for food.	Land use for energy production, ILUC.	

Table 35 illustrates the interlinkages between the different Nexus elements. Although water is not explicitly included as changing component via climate, land and energy linked to water use. Water is covered as changing components that affect water quality. Changes in land and energy have impacts on most Nexus components

8.7.2 Description of the policies targeted for recommendations

We explicitly aim to address more than just the central government, although it is the central policy maker. We also want to address the other governmental levels as well as the business sector as the main driver and investor of (business) technology and practice. In addition, we want to emphasize the need for change within all the Nexus-sectors, and the citizen/consumer.

Table 36 List of policies relevant for recommendations in in the Dutch case study

NEXUS SECOTRS	DESCRIPTION OF THE EXISTING POLICIES
CLIMATE ADAPTATION AND MITIGATION	NATIONAL CLIMATE ADAPTATION STRATEGY, MINISTRY OF INFRASTRUCTURE AND THE ENVIRONMENT (2016)
	'KABINETSAANPAK KLIMAATBELEID', LETTER TO LOWER CHAMBRE 32 813 NR. 163, MINISTER OF ECONOMIC AFFAIRS (2018). FOLLOW-UPPROCESS (2018): CLIMATE CONSULTATION, LEADING TO A NEW NATIONAL CLIMATE AND ENERGY AGREEMENT
	THE MAJOR POLICY UPDATES ARE THE CLIMATE AGREEMENT FROM 28 JUNE 2019 AND THE NETHERLAND'S VISION ON CIRCULAR AGRICULTURE FROM THE MINISTRY OF AGRICULTURE, NATURE AND FOOD (SEPTEMBER 2018, VALUABLE AND CONNECTED) AND AN IMPLEMENTATION PLAN FROM MAY 2019.
CIRCULAR ECONOMY (WASTE, BIOMASS)	NATIONAL WASTE POLICY PLAN, 2009-2021, MINISTRY OF INFRASTRUCTURE AND THE ENVIRONMENT (2014)
	PROGRAMME FROM WASTE TO RESOURCE, MINISTRY OF INFRASTRUCTURE AND THE ENVIRONMENT (2014)
	A CIRCULAR ECONOMY IN THE NETHERLANDS BY 2050. MINISTRIES OF INFRASTRUCTURE AND THE ENVIRONMENT, ECONOMIC AFFAIRS, FOREIGN AFFAIRS, INTERIOR AND KINGDOM RELATIONS (2016).
	TRANSITION AGENDA BIOMASS AND FOOD (2018) GUIDELINES FOR A BIO-BASED ECONOMY. ATTACHMENT NO.2 OF A LETTER TO THE PARLIAMENT OF THE MINISTER OF ECONOMIC AFFAIRS (2012) BIOMASSA 2030: STRATEGISCHE VISIE VOOR DE INZET VAN BIOMASSA OP WEG NAAR 2030. **REPORT NR. 89293. MINISTRY OF ECONOMIC AFFAIRS (2015), THE HAGUE.**
LAND	VISION FOR INFRASTRUCTURE AND SPATIAL PLANNING: NETHERLANDS COMPETITIVE, ACCESSIBLE, LIVEABLE AND SAFE. MINISTRY OF INFRASTRUCTURE AND ENVIRONMENT (2012)
	THE ENVIRONMENTAL PLANNING ACT: THE PARLIAMENT ADOPTED IN 2016 THE NEW LAW SUBMITTED BY THE MINISTRY FOR INFRASTRUCTURE AND ENVIRONMENT. THE NEW ACT IS EXPECTED TO ENTER INTO FORCE IN 2021. THE ACT SEEKS TO MODERNISE, HARMONISE AND SIMPLIFY CURRENT RULES ON LAND USE PLANNING, ENVIRONMENTAL PROTECTION, NATURE CONSERVATION, CONSTRUCTION OF BUILDINGS, PROTECTION OF CULTURAL HERITAGE, WATER MANAGEMENT, URBAN AND RURAL REDEVELOPMENT, DEVELOPMENT OF MAJOR PUBLIC AND PRIVATE WORKS AND MINING AND EARTH REMOVAL, AND INTEGRATE THESE RULES INTO ONE LEGAL FRAMEWORK.
ENERGY	'KABINETSAANPAK KLIMAATBELEID', LETTER TO LOWER CHAMBRE 32 813 NR. 163, MINISTER OF ECONOMIC AFFAIRS (2018). FOLLOW-UP PROCESS (2018): CLIMATE CONSULTATION, LEADING TO A NEW NATIONAL CLIMATE AND ENERGY AGREEMENT.
	THE ENERGY AGENDA, TOWARDS A CO_2-LOW ENERGY SUPPLY. MINISTRY OF ECONOMIC AFFAIRS (2016)
	UITVOERINGSAGENDA ENERGIEAKKOORD VOOR DUURZAME GROEI 2018 (ENERGY AGREEMENT SUSTAINABLE GROWTH). SOCIAL ECONOMIC COUNCIL SER (2018), THE HAGUE. THE NETHERLANDS.
	UITVOERINGSAGENDA ENERGIEAKKOORD VOOR DUURZAME GROEI 2017 (ENERGY AGREEMENT SUSTAINABLE GROWTH). SOCIAL ECONOMIC COUNCIL SER (2017), THE HAGUE. THE NETHERLANDS.
	ENERGIEAKKOORD VOOR DUURZAME GROEI (ENERGY AGREEMENT SUSTAINABLE GROWTH), SOCIAL ECONOMIC COUNCIL SER (2013), THE HAGUE. THE NETHERLANDS
AGRICULTURE AND FOOD	CAP IN YOUR COUNTRY: THE NETHERLANDS, EUROPEAN COMMISSION (2016)
	FACTSHEET ON RURAL DEVELOPMENT PROGRAM OF THE NETHERLANDS, 2014-2020. EUROPEAN COMMISSION (2016), BRUSSELS, BELGIUM.
	IMPLEMENTATION OF THE RURAL DEVELOPMENT PROGRAMME 2014-2020. LETTER TO PARLIAMENT, MINISTRY OF ECONOMIC AFFAIRS (2014)
	AGENDA FOR SAFE, HEALTHY AND SUSTAINABLE FOOD. LETTER TO THE PARLIAMENT, MINISTRY OF ECONOMIC AFFAIRS, MINISTRY OF INFRASTRUCTURE AND THE ENVIRONMENT AND MINISTRY OF FOREIGN AFFAIRS (2015)

	BELEIDSBRIEF DUURZAME VOEDSELPRODUCTIE (POLICY BRIEF SUSTAINABLE FOOD PRODUCTION). LETTER TO THE PARLIAMENT. MINISTRY OF ECONOMIC AFFAIRS AND MINISTRY OF HEALTH, WELLBEING AND SPORTS (2013), THE HAGUE, THE NETHERLANDS.
	AGENDA FOR MORE SUSTAINABLE FOOD. REPORT. MINISTRY OF ECONOMIC AFFAIRS AND THE ALLIANCE OF MORE SUSTAINABLE FOOD (2013)
ENVIRONMENT (NATURE, BIODIVERSITY, FORESTRY)	IMPLEMENTATION OF NATURAL CAPITAL ACCOUNTING: PRESERVATION AND SUSTAINABLE USE OF BIODIVERSITY. REPORT. MINISTRY OF ECONOMIC AFFAIRS (2013) VISION ON NATURE POLICY 2014. REPORT. MINISTRY OF ECONOMIC AFFAIRS (2014)
WATER	AGREEMENT WATER FOR THE NETHERLANDS, UNION OF WATERBOARDS, IPO, VEWIN, MINISTRY OF INFRASTRUCTURE AND ENVIRONMENT, VNG (2011)
	DELTA PROGRAMME 2018: WORKING ON A SUSTAINABLE AND SAFE DELTA. DELTA PROGRAMME OFFICE (2017) AND IMPLEMENTATION PROCESS
	FLOOD PROTECTION PROGRAMME 2016: PROJECT BOOK, WATERBOARDS, RIJKSWATERSTAAT, HWBP (2016)
	RIVER BASIN MANAGEMENT PLANS: 2ND GENERATION, MINISTRY OF INFRASTRUCTURE AND THE ENVIRONMENT (2015) AND ANNUAL REVISIONS

Table 36 present the existing policies for the Nexus challenges in the Netherlands. The policy recommendations from the Dutch case study will be presented in the next section. As part of the policy recommendations, the link with the existing policies will be addressed for each policy recommendation.

8.7.3 Policy recommendations

8.7.3.1 Changes in policy outputs

Main governmental target: a single goal of 49% domestic greenhouse gas emission reduction by 2030
The Climate Agreement of 2019 concerns merely how to achieve the single goal of a 49 % reduction of the national greenhouse gas emissions by 2030 compared to the 1990 level (Dutch Government 2019). There have been no recent changes in the main policy targets in the Netherlands.

Implementation: sector-specific but also explicit focus on cross-sector cohesion
For the implementation of the Climate Agreement there are sector-specific issues but there is also a need for an explicit focus on cross-sector cohesion. It is a system-oriented approach based on more investments in integrated knowledge, innovation, societal support and a spatial planning with more regional investments.

Biomass: a new initiative to improve practice – Climate Agreement (Dutch Government 2019)
In the Climate Agreement of 2019 biomass is addressed as one of the cross-sector themes'. The use of biomass is built on the conviction that the use of biomass at present and to 2030 and 2050 is crucial for the sustainability of our economy and the realisation of the climate target. The main points are the following:

1. Biomass will also increasingly begin to serve as a material and feedstock. Optimal and efficient use of the available volume of biomass is crucial to maximise climate gains and to increase the economic value of biomass.
2. only sustainable biomass truly contributes to making the economy more sustainable
3. at a global level, sustainable biomass will in time become scarce.
4. At present, agreements on the sustainability criteria for biomass have been made with the electricity sector at a national level. Accordingly, the government also wishes to develop the framework for sustainable biomass with other climate sectors.
5. Sustainability criteria (in the making) will apply to all biomass and all uses;

6. The process for the creation of a comprehensive sustainability framework consists of
    - an analysis and a proposal for sustainability criteria for all applications of biomass;
    - enforceable sustainability criteria per biomass stream;
    - an analysis by the Netherlands Environmental Assessment Agency (PBL) of the maximum availability per biomass stream to be used, taking into account the various interpretations of the fair share principle;
    - an analysis by the PBL of the options for use per biomass stream to be used, based on the most optimal and efficient use (cascading);
    - an analysis of the actual climate gains and corresponding costs;
    - an opinion of the special SER committee on support for and the feasibility of the sustainability framework, based on consultation of stakeholders, which will examine relevant decisions and choices in the field of allocation (fair share), desired prioritisation of applications and cascading;

The market for biomass is global and supply and demand are matched because of market forces. Since biomass is considered for many applications and supply cannot grow without limit, it is expected that a biomass scarcity will develop at a global level in time. There is currently still untapped potential for biomass, including in the form of roadside grass, cuttings and sewage sludge and waste flows from the food industry. Given the binding nature of the European sustainability criteria in Renewable Energy Directive II (RED2), all biomass streams that require legal commitment should be reviewed on whether and how this can be achieved.

The government announced that a roadmap will be developed across all the various sectors, together with the relevant parties, aimed at doubling the domestic supply of sustainable biomass. Knowledge development and innovation for the development of new forms of biomass production and the processing of biomass as a feedstock or fuel will also be part of this roadmap.

The parties to the Climate Agreement will also pledge to actively advance the sustainability of imported biomass in the countries of origin with public-private initiatives, as well as the recent European commitments on biomass for energy applications beyond 2020 (RED2) where these are not required and entering a dialogue with the countries of origin or with parties producing biomass. The government will also call on all parties who wish to make use of biomass to actively support the expansion of the supply of sustainable biomass, from an enlightened perspective of self-interest.

The objective of the parties is to work toward the best possible high-grade application of sustainable biomass. The Netherlands Environmental Assessment Agency (PBL) expects there to be several obstacles in the supply beyond 2030 (Dutch Government 2019). For that reason, moving toward 2050, prioritisation of the use of sustainable biomass in the Netherlands is to be desired.

In the period leading up to 2030, biomass can serve as a transition fuel for various applications, which is reflected in the proposals for additional use of sustainable biomass in the sectors. In the long term, the parties aim to use sustainable biomass for high-grade applications in those commercial sectors where there are few alternatives, for example as a feedstock in the industry and as a fuel for heavy vehicles and in shipping and aviation. As we head toward 2030, this must already be considered in the extent to which applications are stimulated or discouraged. This is also specifically reflected in parties' commitment to the development and upscaling of biomass-free alternatives for all applications, including through the knowledge and innovation agendas. In addition, the Mobility Platform, as part of the Climate Agreement, will make commitments aimed at increasing the production and supply of sustainable advanced gaseous and liquid biofuels, chiefly those that will be required for heavy goods road transport, aviation and shipping in the future and for which insufficient alternative sources of energy will be available even after 2030.

The commitment of the parties in all the platforms and cross-platform cooperation is also required to develop a cascaded use of biomass and for the development of favourable business cases. In this context, the following agreements have been made:

a. Parties to the Industry Platform will make agreements in 2019 to actively contribute to the actions that are to be developed under the Implementation Programme for the Circular Economy with regard to the production and use of biomass for materials and chemicals that contribute to the national climate target.
b. The Industry Platform and the Electricity Platform will jointly develop a roadmap in 2019 regarding the way in which parties will work toward the exclusive use of cascaded, sustainable biomass in the mid to long term.
c. The Industry Platform will make commitments regarding the development of a roadmap/programme for the maximum achievable reuse of carbon dioxide (CCU) from biomass.

The use of biomass in small-scale plants has a negative impact on air quality. As the application of biomass for energy production purposes should lead to a deterioration in air quality, the government wishes to make the air quality emissions standards for small production plants stricter as of 2022, where possible (particularly regarding nitrous oxide and nitrogen). In addition, as part of the evaluation of the ISDE in 2019, the government will conduct a critical review of the desirability of further stimuli for small-scale combustion of biomass (wood chip boiler and plants <0.5 MW).

Although the PBL only expects obstacles to emerge in the availability of sustainable biomass after 2030, it is prudent to take into account uncertainties in supply and demand forecasts. Set against this background, the following agreements have been made:

a. Once the government has established the integrated sustainability framework, the PBL will assess the impact of the framework on the use of sustainable biomass in the period up to 2030. Based on the results of this assessment, a decision will be made on any additional steps that may be required to realise the 49% target.
b. The PBL will be asked to provide insight into the development of the supply and demand of sustainable biomass on an annual basis and to identify any problems regarding the availability of sustainable biomass in a timely fashion.
c. The government will have the options for flexibility in the context of electricity production, such as demand-side response, storage of energy, conventional standby power and carbon-free controllable power, including – if other alternatives are not available to a sufficiently cost-effective degree – biomass (which must be cascaded as much as possible, developed as independently as possible, aimed at the public interest. In this way, the government aims to arrive at an assessment framework that clarifies which decisions should be taken and when.
d. Based on the heating plans that will become available in 2021, the Built Environment Platform will review whether and how to increasingly steer toward efficient use of biomass for heating purposes by only using biomass where no sustainable alternatives are available or in cases where those alternatives are much more expensive.
e. In relation to the uncertainties in the supply and demand forecasts for sustainable biomass, additional guarantees are required for the period during which the comprehensive sustainability framework has not yet been implemented. During that period, the government will commit itself to a restrained approach to issuing new subsidy decisions for the stimulation of the use of sustainable biomass, as soon as parties expect problems regarding the availability of sustainable biomass ahead of 2030, based on the annual monitoring mechanism.

Biomass: letter from the Minister of Economic Affairs and Climate to parliament

The ministers' letter was a reaction on concerned members of the European Academies Science Advisory Council (EASAC) who questioned the use of wood biomass for energy. The minister explained that the Cabinet embraces the scientific concerns and states that the Netherlands will take due notice of the need for a trustworthy storyline concerning the timeframe of carbon storage in wood, as it takes a long time before newly planted forest takes up the carbon. Besides, the minister says he will take the local pollution of biomass into his plans. The role of biomass should not be exaggerated.

The government is currently having TNO energy research investigate whether the emission requirements for smaller and medium-sized biomass plants (0.5 - 50 MW) can be further tightened from 2022 onwards (see answers from the Minister of Economic Affairs and Climate Policy to questions of the Second Chamber of the Dutch Parliament, 19 November 2019). In the Climate Agreement, the government has indicated that it aims to complete a sustainability framework in the course of 2020 to ensure the sustainable use of biomass (Dutch Government 2019). In September 2019, the Social and Economic Council (SER) has been asked to advise the government on a sustainability framework for biomass. To support this process, Netherlands Environmental Assessment Agency is conducting a comprehensive study on the availability of biomass, and on application possibilities within the Netherlands. This report is expected to be finished in the first half of 2020.

Recommendations building on the stakeholder workshops

During the stakeholder process many have pointed out the need to clarify the criteria the criteria for a sustainable biomass usage from imports. Recent media attention on sustainability of biomass, the work of the Social and Economic Council (SER) on a sustainability framework, and the questions within the House of Representatives (19 November 2019) illustrate the need for such a goal. The need for solid criteria is also vital to improve the image of biomass, as pointed out in the workshops, and to provide a trustworthy usage, as pointed out by the EASAC and the ministers' reaction to EASAC. The table below briefly describes out policy suggestions:

In short	Recommendation name: clarify criteria for sustainable biomass use
Target group	The Ministries of Economic Affairs and Climate Policy, Infrastructure and Water Management, and the Ministry of Agriculture, Nature and Food Quality.
Target policy goal	Sustainability criteria for the import of biomass
Target policy instrument	Trade rules
Target policy process phase	Climate Agreement
Administrative level	National and EU
Time scale	Short term till 2030
Cost-effectivity	More expensive import and higher cost biomass; possibly new domestic business-models
Social implications	Improved image of biomass in a low-carbon and resource efficient economy and by that more public trust in using (imported) biomass.

8.7.3.2 Changes in policy contents

Based on the input of stakeholders, policy cards have been formulated in in a 'neutral' way. By neutral we mean that we cover technological and behavioural changes but not the way they are realized. Stakeholders argued that this would lead to an unnecessary complex game, and easily end up in a normative approach that even could be disputed. In effect, we did not include terms like levies, taxes and subsidies in the policy cards. For instance, a player can play cards that increases the price of CO_2 permits but not the policy mechanism. The main reason is that policies are containers of different instruments and prone interpretation what is included and what is excluded in the Serious Game.

Biomass production for energy is competing for land use in the Netherlands. Renewable energy (solar and wind) is competing with biomass for land. Land use for wind energy is limited. Solar panel fields are for some an attractive form of land use but results in less biomass.

In short	Recommendation: More and continued focus on **competing claim**s for land for feed**, fibre** and bio-energy purposes. This on **different scale levels:** global, national, regional, local and personal.
Target group	The responsible Ministries should initiate action including relevant economic sectors should engage and stay involved
Target policy goal	Resource efficiency
Target policy instrument	Climate Agreement and Roadmap
Target policy process phase	Implementation
Administrative level	National (for the initiative), regional (for implementation)
Time scale	Short term till 2030
Cost-effectivity	Cost effectiveness depends on the type of biomass and the scale of targeting
Social implications	More land for biomass for energy at cost of e.g. food production and water resources could have to deal with low acceptance of consumers. Several sectors of the Nexus are involved.

In short	Recommendation: More and continued focus on competing claims for land for feed, fibre and bio-energy purposes. This on different scale levels: global, national, regional, local and personal.
Target group	The responsible Ministries should initiate action including relevant economic sectors should engage and stay involved
Target policy goal	Resource efficiency
Target policy instrument	Climate Agreement and Roadmap
Target policy process phase	Implementation
Administrative level	National (for the initiative), regional (for implementation)
Time scale	Short term till 2030
Cost-effectivity	Cost effectiveness depends on the type of biomass and the scale of targeting
Social implications	More land for biomass for energy at cost of e.g. food production and water resources could have to deal with low acceptance of consumers. Several sectors of the Nexus are involved.

The potential of biomass from national production in the Netherlands is limited. Biomass use for other purposes like maintaining biodiversity in forests or as input for industry is more important. When the Netherlands wants to increase the share of biomass for energy production it needs to import.

The SDM shows that biomass is an heterogenous resource originating from 8 different sources that are strongly connected to economic development (GDP per capita, number of animals, agricultural production, etc.). The implementation of policies directed at increasing the share of biomass for energy needs to consider the impact on other prioritized policies areas like Natura 2000, Water framework directive, policies oriented on droughts, and polices to promote circularity. It could be needed to compensate the effects on other policy areas in a coherent way.

Phasing out coal could be compensated by biomass production or to increase natural gas. For biomass to contribute in a significant way, a huge restructuring of the energy is needed where imports of biomass will play an important role. Off-shore wind energy and/or solar panel fields could be alternatives, certainly in the short run.

Oil and gas are important to produce electricity and oil-based products (petrol for instance) in the Netherlands. Transport is linked to oil and offices and householders are linked to gas.

In short	Bring more clarity and transparency in the various uses of different types of biomass and link the usage to business models
Target group	There is a strong role for the business sector is here to be expected, but the national government can facilitate the policy agenda and networking/meetings.
Target policy goal	Resource efficiency
Target policy instrument	Useful to look closer at the link to the investment instrument SDE+, which is an exploitation instrument
Target policy process phase	The up-coming Roadmap
Administrative level	Country, then region, maybe EU for a link to for instance CAP
Time scale	Short term till 2030, middle-term till 2050
Cost-effectivity	Inclusion of external costs in new biomass business-models would at least make the cost-benefits and cost-effectivity clearer
Social implications	Improved acceptance concerning the use of biomass due to fair pricing. See for instance the debate on fair pricing (https://www.wur.nl/nl/project/Echte-en-eerlijke-prijs-voor-duurzame-producten.htm)

8.7.3.3 Innovations

In general, the Dutch government has been engaged in a lengthy multi-stakeholder approach to tackle many of the Nexus-issues we cover here including on stimulating innovations. Besides, as discussed in Section 2.6.1, the Netherlands has also favourable conditions for bio-based investments because of its strategic location with big harbours, a good infrastructure, high quality knowledge institutions, a well-educated population and strong agricultural, chemical and energy sectors.

Innovation is seen as a key factor to deal with biomass in the Netherlands. Both public and private parties aim to invest both at the national and international level. The Dutch government stimulates investments through public programmes for research, investments and business development for the short and long term. The policy is characterised by public-private partnerships on developing innovations. An example is the Transition House which offered a way to ventilate business challenges, the Front Runners Office improved innovation ideas, the Acceleration Team Green Gas from 2013 worked on better procedures and licenses. Market parties could with these arrangements signal issues to the Program Department (*Programmadirectie*) Biobased Economy. This has led to shorter procedures and improvements in the Investment Subsidy SDE+. To support the implementation of innovative environmental/sustainable initiatives by industry and agriculture by removing obstacles, the government launched the ‘Green

Deals' programme in 2011. The Green Deal approach is often used when innovations are put into practice, a phase during which projects often encounter barriers. The central idea is that the government facilitates and accelerates initiatives by removing barriers. Barriers may be formed by legislation, or by a lack of market incentives, innovation and networking. Another example was the PPS call "Value from biomass" (https://www.nwo.nl/financiering/onze-financieringsinstrumenten/enw/waarde-uit-biomassa/waarde-uit-biomassa.html). The aim of the call is to finance fundamental research that can offer socially relevant and responsible innovations in the field of biomass conversion.

In short	To continue **supporting** innovations through public-private partnerships
Target group	Government and private parties
Target policy goal	Resource efficiency
Target policy instrument	Setting up research programmes and supporting implementation
Target policy process phase	Removing barriers when innovations are put in practice
Administrative level	Community, region, country
Time scale	Till 2050
Cost-effectivity	Risky investments and cost effectiveness of individual projects is often difficult to assess in advance. This will potentially lead to more cost-effective solutions.
Social implications	The social implications of the instrument are limited given the relatively limited budget needed many (fundamental) innovation projects. However, it can stimulate different stakeholders (public and private) to co-operate.

8.7.3.4 Changes in the policy process

Based on the stakeholder interaction, a policy debate starts with what you want to achieve (national) followed by a separate discussion on how you want to achieve it (regional). The "what to change discussion" is supported by the model and how in the play of the game of which the Serious Game is a part. For the policy process the workshop participants argued for an including process, a process which engages the many different interests involved in transparent way.

In short	To apply an including process for the road map
Target group	Ministries initiate the engagement: business, citizens, and NGOs central in the agenda-setting
Target policy goal	Resource efficiency
Target policy instrument	Tailor made stakeholder engagement solutions
Target policy process phase	Implementation
Administrative level	Agenda setting at the national level and regional implementation
Time scale	Till 2030
Cost-effectivity	Better view to reliable cost-benefits and involvement of stakeholders
Social implications	More awareness raising, leading to social acceptance

8.7.3.5 Changes in the science-policy interface

The science debate is important in the Netherlands as illustrated by the current study on biomass, based on Joint Fact Finding (JFF) and dialogue sessions, among other things. Also stakeholders want to contribute to this debate as illustrated by the position paper "Biomass and Bioenergy" prepared by Dutch Association Sustainable Energy in close cooperation with the sector (Dutch Association Sustainable Energy 2019). The Dutch Association Sustainable Energy is an association with approximately 6000 members being companies and cooperatives.

Also, in separate elements of the Nexus the debate in ongoing like the nitrogen depositions. The Netherlands has in 2019-2020 faced major protests and a series of civil disobedience demonstrations by Dutch livestock farmers concerning nitrogen emissions. The Court ruled against the license for a part of the farmers to farm. The science-policy issues here are that the farmers also revealed that they do not trust the way the RIVM, the National Institute for Public Health and the Environment, is measuring nitrogen emissions. We see here that science is not an uncontested issue, it must be discussed repeatedly. The same is the case with the measurements and predictions for the climate policy.

In short	Recommendation name: dialogue on the science behind climate and resource efficiency
Target group	Different stakeholders (e.g. universities, governments, NGOs) should initiate and facilitate the science-policy dialogue
Target policy goal	Improved quality of the decision making and by that enhanced trust/support within society.
Target policy instrument	Communication tools
Target policy process phase	Agenda setting for the Roadmap
Administrative level	Eventually all: community, region, country, EU
Time scale	Till 2030--2050
Cost-effectivity	Better informed decisions leading to more informed decisions and potentially lower costs
Social implications	More support of stakeholders

8.7.3.6 Conclusion on coherent, Nexus-compliant policies

The Climate Agreement from June 2019 and the proposed Roadmap for biomass (to come) is built on the need for more sector crossing cohesion in the policy for a low-carbon and resource efficient economy. This case study shows that this work could benefit from efforts to enhance the clarity of how to define, regulate and use biomass in a more sustainable way.

8.8 Conclusion

The main issue addressed in the Dutch case study is the ambiguity between on the one hand biomass as a source of renewable energy to reach the goal of a low-carbon economy in 2050, and on the other hand the trade-offs on water, land and food, and the potential discrepancy with the goals of a circular and bio-based economy. Biomass in the Netherlands relates to all Nexus domains climate, energy, food, land and water. The water domain is addressed indirectly in the policy cards through for instance land use or the energy domain.

The results of the policy goals coherence analysis showed a high degree of synergies and there were only a few trade-offs. In the implementation process of the policies, the realisation of the synergies turned out to be hard to realise when focussing on one policy dimension. The value added of the SSrious Game of the Dutch case is that it provides insights in the consequences of the implementation of interventions. In the Netherlands, biomass is seen as an important means for substituting carbon from fossil materials and it can be used for several non-food purposes. A challenge for the policy coherence is that biomass is used for both generating energy from biomass and for higher value usage in the (chemical) industry. The objectives of food and biomass are mostly synergistic.

The Dutch way of policy-making is featured by extensive consultations among public actors and between public and private actors. With the strategy plan Biomass 2030 the government started to bundle much of the public aims, opportunities and stakeholder interaction into a joint framework regarding the biomass supply and/or production. In the policy analysis we saw that the framing of the biomass image is essential but also heavily debated. The Dutch polices on biomass are by stakeholders considered to be fragmented and incoherent. The government has now begun to address these shortcomings. Currently (early 2020) the Social and Economic Council (SER) works on a sustainability framework for biomass (e.g. to provide trustworthy usage). In addition, the Roadmap to 2030 is meant to tackle the question of how to proceed further, as part of the Cabinet climate plan. This plan was launched in 2019 and the implementation has now just started.

The conceptual model consists of 6 systems: energy, land, food, water and climate as well as a socio-economic system. Resource efficiency is operationalised in the SDM in different ways. Resource efficiency links to three different Nexus sectors namely water, energy and land. The SDM covers resources efficiency with respect to nitrogen and phosphate, sustainable use of woody biomass and the sustainability of soil use. The low-carbon economy links to climate policy and focusses on a 95% reduction of total non-agricultural and agricultural GHG emissions in 2050. The link to corresponding policies is strong: energy, agriculture and food, waste, nature, spatial planning and water. Policy objectives on a viable agricultural sector and healthy population (food) and sustainable land use are added as policies to be investigated.

The game uses the baseline scenario and the 2 degrees scenario. The Baseline scenario was used as the reference for the SDM of the Dutch case study. Players will be able to choose policy cards to achieve the policy objectives. The policy cards are constructed in such a way that the 2 degrees scenario can be reached when playing the game. To build the SDM, data is used from E3ME, CAPRI and MAGNET and supplemented with local data.

The Dutch case has three main learning goals: (1) how policies aiming for a low-carbon and resource-efficient economy in the Netherlands work; (2) how to make choices and balance interests between policies by experiencing how changes with policy cards (or policy interventions) will affect the other Nexus sectors over time; and (3) how the need for biomass as a renewable energy source may conflict or have synergies with the creation of a bio-based and circular economy. This resulted in use cases for energy, climate, land and food. To learn about these goals 34 policy cards where developed for different Nexus domains and economic sectors. The play of the game itself is currently under development.

To work on the Dutch case study a joint team was formed consisting of researchers from Wageningen Economic Research, the Netherlands Environmental Assessment agency and IHE Delft. The partners contributed in different roles, e.g. on the conceptual model, policy related issues, and supervision of the SDM development. All the partners participated in most of the workshops contributing from their own background. Stakeholder meetings in all stages of the case study were important for developing functional requirements, determining complexity of the model and Serious Game needed, to give feed-back on (conceptual) model development in different stages of case study development and policy related issues including policy cards. Different types of stakeholders participated (government, business, branches associations, research, NGOs “representing” different domains of the Nexus).

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8.10 Annexes

8.10.1 Conceptual model

The conceptual model of the Netherlands will be presented by means of 6 Figures. Figure 68 presents the general overview of the Dutch conceptual model. More detail will be given in sub models.

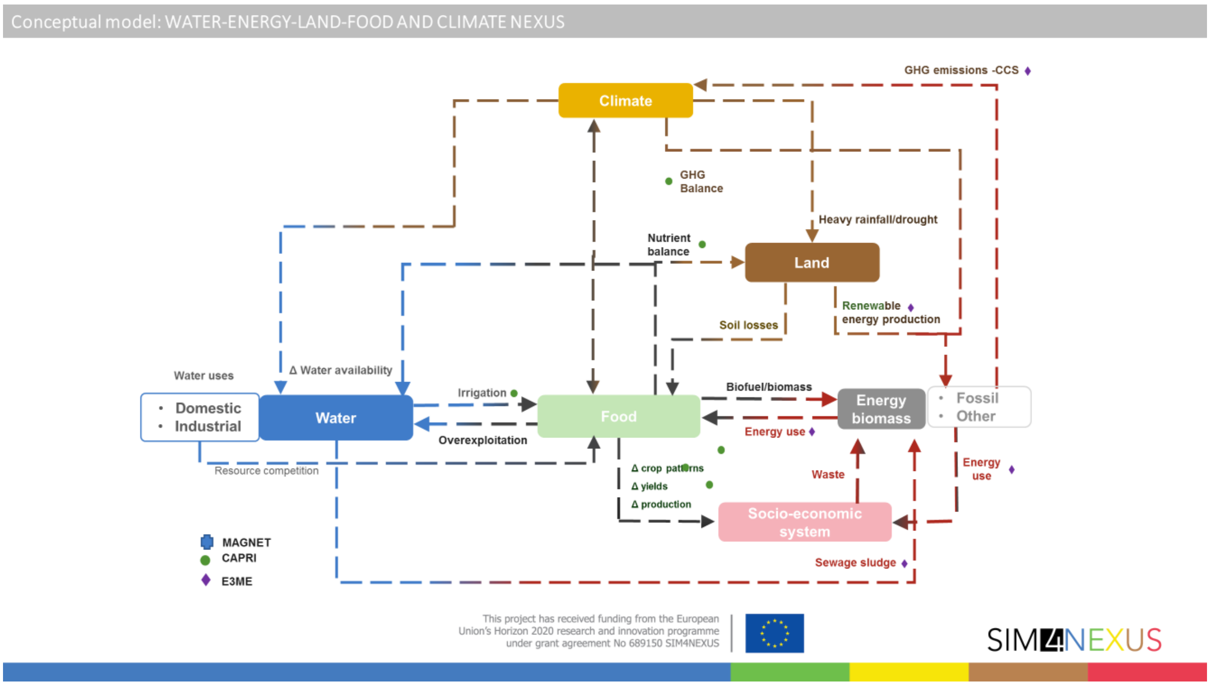


Figure 68 The central picture of the Dutch conceptual model

We will explain the conceptual model using the different components as shown in Figure 68: energy/biomass, agriculture/forestry, food and the socio-economic system, water, land and climate.

Energy/biomass

There are two outputs from energy/biomass namely energy use: (1) flows from energy/biomass to socio-economic system and agriculture and (2) -greenhouse gas (GHG) emissions from energy supply with fossil and renewable fuels which affect climate. The inflow of energy and biomass are the energy sources from water (e.g. energy from waste water, algae, heat in the water), waste for energy from the socioeconomic system, biomass for energy from agriculture, forestry. Renewable energy sources, such as wind power and solar power, require space, so that land availability also affects energy and vice versa.

Climate

Climate is affected by sectors that emit greenhouse gas emissions, such as agriculture and the energy sector from energy from fossil fuel sources and renewables. GHG's can be stored in vegetation and soils, and by applying Carbon Capture and Storage (CCS). Climate affects also several sectors. Climate change includes change of temperature, weather, rainfall and drought, and hydrology. Water availability and crop growth (productivity of agriculture and forestry) are affected by climate change. Climate change also affects the rainfall and the storage capacity of the soil for water and carbon.

Land

Land, space and soil are important for agriculture, water and climate change (e.g. GHG emissions from peat soils, carbon sequestration).

Water

Water is used by agriculture and for energy production, among others. Climate change will have impact on available water resources for different users. Water can be a source of biomass and energy (sewage sludge, algae, heat).

Food (agriculture)

Food is one of the main outputs of the agricultural sector (besides other types of biomass). It is not worked out as separate sector but included in the agricultural sector.

Socioeconomic system

The socio-economic system is crucial in the conceptual model as it shows the important user of outputs of other parts of the system. The system produces waste, biodegradable waste is a potential source of bioenergy. The socio-economic system is important with respect to GHG emissions. Finally, several policy interventions act by way of changing the socio-economic system.

References are included for the expected usage of the results of the thematic models such as MAGNET, CAPRI and E3ME or illustrative purposes. The categories of instruments/policies that we would like to investigate are subsidies (e.g. on CCS), financial economic instruments: e.g. a directed levy in combination with specific subsidy; increasing use efficiency; communication and education; and research and knowledge.

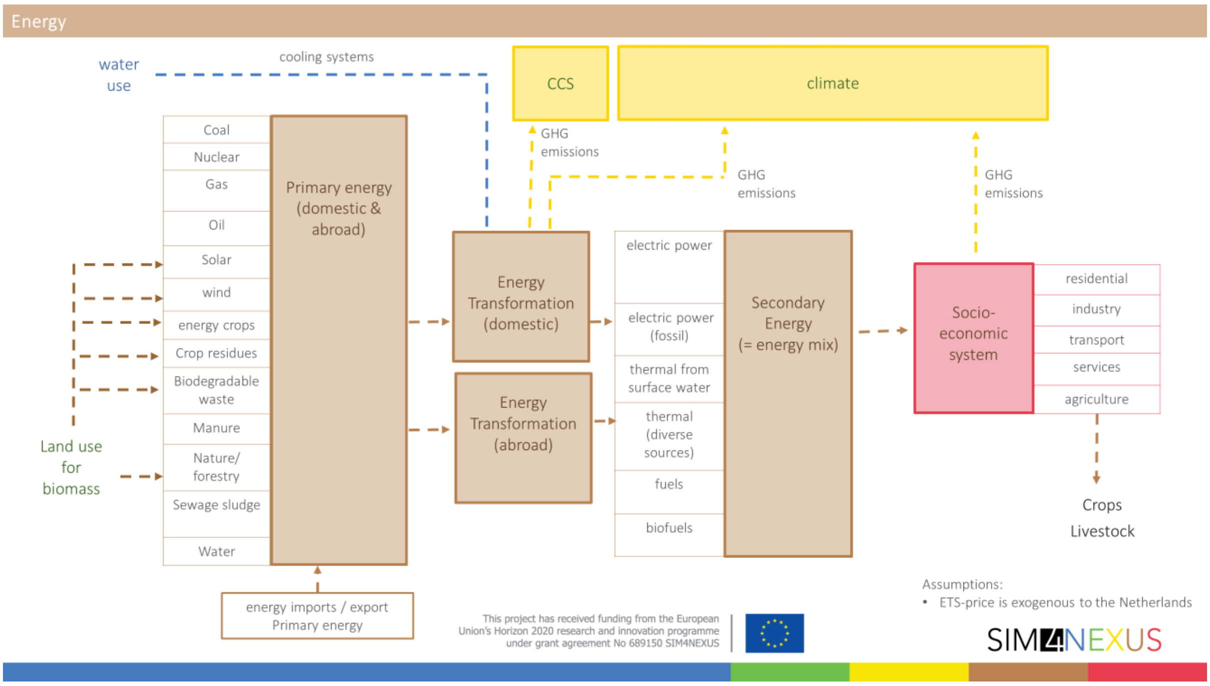


Figure 69 The energy component of the Dutch conceptual model

The energy component consists of primary energy and secondary energy, see Figure 69. The latter is input for the socio-economic system. We include several renewable energy sources into the primary energy mix. Many of the renewable energy types are either innovative and/or have a low share in the current energy mix. However, they have potential to become a substantial share of our future energy mix. In particular, we have included several types of biomass for energy production such as energy crops, biodegradable waste, manure, wood/timber from nature and forestry, sewage sludge and water. For some of these biomass sources, the application relates directly to secondary energy, such as with fuel for transportation. Energy transformation can take place both in the Netherlands and outside the Netherlands. As we consider the energy mix in the Netherlands, we can also import secondary energy from hydropower from Norway or renewable energy from Germany for instance.

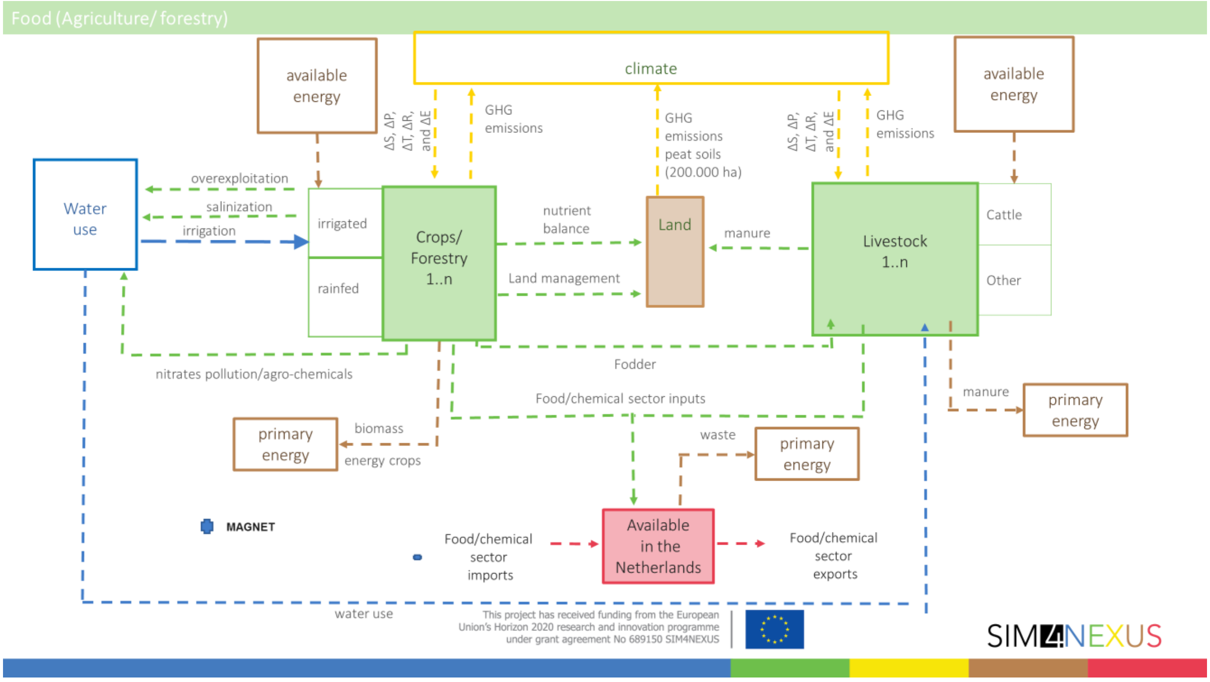


Figure 70 The Food (agriculture/forestry) component

Figure 70 reflects the sectors agriculture and forestry, which use land and water, and produce biomass for energy as well as food and other products. Agriculture and forestry produce different types of biomass that can be used for energy. From agriculture, it can be from energy crops, residues of food crops, manure, and from forestry it is timber from natural reserves or plantations. Next to that, we also consider biomass waste from the management of roads (roadside verges) and ditches. In Figure 3, these different types of biomass from agriculture and forestry are not explicitly indicated, therefore, we added an index "1..n" for biomass from crops/forestry and livestock.

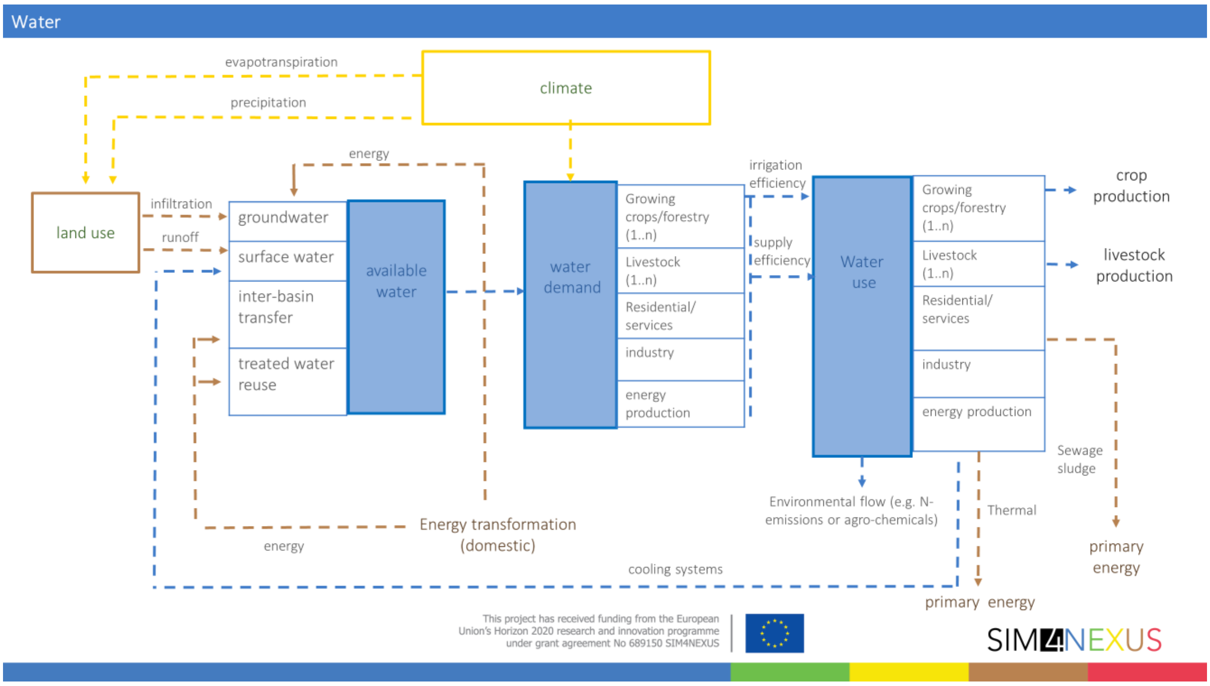


Figure 71 The water component

Figure 71 gives the water component. It distinguishes different sources of water (=available water) and recognizes different types of water demand, both agricultural and non-agricultural. Water demand leads to different types of water use in which we also take into account the efficiency of water use. Note that the improvement of water use efficiency might require more electricity or energy. Innovative uses of water – e.g. thermal energy – will be explored. Different indicators will be calculated to show impact of water use on water quality, like N emissions or agro-chemicals.

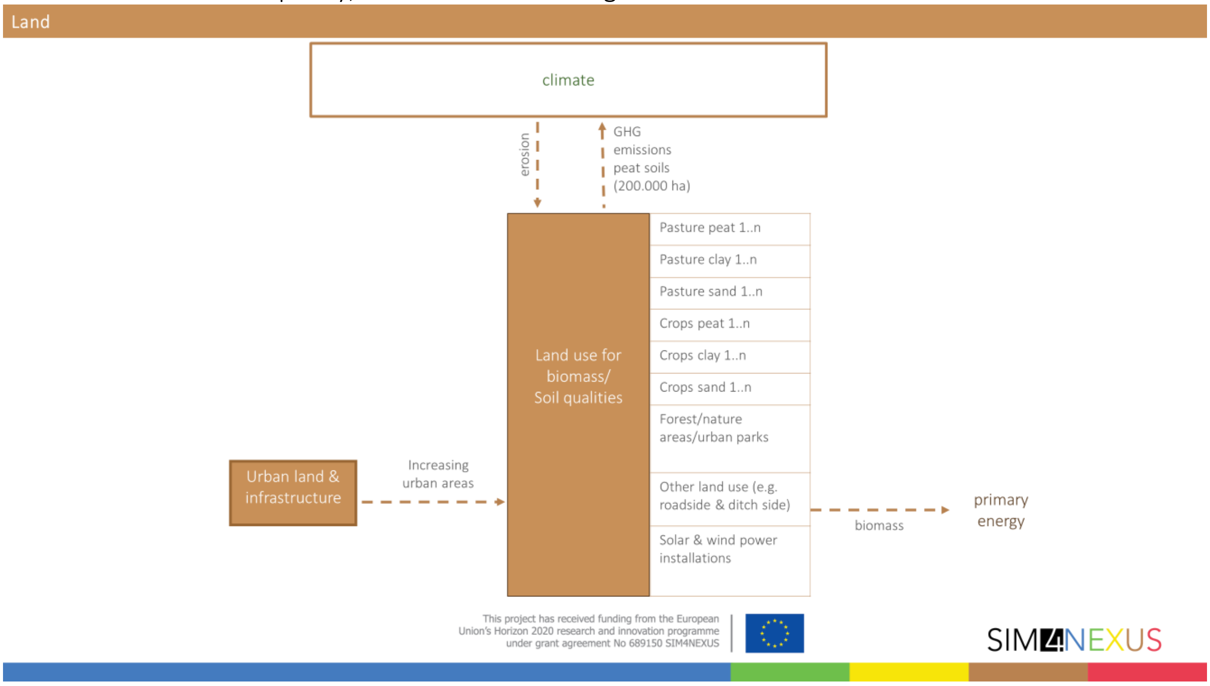


Figure 72 The land-use soil component

The soil component is given in Figure 72. It shows different types of land-use for biomass production. Land can be of different qualities and soil types (depicted in 1..n) for the different types of land use (differences soil carbon sequestration). We will distinguish 2 forms of agricultural land use namely pastures for cattle and growing crops and 3 main types of soil: clay, peat and sand. Other types of land use are forest and nature areas. Innovative land use types that will be considered are land that is used for large scale solar installations and wind power installations.

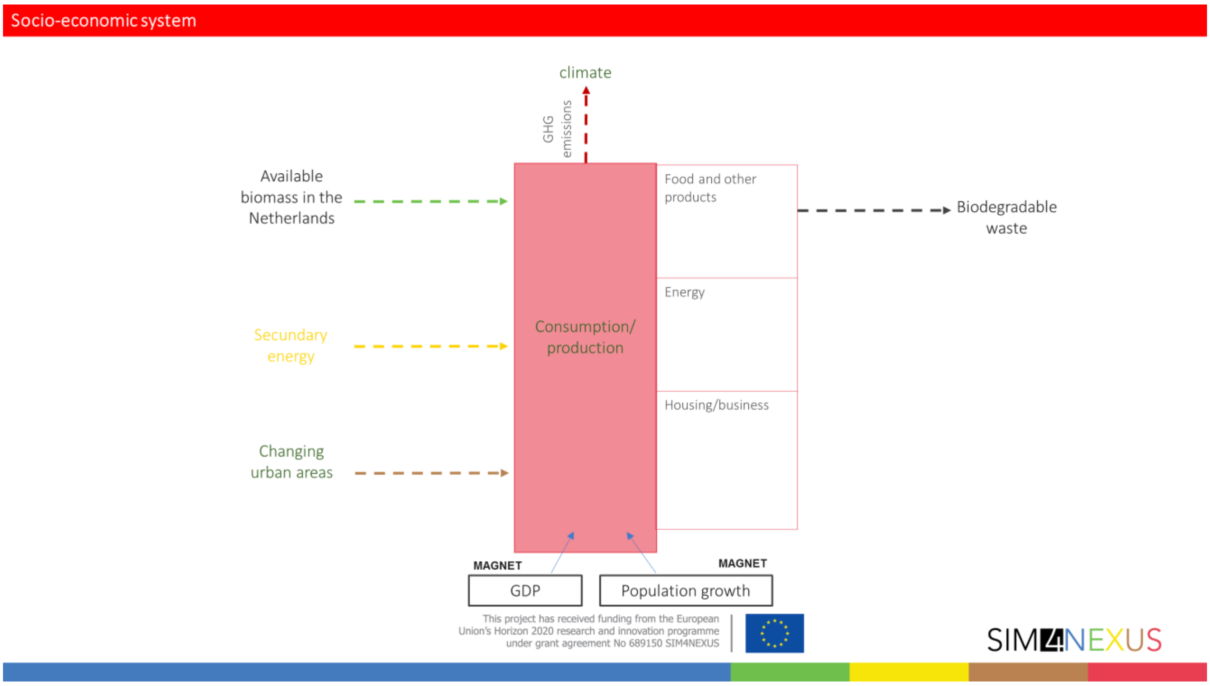


Figure 73 The socio-economic system.

Finally, Figure 73 shows the socio-economic system. It reflects the consumers and the economic sectors that use biomass/energy. The major component in the socioeconomic system is the food consumption/production. So, the socioeconomic system allows to consider changes in biomass due to different reasons, such as altered diets, changes in income or changes in population growth. Changing demand for land for housing and infrastructure restricts or offers opportunities for agriculture/forestry and thus the production of agriculture and the production of biomass. Due to food waste as well as garden waste, the socioeconomic system supplies biodegradable waste for energy production and the bio-economy.

8.10.2 SDM screenshots

The SDM of the Dutch case study consists of six subsystems: socioeconomic, land, food, energy, water and climate subsystems.

The socioeconomic subsystem includes the developments of the population and value added/GDP, see Figure 74. This part of the SDM is exogenous. Both developments are given for the development in other subsystems.

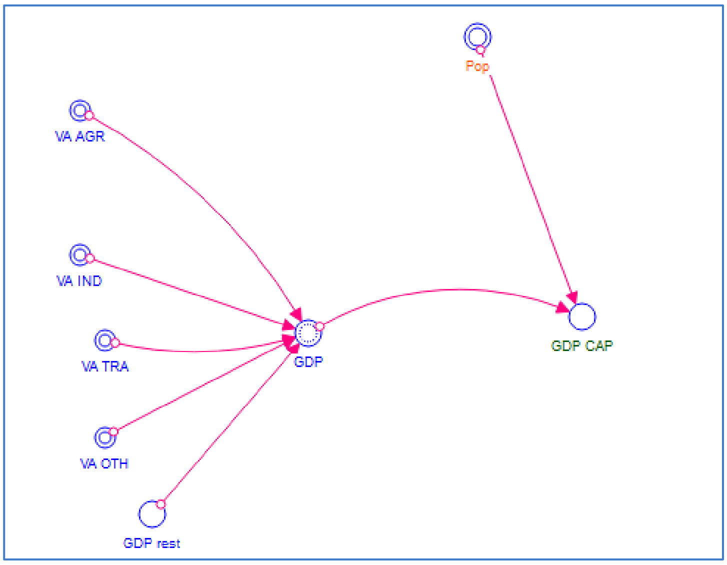


Figure 74 The socioeconomic subsystem

The land subsystem considers four main land covers: urban areas, agriculture, nature areas and areas for renewable energy such as on-shore wind power turbines and solar power fields, see Figure 75. For the solar power fields, the so-called "solar rural" in the model, we consider it to be an alternative for agricultural activities. Note that solar power options in urban areas, on farms or stables, and near infrastructure are not included. In particular, we refer to these types of solar power generation as "solar_urban", which is part of the energy subsystem.

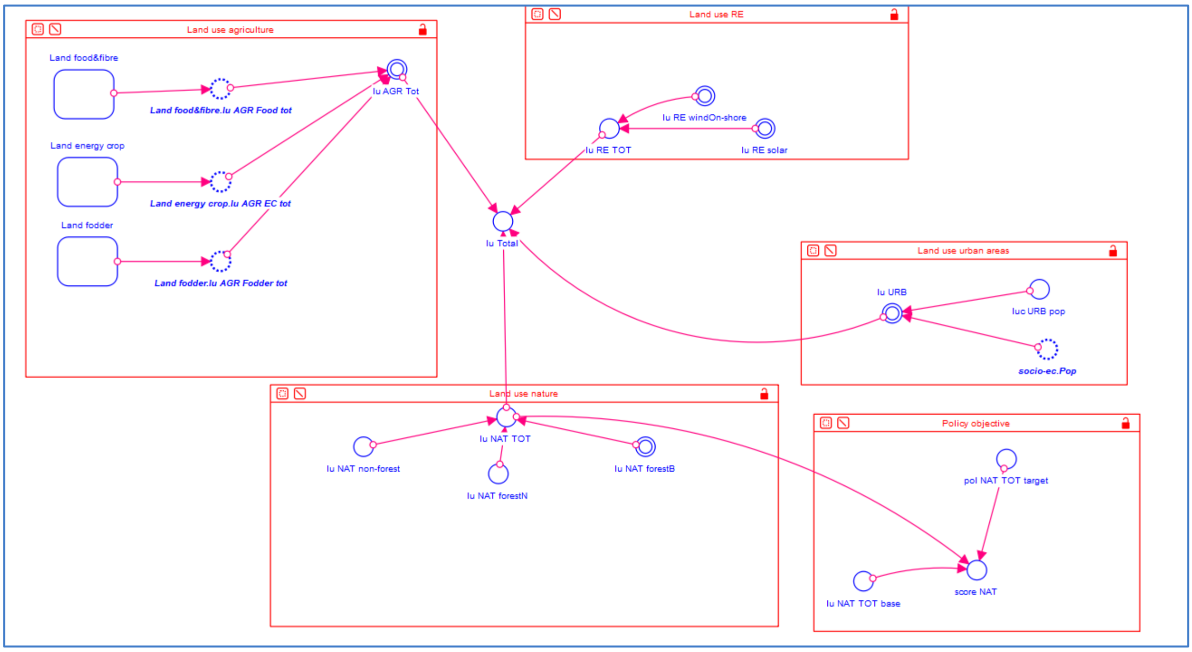


Figure 75 The land subsystem

The food subsystem consists of two main subsystems: the agricultural production of food, fodder and energy crops, and the food consumption/food demand, see Figure 76. Agricultural production includes livestock production, crop production, fodder production and energy crop production. In addition, the production of biomass from forests are also part of the production part of the food subsystem.

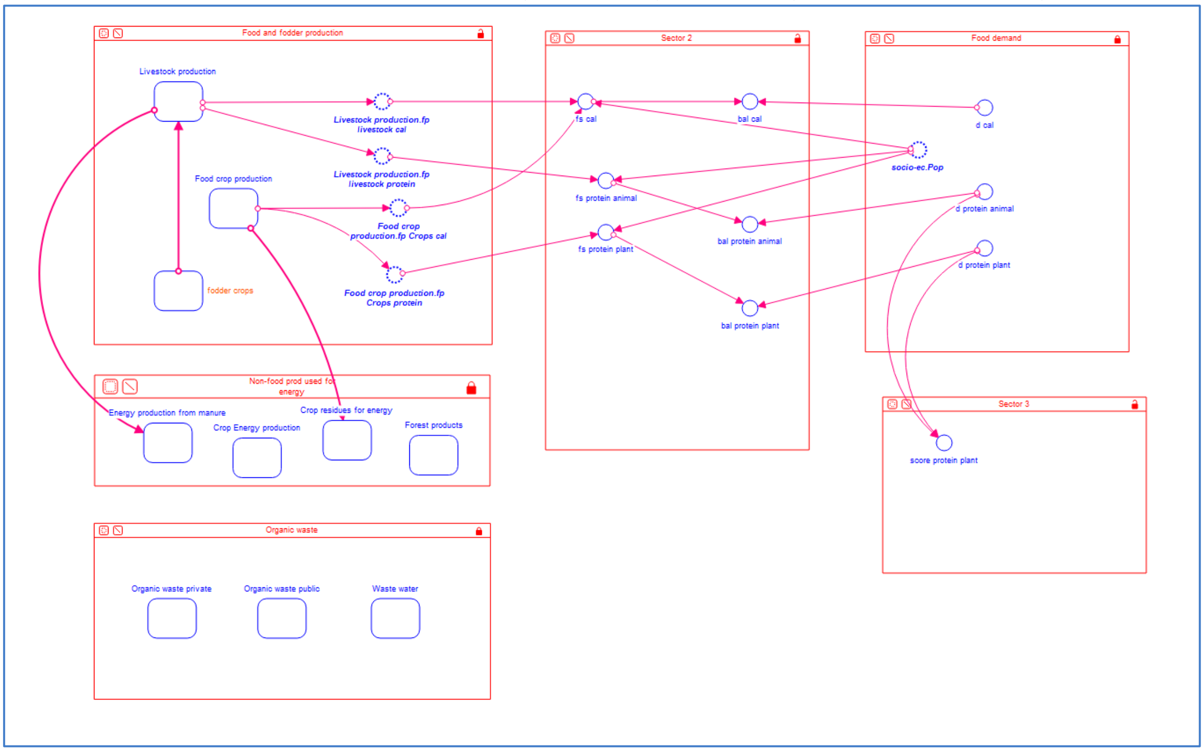


Figure 76 The food subsystem

The energy subsystem includes the energy production and the energy consumption, see Figure 77.

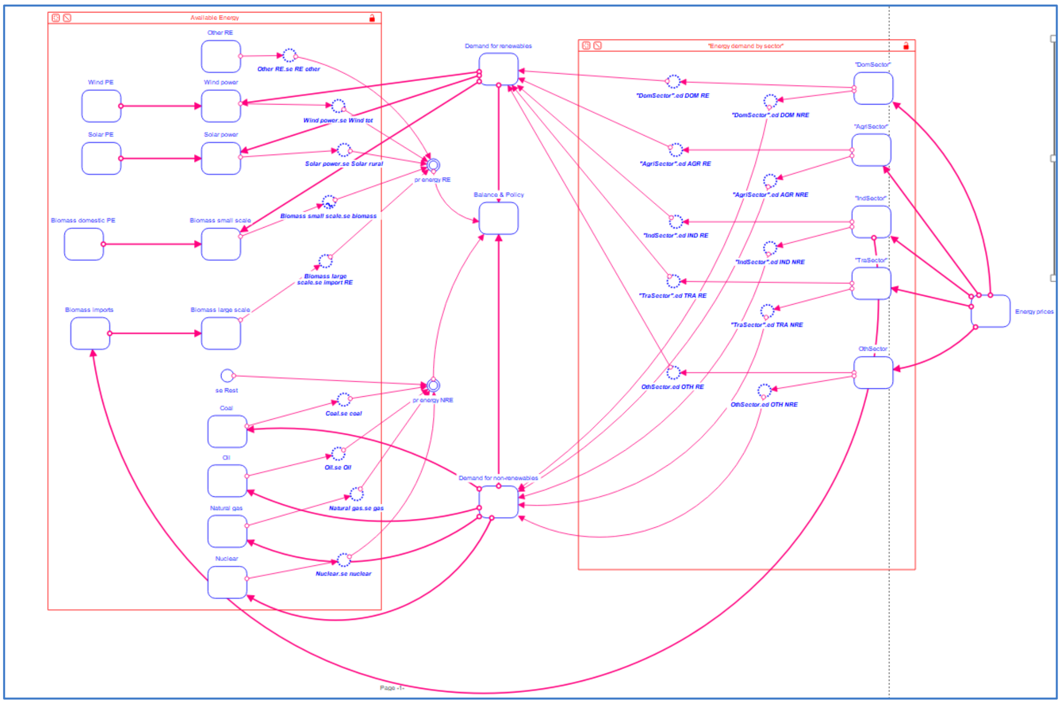


Figure 77 The energy subsystem

The water subsystem has got two subsystems. First, there is the agricultural emissions to water subsystem, see Figure 78. In this system, the diffuse sources of nitrogen and nitrous dioxide emissions related to agricultural activities are included.

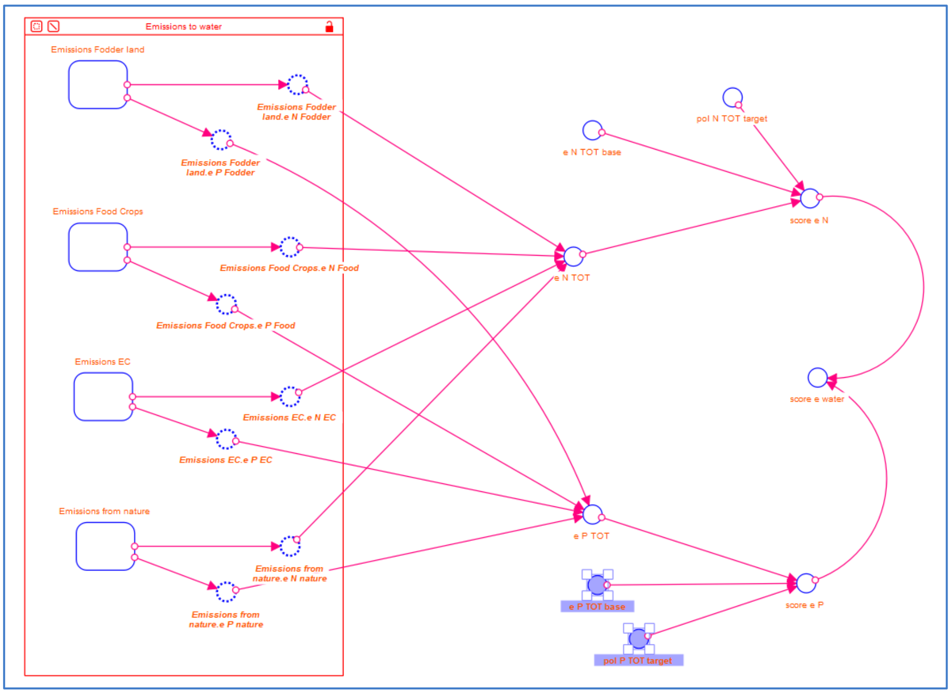


Figure 78 The nutrient emissions to water subsystem

Second, there is the agricultural water demand subsystem, see Figure 79.

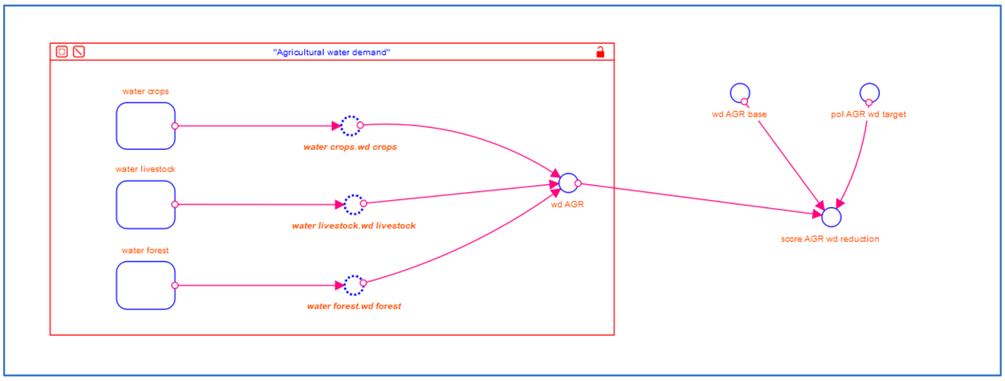


Figure 79 The water demand subsystem

The climate subsystem reflects the GHG emissions from the whole system, see Figure 80. It includes GHG emissions from energy production, GHG emissions not related to energy production from economic sector and agricultural GHG production related to agricultural activities.

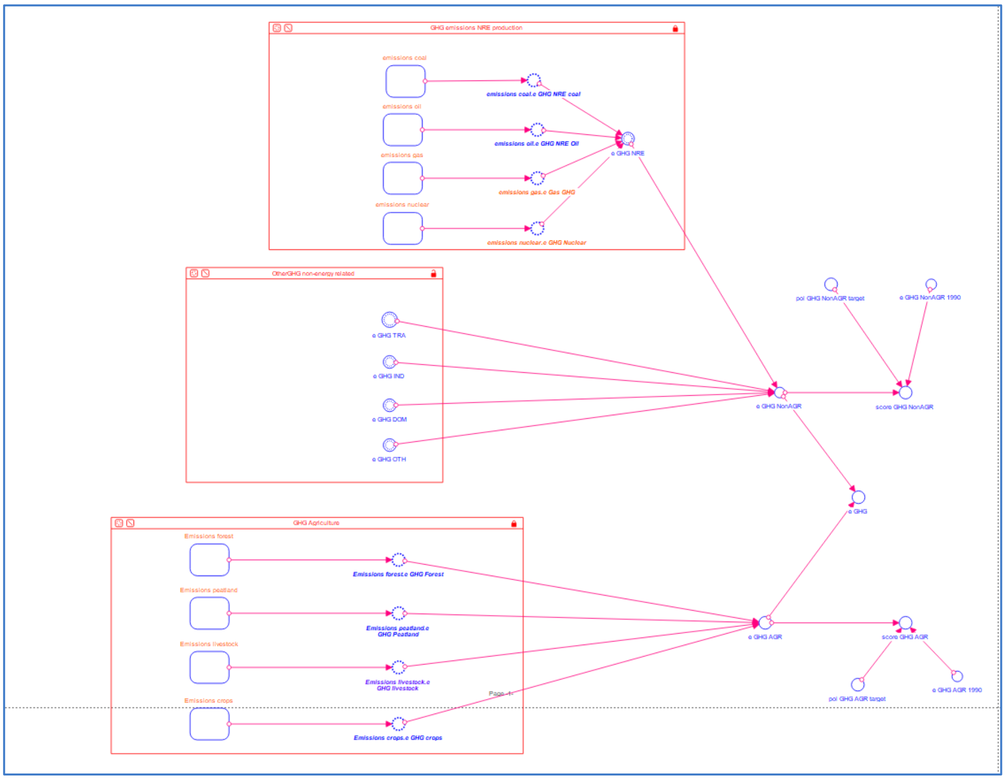


Figure 80 The climate subsystem

8.10.3 Policy cards

Table 37 presents the list of policy cards considered in the SDM for the Dutch case study. The ID of the policy cards identifies the connection of the policy card to the Nexus sectors and the economic sector(s). The first character relates to the Nexus sectors: energy ("E"), climate ("C"), land ("L"), food ("F"), and water ("W"). The second character relates to the economic sectors: agriculture ("A"), manufacturing industry ("I"), transport ("T"), Service sector ("O"), and domestic sector or households ("D"). IN addition, there are some policy cards for all sectors. Then, the second character is a "W".

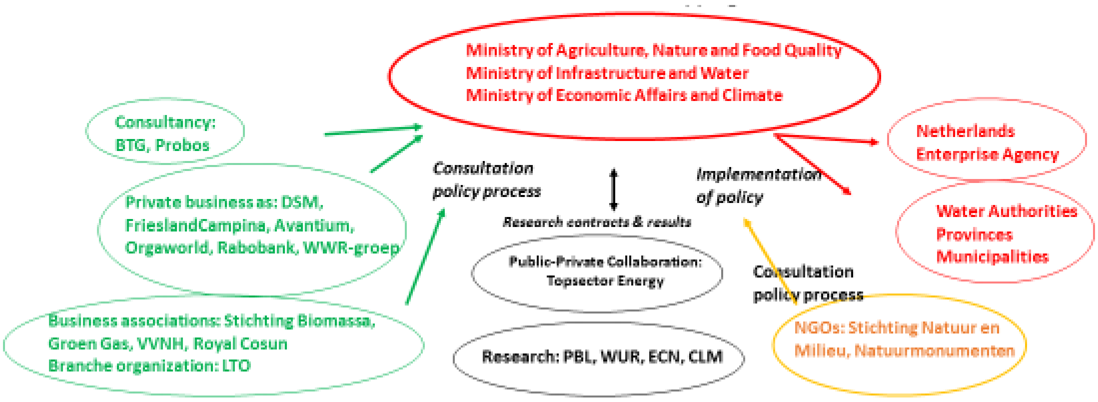
Table 37 List of policy cards for the Dutch case study

NR.	NEXUS SECTOR	SHORT NAME	NAME

1	CLIMATE	SUBSIDY SUSTAINABLE FARMING	SUBSIDY SUSTAINABLE FARMING AIMED AT REDUCING GREENHOUSGAS EMISSIONS FROM LIVESTOCK THROUGH CAP REFORM
2	CLIMATE	LOWERING EMISSION CEILING	ACCELERATED LOWERING OF THE EMISSION CEILING
3	CLIMATE	INCREASE COST CARBON FOR INDUSTRY	INCREASE IN COST NON-ETS GREENHOUSE GASES (OR NON-ENERGY GHG EMISSIONS)
4	CLIMATE	BAN ON WOOD STOVES	BAN ON WOOD-BURNING STOVES FOR HOUSEHOLDS
5	CLIMATE	TREES IN URBAN AREAS	CITIZEN ENGAGEMENT TO PLANT 160 MN TREES
6	CLIMATE	MORE CCS CAPACITY	INVESTMENT IN CCS BY ENERGY PRODUCERS
7	CLIMATE	INVESTMENT IN NON-ENERGY CCS	CCS INVESTMENT FON NON-ENERGY RELATED GHG EMISSIONS BY INDUSTRIAL PRODUCERS
8	ENERGY	BIOMASS EFFICIENCEY IMPROVEMENT	GREEN DEAL HIGH QUALITY BIOMASS
9	ENERGY	IMPLEMENT SUSTAINABLE BIOMASS PRODUCTION	FINANCIAL SUPPORT FOR MORE SUSTAINABLE BIOMASS PRODUCTION
10	ENERGY	MORE EFFICIENT FOSSIL FUEL	ENERGY EFFICIENCY FOR FOSSIL FUELS
11	ENERGY	REPLACE FOSSIL FUEL BY BIOFUEL	INVESTMENT IN BIOFUEL TECHNOLOGIES IN AGRICULTURE
12	ENERGY	INCREASE RENEWABLE ENERGY USE	INFORMATION CAMPAIGN ON PROMOTION OF RENEWABLE ENERGY USE
13	ENERGY	ENERGY SAVING BEHAVIOUR HOUSEHOLDS	STIMULATING ENERGY SAVINGS IN BEHAVIOUR
14	ENERGY	BIOGAS USE HUMAN MANURE	PRODUCING BIOGAS FROM HUMAN MANURE (= INNOVATION), INCREASE ENERGY PRODUCTION OF WASTE WATER
15	ENERGY	HIGHER ENERGY EFFICIENCY	INVESTING IN THE ENERGY EFFICIENCY OF EXISTING ENERGY TECHNIQUES BY 20%
16	ENERGY	INCREASE BIOMASS IMPORTS	IMPORT OF BIOMASS FOR LARGE SCALE USE IN ENERGY PRODUCTION OF (CHEMICAL) INDUSTRY; LESS FOSSIL FUELS FOR ENERGY PRODUCTION
17	ENERGY	CLOSURE COAL POWER PLANTS	CLOSURE OF COAL-FIRED POWER STATIONS
18	ENERGY	SWITCH FROM COAL TO BIOMASS	SWITCH FROM COAL POWER PLANT TO BIOMASS GENERATION
19	ENERGY	ENERGY SAVING OFFICES OF 10%	ENERGY SAVINGS IN OFFICES
20	ENERGY	SWITCH FROM NRE TO RE	INVEST IN RENEWABLE ENERGY TECHNOLOGIES IN OFFICES ETC.
21	ENERGY	BIOFUELS CARS	SWITCHING FROM DIESEL CARS TO BIOFUELS
22	ENERGY	ENERGY SAVING TRANSPORT	INVESTING IN ENERGY-EFFICIENT CAR ENGINES/TRANSPORTATION

23	ENERGY	SWITCH TO ELECTRIC/HYDROGEN CARS	SWITCHING FROM FOSSIL FUEL CARS TO LOW-CARBON CARS (ELECTRIC OR HYDROGEN)
24	ENERGY	SOLAR POWER ROOFS	INCREASE SOLAR POWER ON ROOFS IN URBAN AREAS
25	ENERGY	OFF SHORE POWER	INCREASE OF THE POWER PRODUCTION FROM OFF-SHORE WIND ENERGY
26	ENERGY	SWITCH TO RENEWABLE	INVESTMENT TO SWITCH FROM NON-RENEWABLE TECHNOLOGIES TO RENEWABLE TECHNOLOGIES
27	FOOD	IRRIGATION FOR HIGH VALUE CROPS	STIMULATE HIGH VALUE CROP PRODUCTION
28	FOOD	CHANGE OF DIET CONSUMERS	PUBLIC CAMPAIGN FOR A PLANT-BASED PROTEIN DIET.
29	LAND	REDUCTION HERD SIZE	RESTRICTION HERD SIZE TO REDUCE GREENHOUS GAS EMISSIONS
30	LAND	INVESTEMENT WATER STORAGE PEAT LAND	INVESTMENT WATER STORAGE PEAT LAND (HIGHER GROUND WATER TABLES)
31	LAND	ADDITONAL PRODUCTION FORESTS	INCREASE AREA UNDER FORESTS
32	LAND	IMPROVE SOIL QUALITY	IMPROVE SOIL QUALITY WITH BIOMASS (CIRCULARITY) BY 20,000 HA OF CEREALS INSTEAD OF FODDER CROPS (MAXIMUM 100,000)
33	LAND	SOLAR FIELDS	SOLAR POWER FIELDS
34	LAND	WINDPOWER ON LAND	INCREASE WIND POWER CAPACITY ON LAND

8.10.4 Stakeholders maps



Legend: green=private; red=government; orange=NGOs; black=research/consultancy
Source: Selnes et al. (2018, p. 30).
Figure x Stakeholder map for the Netherlands

9 Azerbaijan

9.1 Introduction

This case study on the Republic of Azerbaijan is performed as part of the Horizon 2020 project SIM4NEXUS. The case study is led by KTH Royal Institute of Technology and executed in collaboration with Wageningen University & Research, Cambridge Econometrics and PBL Netherlands Environmental Assessment Agency. It addresses the five sectors of the nexus Climate, Land, Energy, Water, and Food.

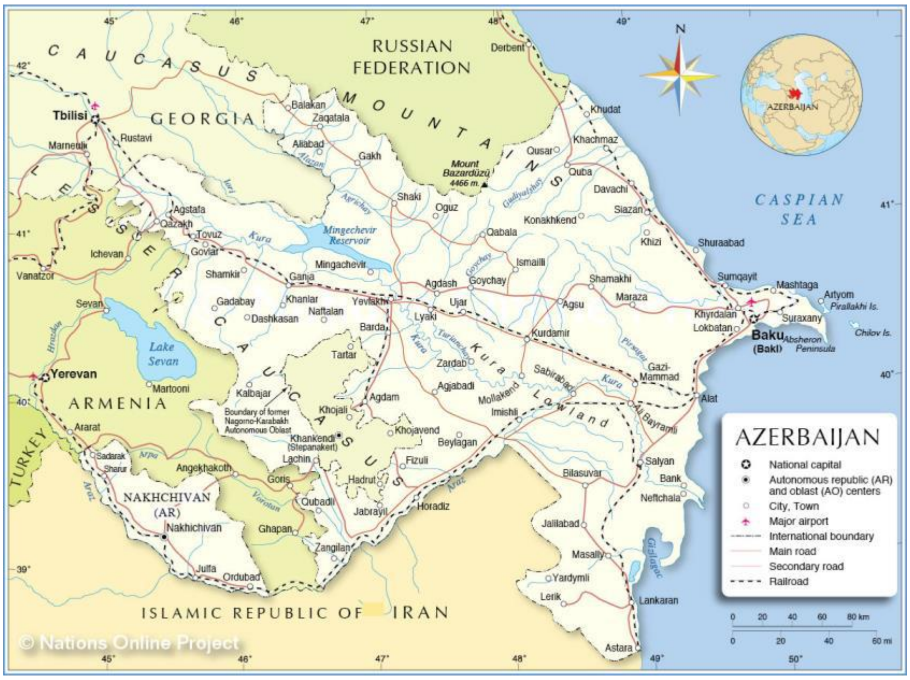


Figure 81 Political map of the Republic of Azerbaijan (source: nationonline.org)

Key nexus challenges are the high dependency on transboundary water resources and the dependency on income from oil and gas exports of the Azeri economy. The high dependency on transboundary water resources results out of the fact that the country is in the downstream area of the Kura and Aras river basins. Wastewater treatment is practically non-existent and water re-use is being investigated for irrigation purposes. Furthermore, Irrigated land is located in the lowlands, characterised by less precipitation. The climate is arid, the region is prone to floods and climate change is likely to affect water availability in the future.

Building on the key nexus challenges, the main research question of this case study is: *"What is the optimal way for Azerbaijan's transition to a low carbon economy while minimizing the stresses on the energy, water, climate, land use and food sector?"*

9.2 Overview of tasks performed

9.2.1 Organisation to carry-out Task 5.2

The tasks on KTH side related to the case study have been mainly executed by one research engineer or PhD candidate. In the model development phase this person has been supported by one Master's thesis student. The preparation of workshops has been partly supported by another research engineer or PhD candidate.

The pre-modelling step of a policy analysis in Azerbaijan has been supported by a local subcontractor and one person from the SIM4NEXUS partner PBL.

The modelling tasks related to Azerbaijan using the macroeconomic model E3ME and the Modular Agricultural GeNeral Equilibrium Tool – MAGNET have been conducted at Wageningen University & Research and Cambridge Econometrics respectively. Both of the modelling exercises were performed by one person.
The main communication measure were emails and discussions at project meetings and workshops. The key challenge in conducting the case study with three different models was to define common scenarios for tools with very different structure and behaviour.

9.2.2 Schedule of Task 5.2

Task 5.2 in the CS on Azerbaijan in the SIM4NEXUS project has been structured in the following steps:

- Literature review
- Development of an initial conceptual model
- Policy analysis
- 1st WS in Baku, Azerbaijan
- Refinement of conceptual model based on WS outcome
- Thematic models development
- SDM development
- SG development
- 2nd WS (pending)

The initial step in this case study was a literature review that collected information and data on the country and its nexus. Based on the information collected an initial conceptual model was developed. This conceptual model was presented and discussed at the first workshop in Baku, Azerbaijan with local stakeholders from ministries and other institutions from research and private sector. The outcomes of the discussions at the WS were used to refine the conceptual model. In parallel to the WS preparation, a policy analysis for the nexus sectors in Azerbaijan has been carried out and built the core of D2.2. The outcome of literature review, WS and conceptual model has built the starting point to develop the thematic models (OSeMOSYS model of Azerbaijan) or the scenarios in existing models (E3ME and MAGNET). Initially the intention was to use four thematic models. The original plan was to use an energy model build in OSeMOSYS, the macroeconomic model E3ME, and the agricultural general equilibrium model MAGNET. Initially it was also intended to use the agricultural economic model CAPRI (Gocht 2020). However, due to the initially not identified effort that creating a model for Azerbaijan would have meant, the CAPRI model was not used for the CS.
The conceptual model developed at the beginning of the CS built also the starting point for the development of the SDM. A bottleneck here was that the software used for building SDMs was not available for all consortium members since it had license cost. The SDM uses data as input from different sources. An important source for the SDM is the State Statistical Committee of the Republic of Azerbaijan (State Statistical Committee of the Republic of Azerbaijan 2020). Furthermore, the three thematic models provide input to the SDM.
Building on the SDM, the SG has been developed giving the SDM an appealing graphical interface with options to see the development of different parameters through the modelling period and the option to explore the dependencies of the variables in the SDM. The interactive component of the SG is added by policy cards that the user can play and that affect selected variables in the SDM. The policy cards were developed using the structure of the SDM, the policy analysis and the outcome of the first WS. A challenge in the development of the policy cards was the estimation of the effects of policies on the nexus.
A first public test of the SG took place at the wexglobal 2020 conference moderated by Mehdi Khoury. The final version of the SG will be played at the second stakeholder WS in Azerbaijan, presumably in the first week of May. The WS will be dedicated to providing input to finalise the initial policy recommendation presented in this report. To foster the discussion the results of the scenarios of the thematic models will be presented and the SG will be played.

9.3 Engagement of stakeholders in the process

9.3.1 Overview of stakeholders' engagement in the case study

The stakeholder engagement in the case study of Azerbaijan consists of two workshops. The first workshop had the goal to finalise the development of the conceptual model that captures the interlinkages of the different sectors of the nexus and to get an overview of nexus challenges and potentially interesting policies that could be considered in the modelling activities and in the development of the SG. The second WS is still pending and will have the purpose to present the outcome of the CS, namely the results of the scenarios modelled in the thematic models and the SG. Based on this, a discussion shall be held to get input for finalising the policy recommendations for the country.

Both WSs are designed for a wide range of stakeholders. Participants come from ministries, research institutions and the private sector. The wide field of different stakeholders has the purpose to get a comprehensive picture of the country and to receive diverse input and feedback on the work.

Table 38 Stakeholder Interactions

Interactions with stakeholders	Date Location	Number of participants and indicative distribution by nexus sector	Topics discussed	Outcomes / Achievements
1st Workshop	5.9.2018, Baku, Azerbaijan	25, Water: 5, Food: 7, Energy: 4, Other: 9	energy-water-food-climate-land nexus interlinkages, identification of challenges from a biophysical and a socio-economic perspective	- Sectoral trends - Nexus interlinkages
2nd Workshop	upcoming	Similar format as first WS	- Modelling results - Serious game - Potential policy recommendations	Final policy recommendations

In the above table each person is just counted once, therefore the number indicated is equal to the number of people involved in the CS stakeholder interaction.

9.3.2 Feedback on stakeholders' engagement in the case study

The goal of the workshop that has been conducted was to identify and confirm challenges in the different sectors and map the nexus sector interlinkages. This goal has been achieved and the workshop has been very useful to validate and improve the conceptual model. The participation from different sectors and backgrounds was good. As shown in Table 38 the workshop was attended by representatives of the sectors Water, Food and Energy. One can also highlight that not only the different sectors of the nexus were represented but also a set of different institutions. There were representatives from several Azeri ministries, research institutes, universities and from private companies present at the workshop.

A challenge for the case study team was the lack of a local partner in the consortium. A local partner might have facilitated finding more up-to-date and more detailed data to use as input for the models.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement NO 689150 SIM4NEXUS

With a local partner a more iterative process of defining the conceptual model and identifying the challenges in the nexus of Azerbaijan including stakeholders might have been possible.

9.4 From conceptual models to System Dynamic Modelling

9.4.1 Case study conceptual model

The conceptual model for the case study of Azerbaijan has been developed based on the findings in the first workshop with local stakeholders. The interlinkages between the five sectors of the nexus Water, Food, Land, energy and Climate are shown in Figure 82. More detailed graphs are listed in Annex 1.

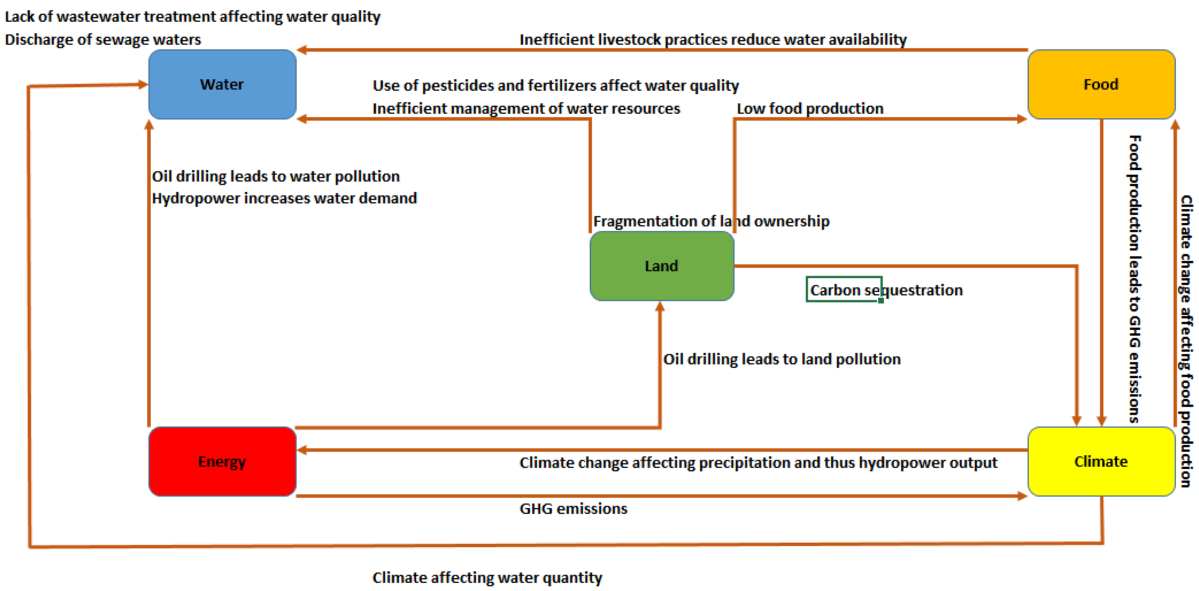


Figure 82 Conceptual model of the SDM for Azerbaijan and its interlinkages between sectors

9.4.2 Modifications introduced to model policy scenarios

9.4.2.1 Development of policy scenarios for the case study

Three scenarios were developed for the Azerbaijan CS. First, a baseline scenario consistent with the SSP2 projections. The baseline scenario forms the reference for the two so-called pathway scenarios. In these scenarios the impacts of climate change on the country and its different sectors are pictured while varying between a scenario with mitigation measures and a scenario without such measures. The scenarios can be described as below.

- Baseline: This scenario is constructed upon techno-economic data taken from the SSP2 (IIASA n.d.). No government policies are considered.
- Bad scenario (Climate change without mitigation): Climate change effects are considered, including extreme climate events, while no adaptation is considered.
- Good scenario (Climate change with mitigation): This scenario revolves around the transition of a carbon intensive economy to a low carbon future. Azerbaijan also aims at shifting from being an oil-based economy to become a more diversified one, reducing the risks and vulnerabilities of a hydrocarbon-centred economy, while promoting sustainable development.

In the table below the model set-up for each of the three scenarios are briefly described.

Table 39 Azerbaijan Case Study scenario assumptions across models

	E3ME	MAGNET	OSeMOSYS
Baseline	Population and GDP growth in line with SSP2	- Population and GDP growth consistent with SSP2 - Climate impacts on crop yields as in RCP6.0	- No particular policies considered - Gradual improvement of transmission-system assumed
Bad scenario	Emission levels from the baseline scenario used to estimate damage by climate change. These were then induced into the model	Crop yields as in RCP8.5, otherwise like baseline	Demand updated with E3ME output
Good scenario	Damages induced as in the "Bad scenario". 2% of GDP dedicated to adoption and mitigation.	- 20% renewables generation by 2050 - Increased crop productivity - 10% reduction in transport cost by 2030 - 2.5% increase per period in household energy efficiency - CO2 tax to achieve 35% reduction in GHG emissions by 2030 compared to 1990	- Demand updated with E3ME output - 20% decarbonisation by 2050 in comparison to 2020

9.4.2.2 Introduction of policy scenarios in the SDM

In the Azerbaijan CS the only linkage between policies and the SDM are policy cards from the Serious Game (SG). The linkages between policy cards and the SDM are described in section 9.5.3.

9.4.3 Modifications introduced to account for data availability

9.4.3.1 Data available from the thematic models

Some of the input data of the SDM originate from the thematic models of the case study. In the energy sector the data on energy demand, production and total annual capacities of different energy sources was collected using Energy-Environment-Economy Macro-Econometric (E3ME) and Open Source Energy Modelling System (OSeMOSYS) models (Fazekas, Alexandri, and Pollitt 2017). The demand for energy in the agricultural, industrial, residential, service and transportation sectors was retrieved from the E3ME model whereas the OSeMOSYS model was used to forecast energy production as well as the annual capacity of wind, solar, hydro, oil, closed cycle (Gas CC) and open cycle (Gas OC) gas energy sources. In the food sector results from the Modular Applied General Equilibrium Tool (MAGNET) are used. Specifically for the development of import and export balance of meat products (Fazekas, Alexandri, and Pollitt 2017). All other input data is retrieved from local sources.

9.4.3.2 Local data to be collected

The key local data source for the SDM was the State Statistical Committee of the Republic of Azerbaijan (State Statistical Committee of the Republic of Azerbaijan 2020).

9.4.4 Case Study SDM in Stella/R

The SDM is designed to contain all five segments of the NEXUS and the interconnections between those.

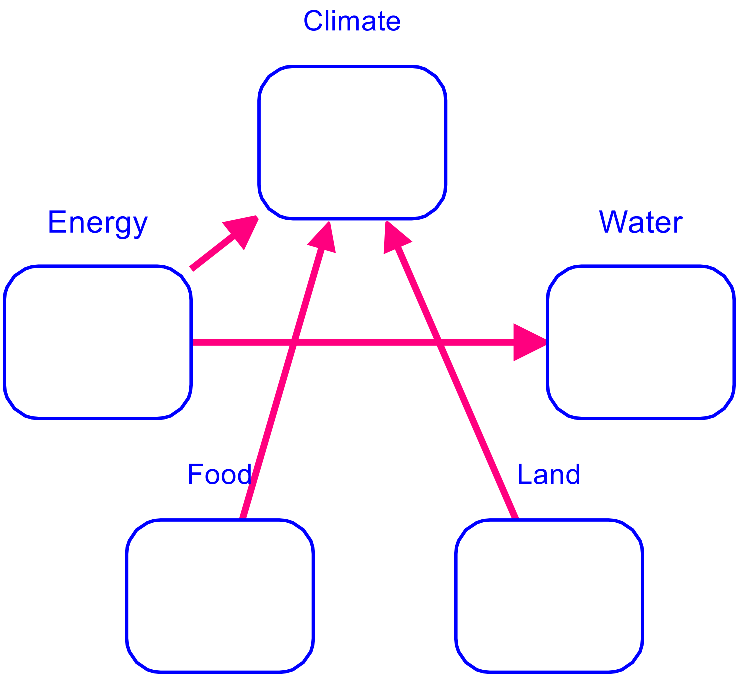


Figure 83 Structural Overview of the Highest Level SDM of Azerbaijan

Figure 83 shows that the energy, food and land segments have impact on the climate sector while energy is also interlinked with the water segment. In the following the links between the sectors and dynamics in the model are described.
The aim in designing the water segment of the SDM is to achieve a balance between the available water, water consumption and demand as shown in Equation 1.

$$\mathrm{water\_balance(t)} = \mathrm{water\_balance(t - dt)} + \mathrm{(Available\_water\_1} - \mathrm{W\_Demand)} * \mathrm{dt} \qquad (1)$$

The ground and surface water resources of Azerbaijan and recycled water are combined in the model resulting in available water. Domestic, agricultural and industrial water demand are included on the demand side of the model. The population of the country and per capita water consumption are considered to compute the domestic water demand. Moreover, water consumption in the cooling processes of the energy production systems are included in the SDM. The annual energy production data from the Energy segment of the model is linked to this segment of the SDM as an input. Finally, the water retained in the small hydro power plants is included in the consumption. This links the Water segment to the Energy segment by accessing the hydro energy production values from that sector.
In the land segment irrigated, non-irrigated and fallow land as well as the area covered by wetlands and forests are considered as a part of the total land use. Moreover, the land utilized for livestock is also included as an input to the total land use. The fertilizer use in agricultural land is added into the model inputs by using per hectare fertilizer consumption data and agricultural land use data to obtain the total fertilizer consumption in agriculture.

The design of the food sector is based on achieving the balance between the available food resources and food consumption. On both sides of the balance food products are divided into grain, vegetable, fruit, meat, dairy and other basic food products categories. In the 'available food' section, food stocks at the beginning of each year, the production and imports of the food products are summed to obtain the total resources for considered food products. In the food consumption section, the use of food products, their exports, losses and stocks at the end of a year are accumulated. For milk products, for instance, use of milk as fodder for cattle and poultries and industrial use of milk are added to the model.

In the energy segment of the model, the balance between the available energy and the energy demand is built. Available energy is segregated into energy produced from fossil fuels (oil and gas) and renewable energy sources (hydro, wind and solar energy).
On the demand side, however, energy consumption in the residential, service, agricultural, industrial and transportation sectors are included.

The climate segment is the final segment of the SDM, which is directly linked to water, land, food and energy sector. Figure 84 shows that this part of the model is designed to balance the GHG emissions and sequestration.

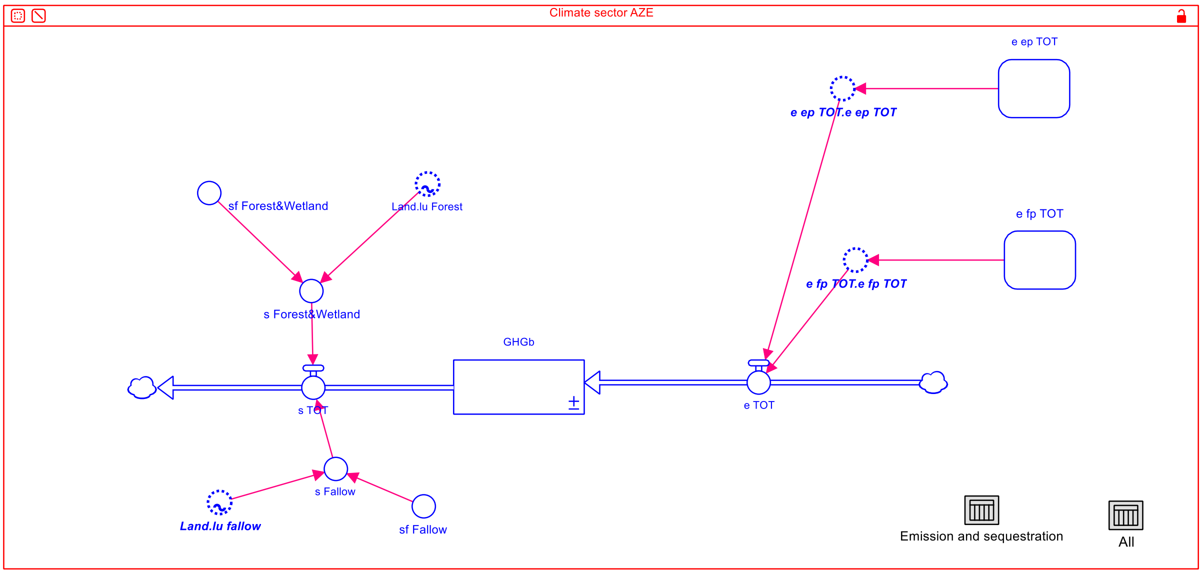


Figure 84 Structure of the Climate Segment of the SDM

The sequestration side of the balance links this section of the model with Land segment as both forests and fallow lands are sequestering the GHGs. The total sequestered GHG are obtained by using the sequestration factors and the forest and fallow land areas. The emission side, however, builds a dynamic connection between the food and energy segments with the climate sector. Here, the energy and food production values from the corresponding segments are multiplied by the emission factors to estimate the total emissions.

Please find a graphical representation of the SDM of Azerbaijan in Annex 9.10.2.

9.5 From the System Dynamic Modelling to the Serious Game

9.5.1 Case studies learnings goals

The CS of Azerbaijan has the following learning goal: *"You will learn how policies in the domains of agriculture, sustainable water management, and renewable energy can affect each other under climate change conditions, in a region where high agricultural production and tourism are competing for water."*
The learning goal of the case study caused a special focus on highlighting the interlinkages between nexus sectors. This is also visually shown in the SG. Clicking a policy card icon in the SG highlights the affected variables in the different sectors. Particularly important in the design of the policy cards in the SG was to indicate the policies effect across sectors, not only in one sector.

9.5.2 From generic to specific use cases

Two use cases were developed for the CS of Azerbaijan. Both are aiming to improve the understanding of the interlinkages between different sectors of the nexus. The first use case focuses on the interlinkage between Energy and Climate sector. The second use case focuses on the interlinkage between Energy and Water sector. The generic use cases provided were used as a template and source of ideas when defining use case adapted to the specific focus of the CS on Azerbaijan. The definition of users was done having in mind the different participants at the workshop with local stakeholders.
The use cases for the CS on Azerbaijan were developed at KTH (Hauke Henke) with support from NTUA (Chrysaida-Aliki Papadopoulou). They are displayed in Annex 9.10.5.

9.5.3 Policy cards

The SG of the Azerbaijan CS contains nineteen policy cards. Each of the five sectors Water, Food, Energy, Land and Climate is addressed by at least one policy card. The policy cards and a brief description is shown in Table 40.

Table 40 Policy Cards of the Serious Game on Azerbaijan

PolicyID	Nexus Sector	Policy card name	Description of intervention as captured by the policy card
1	Water	Water collection systems	Development of new water collection systems
2	Water	Management of reservoirs	Improved management of reservoirs
3	Water	Water recycling	Expansion of water recycling projects
4	Water	Flood management	Development of flood management projects
5	Water	Desalination of Caspian Sea water	Development of projects for the desalination of the Caspian Sea
6	Water	Innovative irrigation systems	Development of innovative irrigation systems
7	Water	Raising awareness for water savings	Training programs to raise awareness for water savings
8	Food	Optimal use of fertilisers	Campaigns for optimal use of fertilisers
9	Food	Optimal use of pesticides	Campaigns for optimal use of pesticides
10	Food	Optimal irrigation	Campaigns for optimal use of water resources in agriculture
11	Food	Selection of the most suitable seeds	Campaigns for selection of the most suitable seeds
12	Food	Soil tests	Campaigns for crop rotation
13	Food	Crop rotation	Campaigns for soil tests
14	Energy	Raising awareness for energy efficiency	Training programs to raise awareness for energy savings
15	Energy	Subsidies for renewables	Adoption of subsidies for renewables
16	Energy	Direct investments in renewables	Direct investments in renewables by the government
17	Land	National reforestation program	National reforestation program
18	Land	Voluntary reforestation	Voluntary reforestation
19	Climate	Campaigns for reducing carbon footprint in food production	Reducing carbon footprint in food production

The interventions captured by the policy cards were designed at KTH (Georgios Avgerinopoulos) using the findings from the first stakeholder workshop in Azerbaijan. The design included the estimation of cost and social acceptance. In a second step the implications of the policy cards on the SDM were developed. The policy cards affect different input variables in the SDM. For each input variable a change

per application of the policy card is defined and a total max change that can be achieved by applying the policy card several times.
By applying policy cards and by modifying input variables in the SDM, output parameters are affected. The score in the SG is calculated based on a set of output parameters of which a weighted average is calculated. Figure 85 shows the score overview at the beginning of a session. The overall score is the average of the scores of the different sectors.

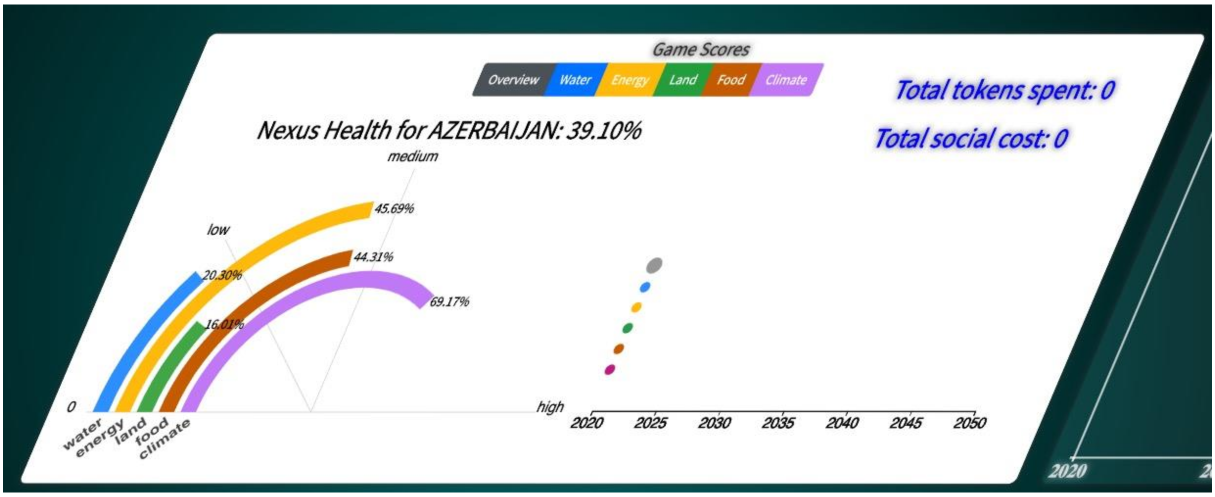


Figure 85 Serious game – Score overview

When clicking on one of the sectors at the top of the box shown in Figure 85 the box changes to a view like shown in Figure 86. Here the different policy goals for the sector are shown on the left. On the right the policy objectives that constitute are listed (O1, O2, etc.).

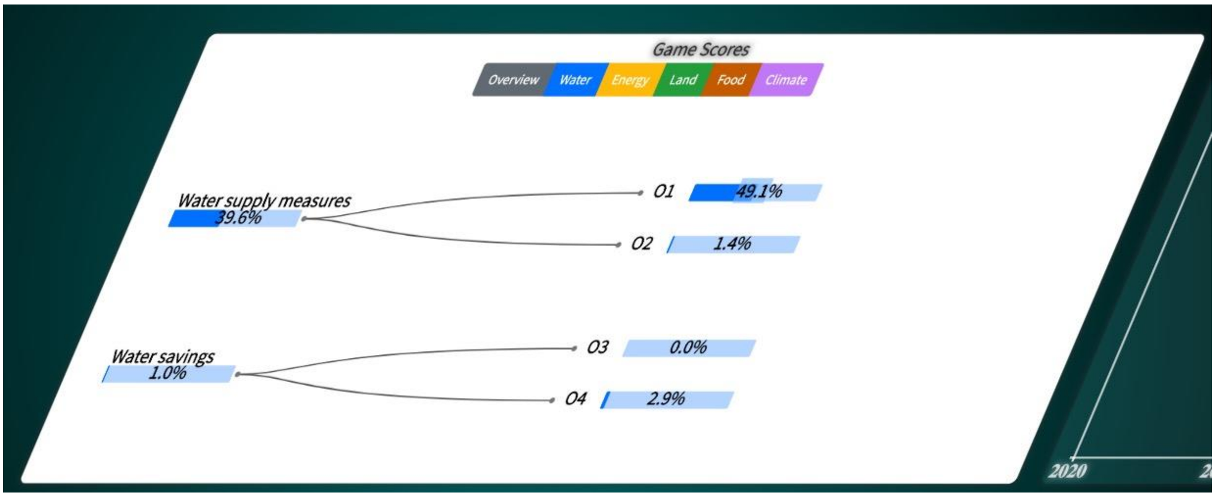


Figure 86 Serious game – Sector score composition

Each of the policy objectives shows a pop-up-window when right-clicked like shown in Figure 87. In the pop-up the policy objective’s title, the weight in the policy goal and the formula for its calculation are listed.

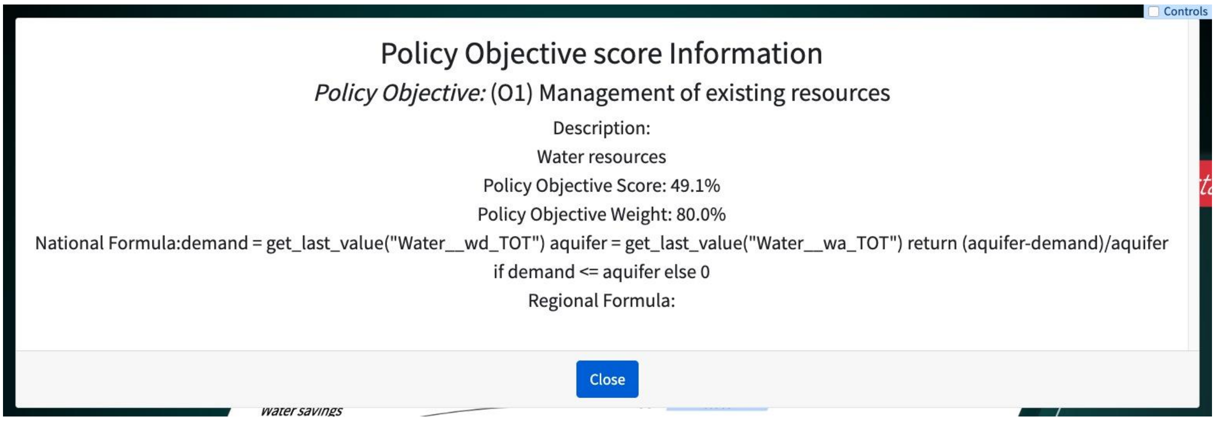


Figure 87 Serious game – Calculation of policy objective achievement

In the case shown in Figure 87 the policy objective is the management of existing [water] resources. In the lower section of the pop-up- window the formula for the calculation of the policy objective score is shown. In the illustrated case in Figure 87 the water demand and the available aquifer are retrieved from the SDM. As score the result of Equation 2 is returned, i.e. the smaller the demand in comparison to the available aquifer the higher the score.

$$\text{return} = \frac{(\text{aquifer} - \text{demand})}{\text{aquifer}} \tag{2}$$

9.5.4 Serious Game interface

The general layout of the SG for the CS of Azerbaijan is the same as for other CSs in the SIM4NEXUS project like for example the Greek CS. Up on start the interface of the game shows four panels. The panel in the top left show the current score and allows to select a specific score. On the top right a panel shows the time-line and the played policy cards. In Figure 88 one policy card concerning the water sector has been applied so far.

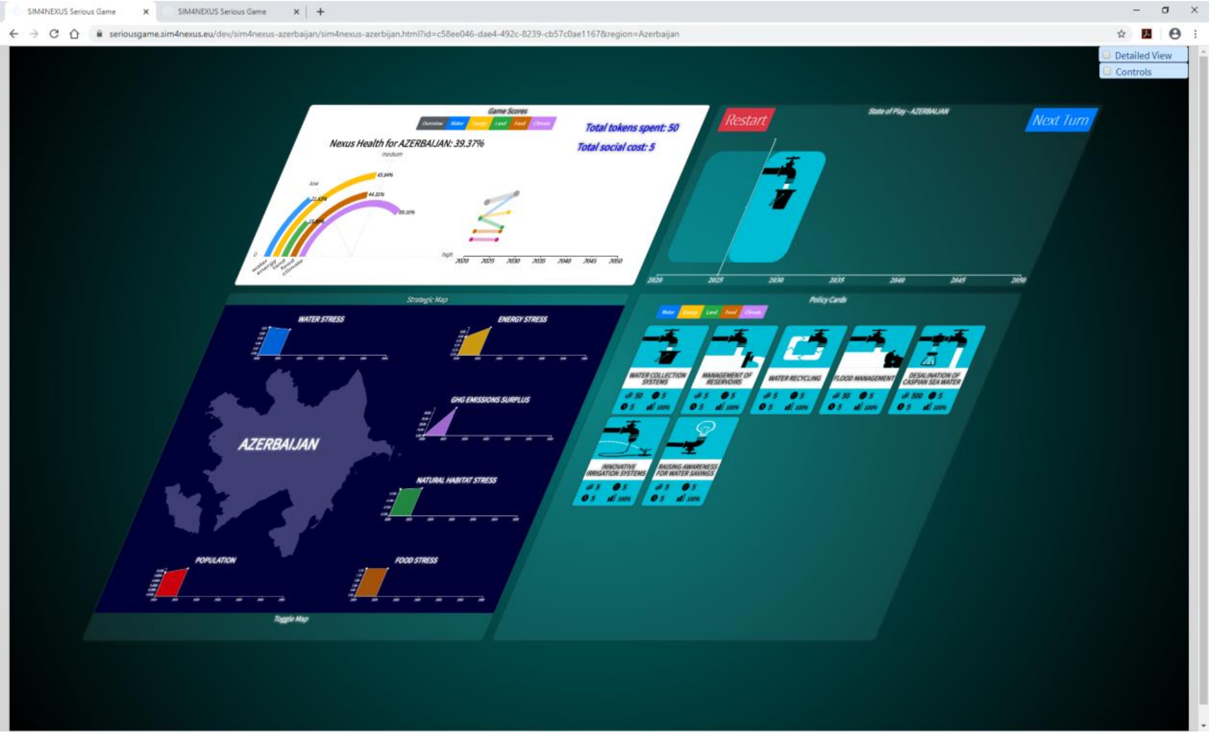


Figure 88 Interface Serious Game Azerbaijan

In the bottom left the shape of Azerbaijan is shown with six graphs arranged around it showing the stress level of the different nexus sectors and the population development. The bottom right panel shows the different policy cards that one can play. At the top of the panel the player can select the sector of interest. In Figure 88 the policy cards for the water sector are shown. At the top right corner of the window one can see two small boxes. The lower one opens a window with information on how to control and navigate in the game. The top box opens additional panels to provide more information. A view of the game with the additional panels is shown in Figure 89.

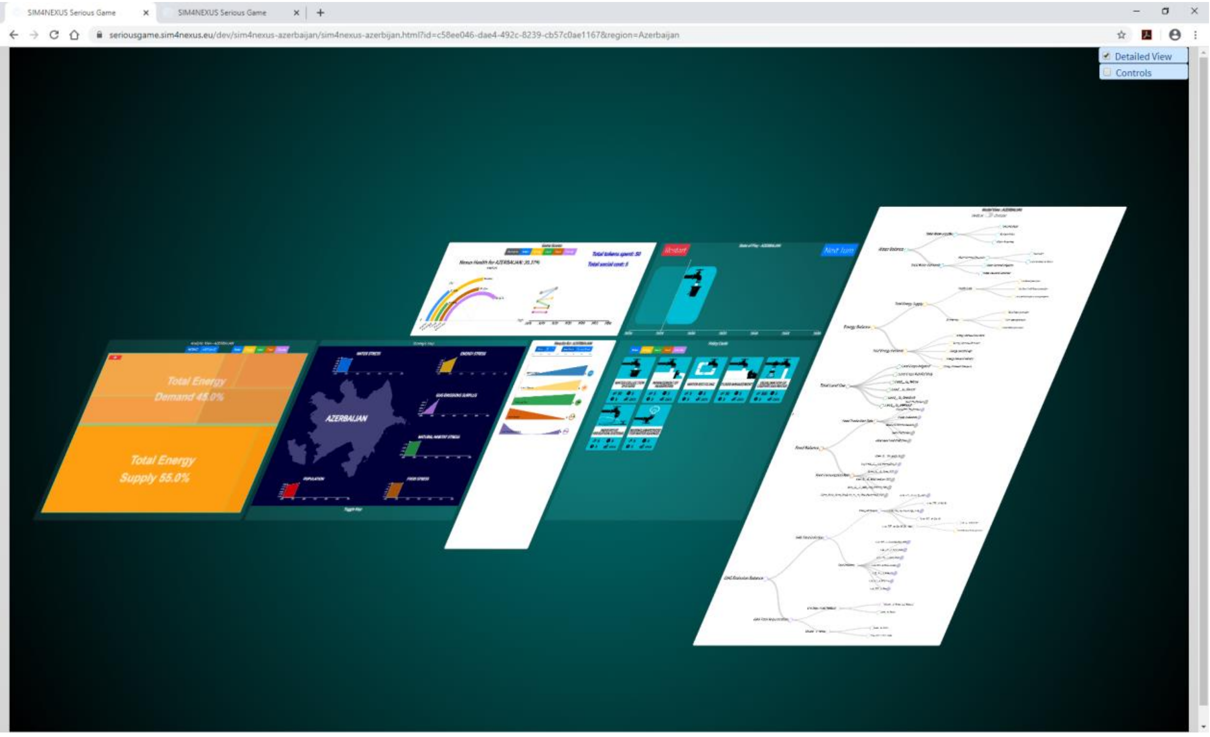


Figure 89 Detailed view of the interface of the Serious Game Azerbaijan

Most of the panels allow the user to retrieve more detailed information on the illustrated content. For example a right click on the circular graph of one of the scores in the top left panel opens a graph showing the development of the score in detail, see also Figure 90.

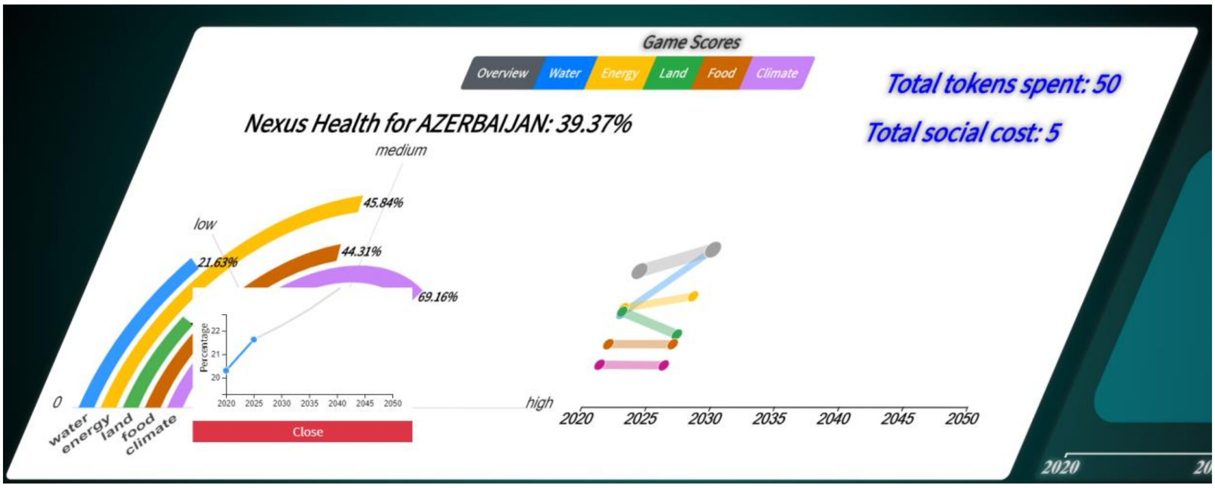


Figure 90 Detailed score development window

After selecting a sector in the games score panel, a right click on one of the policy objectives opens a window with the formula that calculates the score, as shown in Figure 91. This allows the user to develop an understanding of how the game works.

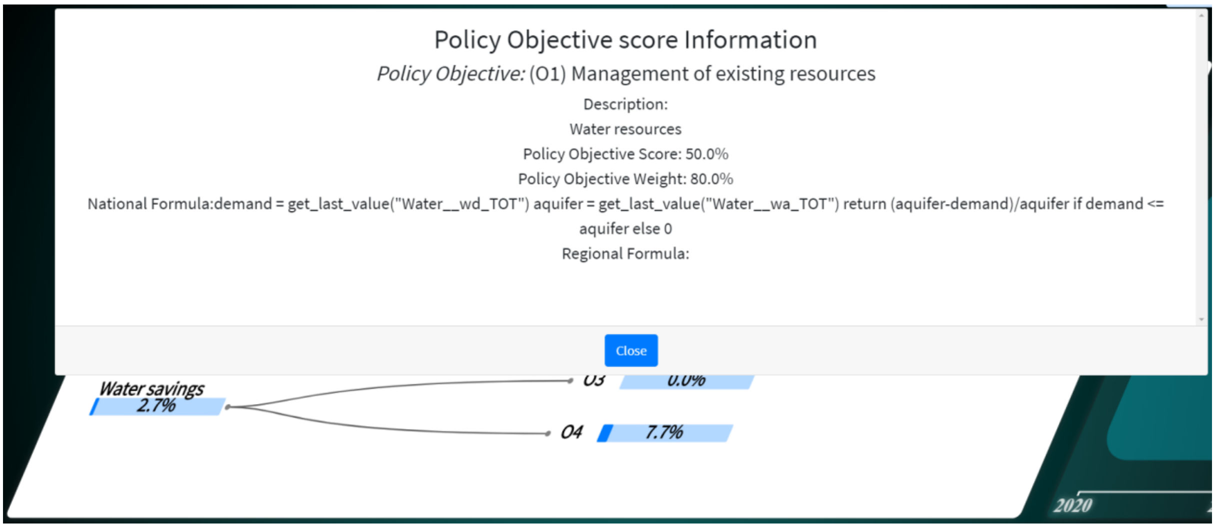


Figure 91 Calculation of score for policy objective

The connection of policy cards to variables in the SDM can be explored by clicking on them. After clicking a policy card the panel on the right of the window marks the variables affected. In Figure 92 the policy card on energy efficiency has been clicked and in the tree structure of the variable the path to the variables affected are marked in blue.

Figure 92 Linkage of policy cards to variables in the SDM

The panel in the bottom centre (when detailed view is selected) shows a balance for each sector, e.g. for climate the balance between emissions and sequestration is shown. However, by clicking on a graph of interest one gets a more detailed view of the sector. In Figure 93, the energy balance has been selected in a first step. Then the demand side was selected. The graph shows the development of the different types of demand during the period of the game.

Figure 93 Detailed results in the SG for Azerbaijan

9.6 From the SDM and SG to policy recommendations

9.6.1 Answering main research questions of the case study

The initial research question of the Azerbaijan CS has been *"What is the optimal way for Azerbaijan's transition to a low carbon economy while minimizing the stresses on the energy, water, climate, land use and food sector?"*, as mentioned in chapter 9.1.

Looking back this research question has probably been formulated to broad to be answered concisely. However, the analysis of the different sectors of the nexus and their interlinkages produced some valuable indications to consider for Azerbaijan's transition to a low carbon economy. The analysis shows that the sector offering most jobs in Azerbaijan is the agricultural and will probably also remain the sector with most jobs in the country. The agriculture is strongly depending on the water availability in the country. Due to the arid climate of Azerbaijan water is a valuable resource. It has been identified that cross-sectoral water resource planning would be needed. This also implies permanent cooperation with neighbouring countries for example for flood management. The cooperation across borders is of high relevance for a proper water resource planning since Azerbaijan is located downstream of its main river basins, i.e. the major rivers flowing through the country originate in neighbouring countries.

Cooperation is also needed in a different field. In 2017 about 16% of the Azerbaijan's GDP originated from fossil fuel exports. This implies that the Azeri economy is significantly relying on the demand and the global price development of fossil fuels. Considering that global push for decarbonisation might reduce the demand for fossil fuels, Azerbaijan needs to evaluate options to reduce the impact of a declining income from fossil fuel exports. This could potentially be done with foreign partners. For example to convert the knowledge of the oil and gas industry into new industrial business.

The modelling results from the three thematic models used in the case study indicate that the impacts of climate change on the country reduce when adaptation and mitigation measures are taken. In correspondence to the initial research question, one could therefore say that the ideal pathway of Azerbaijan to a low carbon economy leads through cooperation with neighbouring countries and trade partners and policies that foster alternative industries to the oil and gas business.

9.6.2 Supporting policy coherence

This section cannot be filled for the CS of Azerbaijan since no policy coherence analysis has been conducted.

9.6.3 Testing policy scenarios

So far, the testing of the SG has brought up two messages. However, it needs to be taken into consideration that the SG for Azerbaijan is still a beta version where some final improvements still need to be made.

The first message that can be drawn from the testing of the game is that applying no policies is the worst option. On the long-term score and nexus health are going to decrease. However, one needs to consider that the SG does not provide policy options that clearly work against the overall nexus health, e.g. there is no fuel subsidy for poor people considered. Such a policy could be of interest in case that there is a significant share of the population having affordability problems concerning fuels for heating or cooking. Such a policy would increase GHG emissions if it would be applied on fossil fuels. Therefore, there are certainly worse possible futures concerning the nexus health in Azerbaijan than pictured in the SG. For a future improvement or new SGs this is certainly an aspect to consider in the development. One could say that the aim to provide suggestions and insights on how to improve the nexus health narrowed down the scope on possible policies and resulted in a set of policies that are in support of the nexus health.

The second message from playing the SG of Azerbaijan is that there is not the one policy that solves the issues in all sectors, but that most policies affect more than one sector. This implies that policies related to the sectors of the nexus require a coordinated planning, which includes the stakeholders from all affected sectors to minimize unwanted side effects and to reduce double planning.

9.6.4 Addressing Nexus challenges

In D5.2 challenges for the sectors water, land, energy and climate were identified. Many of them are addressed in the SDM and SG. However, not all of them.

A key issue in the water sector is the dependency on neighbouring countries. 75% of the renewable water resources originate in neighbouring countries. There could be two approaches to tackle this problem.

- Firstly regional coordination and cooperation in water management.
- Secondly national efforts to manage the water resources and limit the demand.

To picture the first approach with a modelling technique, a hydrological modelling of the river basins would have been necessary. However, this was beyond the capabilities and time availability of the partners involved in the CS. Anyhow, the second approach is captured in SDM and SG where its effects can be explored with a set of policies: reaching from policies for water collections systems over water recycling to raising awareness for water savings.

In comparison to other countries, Azerbaijan has a low share of land covered by forest, only 12%. This is addressed in the SG by providing different policy options for reforestation. However, policies are not available against the identified issue of illegal logging in Azeri forests.
As mentioned previously the Azeri energy sector relies heavily on domestic sources of oil and gas. In the power sector a shift from oil to gas has been identified. The SG provides the user to explore policy options to reduce carbon emissions by supporting the implementation of renewable power generation technologies and by increasing energy efficiency. However, it was not accomplished to reflect the high importance of fossil fuel exports to the Azeri economy in the game since the interactions with the rest of the world were not considered in all models.
A highly vulnerable sector to climate change in Azerbaijan is the food sector, especially since about 40% of the working population are employed in agriculture. The high share of population working in the agricultural sector and the risk of being dependant on food imports in case of reduced productivity in the food sector (as a consequence of climate change and dryer weather) are severe risks for the country. To maintain and increase productivity of the food sector, the SG provides a wide range of policies: starting from an improved use of fertilizers over better irrigation to crop rotation.
Summarising, the SG and the SDM do not cover the Republic of Azerbaijan and its nexus in all its complexity and all its challenges. But it provides a starting point for a cross sectoral discussion and an increase in awareness of the challenges and the possible solutions of the country for a transition to a low carbon economy.

9.7 Short-term and long-term policy recommendations

9.7.1 Summary of the Nexus issues in the case study

An important factor for successful cooperation in Azerbaijan seems to be international support, as highlighted in D2.3. In different sectors, a wide range of projects and initiatives with international participation have been conducted or are going on. It can be seen as an indication that institutions in Azerbaijan welcome foreign help when domestic know-how is lacking or not sufficient. However, it was also noted that there are no or only very few initiatives that work cross-sectoral. Cross-sectoral cooperation could be an important factor for success of Azerbaijan's transition to a low-carbon economy. The literature review, the first workshop in Azerbaijan, the modelling exercise conducted as part of the CS, the SDM and the SG indicate that the nexus sectors are connected in many ways. Previously, the example of employment in agriculture and the issue of illegal logging in forests were mentioned. Both examples indicate that there are even more linkages and effects on society to expect from policies on nexus sectors that are pictured in this simplified CS. Therefore, one recommendation of this CS shall be for the Government to take measures to improve the dialogue between sectors and enable joint policies of ministries responsible for different sectors.
From the analysis carried out in the CS the connection between food sector and climate seems of particular importance. Decreasing water availability due to climate change could not only cause a reduction in productivity of the agriculture in Azerbaijan, which might lead to import dependencies, but it would also affect large parts of the population and their income. Therefore, measures to increase the climate change resilience in the food production sector seem necessary. The CS aims to give an indication on what could be done in this regard.
Anyhow, the recommendations and suggestions of this deliverable are preliminary, since there is still the second workshop (WS) in Azerbaijan pending. The WS is expected to be held in the first week of May 2020 in Baku, Azerbaijan.

9.7.2 Description of the policies targeted for recommendations

In the previous section it has been discussed that this CS aims to provide at least two (policy) recommendations. More might be developed depending on the outcome of the second stakeholder WS of the CS in May in Baku, Azerbaijan.

The first recommendation suggests creating procedures in the policy design process which facilitate the consistency of policies across sectors. Such procedures could be for example committees with representatives from the affected sectors which need to discuss or even give consent on new policy developed. Such cross-sectoral committees could improve the consistency of the overall policy framework and reduce contradictions between different sectors or policies that are working against each other. Certainly involved and affect in such a procedure would be the five ministries that are part of the stakeholder map defined in D2.2, i.e. Ministry of Economy, Ministry of Ecology and Natural Resources, Ministry of Energy, Ministry of Emergency Situations and the Ministry of Agriculture. Depending on the design of such committees, other stakeholders might also be involved, e.g. for providing expertise. In any case, a more holistic process of policy design could affect all kind of stakeholders that were identified.

The second policy recommendation considered concerns the climate resilience of the agricultural sector in Azerbaijan. From the policies mapped in D2.2, only law no. 344-IIQ "About stimulation of insurance in agricultural industry" indirectly addresses this matter. The policy aims at enabling producers of agricultural products to insure their property. Depending on the design of the insurances, this could protect the producers from certain climate change impacts, e.g. production losses due to draught years. However, to tackle climate change while not getting very dependent on food imports and without disruptions on the labour market is a major challenge and needs to be addressed by more than one policy or ministry. The measure proposed is the development of a catalogue of climate change mitigation and adaptation measures for the agricultural sector. These measures would be implemented at a producer level or at municipality level. Measures could be provided with different kind of support. Depending on their nature, they could be either provided with know-how support, financial for implementation or similar. The development and the implementation of the measure would involve Ministries like the Ministry of Agriculture, Ministry of Ecology and Natural Resources, Ministry of Economy and Ministry of Energy. Furthermore, institutions like the National Science Academy, the State Company for Alternative and Renewable Energy, the Amelioration & Water Management Company and others could be involved in the development and implementation of measures to make the agriculture resilient to climate change.

9.7.3 Policy recommendations

9.7.3.1 Changes in policy contents

The suggested catalogue for local measures to increase climate change resilience in the agricultural sector aims to create a set of measures that could increase the resilience of the Azeri agriculture to climate change. The measures should start from building an understanding at the local level what potential implications might be to measures that reduce the impact or adjust to the change. The policy has two goals. On the one hand the productivity of the Azeri agriculture shall be secured to avoid increasing import dependencies. On the other hand, the policy shall prevent an abrupt reduction in jobs provided by the sector, which could occur in case that climate change effects like e.g. draughts hit the sector. In the proposed bottom-up approach the first step is the creation of local knowledge concerning the potential implications. The concrete mitigation and adaptation measures are then locally agreed on and implemented with support from the central government. The bottom-up approach has several advantages in comparison to centrally driven policy. Firstly, the creation of local awareness will increase the acceptance and willingness to implement measures, especially if the measures are affecting habits and routines. Secondly, the local needs might vary quite strongly and therefore the measures will address those needs a lot better if the measures have been agreed on locally. Important will be that the catalogue provides a sufficiently large variety of measures to allow the local stakeholders to develop a tailor-made mix of measures for which they can get support, either financially or in know-how.

Such a kind of catalogue and the proposed bottom-up approach are naturally challenging, especially for a country that is more used to a centralised organisation. However, it brings many advantages. Local tailor-made solutions are more prone to fit the needs. There are of course similar settings at different locations for which one could argue that it would be more efficient to simply apply the same solution. However, if this solution is not working then one needs to start from scratch again and won't have the example of a different solution in similar setting that might have worked out. Therefore, the catalogue for local solutions has the potential to be more robust than a centralised plan.

Table 41 In short - Catalogue for local measures to increase climate change resilience in the agricultural sector

In short	Catalogue for local measures to increase climate change resilience in the agricultural sector
Target group	Ministries directly or indirectly involved with agricultural matters, utilities, and research institutions
Target policy goal	Providing farmers a tool box to make their business resistant against climate change
Target policy instrument	Defined support measures to improve know-how and infrastructure locally in the agricultural sector
Target policy process phase	Implementation
Administrative level	community, region, country
Time scale	short term till 2030, middle-term till 2050
Cost-effectivity	Medium
Social implications	Securing jobs, goal to change behaviour

9.7.3.2 Changes in the policy process

The suggested policy on a procedure for cross-sectoral policy consistency aims directly at the policy design process. The suggestion is held open in how it should be designed. The goals could be achieved for example by a committee that has to approve policy drafts. But a working procedure in which the different ministries involved give feedback could be a solution as well. The suggestion is to implement a mechanism that ensures that new policies that are affecting several sectors of the nexus are designed consistently with other existing or planned policies in the nexus which might be developed by other ministries. The procedure shall enable ministries to get insight in policy drafts of other ministries at an early stage to get the opportunity to contribute or add comments or even raise a veto in case the planned policy will conflict with other policies in a sector.

Important in the design of this mechanism is to create the process in a way that the steps of the process encourage cooperation among the involved ministries. A wrong design could create blockades among the ministries. It is therefore necessary to establish a process in which contributions need to be considered and vetoes need to be explained and be complemented with indications how to solve the identified issues. To avoid that the policy making process becomes unreasonably long, times for responses need to be defined, e.g. how much time does a ministry have to respond to shared drafts.

Summarising this policy aims to create a procedure that enables the government of Azerbaijan to develop consistent policies for the nexus by improving the cooperation between the ministries involved.

Table 42 In short – Procedure for cross-sectoral policy consistency

In short	Procedure for cross-sectoral policy consistency
Target group	All Ministries affecting sectors of the nexus or being affected by changes in the nexus
Target policy goal	Consistency among policies affecting the nexus
Target policy instrument	Cross-sectoral committee or procedure to create consistent policies across the sectors of the nexus
Target policy process phase	Policy planning

Administrative level	Country
Time scale	short term till 2030
Cost-effectivity	High
Social implications	Positive

9.8 Conclusion

The suggestions developed in this deliverable address two key nexus challenges.

The proposed procedure to avoid policy conflicts tackles the challenge of designing policies from different ministries to a consistent policy framework for the nexus. Such a procedure addresses the issue of overlapping policies and responsibilities, and contradicting policies at the root.

The second proposal aims at a nexus challenge that was identified by the combination of results from literature review, modelling exercise, and SG. The agricultural sector in Azerbaijan has been identified as particularly sensitive for the country. It's linkages with other sectors should give it a high importance on the political agenda. Firstly, there are the negative impacts that need to be expected from climate change. This could then cause import dependencies for the sensitive product of food. Furthermore, the agriculture is depending on the water, which comes to a large extend from rivers that originate in neighbouring countries. Especially under a climate change scenario this could become critical. And lastly the agricultural sector provides jobs to 40% of the working society. Potential problems in the agricultural sector would directly affect a large part of society.

Considering this cross-sectoral challenges with potentially high impacts on society, the suggestion has been made to develop a catalogue of measures combined with a campaign to raise awareness. The measures taken shall be agreed on locally to foster acceptance and develop a robust know-how on solutions. It is consciously suggesting a process that is requiring interaction between local stakeholders and governmental representatives to avoid one-size-fits-all solutions which might not work out for many locations or not at all and therefore come with the risk that measures taken might turn out useless while not having an alternative at hand.

This CS is an initial attempt to create a picture of the challenges that the climate, land, energy, water, and food nexus faces in Azerbaijan. Due to the circumstances of the CS - without having a permanent local partner - this work remains an initial attempt. However, there are some lessons learned, in the scenario development but especially in the development of policy cards for the SG. It would have been of value to also consider options that might seem attractive when only looking at one specific problem or sector, but not keeping in mind or ignoring the implications for other sectors. Earlier the example of a subsidy for gas and oil for the use for cooking and heating was mentioned. This could reduce illegal logging but would cause additional emissions of GHG.

The input to the CS from stakeholders was limited, since so far only one of two WSs has been held. Nevertheless, the input received at the first WS was very valuable for the development of the conceptual model.

The nexus approach has facilitated the CS to identify the challenge of the agricultural sector with its dependencies and relation to other sectors. This would probably not have been achieved by an analysis that would have focused only on one sector. The challenge probably would have been discovered only partly. A more detailed analysis with more stakeholder engagement and with a better consideration of the interconnections of the country with the rest of the world would probably discover even more challenges and draw a more precise picture. For such objective, the work carried-out in this CS could provide a good starting point.

9.9 References

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9.10 Annexes

9.10.1 Conceptual model

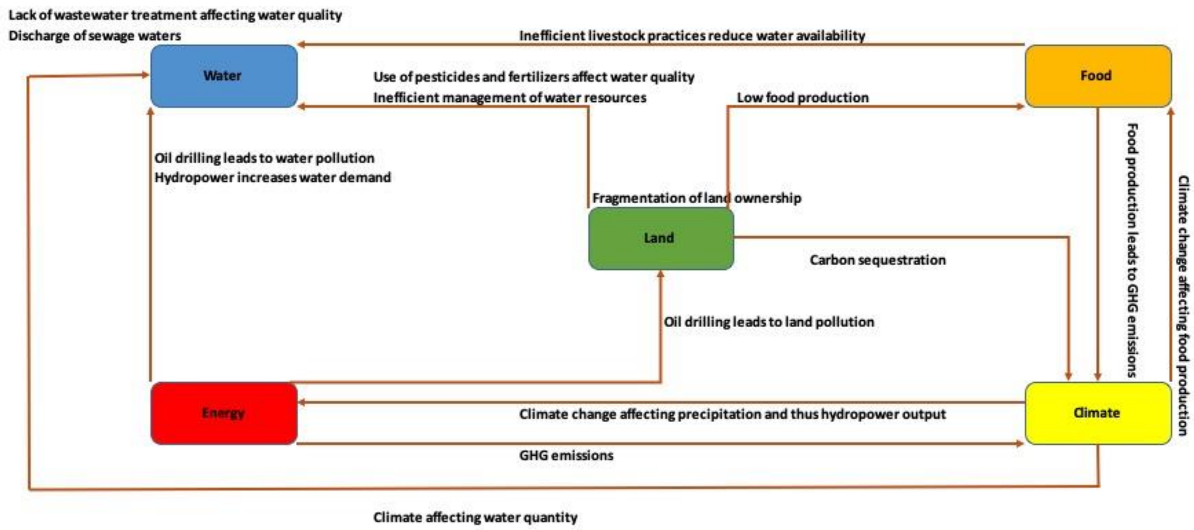

Figure 94 Conceptual model – interlinkages

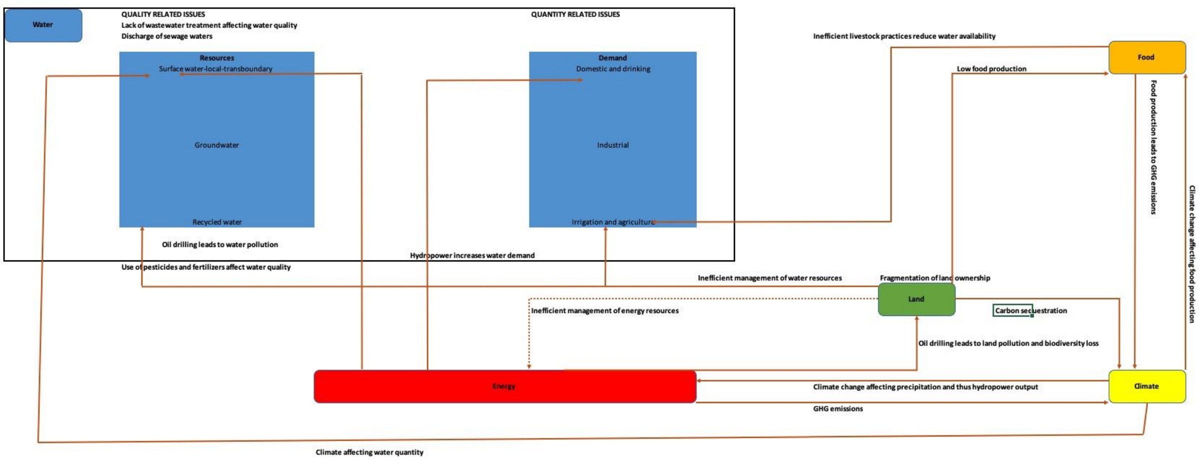

Figure 95 Conceptual model – Water

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement NO 689150 SIM4NEXUS

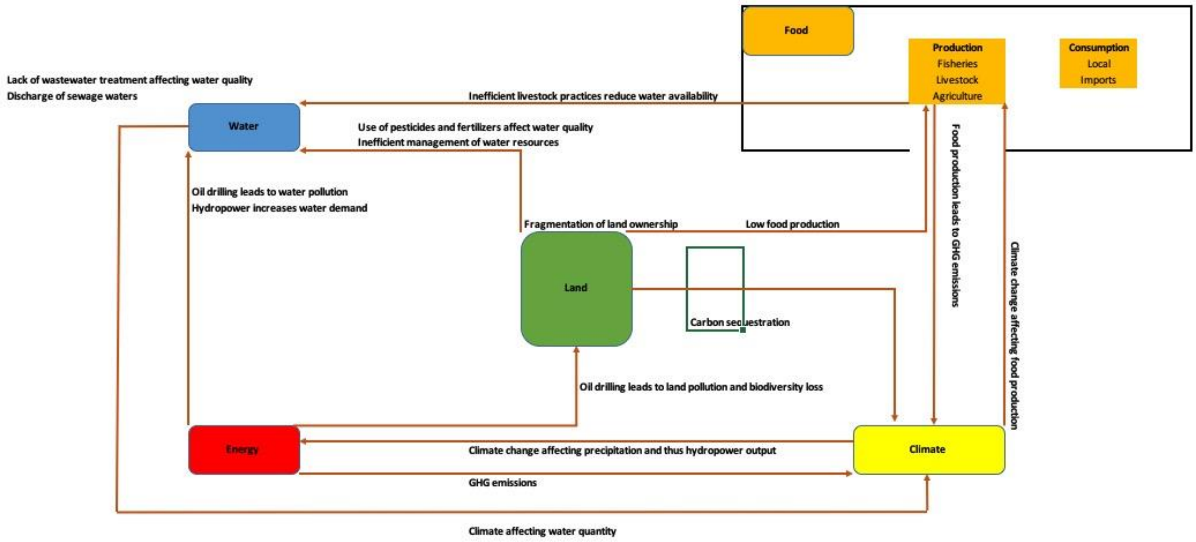

Figure 96 Conceptual model – Food

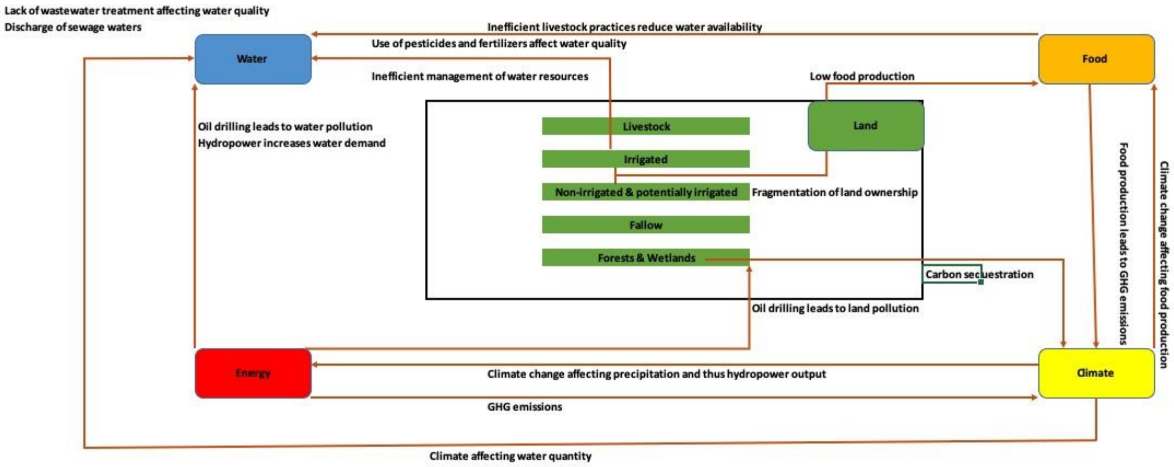

Figure 97 Conceptual model – Land

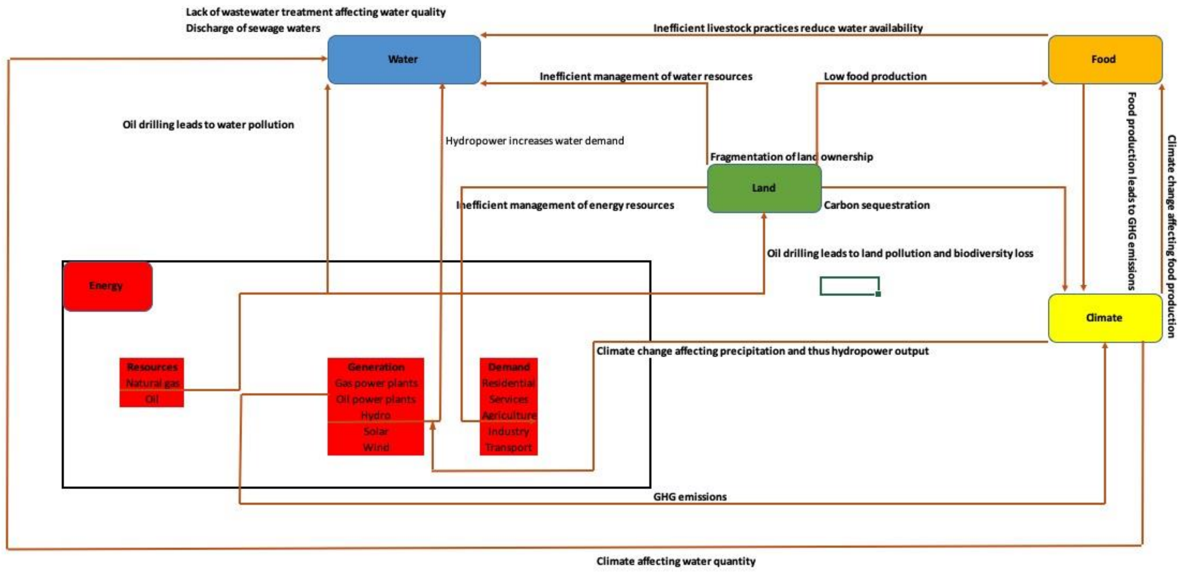

Figure 98 Conceptual model – Energy

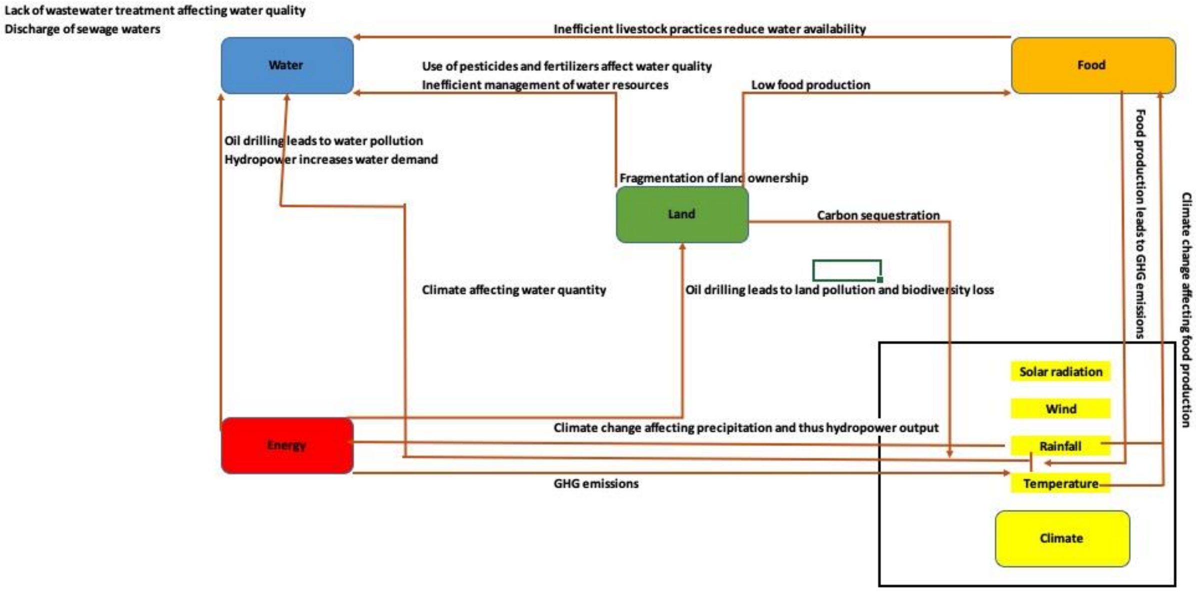

Figure 99 Conceptual model – Climate

9.10.2 SDM screenshots

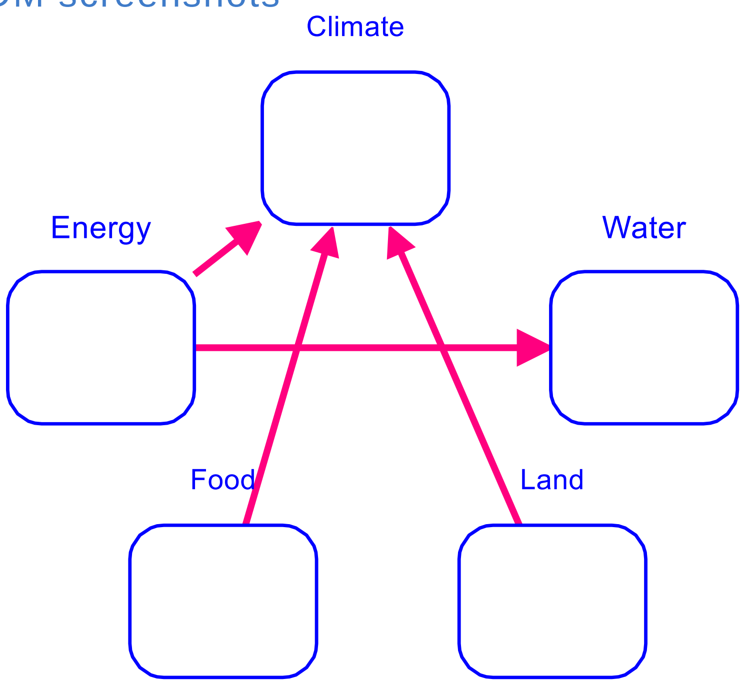

Figure 100 Structural Overview of the Highest Level SDM of Azerbaijan

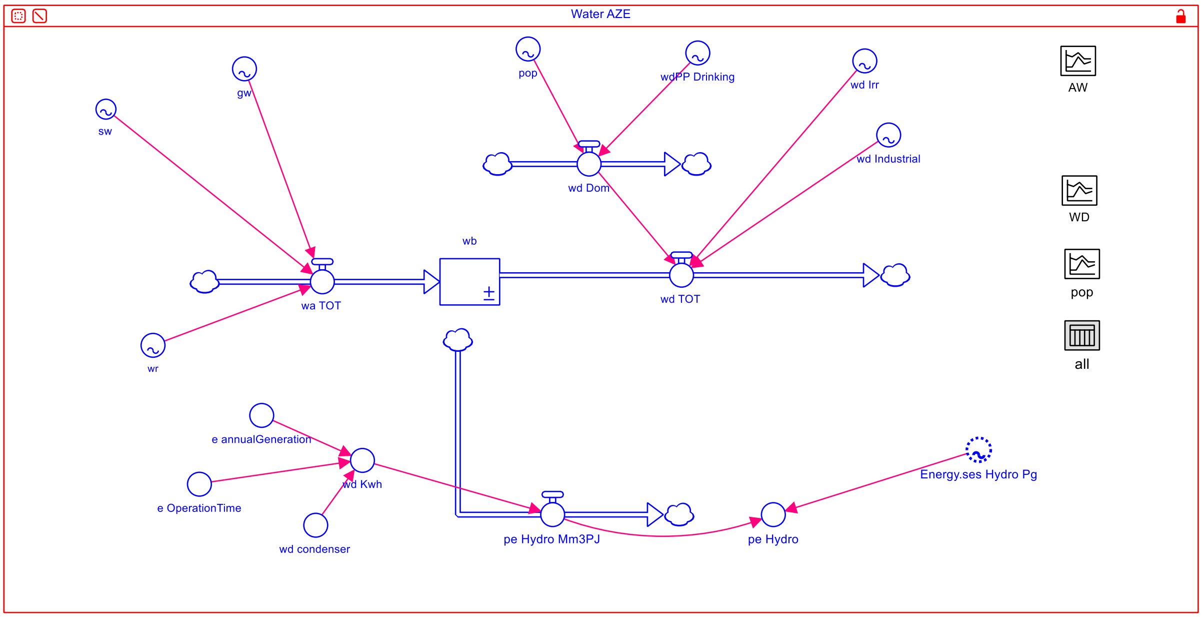

Figure 101 Structure of Water Segment of the SDM

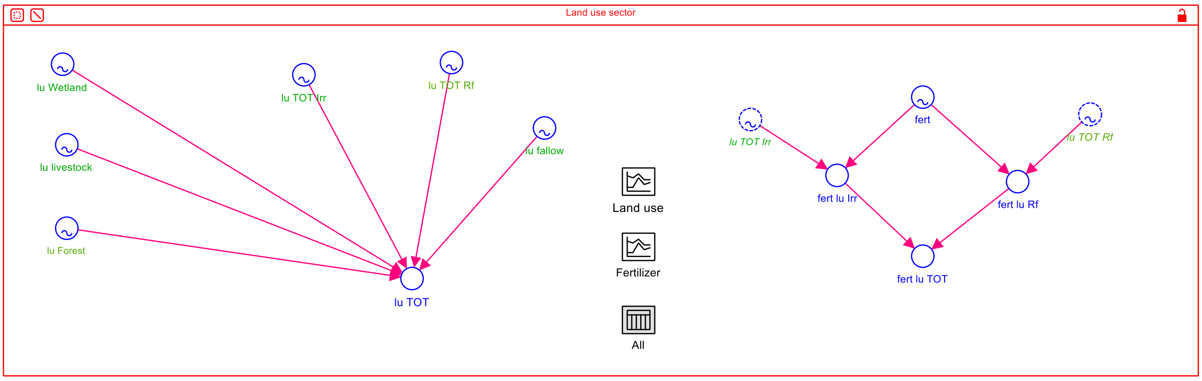

Figure 102 Structure of the Land Segment of the SDM

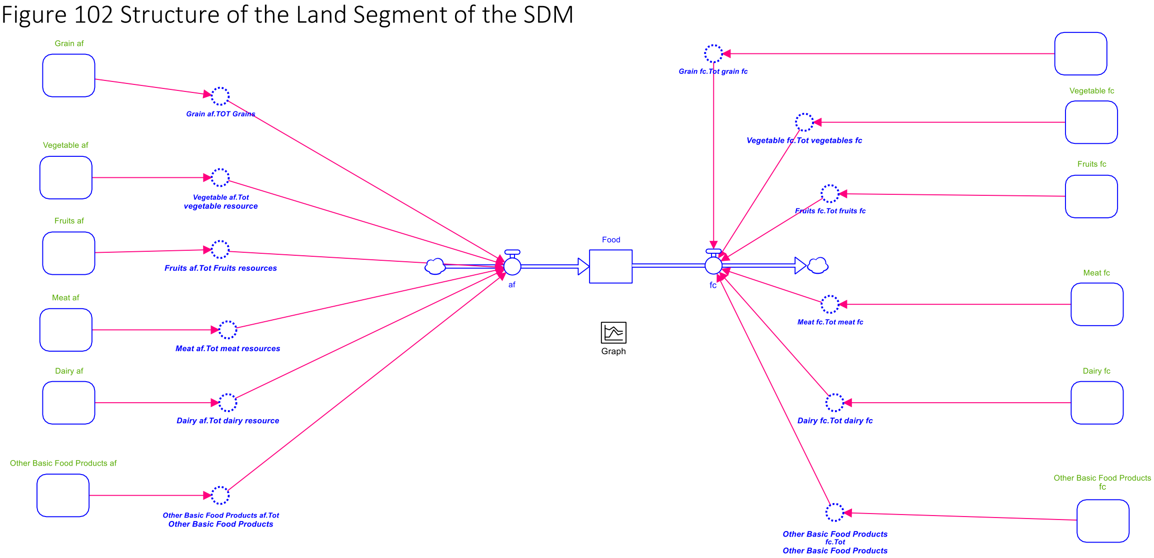

Figure 103 Structure of the Food Segment of the SDM

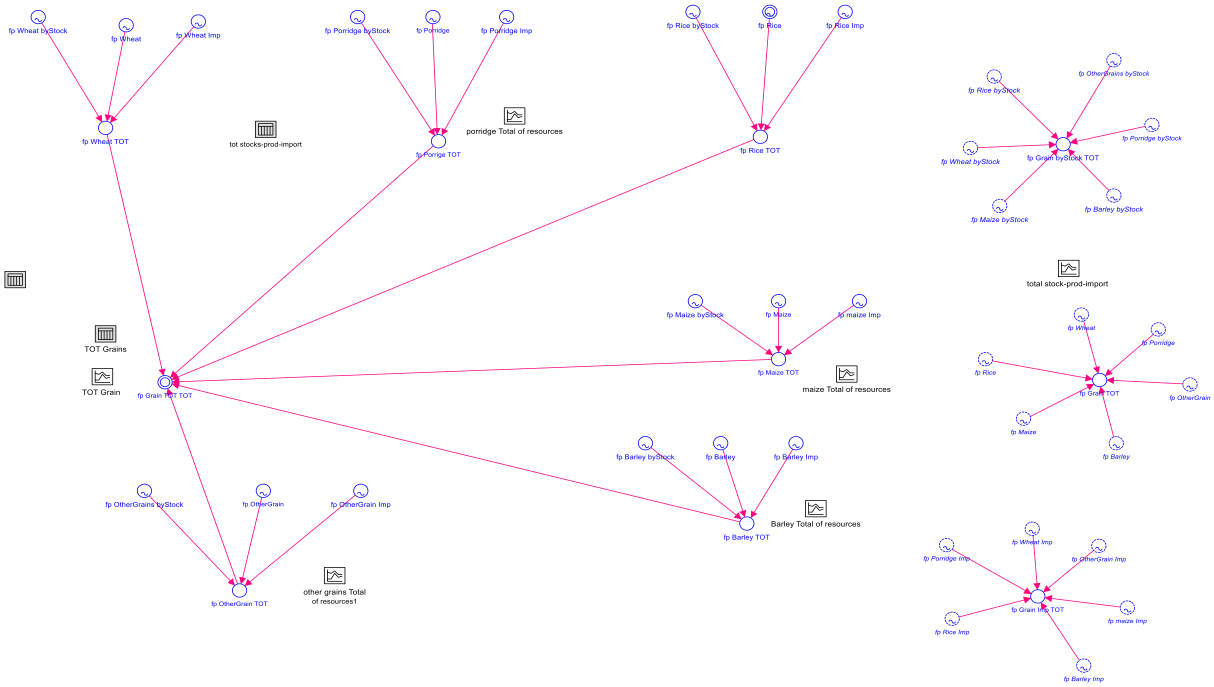

Figure 104 Structure of the Grain Food Production Segment of the SDM

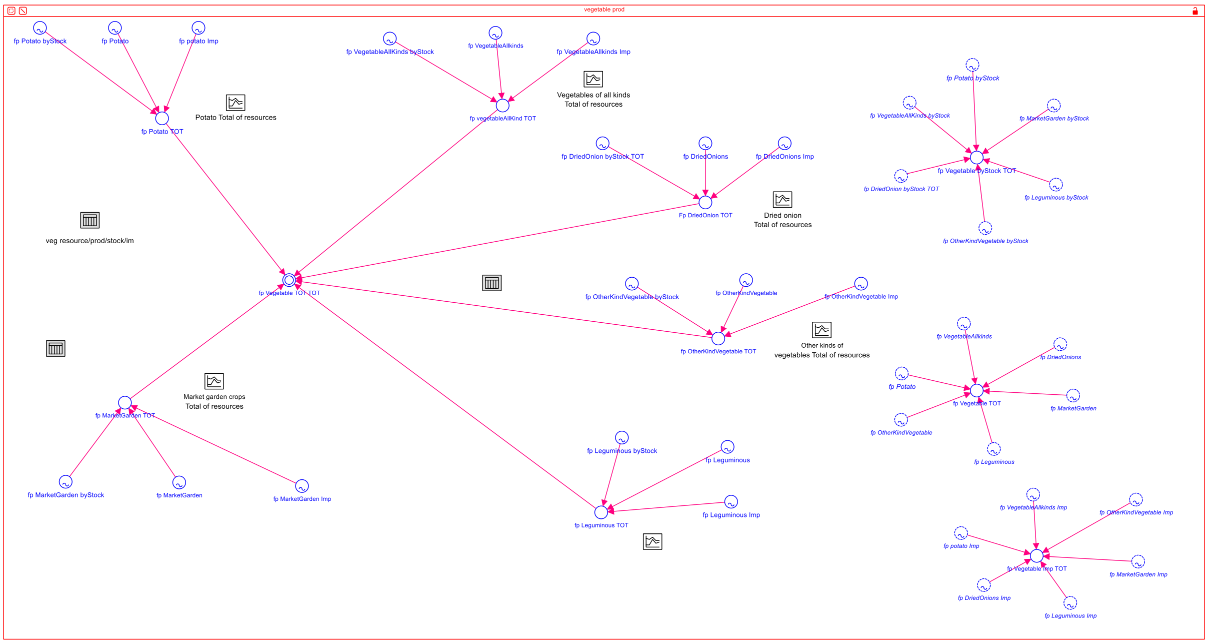

Figure 105 Structure of the Vegetable Food Production Segment of the SDM

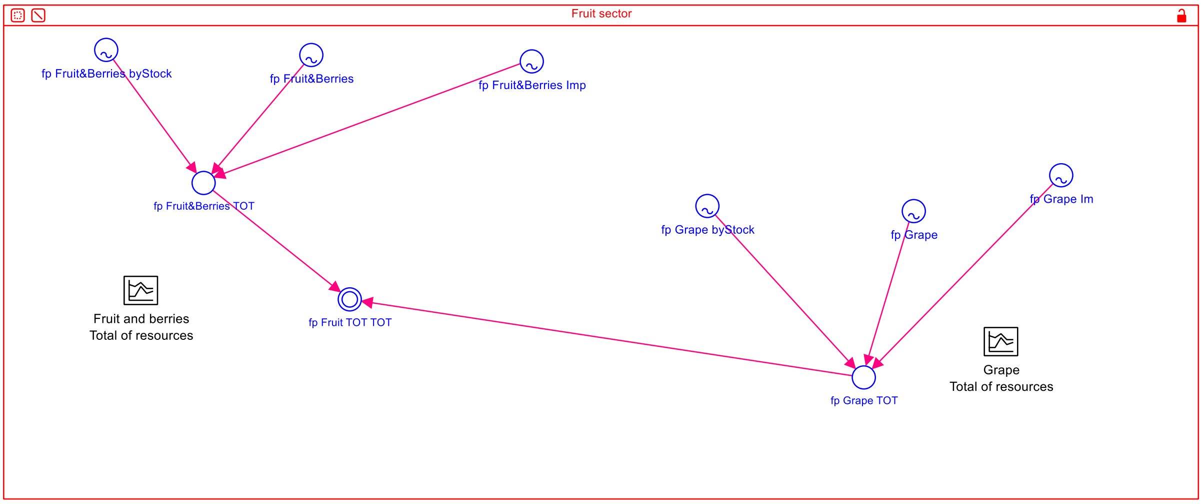

Figure 106 Structure of the Fruits Food Production Segment of the SDM

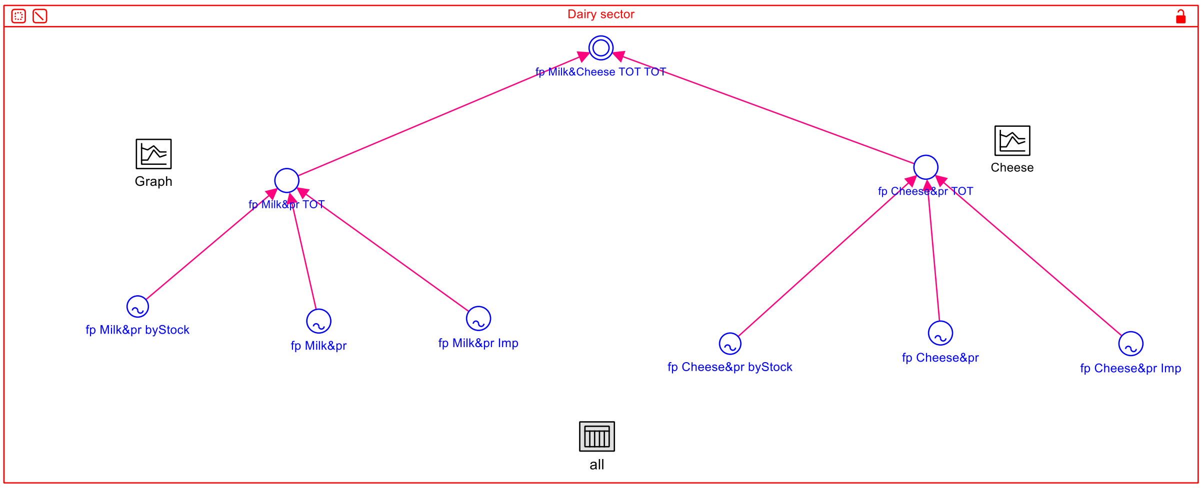

Figure 107 Structure of the Dairy Food Production Segment of the SDM

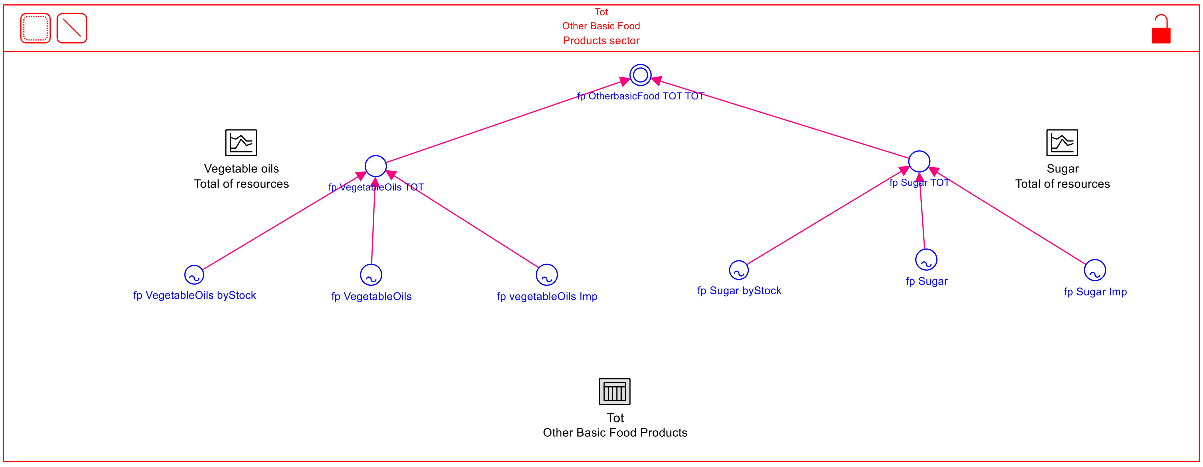

Figure 108 Structure of Other Basic Food Products Production Segment of the SDM

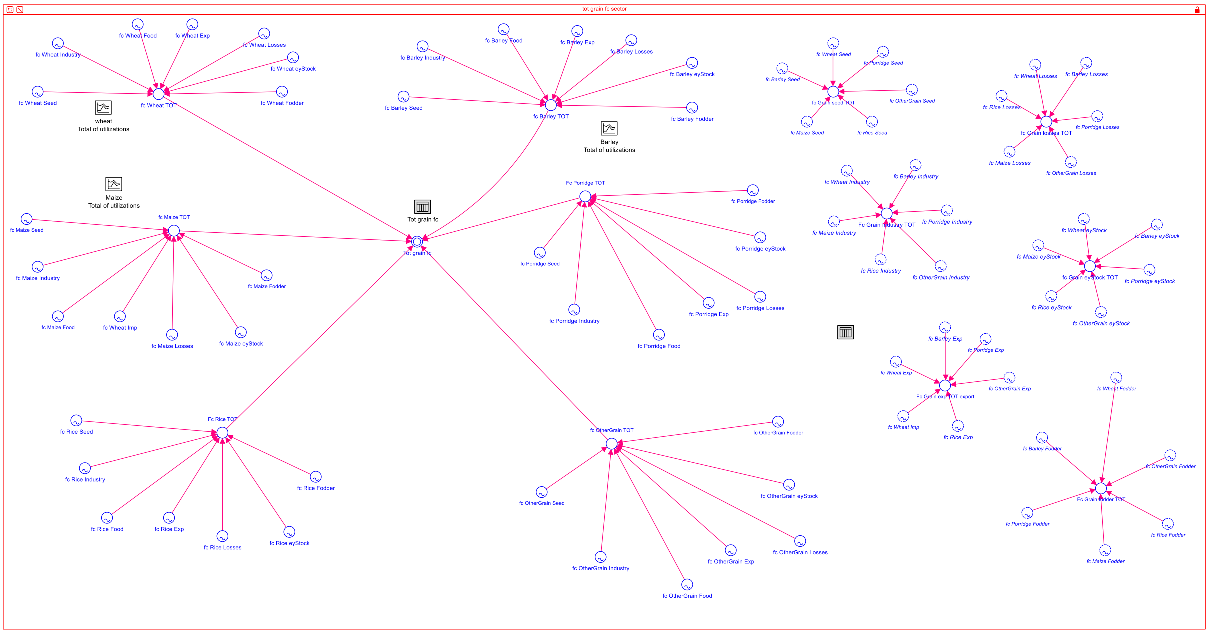

Figure 109 Structure of the Grain Food Consumption Segment of the SDM

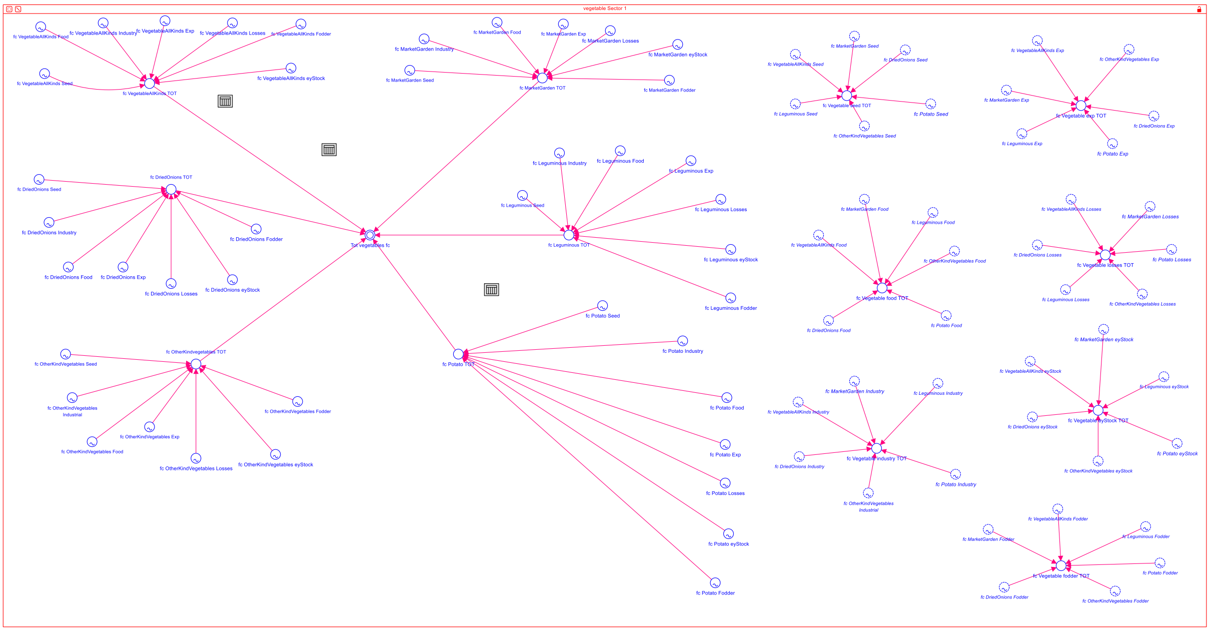

Figure 110 Structure of the Vegetable Food Consumption Segment of the SDM

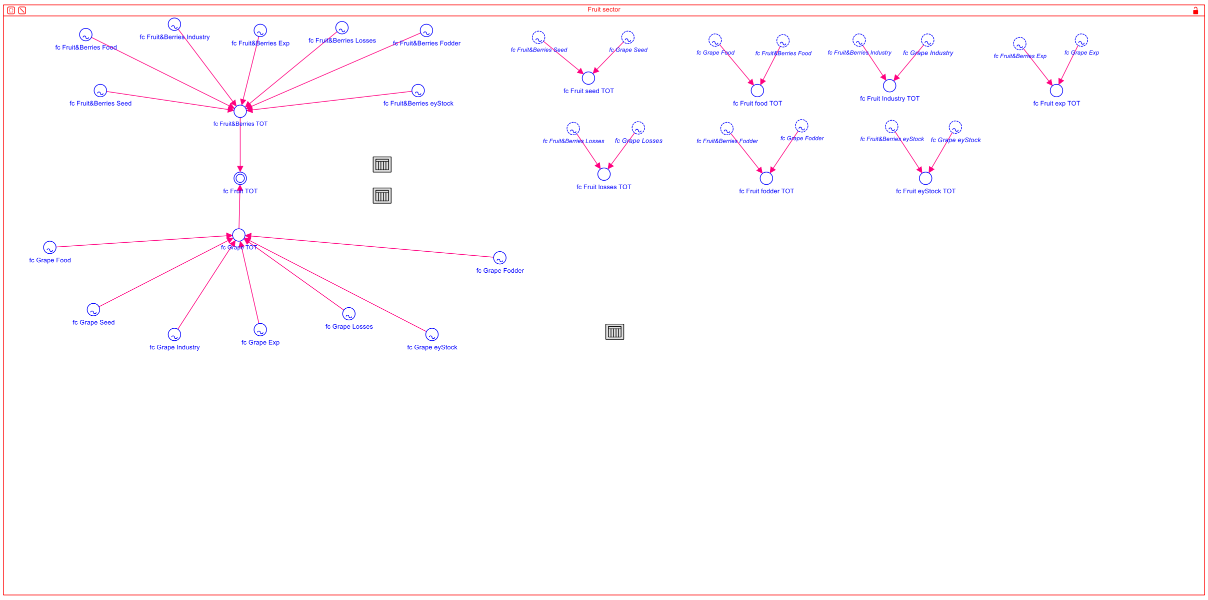

Figure 111 Structure of the Fruits Food Consumption Segment of the SDM

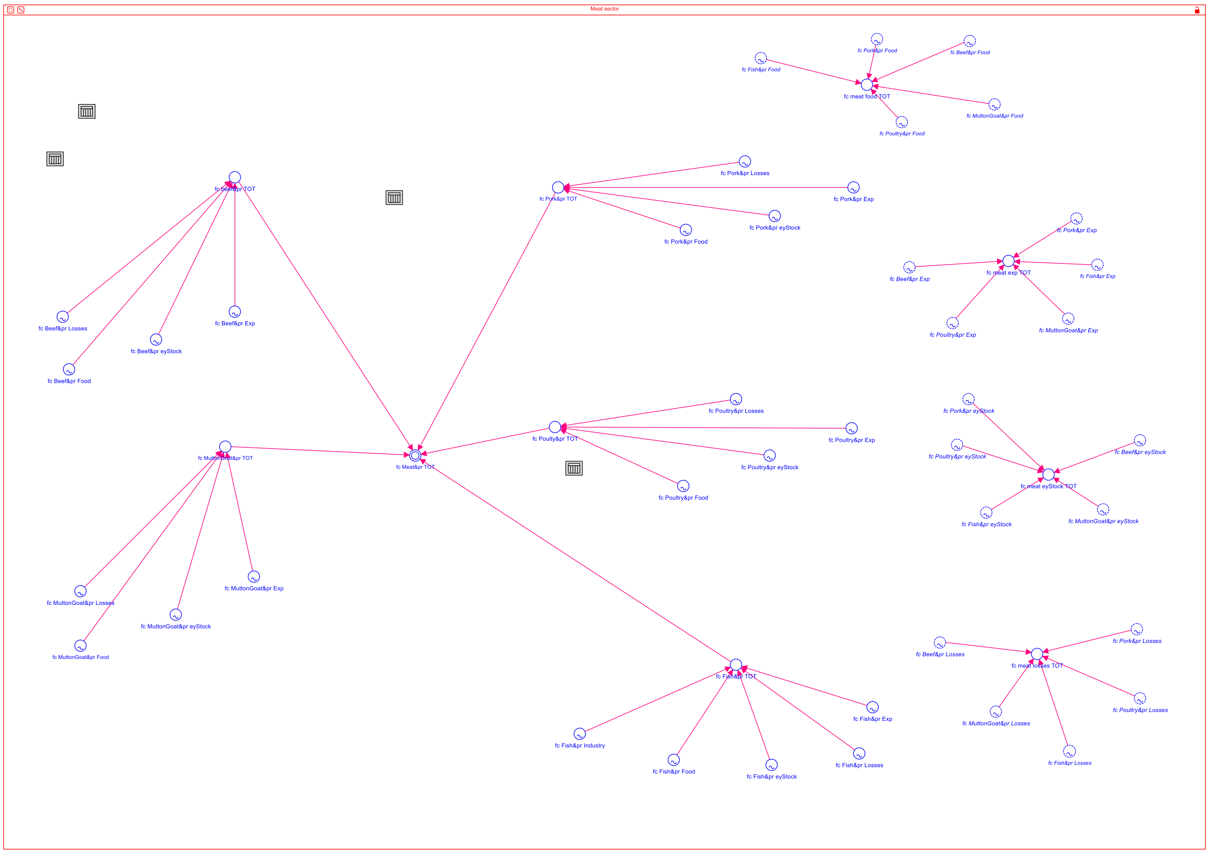

Figure 112 Structure of the Meat Food Consumption Segment of the SDM

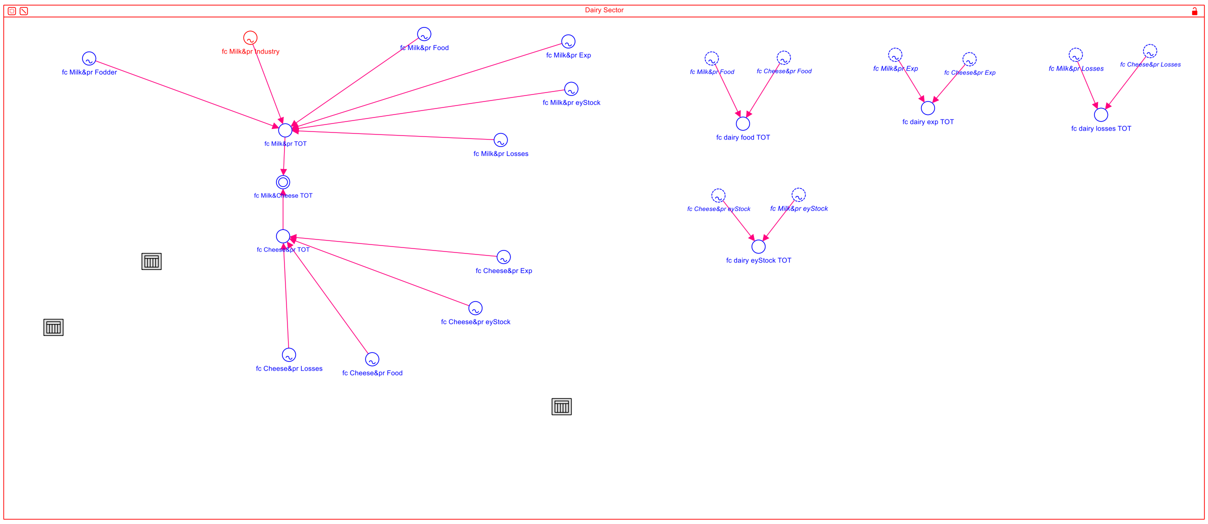

Figure 113 Structure of the Dairy Food Consumption Segment of the SDM

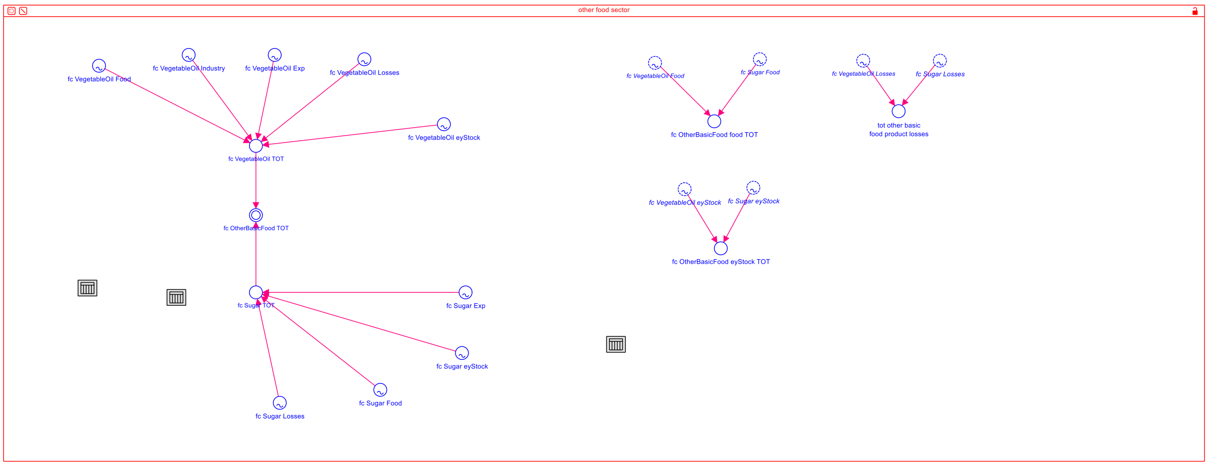

Figure 114 Structure of Other Basic Food Products Food Consumption Segment of the SDM

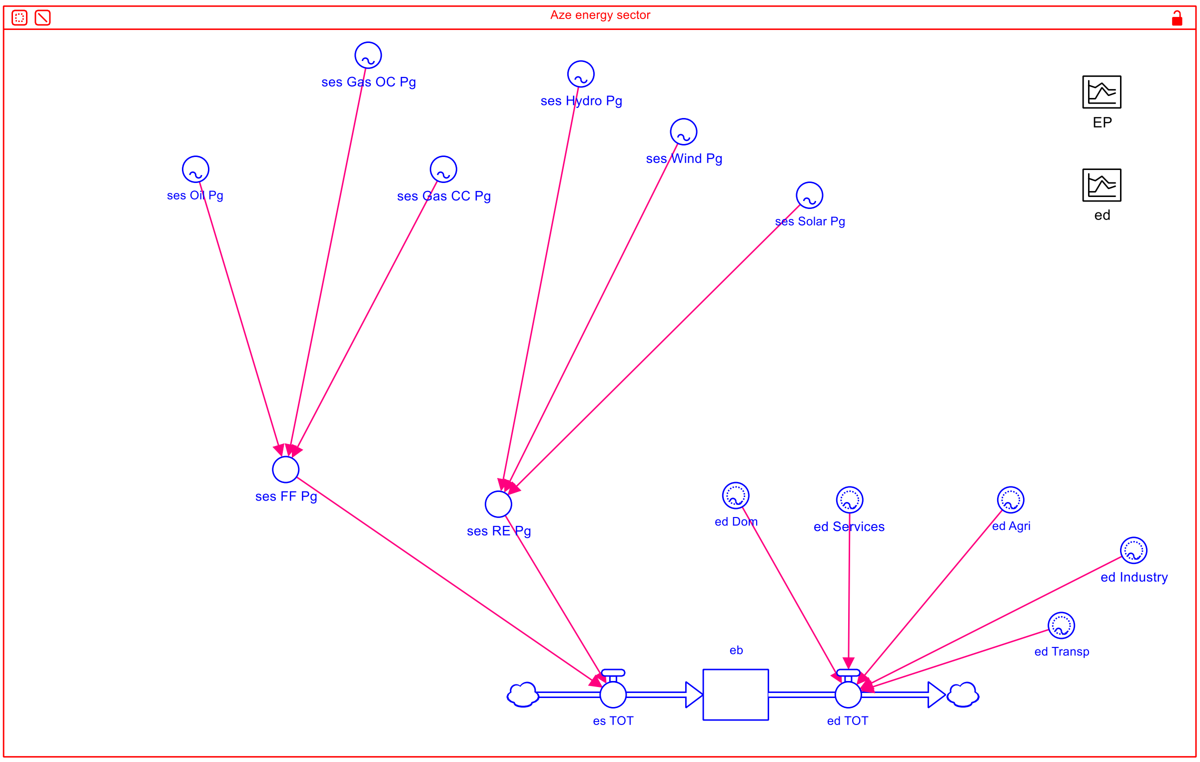

Figure 115 Structure of the Energy Segment of the SDM

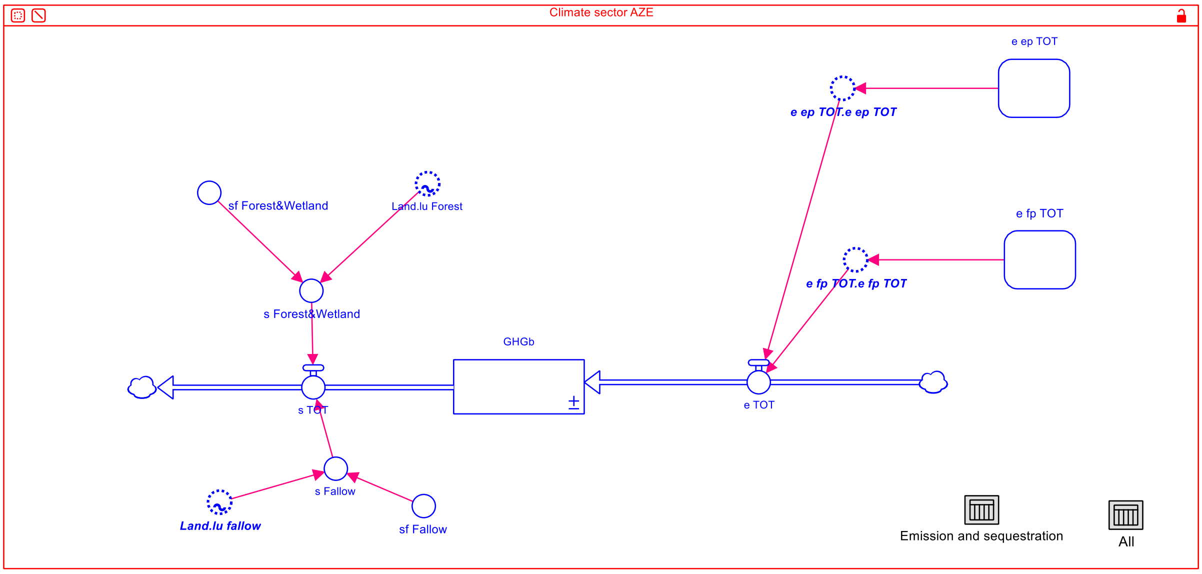

Figure 116 Structure of the Climate Segment of the SDM

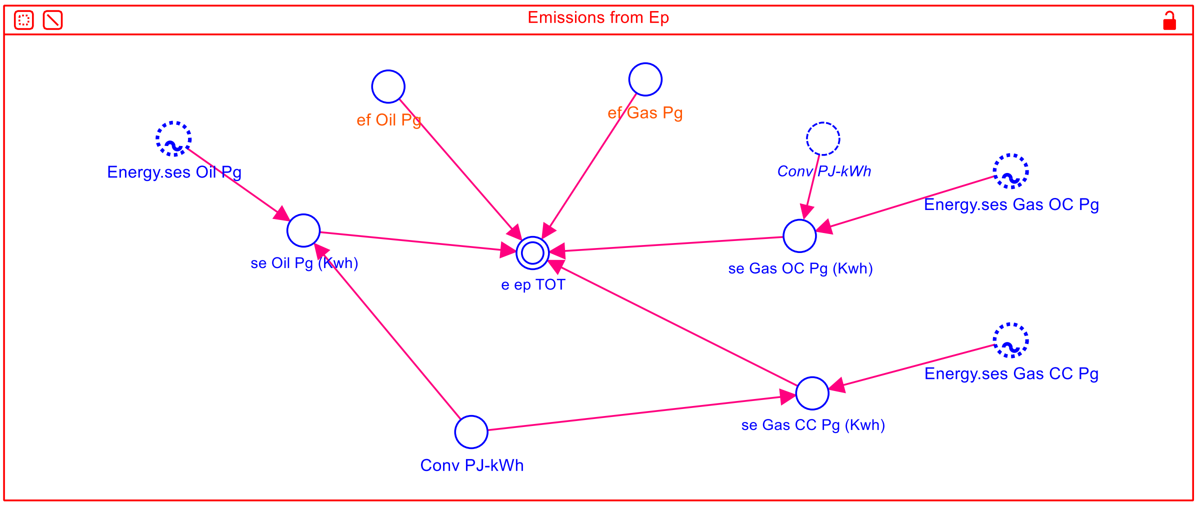

Figure 117 Structure of the Emissions from Electricity Production Segment of the SDM

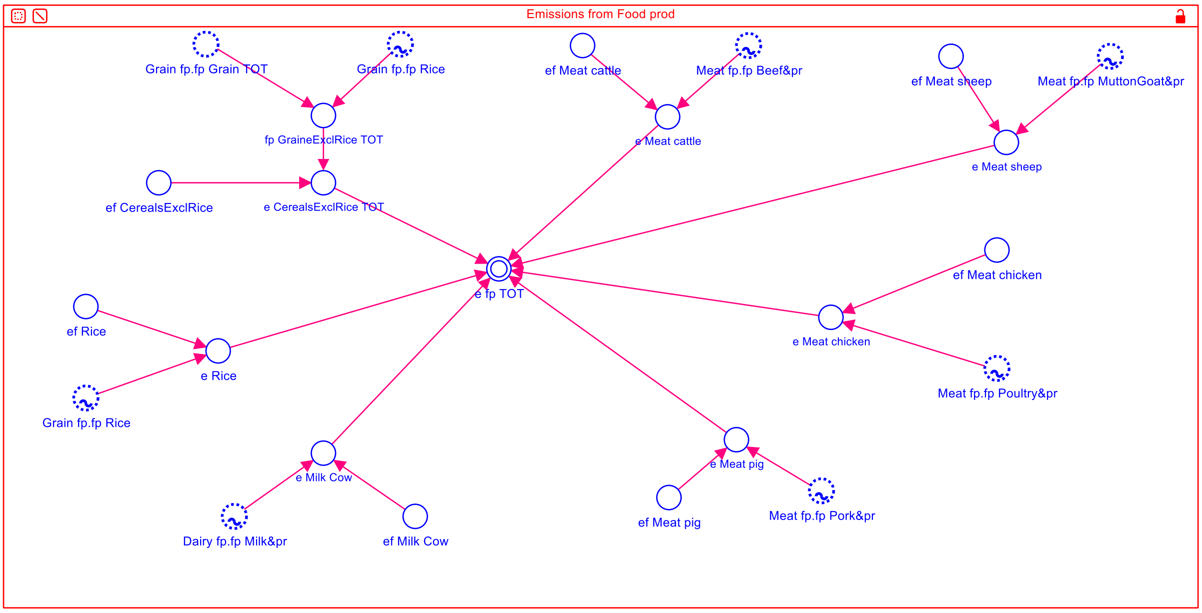

Figure 118 Structure of the Emissions from Food Production Segment of the SDM

9.10.3 Policy cards

Table 43 Policy cards

PolicyID	Nexus Sector	Policy card name	Description of intervention as captured by the policy card
1	Water	Water collection systems	Development of new water collection systems
2	Water	Management of reservoirs	Improved management of reservoirs
3	Water	Water recycling	Expansion of water recycling projects
4	Water	Flood management	Development of flood management projects
5	Water	Desalination of Caspian Sea water	Development of projects for the desalination of the Caspian Sea
6	Water	Innovative irrigation systems	Development of innovative irrigation systems
7	Water	Raising awareness for water savings	Training programs to raise awareness for water savings
8	Food	Optimal use of fertilisers	Campaigns for optimal use of fertilisers
9	Food	Optimal use of pesticides	Campaigns for optimal use of pesticides
10	Food	Optimal irrigation	Campaigns for optimal use of water resources in agriculture
11	Food	Selection of the most suitable seeds	Campaigns for selection of the most suitable seeds
12	Food	Soil tests	Campaigns for crop rotation
13	Food	Crop rotation	Campaigns for soil tests
14	Energy	Raising awareness for energy efficiency	Training programs to raise awareness for energy savings
15	Energy	Subsidies for renewables	Adoption of subsidies for renewables
16	Energy	Direct investments in renewables	Direct investments in renewables by the government
17	Land	National reforestation program	National reforestation program
18	Land	Voluntary reforestation	Voluntary reforestation
19	Climate	Campaigns for reducing carbon footprint in food production	Reducing carbon footprint in food production

9.10.4 Stakeholders maps

Table 44 Stakeholder – The Ministry of Ecology and Natural Resources

THE MINISTRY OF ECOLOGY AND NATURAL RESOURCES (MENR)		
Dimensions	**Sub-dimension**	**Description**
Stakeholders' role		Public stakeholder, responsible for formulating and implementing the environmental policy; developing environmental protection measures; screening of development activities for potential adverse environmental impact; monitoring of the quality of air, soil, precipitation, surface and groundwater, biodiversity, forests, radioactivity; monitoring the implementation of environmental legislation and imposing sanctions; and administering a pollution permit system
	Formal power	Design of policies for: environmental management, climate change adaptation, mitigation of climate change impacts, water resources management

Stakeholders' power and its source	***Informal power***	Consultant in case where cross-sector policies are designed (e.g. policies on agriculture, policies energy activities)
	Source of power	Legal public authority, available knowledge-expertise-experience, linkage with other public authorities and ministries.
Stakeholders' interests		- water policies (very strong interest) – official decision/policy maker (water security, water allocation, water quality, water pollution, etc.). - energy policies (moderate interest) - Agriculture policies (moderate interest)– limited issues concerning pressures put on natural resources by agriculture sector - Forestry (very strong interest)- Official decision/policy maker on issues regarding forest restoration and forestation work - Climate (very strong interest) - Official decision/policy maker on issues regarding climate change adaptation and mitigation strategies.

Table 45 Stakeholder – The Ministry of Emergency Situations

Ministry of Emergency Situations		
Dimensions	**Sub-dimension**	**Description**
Stakeholders' role		Public stakeholder, managing emergency situations in Azerbaijan. It coordinates activities for protection of the population from natural and man-made disasters, including fire; for elimination of consequences of disasters; and implementation of the state policy in the field of civil defense, rescue and restoration works
Stakeholders' power and its source	***Formal power***	Design of policies for: civil defense, protection in water areas, safety measures in industry, mining and construction, prevention of emergency situations and consequence management
	Informal power	Consultant in case where cross-sector policies are designed (e.g. policies for the agricultural and food sector, policies concerning the forestry sector etc.).
	Source of power	Legal public authority, available knowledge-expertise-experience, linkage with other public authorities and ministries
Stakeholders' interests		- water policies (very strong interest) – official decision/policy maker (water security, integrated water resources etc) - energy policies (moderate) – limited on issues related on hydropower energy production, and their security - Agriculture policies (weak interest)- limited to issues related natural and manmade disasters in agricultural sector - Forestry (weak interest) - limited to issues related forestry fires and protection - Climate (no interest)

Table 46 Stakeholder – The Ministry of Health

The Ministry of Health		
Dimensions	**Sub-dimension**	**Description**

Stakeholders' role		Public stakeholder, main functions of the ministry are organization and regulation of healthcare system in the country; preparation and implementation of state healthcare programs; regulation of sanitary-epidemiology stations in the country; prevention of dangerous diseases in the country etc.
Stakeholders' power and its source	***Formal power***	Design policies for drinking water standards and regulation of sanitary-epidemiology stations in the country
	Informal power	Consultant in case where cross-sector policies are designed (e.g. policies for the agricultural and food sector).
	Source of power	Legal public authority, available knowledge-expertise-experience, linkage with other public authorities and ministries
Stakeholders' interests		- water policies (strong interest) – official decision/policy maker (setting drinking water standards and monitoring the quality of surface waters used for drinking water supply and for recreational purposes) - energy policies (weak interest) – limited on issues related on human health - Agriculture policies (strong interest)- official decision/policy maker (using of pesticides, food security) - Forestry (no interest) - Climate (moderate interest) – limited on issues related human health

Table 47 Stakeholder – Azersu JSC

Azersu JSC		
Dimensions	**Sub-dimension**	**Description**
Stakeholders' role		Responsible for arrangements for extraction of water from sources followed by treatment, transportation and sales. It also takes necessary actions for wastewater treatment. The Company engages in design, construction, operation and maintenance of intake structures, reservoirs, pumping stations, water pipelines and sewer collectors.
Stakeholders' power and its source	***Formal power***	Policy on water supply and waste water system
	Informal power	Consultant (management level) – consultant on water management policies
	Source of power	Legal public authority, Knowledge – experience linkage water supply, waste water management
Stakeholders' interests		- water policies (strong interest) – implementing the state policy and strategy in the field of water supply – drinking water - and sanitation services - energy policies (weak interest) – designing pilot projects related energy production from sludge at WWTP - Agriculture policies (no interest) - Forestry (no interest) - Climate (no interest)

Table 48 Stakeholder – The "Amelioration & Water Management" (AWM JSC)

The "Amelioration & Water Management" (AWM JSC)		
Dimensions	**Sub-dimension**	**Description**
Stakeholders' role		Public stakeholder, provides with water various sectors of the economy, arranges exploitation of state-owned land reclamation and irrigation systems, ensures state control in water use and protection, removal of saline waters from reclaimed lands, arranges measures to combat against the flood and flood waters, prepares main scheme of complex using of surface water recourses and protection, prepares together with relevant state bodies basin and territorial schemes, ensures the use of trans-boundary water objects, inter-state joint use of land reclamation and irrigation systems, and acts as customer for the construction of irrigation and water objects.
Stakeholders' power and its source	***Formal power***	Design of policies for: water resources management, reclamation and irrigation
	Informal power	Consultant in case where cross-sector policies are designed (national, regional and international level).
	Source of power	Legal public authority, available knowledge-expertise-experience, linkage with other public authorities and ministries
Stakeholders' interests		- Water policies (Very strong interest): Availability of water resources, meeting the needs of the different sectors - energy policies (weak interest) – designing pilot projects related energy production from sludge at WWTP - Agriculture policies (very strong interest) - Policies regulating the development of the agricultural sector - Forestry (moderate interest) - implementation of protective forest strips along melioration and irrigation facilities - Climate (weak interest)

Table 49 Stakeholder – The Water Users Association

Water Users Association		
Dimensions	**Sub-dimension**	**Description**
Stakeholders' role		voluntary community farmer associations responsible for management of on-farm irrigation systems
Stakeholders' power and its source	***Formal power***	No formal power mandated by law
	Informal power	Consultant to the AWM JSC as an expert – cooperation with farmers
	Source of power	Knowledge-expertise-experience – Linkages to stakeholders (farmers)
Stakeholders' interests		- Water policies (strong): Availability of water resources, meeting the needs of the agricultural users

		- energy policies (no interest) - Agriculture policies (strong) - Policies regulating the development of the agricultural sector - Forestry (no interest) - Climate (no interest)

Table 50 Stakeholder -The State Agency for Alternative and Renewable Energy Sources

The State Agency for Alternative and Renewable Energy Sources		
Dimensions	**Sub-dimension**	**Description**
Stakeholders' role		1) Public stakeholder, providing public services in the field of alternative and renewable energy sources.
Stakeholders' power and its source	***Formal power***	Design of policies for creating the infrastructure of renewable energy, and ensure the accomplishment of this policy
	Informal power	Consultant in case where cross-sector policies are designed (national, regional and international level).
	Source of power	Legal public authority, available knowledge-expertise-experience, linkage with other public authorities and ministries.
Stakeholders' interests		- Water policies (moderate): Availability of water resources, meeting the needs of the small hydropower plants (HPP) - energy policies (very strong interest) – policy design for renewable energy, and ensure the accomplishment of this policy - Agriculture policies (moderate interest) - limited to issues concerning biogases, biomass for energy production - Forestry (weak interest) - Climate (strong interest) – issues concerning carbon emission

Table 51 Stakeholder – The Ministry of Energy of the Republic of Azerbaijan

Ministry of Energy of the Republic of Azerbaijan		
Dimensions	**Sub-dimension**	**Description**
Stakeholders' role		Public stakeholder, responsible for regulating the activities in the production and energy production complex. These activities include upstream and downstream activities, exploration and development of fields, operations of oil and gas refineries, power and heat generation, its supply and distribution through the networks, and so forth
Stakeholders' power and its source	***Formal power***	Design of energy policies at national level and related regional energy programs; research and development in the sphere of energy, preparation of programs ensuring energy security of Azerbaijan Republic
	Informal power	Consultant in case where cross-sector policies are designed (national, regional and international level).
	Source of power	Legal public authority, available knowledge-expertise-experience, linkage with other public authorities and ministries.

Stakeholders' interests		- Water policies (moderate): Availability of water resources, meeting the needs of the HPP - energy policies (very strong interest) – policy design for energy sector - Agriculture policies (moderate interest) - biomass for energy production - Forestry (moderate interest) – limited to issues concerning biogases, biomass for energy production - Climate (moderate) issues concerning carbon emission

Table 52 Stakeholder – The State Statistical Committee of the Republic of Azerbaijan (SSCRA)

The State Statistical Committee of the Republic of Azerbaijan (SSCRA)		
Dimensions	**Sub-dimension**	**Description**
Stakeholders' role		Public stakeholder, conduction of official statistics in the energy, agriculture and environmental statistical field, collection of the statistical information and adjustment of them to the social-economic processes in the country
Stakeholders' power and its source	***Formal power***	No formal power mandated by law
	Informal power	Consultant in case where cross-sector policies are designed (national, regional and international level).
	Source of power	Legal public authority, available knowledge-expertise-experience, linkage with other public authorities and ministries.
Stakeholders' interests		- Water policies (weak interest) - Statistics on water resources management. - energy policies (weak interest): Statistics on energy resources - Agriculture policies (weak interest): Statistics on agriculture. - Forestry (weak interest): Statistics on forestry. - Climate (weak interest): Statistics on climate data's.

Table 53 Stakeholder - SOCAR

SOCAR (Azerbaijan Oil Company)		
Dimensions	**Sub-dimension**	**Description**
Stakeholders' role		The State Oil Company is involved in exploring oil and gas fields, production, processing, and transport of oil, gas, and gas condensate, supplying natural gas to industry and the public in Azerbaijan
Stakeholders' power and its source	***Formal power***	No formal power mandated by law
	Informal power	Consultant in case where cross-sector policies are designed (national, regional and international level).
	Source of power	Available knowledge-expertise-experience, linkage with other public authorities and ministries.
Stakeholders' interests		- water policies (no interest)

		- energy policies (very strong interest) – availability of energy resources - Agriculture policies (no interest) - Forestry (weak interest) – involved to cleaning of polluted soils, and new forestry lands - Climate (strong interest) - issues concerning carbon emission reduction

Table 54 Stakeholder – Azerenergy JSC

Azerenergy JSC		
Dimensions	**Sub-dimension**	**Description**
Stakeholders' role		Public stakeholder, responsible for operation of the country's electro energy system, responsible for electric power generation and transmission, centralized power plants, sub-stations
Stakeholders' power and its source	***Formal power***	No formal power mandated by law
	Informal power	Consultant in case where cross-sector policies are designed, consultant to Ministry of Energy
	Source of power	Available knowledge-expertise-experience, linkage with other public authorities and ministries.
Stakeholders' interests		- water policies (moderate interest) – In relation to the water for energy production - energy policies (very strong interest) – operation of electro-energy - Agriculture policies (no interest; they only distribute energy) - Forestry (no interest; they only distribute energy) - Climate (moderate) issues concerning carbon emission

Table 55 Stakeholder – Azerishiq JSC

Azerishiq JSC		
Dimensions	**Sub-dimension**	**Description**
Stakeholders' role		Public stakeholder, responsible for selling energy to population
Stakeholders' power and its source	***Formal power***	No formal power mandated by law
	Informal power	Consultant in case where cross-sector policies are designed, consultant to Ministry of Energy
	Source of power	Available knowledge-expertise-experience, linkage with other public authorities and ministries.
Stakeholders' interests		- water policies (no interest) - energy policies (very strong interest) – selling of electro energy - Agriculture policies (no interest) - Forestry (no interest)

		- Climate (no interest)

Table 56 Stakeholder – The Ministry of Agriculture of the Republic of Azerbaijan

Ministry of Agriculture of the Republic of Azerbaijan		
Dimensions	**Sub-dimension**	**Description**
Stakeholders' role		Public stakeholder, ensures public policy on the rational use of arable lands and the working out and implementing of state policy in the development of rural infrastructure and social sectors. It develops and implement the state policy in the field of land reclamation and water management and irrigation, realizes the unified scientific-technical policy in the field of agriculture, for increasing agricultural productivity, agricultural products processing, effective use of biological diversity, plant growing and cattle
Stakeholders' power and its source	***Formal power***	Design of policy on the arable lands and development of rural infrastructure
	Informal power	Consultant in case where cross-sector policies are designed (e.g. policies for the food security, policies concerning water for irrigation etc.)
	Source of power	Legal public authority, available knowledge-expertise-experience, linkage with other public authorities and ministries.
Stakeholders' interests		- water policies (very strong interest) – Availability of water resources for irrigation - energy policies (moderate) – limited to issues concerning biogases, biomass for energy production - Agriculture policies (very strong interest) – design of policies related agriculture and food security - Forestry (moderate) – limited to issues concerning land use - Climate (strong) –issues to climate change and mitigation measures related food security, reduction of carbon emission

Table 57 Stakeholder – Azerbaijan National Science Academy

Azerbaijan National Science Academy		
Dimensions	**Sub-dimension**	**Description**
Stakeholders' role		Public stakeholder, state scientific organization responsible for developing science for policy making
Stakeholders' power and its source	***Formal power***	No formal power mandated by law
	Informal power	Consultant in case where cross-sector policies are designed (e.g. policies for the food security, policies concerning water for irrigation etc.)
	Source of power	Legal public authority, available knowledge-expertise-experience, linkage with other public authorities and ministries.
Stakeholders' interests		- water policies (moderate interest) – scientific research on water resources

		- energy policies (moderate interest) - scientific research on energy resources - Agriculture policies (moderate interest) – scientific research on agriculture resources - Forestry (moderate interest) – scientific research on forestry - Climate (moderate interest)- scientific research on climate

Table 58 Stakeholder – The Ministry of Economy of the Republic of Azerbaijan

The Ministry of Economy of the Republic of Azerbaijan		
Dimensions	**Sub-dimension**	**Description**
Stakeholders' role		Public stakeholder, develops the economic policy, economic and social forecasts, carries out development of different areas of economy, foreign economic and trade relations, investment activity, attraction of investments in the Republic of Azerbaijan
Stakeholders' power and its source	***Formal power***	Design of policy on cross section issues
	Informal power	Consultant in case where cross-sector policies are designed
	Source of power	Legal public authority, available knowledge-expertise-experience, linkage with other public authorities and ministries.
Stakeholders' interests		- water policies (strong interest) – funding the development of water management activities - energy policies (strong interest) - funding of renewable energy sector - Agriculture policies (strong interest) – funding the development of agricultural activities, - Forestry (strong interest) – funding the development of agricultural activities - Climate (strong interest) – funding the development of agricultural activities

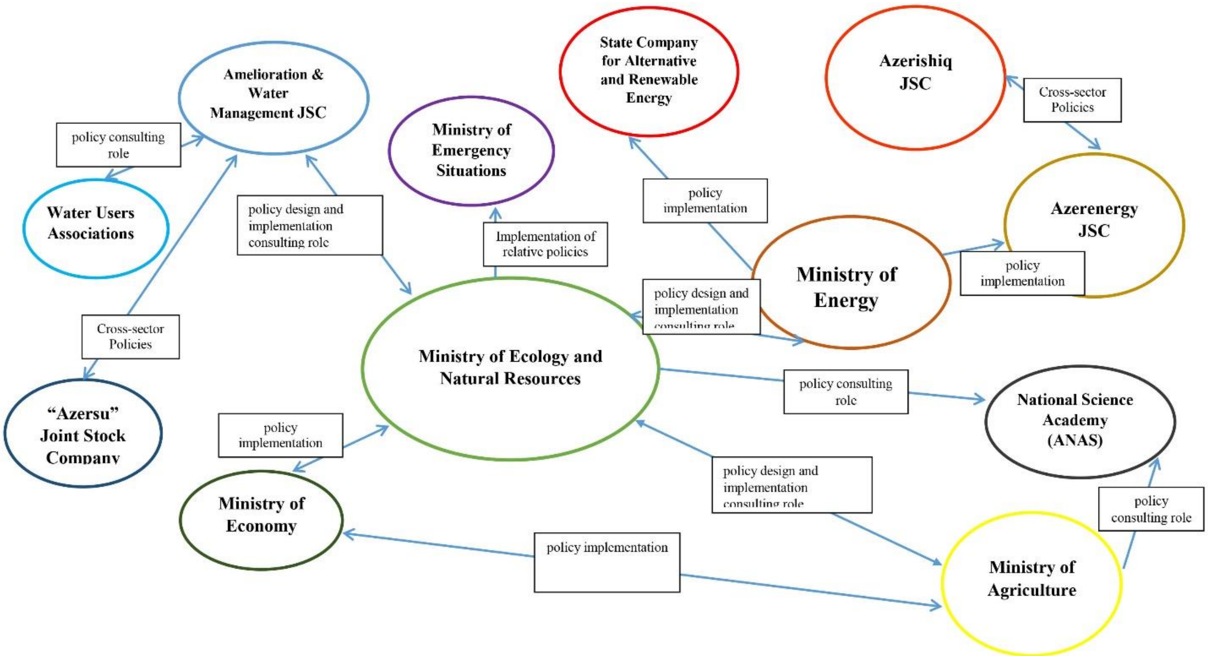

Figure 119 Stakeholder map of Azerbaijan

9.10.5 Use case for the Azerbaijan Case Study

Energy

Table 59 Use Case E.1.1

Use Case E.1.1	Energy/Climate
Related Learning Goals	Gain understanding of the relation of energy policies and emission reduction.
Goal	Reduction of greenhouse gas emissions from the energy sector
User	Public Sector: e.g. Ministry of Energy, Ministry of Environment
Actions	• Training programs to raise awareness for energy savings • Adoption of subsidies for renewables • Direct investments in renewables by the government
Indicator	• Emission from energy production • Power generation mix • Power generation capacity mix • Energy consumption • Power generation from renewables • Power generation from fossil fuels • Energy demand industry • Energy demand agriculture • Energy demand services • Energy demand transport

Table 60 Use Case E.1.2

Use Case E.1.2	Energy/Climate
Related Learning Goals	Gain understanding of the relation of energy policy and emission reduction.
Goal	Reduction of Greenhouse gas emissions from the energy sector
User	Private sector: e.g. Power utilities, Transmission system operators

Actions	• Training programs to raise awareness for energy savings
Indicator	• Emission from energy production • Power generation mix • Power generation capacity mix • Energy consumption • Power generation from renewables • Power generation from fossil fuels • Energy demand industry • Energy demand agriculture • Energy demand services • Energy demand transport

Table 61 Use Case E.1.3

Use Case E.1.3	Energy/Climate
Related Learning Goals	Gain understanding of the relation of energy policy and emission reduction.
Goal	Reduction of Greenhouse gas emissions from the energy sector
User	NGOs
Actions	• Training programs to raise awareness for energy savings
Indicator	• Emission from energy production • Power generation mix • Power generation capacity mix • Energy consumption • Power generation from renewables • Power generation from fossil fuels • Energy demand industry • Energy demand agriculture • Energy demand services • Energy demand transport

Table 62 Use Case E.2.1

Use Case E.2.1	Energy/Water
Related Learning Goals	Develop an understanding of the linkage between water sector and power generation.
Goal	Reduction of water usage by the energy sector
User	Public sector, e.g. Ministry of Energy, Ministry of Water
Actions	• Coordinated management of reservoirs • Adoption of subsidies for renewables (not including hydropower) • Direct investments in renewables by the government
Indicator	• Water consumption by hydro power • Water consumption by per kWh • Water consumption per condenser • Water consumption for energy produced

Table 63 Use Case E.2.2

Use Case E.2.2	Energy/Water
Related Learning Goals	Develop an understanding of the linkage between water sector and power generation.

Goal	Reduction of water usage by the energy sector
User	Private sector, e.g. Energy utility company, Water utility
Actions	• Coordinated management of reservoirs
Indicator	• Water consumption by hydro power • Water consumption by per kWh • Water consumption per condenser • Water consumption for energy produced

10 France-Germany

10.1 Introduction

The transboundary France-Germany case study is situated in the Upper Rhine region and covers the federal state of Baden-Württemberg on the German side and the newly formed Grand Est Region[20] on the French side, with the (Upper) Rhine playing the role of physical and administrative border in its middle[21]. The area along the Rhine is one of the most densely populated and highly industrialized zones on the European continent. Both sides of the river are historically intertwined and cooperation beyond borders, be it between France and Germany or between all riparian countries of the Rhine River, is the norm in particular in the field of water management as illustrated by the activities of the International Commission for the Protection of the Rhine (ICPR)[22]. At a more local level, urban development around its main cities are today truly transboundary, as illustrated by growth and planning of the Eurodistrict (around the city of Basel) and the Eurométropole (around the city of Strasbourg).

The case study focuses on the links and synergies between energy policy and the transition to a low-carbon economy on one side, and the management of natural resources (in particular water) and ecosystems on the other side. Because of its transboundary character, it investigates also the links between policy development and implementation on both sides of the Rhine, and whether there would be opportunities for enhancing cooperation and policy coherence between France and Germany for achieving jointly set policy objectives in a more cost-effective manner.

Main research questions

The research questions identified for this case study at the beginning of the project (2016) were :

- What are today's policies put in place in France and in Germany for achieving transition to a low-carbon economy? What are the similarities and differences between France (Grand Est) and Germany (Baden-Württenberg)? And what are current mechanisms and initiatives made for establishing synergies and coherence between the two countries?

- What are (visible or foreseen) impacts, positive and negative, of these policies on the management of natural resources, in particular water, ecosystems and biodiversity? Which sectors targeted by a transition to a low-carbon economy are mainly responsible for these impacts? What are the mechanisms and instruments put in place that limit, or enhance, these impacts? How do these impacts affect indirectly other economic activities and sectors of the Upper Rhine economy? Would the foreseen impacts on natural resources and ecosystems, and also on activities benefiting from these ecosystems, be aggravated, or reduced, under scenarios of climate change?

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[20] Integrated the former Alsace, Lorraine and Champagne administrative regions.

[21] The case study does not include the Swiss part of the territory usually defined as the Upper Rhine in a water management context.

[22] Transnational cooperation along the Rhine started effectively after the Sandoz (chemical plant near Basel) accident in 1986 which polluted the entire downstream aquatic ecosystems and affected all adjacent countries and their economies. In 1994, most of the pollution reduction levels set were achieved. Cooperation also addresses issues of fish (Salmon in particular) migration, flood protection and more generally the coordinated implementation of the EU water policies (the Water Framework Directive and the Floods Directive in particular). http://www.archive.riversymposium.com/index.php?element=09_SculteWL_Paper

- Which changes in policies could enhance the coherence between both policy domains – in France (Grand Est) and in Germany (Baden-Württenberg) considered as separate entities? What would be the social, economic and environmental impacts of such policy changes?

- How could cooperation between France (Grand Est) and Germany (Badden-Württenberg) be strengthened so as to reach jointly the policy objectives of transition to a low carbon economy in a more cost-effective manner? Would such cooperation modify significantly the impacts on natural resources and ecosystems as compared to policies being implemented independently in both countries? More generally, what would be the social, economic and environmental impacts of such cooperation?

- How should cooperation be designed, accounting for today's situation and for climate change, so as negative impacts on natural resources and ecosystems are minimized, and positive impacts on natural resources and ecosystems are maximised?

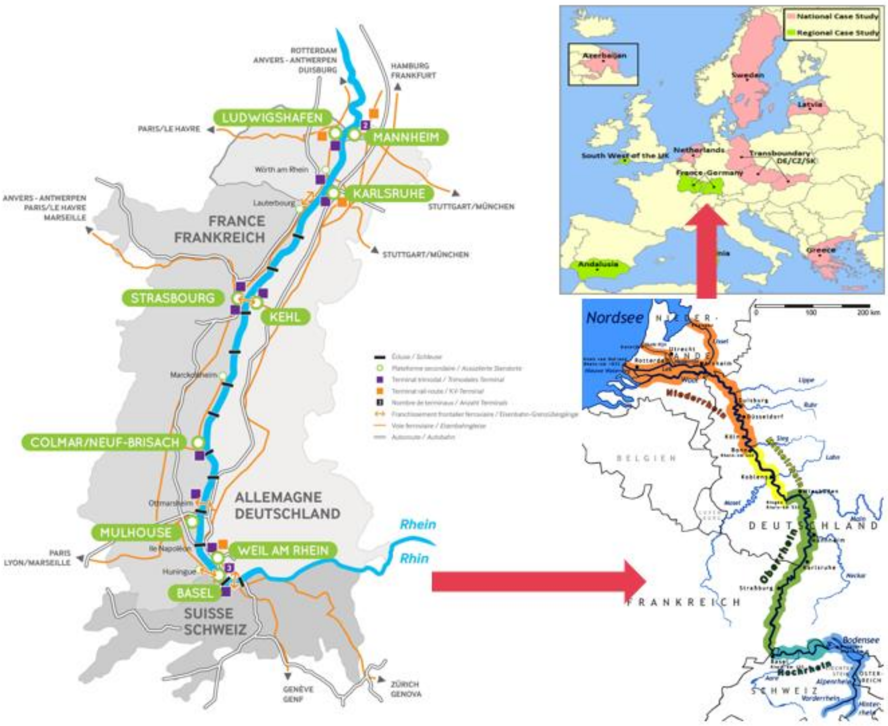

Figure 120 Map of the Rhine river, its 5 sections and a focus on the Upper-Rhine inland navigation system

Main Nexus challenges

The main Nexus challenge identified corresponds to the implementation of a "Nexus-compatible" energy transition. Indeed, we have observed that the energy transition and the associated evolution of the energy mix in the Upper Rhine seems to result in the emergence of several trade-offs between Nexus domains, with in particular negative impacts on water and land resources. Nexus domains addressed: the case study considered all five Nexus domains with an emphasis on the Energy and Water sectors.

Main stakeholders involved: the main stakeholders involved in the interviews and workshops are the following:

Baden-Württemberg:

Regional government bodies :

- Forst Landesbetrieb Baden-Württemberg
- Regierungspräsidium Freiburg
- Regierungspräsidium Karlsruhe

Research:

- EIFER
- Karlsruhe Institute of Technology

NGOs and stakeholders networks:

- Bund fur Umwelt und Naturschutz Deustchland
- International Council for Local Environmental Initiatives
- ITG mbH & Co. KG
- Klimapartner Oberrhein

Grand Est:

Regional government bodies :

- Agence de l'Eau Rhin Meuse
- Chambre d'agriculture d'Alsace
- Chambre du Commerce et de l'Industrie Alsace
- Direction Départementale du territoire Bas-Rhin
- Directions régionales de l'environnement, de l'aménagement et du logement Grand Est
- Préfecture Grand Est (Secrétaire Général pour les Affaires Régionales et Européennes)
- Région Grand Est

Research :

- École Nationale du Génie de l'Eau et de l'Environnement de Strasbourg

NGOs and stakeholders networks :

- Alsace Nature
- APRONA Observation de la Nappe Alsace
- France Nature Environnement
- IdéeAlsace

Transboundary cooperation bodies/networks:

- Upper Rhine Conference
- TRION

10.2 Overview of tasks performed

10.2.1 Organisation to carry-out Task 5.2

The Case Study is led by ACTeon. ACTeon team in SIM4NEXUS is under the supervision of Pierre Strosser. The case study is led by one person, who changed over the course of the project.

The succession of Case Studies leaders had pros and cons. The diversity of people’s profiles and expertise was a clear added-value to manage a wide diversity of tasks (stakeholders involvement, policy analysis, modelling) and bring knowledge from all Nexus sectors. However, it also generated delay in the development of the case study : each new-comer in the Project requiring a few weeks to understand the scope of tasks, identify support within the consortium and finally be able to take the lead.

Complementary expertise was also mobilised within ACTeon, be it for the socio-economic description of the case study (Alexandra Rossi, Camille Parrod), the collection of sectoral policies (Anaïs Hanus) or the stakeholders engagement process (Manon Berge, Océane Ziebel).

The team was also supported by interns and young professionals working full time on the project:

- Gitta Kollner [April-October 2017] contributed to D5.2, initiated most contacts with local stakeholders, and drafted the preliminary conceptual model
- Maya Taselaar [April-June 2018] contributed to D2.2 and wrote a thesis on the “Conditions for more coherent governance of the water, land, energy, food, and climate nexus sectors in Upper Rhine River Basin” under the supervision of ACTeon and PBL.

Overall, the France-Germany case study development represents about 450 days of work from June 2016 to February 2020.

ACTeon could benefit from the support of many Partners within SIM4Nexus to develop the case studies. The closest collaborations involved PBL (policy analysis), EXETER (conceptual model), UN-IHE (SDM), CamEcon (E3ME model) and UPM (CAPRI model). The case study leader participated to as many weekly SIM4NEXUS WP3/WP4 Teleconference meetings as possible, to share experience with the other case studies and benefit from EXETER’s expertise. In addition, bilateral discussions (phone, Skype, mail) were initiated when relevant and one physical meeting was organised in Paris to discuss the SDM with UN-IHE. The consortium Partners were invited to the stakeholders workshops ; DHI, WUR-LEI and CamEcom could attend.

The main challenge was to learn the other Partners’ professional language and concepts. Despite the wide expertise of ACTeon staff, the technicalities of thematic modelling, complexity science or Serious Gaming were hard to understand. This was overcome by countless email exchanges and the development of common frameworks to communicate (i.e. a glossary, a list of models parameters, …) to which ACTeon actively contributed. Finally, ACTeon could also benefit from the support and experience of other case-studies (Latvia, South-West-UK, Europe) in several stages of the project (development of policy cards and policy goals for the Serious Game, development of serious game training sessions).

10.2.2 Schedule of Task 5.2

The main bottlenecks – highlighted in red – are due to the performance of the described task by a limited number of project partners (development of the SDM by IHE-Delft for six case studies, provision of data by E3ME and CAPRI for several case studies).

<table>
<tr><th>DATE</th><th>Stakeholders process</th><th>Policies</th><th>Nexus definition</th><th>Modelling</th></tr>
<tr><td>06/2016</td><td>Identify relevant stakeholders</td><td></td><td rowspan="3">Write (D5.2) Nexus challenges</td><td></td></tr>
<tr><td>01/2017</td><td>Bilateral interviews</td><td></td><td></td></tr>
<tr><td>05/2017</td><td>Stakeholders mapping</td><td></td><td></td></tr>
</table>

<table>
<tr><td>12/2017</td><td></td><td>Collection of sectoral policies</td><td rowspan="4">Conceptual model development</td><td></td></tr>
<tr><td>04/2018</td><td>Bilateral interviews</td><td>Policy coherence analysis</td><td></td></tr>
<tr><td>06/2018</td><td>Workshop n°1, Kehl
“Which challenges for policy integration in the Upper Rhine region?”</td><td rowspan="2">Write (D2.2)
Policy analysis</td><td></td></tr>
<tr><td>07/2018</td><td></td><td></td></tr>
<tr><td>08/2018</td><td></td><td></td><td rowspan="7">SDM development</td><td></td></tr>
<tr><td>11/2018</td><td></td><td rowspan="2">Policy scenarios development</td><td>Identify relevant data</td></tr>
<tr><td>04/2019</td><td></td><td>Contact model owners to deliver data</td></tr>
<tr><td>05/2019</td><td></td><td>Simplify and validate the policy scenarios</td><td>Identify data not covered by thematic models to be collected from national / regional databases</td></tr>
<tr><td>07/2019</td><td></td><td rowspan="5">Policy cards development</td><td>Data received from CAPRI / E3ME</td></tr>
<tr><td>11/2019</td><td>Workshop n°2, Strasbourg
“Towards balanced public policies for the efficient use of resources in the Upper Rhine regions - Issues and options”</td><td>Local data collection continues</td></tr>
<tr><td>12/2019</td><td></td><td>Data received from SWIM / IMAGE</td></tr>
<tr><td>01/2020</td><td rowspan="2">Development and organization of serious game training sessions</td><td></td><td>Additional data received from E3ME for the development of policy cards</td></tr>
<tr><td>03/2020</td><td>SDM validation</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
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Figure 121 Synthetic overview of tasks performed on the France-Germany case study

10.3 Engagement of stakeholders in the process

10.3.1 Overview of stakeholders’ engagement in the case study

A first list of potential stakeholders was drafted based on acquaintances from ACTeon team and a quick internet search on the websites of the main institutions, administrations or companies in Baden Wurttemberg and Grand Est regions.
The persons identified were first contacted for bilateral interviews. The aim of these interviews was to collect perceptions regarding the Nexus concept, understand the Nexus challenges on the territory and clarify the potential involvement of the persons in the case study's activities. The interviews took place from January 2017 to May 2017.
The stakeholders list was shortened after the interviews, with the persons who declared to be interested to follow SIM4NEXUS.
A second round of interviews was organised in March-April 2018 to support the policy analysis work.
A total of 30 interviews was made.
The 1st workshop was organised on June 11th, 2018 in Strasbourg (10 participants). The agenda included a discussion on the policy analysis results, a validation of the conceptual model of the Upper-Rhine Nexus, a debate on good practices to improve Nexus-compliance.
The 2nd workshop was organised on November 15th, 2019 in Kehl (25 participants). The agenda included a presentation of thematic models results for the Baseline scenario (E3ME and CAPRI), a discussion on policy scenarios envisaged and group work on the policy cards.

A 3rd and final workshop is envisaged in June 2020 to present the final outcomes of the case studies and draw lessons learnt from the process.

All sectors are represented among the contacted stakeholders. The water sector remains dominant in the participants involved in the workshops, agriculture and biodiversity came second. The energy sector was represented mainly by researchers, not practitioners. Land and climate issues were a secondary field of expertise of the stakeholders (for example, expert working on climate change impacts on the hydrology or expert working on agriculture and land management).
Our main concern was to involve equally representatives from France and Germany in order to take into account the challenges or solutions stemming from both sides of the Rhine. Efforts were therefore put into the identification of interested practitioners or scientists in Germany.
The workshops were held in both languages, some sessions used English when a translation was not available.

The stakeholders' involvement widely consisted in sharing experiences and knowledge about the Nexus challenges, policies implemented or currently designed, practical solutions to overcome the inconsistencies and recommendations to improve resource-efficiency and resilience of the economy. During the last phase of the project (SDM development, use of thematic models results, development of policy cards, etc.), the involvement of stakeholders was very complementary to other project outputs. The discussions during the second workshop especially allowed to enrich, quality and complement what could be deduced from thematic models in terms of Nexus challenges and policy recommendations. Approximately 30 persons were involved in the case study.

10.3.2 Feedback on stakeholders' engagement in the case study

We were able to alternate different forms of interaction with stakeholders all along the project (interviews, focus groups and workshops). This combination of the different engagement modes resulted in a collaborative development of the case study in an appropriate and efficient way. Individual interviews allowed to gather specific input for the policy coherence analysis, stakeholder workshops made it possible to validate key results/developments of the case study (conceptual model, policy coherence analysis, results of thematic models) and to develop collectively (and in a balanced way) the policy scenarios and policy cards covering all 5 Nexus domains.

We could also observe that stakeholders committed well to the project over time and this despite the 18 months break (from June 2018 to November 2019) during which they have not been approached by the case-study team.

The rate at which stakeholders were approached and contacted throughout the project proved to be low: in particular, stakeholders were not contacted for 18 months between the two workshops and were not contacted outside of invitations/solicitations to participate in SIM4NEXUS events. It would have been interesting to develop a bi-monthly or trimestral case-study newsletter to be sent to the stakeholders involved.

Furthermore, the representativeness of Nexus domains and types of stakeholders could have been improved within the group of stakeholders involved: stakeholders of the Water domain were indeed over-represented while Energy and Climate stakeholders were under-represented. Almost all of the stakeholders solicited were representatives of public institutions (local governments, water agency, researchers) or para-public institutions (e.g., stakeholders networks, NGOs). It would have been interesting to include more private organizations (e.g. farmers' representatives, energy producers). We fear that this bias in representation could lead to somewhat biased results (especially for policy cards and policy recommendations) that would not have emerged with as much consent if the representations had been more balanced.

The stakeholders reacted very positively to transdisciplinary research and underlined the need and interest in accounting for not only biophysical aspects but also for socio-economic aspects of the Nexus when studying the latter. However, while some participants were accustomed to the use of models in their own activity, others were quite critical about the modelling tools and their results (especially thematic models during the second stakeholders' workshop) which they considered not comprehensive enough. This was an opportunity for us to remind the participants of the limitations of the modelling tools and to stress the importance of their inputs in the use and interpretation of the model results for the continuation of the project.

10.4 From conceptual models to System Dynamic Modelling

10.4.1 Case study conceptual model

A preliminary representation was drafted while describing the Nexus challenges in the Upper-Rhine region. It was published in D5.2.

Figure 122. First attempt to conceptualise the Nexus on the France-Germany case study.

The conceptual model has considerably changed since this first version (see Annex 10.9.1). The result is more complex, allowing for a fine description of interactions among sectors and feedback influences. It was developed on Powerpoint : one slide for each sector.

The basis diagram is inspired from conceptual models from :

- The systems mapping, developed under Task 1.5 and published in Milestone 11
- Other case studies' conceptual models (the models are presented during the weekly Monday Skype meetings organized by UNEXE)

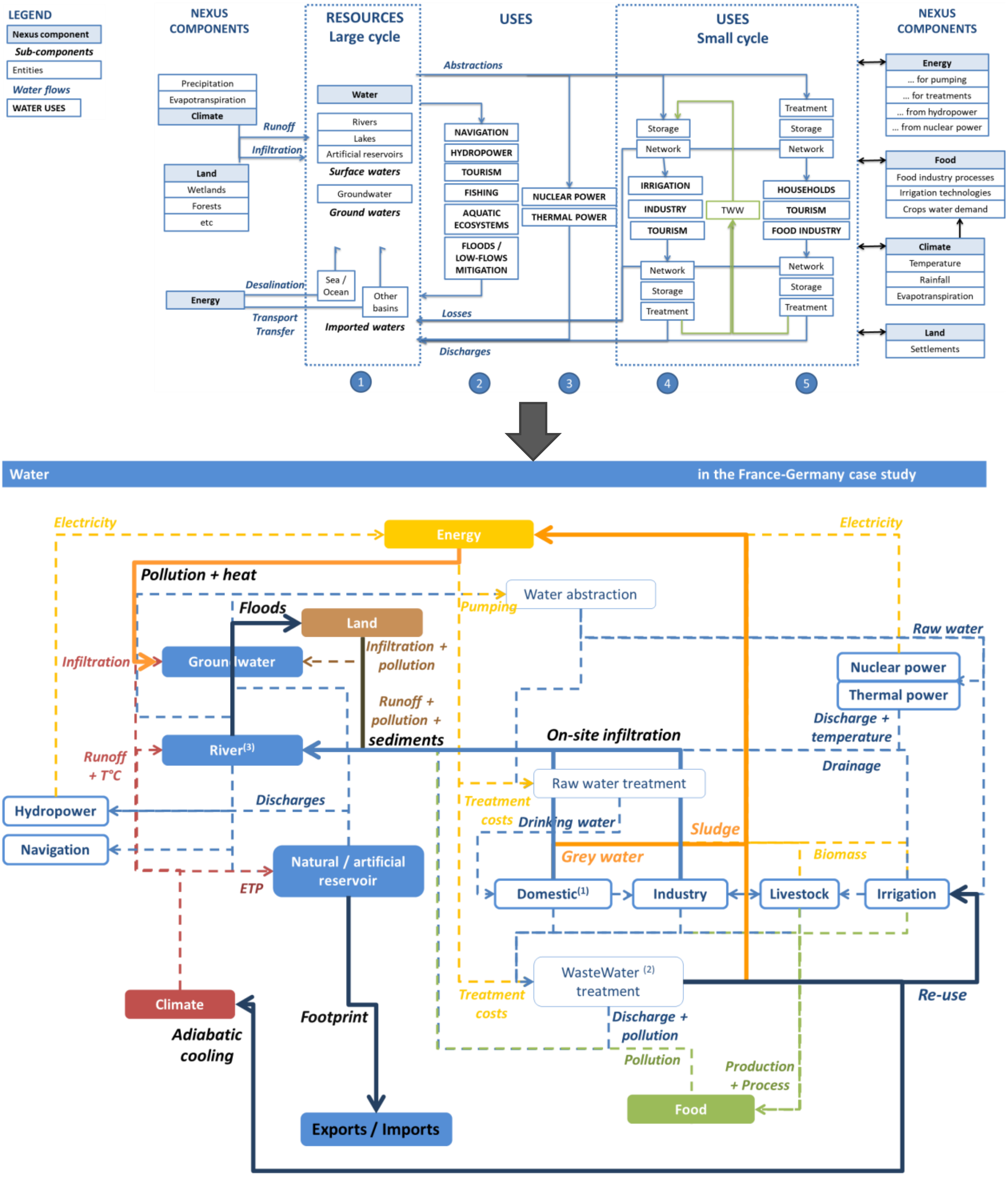

Figure 123 Example of evolution from the water system mapping (ACTeon, 2017) to the conceptual model for the water sector (ACTeon, 2018)

The diagram is then adapted to the Upper-Rhine territory, confronting it to the literature and expertise of consultants at ACTeon.
The conceptual model has also been presented to the stakeholders participating in the 1st workshop and amended according to their remarks. For instance, the following elements were added:

- nuclear power production impact on water temperature
- geothermal energy
- re-use of treated wastewater
- floods.

An initial ambition of the conceptual model was to integrate "aquatic ecosystems" as a Nexus domain, similar to water, energy or food. Several attempts to represent this domain and connect it to the other Nexus sectors were made, including through ecosystems functionalities or services. See Annex 10.9.1. The core difficulty is that ecosystems are not a resource, which can be shared among different users, traded, transported or transformed. The Nexus concept in SIM4Nexus is very much focused on resources and economies – with the ambition to optimize resources uses to match the needs of our economies. Finally, the ecosystems part of the conceptual model was left out and replaced by an impact assessment. The impacts of the sectoral policies will be analyzed in terms of water quality and surfaces of wetlands, which will be used as proxy for aquatic ecosystems.

10.4.2 Modifications introduced to model policy scenarios

10.4.2.1 Development of policy scenarios for the case study

Present the list of policy scenarios for your case study.
Describe how these policies respond to the Nexus challenges identified for your case study.
Explain how the policy scenarios were developed (who was involved, how were they chosen, how they differ from the baseline described in D1.8, how is it derived from D2.2 Policy coherence analysis).

The first list of policy scenarios was as follows :
Scenario 0 – Baseline (identical for all case studies – no new policies included)
Scenario 1 - 2°C scenario: implement climate agreements (through mitigation actions)
Scenario 2- Improve resource efficiency (energy and water)
Scenario 3 - Reduce vulnerability to risks (both floods and nuclear power)
Scenario 4 - Restore functional ecosystems (through better land management and regulations

Business as usual (BASELINE)	Common Agricultural Policy	EU legislation on biofuels	European Water Framework Directive	French law on energy transition for green growth	German Energy package	Prevent - Reduce - Compensate principle	Regional Scheme for Climate Air Energy Alsace	Regional Scheme for Ecological Coherence Alsace	Rhine River Basin Management Plan				
Implement climate agreements (2°C SCENARIO)	Agriculture : low input practices	Ban on fossil fuels	Carbon market for emission permits	Development of renewables	Emissions quota	Funding methane units	Funding solar units	Funding wind units	Optimisation of hydropower	Support to agrofuel chain	Support to fuelwood chain	Transports : low emission mobility
Improve resource efficiency (SIM4Nexus goal)	Energy crops rights	Energy efficiency standards	Energy efficiency technologies	Incentive energy pricing = xx€/kWh	Innovation in water technologies	Irrigation cap	Legislation to better use food wastes	Legislative framework for water re-use				
Reduce vulnerability to risks	Ban on nuclear power	Natural floods mitigation	Resilient cities adapted to flooding									
Restore functional ecosystems	Ban on pesticides	Compensation of soil sealing	Designation of protected areas	Limitation of erosion	Organic farming for all	Organic farming support	Payments for ecosystem services	Sediment + Fish paths program	Soil conservation in agriculture and forestry	Tax x€/ha on land-use change		

Figure 124 First version of policy scenarios and policy cards for the France-Germany case study. The colors represent the 5 Nexus domains

The policy scenarios were first imagined based on:

- D2.2 policy analysis report for the France-Germany case study
- Maya Taselaar's thesis
- Minutes from the 1st stakeholders workshop

Four approaches were combined :

- Option 1 : choose relevant policy documents / goals / instruments for further investigations. This refers to D2.2 / France-Germany case study /chap.3. The relevant documents, goals and measures are in bold in the tables. If instruments are not explicit in the documents, we could test the classic ones: funding / subsidies, conditionality, repartition rules, innovation / new technologies, constraints / bans / restrictions.

- Option 2 : choose coherent / incoherent examples. However, the coherence matrixes are not judged robust enough to support the choice of relevant instruments and goals. The scoring was based on the limited information and understanding of the assessor. The goals vs instruments scoring is the least robust. The "Land" domain was the least investigated.

- Option 3 : focus on highlights from the workshops and interviews. For example, "Methanation" could be investigated. Goals and limitations are clearly set : 10% biogas in the energy mix in 2030, not more than 10% of dedicated crops in the input material of each methanation unit, available funding from ADEME / Region / Lander. However, we would need to be more precise on the type of methanation implemented (what is the input material?): low input crops ? maize ? domestic waste ? industrial waste ? Another appropriate policy would be "Flood plans (PGRI)". But either the protections are too local for our models (effect on land use and hydrology are geographically very limited), or there is no quantification of the effect of preventive measures on the reduction of the flood level. Finally, "Rain water management" in cities is promoted but there is a wide panel of instruments and it is not clear which ones will be promoted and implemented to reach the goals.

- Option 4 : imagine strong policies that do not yet exist, to test them. Some policies have not been assessed in D2.2 because they do not exist yet, though it may be interesting to test them and evaluate the effect (including social and economic consequences). Examples are : Significantly reduce the share of maize by changing laws on land use ; Decide the energy mix, including the possibility of a complete ban on fossil fuels or nuclear power ; Significantly reduce pesticides through a ban on molecules or use.

ACTeon then checked that available input parameters from thematic models exist to cover the policy measures. The thematic models' factsheets give a list of output parameters, not input parameters though. ACTeon requested the list of input parameters to be triggered to simulate the effects of policies. For example: if a policy goal is to reduce pesticides in water, can CAPRI handle different instruments (organic farming vs short lifetime molecules vs buffer zones)?

This "wish list" of policies (objectives and measures) was then confronted to the SDM being developed. Policies that cannot be modelled through the SDM were erased. We also checked the availability of parameters to represent the economic and social impacts of a pathway (or set of policy goals and instruments), as this shall be investigated and communicated to the stakeholders and the players of the future Serious Game (especially employment, food prices, energy prices and GDP).
As a result of this confrontation, we had to modify the "reduce vulnerability to risks" scenario and as well as the "restore functional ecosystems" scenario.
Regarding the "reduce vulnerability to risks" scenario, the structure of the SDM only allows flooding phenomena to be accounted for tin a simplistic manner through the Land sector and the evolution of land-use for artificialized surfaces, urban green spaces and wetlands. In addition, we added a food security dimension to this scenario by considering the degree of food self-sufficiency.
Regarding the "restore functional ecosystems" scenario, we had to give up on several dimensions originally considered by the latter. We could not consider dimensions related to pesticide use, erosion dynamics, the implementation of different agricultural practices and associated instruments (subsidies for organic farming and payments for ecosystem services) as well as the protection of aquatic biodiversity. However, we were able to consider dimensions related to land-use change/land take (and associated compensation policies) as well as the designation of protected areas or the implementation of agricultural and forestry promoting carbon sequestration. Finally, we included a diet dimension to be considered in the 2°C and the "improve resource efficiency" scenarios.

The time constraints that emerged during the project made it impossible to populate the SDM for each of the policy scenarios developed within the case study.
We thus chose to develop a policy card for each public policy intervention/instrument constituting a "brick" of the scenarios described above so that they can be implemented or played in combination in

the SDM or the serious game. Such an approach allows the player to observe and compare the evolution of the different sectors of the Nexus (and thus the Nexus health) for each of the scenarios but also allows the player to create new combinations.

10.4.2.2 Introduction of policy scenarios in the SDM

The structure of the SDM has been adapted to be able to implement the policy scenarios and associated policy cards. In particular, we have modified the structure of the model to take into account the following dimensions:

- The use of agricultural inputs and in particular the use of fertilizers for crops categories in relation to "restore functional ecosystems" scenario. As a result, variables were added into the Land sector (fertilizer use in kg/ha x year to be combined with cultivated areas).
- Biomass energy production and associated energy production/consumption in the relation to the 2°C and Baseline scenarios. As a result, variables were added into the Energy sector
- Food imports/exports in relation to the "reduce vulnerability to risks" scenario and its food security dimension
- Carbon sequestration by (different types of) agricultural and forest soils in order to take into account the impact of agricultural/silvicultural practices that promote carbon sequestration in relation to the "restore functional ecosystems" scenario.

On the hand and as mentioned in the previous section, the development of policy scenarios and policies cards was constrained by data availability from thematic models and local data, which impacted the development of the SDM and its structure (also see sections 10.4.3.1 and 10.4.3.2 below).

Finally, the table provided in Appendix 10.9.3 describes how policies were translated into parameters in the SDM and indicate the triggered parameters for main policy bricks considered.

10.4.3 Modifications introduced to account for data availability

10.4.3.1 Data available from the thematic models

The thematic models mobilised to assess the Nexus on the France-Germany case study are: CAPRI, E3ME, SWIM and IMAGE. In this section we briefly describe, for each thematic model, the use made of models results for the population of the SDM, the data processing performed (when relevant) as well as the impact of data availability/non-availability from thematic models on the SDM development. Appendix 10.9.5 lists, Nexus domain by Nexus domain, all the variables considered in the SDM which directly stem from thematic models (integrated to the SDM with minor data processing).

Before doing so, we describe here the main challenges that we had to overcome during the data collection process from thematic models. Three major challenges had to be overcome:

a) Delay in the delivery of model results. SWIM data came very late, compared to E3ME and CAPRI, which delayed the population of the SDM. It was even considered to use other models' or databases' figures instead of SWIM, to cover the water sector. The reasons for this delay was that the existing version of the Rhine in SWIM had not been maintained for a while and had to be restored nearly from the start. Discussions on the parameters relevant for the Upper-Rhine case study started in April 2018 but modelling results were only delivered in July 2019.

b) Understanding thematic models results. ACTeon did not anticipate so much work on the thematic models. ACTeon had to gain knowledge about all parameters available through the models and ask precisely the ones relevant for the case study. Email exchanges soon proved to be insufficient. We established lists of parameters (including scale and dimension) to communicate with the model owners. These lists later contributed to the "Naming Convention" established by UN-IHE. We had to verify all datasets provided by the modelers and send requests for missing data. The modelers first delivered datasets without any explanation on assumptions taken (we had to email each model owner to access it).

c) Bridging the gaps. We hoped the three models selected for the case study (CAPRI, E3ME, SWIM) would cover most of the Nexus issues of the case study. It turned out we had to collect data on all 5 Nexus dimensions, the models providing only partial results. Important downscaling work was undertaken (i.e. from national to regional level, or from aggregated to individual sectors). Some parameters were also not available in the right dimension and had to be calculated from other parameters.

In January 2019, the case studies were offered the possibility to request datasets from additional thematic models in SIM4Nexus (though they had not been identified as suitable at the beginning of the project). ACTeon requested datasets from IMAGE, which were used to apply trends to local data on Land uses.

10.4.3.1.1 CAPRI

The results from CAPRI have mainly been used to populate the SDM for the Food and Land domains of the Nexus. Besides, CAPRI results for methane output from livestock were also used to populate the SDM for the Climate domain. Finally, CAPRI results were used to extrapolate historical local data for irrigation and water use for cattle.

In particular, we considered the following categories of variables: for the Land domain, we considered the cultivated areas, the use of fertilizers as well as the ammonia output for major types of crops (cereals, oilseeds, vegetables and permanent crops, arable crops and other energy crops). Only a few types of crops were considered individually in the SDM, these are the crops linked to the Nexus challenges being specific to the case study or "traditional" crops in the CS region. We considered, in particular, maize (grain and silage), sunflower and rape (in relation to their use for bioenergy production) as well as vines.

For the Food domain we considered production variables (production as such or as a yield combined with the cultivated area for the crops of interest mentioned above), processing of primary products, human and animal food and feed consumption of primary products (and secondary products for human consumption) as well as importations and exportations of primary and secondary products. Similar to the Land domain, all of these variables were defined for major types of crops (cf. previous paragraph for crop production) and products; in particular, we considered animal products (milk, meat and eggs) and the associated livestock.

Since most of CAPRI results were available at the regional (i.e., NUTS2) level the latter were directly aggregated and used to populate the SDM[23]. A simple aggregation process was implemented to build SDM variables at the Baden-Württemberg and Grand Est regions scale: variables available at the NUTS2 level were summed up or averaged, depending on the variable considered.

As some CAPRI results are only available at a national level, it was necessary to downscale them: these are the variables dealing with importation/exportation, human and animal consumption of primary and secondary products, and the processing of primary products. For all these variables, the national (importations/exportations/processing and consumption) "pattern" was determined and applied at the regional level: we determined importations and exportations as a percentage of the local supply, animal and human consumption and the processing of primary production as a percentage of the domestic market use.

[23] The validity of CAPRI results was first checked by comparing CAPRI figures with historical local data.

The non-availability of these variables at the regional level impacted the development of the SDM for the Food and Land sectors in the following way.

- Initially, we planned to use the CAPRI results to quantify both the cultivated area and the biomass production itself dedicated to biofuel/bioenergy production (even if downscaling national data might have been necessary). In view of the data available, we had to simplify the consideration of this aspect (yet central to our case study) in the SDM by taking into account energy crops in an aggregated and "simplistic" way: the cultivated areas dedicated to each type of energy crop for the baseline scenario were determined by combining the global cultivated areas determined by CAPRI combined with hypotheses from the literature (determining the share of each crop-specific cultivated area dedicated to bioenergy, the latter assumed constant over the entire study period 2006-2050). Such an approach does not allow considering the impact of market dynamics on the development of energy crops for our case study. We were also unable to consider biomass importations/exportations for biofuel production as well as importations/exportations of biofuels itself: the first two variables have been combined in a single importations/exportations balance variable being directly computed by the SDM as the difference between local demand and supply for biomass and importations/exportations variables for biofuel are not accounted for in the model.
- We also aimed at considering different types of agriculture (organic farming, low environmental impact farming practices, etc.) and the corresponding cultivated area so that we could consider the impact of a change in agricultural practices on water resources in the SDM. The results offered by CAPRI did not allow us to consider these different aspects in the SDM, which was therefore simplified: for each crop type we consider only one single cultivated area variable mixing all types of farming practices.

10.4.3.1.2 SWIM

Results from the SWIM model were used as a basis to determine the hydrological dynamics of surface water and groundwater resources to populate the Water sector of the SDM: we considered aquifer recharge and discharge variables as well as evapotranspiration and runoff variables. We could not use SWIM results to populate the SDM for water use variables and had to collect local data to determine these latter variables.

The SWIM results were upscaled (except for the Rhine system) to match the case-study area : the SWIM model covering only a part of the CS area, results for groundwater recharge and discharge variables as well as actual evapotranspiration and runoff (except for the Rhine system) were upscaled simply using the ratio of the CS area covered by SWIM to the actual CS area[24] (results for Grand Est and Baden-Württemberg regions were upscaled separately).

SWIM results were also slightly restructured to render CS-specific issues. First, given the central role of the Rhine for energy generation, navigation and biodiversity conservation, the Rhine system was modelled separately from the rest of the surface water system and is considered as a two-part system comprising the canal and the Old Rhine. The runoff in the Rhine system as determined by SWIM is thus broken down into two parts:

- The annual runoff in the Old Rhine is considered constant and equal to the ecological flow (see EDF, 2010).
- The annual runoff in the canal is computed as the difference between the runoff in the Rhine system as determined by SWIM and the ecological flow.

[24] Ex : Aquifer recharge(Grand Est) = Aquifer recharge(SWIM_Rhine_FR)*(area(Grand Est)/area(SWIM_Rhine_FR))

Second, to render the shared nature of the groundwater table between part of the Alsace and part of the Baden-Württemberg regions, the groundwater resource was considered as a single stock variable for the whole CS area (Grand Est and Baden-Württemberg)[25].

Finally, SWIM results for hydroelectricity generation were also used to populate the Energy sector of the SDM.

10.4.3.1.3 IMAGE

IMAGE results for Europe were used to define trends for the Baseline and 2°C scenario to extrapolate historical local land-use data (Corine Land Cover) for non-agricultural land-use for the Land sector of the SDM. For the 2°C scenario, we use the trend defined based on IMAGE results for Europe to determine the evolution of the share of total utilized agricultural area dedicated to biomass for energy production compared to the Baseline scenario. Thus, these results were not directly used to populate the SDM.

The unavailability of results at a "proper scale" for our case study did not influence the development of the SDM and its structure. However, this requires the careful consideration of the SDM results, particularly with regard to the evolution of the surface area of natural areas (forest, grasslands and wetlands) or the cultivated area dedicated to energy crops: indeed, IMAGE produces results on a very large scale that does not necessarily reflect the specificities of land use and its evolution on a regional scale (e.g., already important development of energy crops within the case study area compared to whole Europe, existing legal frameworks preventing loss of natural areas, etc.).

10.4.3.1.4 E3ME

Similarly to the results of the IMAGE model, E3ME results were not directly used to populate the SDM, but allowed the definition of trends for the extrapolation of local data for the Energy - for energy production and primary and final energy consumption variables - and the Water sectors of the SDM - for water withdrawal/consumption variables for the industry and the energy sectors.

Since E3ME provides results at the national level, we did not wish to use these results directly to populate the energy sector of the SDM. We had access to local data of sufficient quality and considered that the use of downscaled national data would not allow us to render the specificities of the two regions constituting the case study territory in terms of energy consumption and production (e.g., important development of hydroelectricity and energy crops). For the same reasons, the results of the direct application of national trends to predict the evolution of energy production and demand at the scale of the case study territory should be examined critically.

Constraints related to the availability and scale of the results provided by E3ME influenced the development of the SDM when considering supply and demand for bioenergy : E3ME provides very little data for primary energy production from bioenergy (energy supply from biomass being considered only for electricity generation and in a very aggregate way) as well as for demand for biomass (the demand for the different types of biomass is not determined, only the aggregate demand). Thus E3ME results did not compensate the low data availability from CAPRI for the biomass/bioenergy dimension. Simplifications implemented for the SDM structure are described in the previous section 10.4.3.1.1 for

SWIM results for flows coming in and out of the groundwater table were upscaled separately for Grand Est and Baden-Württemberg and finally added. Ex : Aquifer recharge (Grand Est+Baden Württemberg) = aquifer_recharge(Grand Est) + aquifer_recharge(Baden Württemberg).

agricultural biomass production. Similar simplifications were implemented for wood biomass (entirely based on local data).

10.4.3.2 Local data to be collected

In this section we briefly describe, for each Nexus domain, the need for local data collection for the population of the SDM, the data processing performed (when relevant) as well as the impact of data availability/non-availability on the SDM development. Appendix 10.9.5 lists, Nexus domain by Nexus domain, all the variables considered in the SDM which are originally based on local historical data (data sources were directly included in the tables). For all these variables, local historical data was directly used to populate the SDM between 2006 and late 2010s and extrapolated until 2050 (based on TM results or other assumptions).

Before doing so, we describe here the main challenges that we had to overcome during the local data collection. In general, the spatial scale of thematic models results as well as the fact that some variables being central to the case study were not taken into account by latter models (e.g., see previous section for the consideration of bioenergy) significantly amplified the needs in terms of local data collection and thus increased the associated workload in an unexpected way. In particular, two major challenges had to be overcome:

a) An "expertise-intensive" data collection: The need to collect local data for all Nexus domains (as mentioned in the previous section) also made the organization of data collection more complex. Indeed, it was necessary to involve several ACTeon experts with the necessary expertise to identify quality data, collect it and – when required – process it for the case study's scale.

b) Collecting local data for a transboundary case-study – the heterogeneity challenge: Finally, the need to collect data for two different countries also complicated the data collection. We had to combine databases that were originally heterogeneous in terms of quality (Baden-Württemberg having easily accessible annual surveys and centralizing a large part of the data on all Nexus domains, which is not the case for the Grand Est region) but also in terms of structure. It was therefore necessary to take this heterogeneity into account in the development of the SDM and the choice of the different variables. It was possible to aggregate most of the existing data on the German and French sides to obtain a homogeneous structure among both countries, which was eventually translated into variables. One exception is to be noted for the Energy sector of the SDM: we have chosen to consider separately the production of electricity and heat in cogeneration and without cogeneration in the SDM since this dimension was taken into account in the German data, but not for the French data. The production of electricity and heat in cogeneration therefore appears nil for the French part of the SDM.

Finally, access to the Datawarehouse which was announced and presented in SIM4Nexus project meetings would have been an asset, but it came too late.

10.4.3.2.1 Land

For the Land sector, we focused on three main types of land-use: natural areas (forest, grassland and wetlands), artificialized areas (urban, industrial and transport infrastructures) as well as on agricultural areas. Moreover, as mentioned previously particular attention was paid to agricultural land-use and its allocation between food/feed production and biomass production for energy. We had to collect local data from Corine Land Cover to determine surface areas for both natural areas and artificialized areas. Trends determined based on IMAGE results for Europe were used to extrapolate this historical local land-use data for non-agricultural land-use.

As mentioned previously, agricultural land-use and its evolution over time was determined based on CAPRI results. However, we had to apply additional assumptions – based on local data collection and literature review – to the latter results to determine the allocation of cultivated area for each type of crop for food/feed production and biomass production for energy respectively. We combined the following information:

- The share of total utilized agricultural area (or area when available) dedicated to the production of biomass for energy ;
- The relative share of bioethanol, biodiesel and biogas production in total energy biomass production ;
- The crop-specific share in the production of biodiesel or bioethanol.

The value of these parameters is considered constant for the whole 2010-2050 period.

10.4.3.2.2 Water

For the water sector, we aimed at investigating the balanced use of water resources. Since SWIM did not provide any results for water use, we had to collect local historical data to determine ground and surface water use for agriculture (irrigation and cattle being considered separately), for the industry, for public water supply services and for the energy sector.

Trends determined based on CAPRI and E3ME results were used to extrapolate local historical data for water abstraction for the energy, industry and agricultural sectors:

- Industrial output in value (euros 2005m) as determined by E3ME at the national level (France and Germany being considered separately) was used to extrapolate water abstraction from the industrial sector ;
- Energy generation based on thermal power (in GWh/year) as determined by E3ME at the national level was used to extrapolate water abstraction from the energy sector ;
- Crop-specific cultivated area and irrigated area (as a share of total cultivated area for each type of crop) as well as herd sizes (in k heads) as determined by CAPRI were used to extrapolate water abstraction from the agricultural sector.

Water demand for the public water supply services was extended based on population growth while also accounting for water savings stemming from behavioural changes.

10.4.3.2.3 Food

For the food sector, almost all variables included in the SDM were based on CAPRI results. We only needed to collect local data to determine manure production (in m3/kheads/year) for each type of cattle and to determine food waste (in kg/inhabitant/year) in Grand Est and Baden-Württemberg. Both manure production and food waste were considered constant over the entire study period (a 50% decrease trend in food waste between 2010 and 2025 was considered for the 2°C scenario).

10.4.3.2.4 Energy

All variables of the Energy sector were populated with historical local data that were extrapolated to 2050 based on national trends determined from the E3ME results. We considered three main types of variables:

- Variables related to net available primary energy resources: We considered local production and the primary energy imports/exports balance for non-renewable energy sources (coal, petroleum products, natural gas and "other") as well as for forest and agricultural biomass.
- Secondary energy production variables: We considered the production of secondary energy (electricity and heat) from renewable (wind, solar photovoltaic, biomass) and non-renewable (nuclear, coal, petroleum products and natural gas) energy sources in cogeneration and without cogeneration. Electricity production based on hydropower is determined by SWIM. We have also considered the share of primary energy resources consumed "directly" as fuel.
- Final energy demand variables allowing to determine the aggregate annual final energy demand for different sectors (Transport, Agriculture, Water Treatment and Pumping, Households, Industry

excluding Food industry, Food industry and "Others"). From these variables, we have determined the aggregate energy demand. We also considered the balance of electricity imports/exports.

10.4.3.2.5 Climate

Most of the variables in the climate sector on the SDM have been determined and populated with data from the literature (we mainly used the national ADEME database providing emission factors as well as results of the EFESE study for sequestration factors). The aim here was to provide "generic" values for emission and sequestration factors that could be easily combined with land use and primary energy use variables from the Land and Energy sectors respectively, as well as herd sizes from the Food sector. The values for the emission and sequestration factors were considered constant for the whole study period.

10.4.4 Case Study SDM in Stella/R

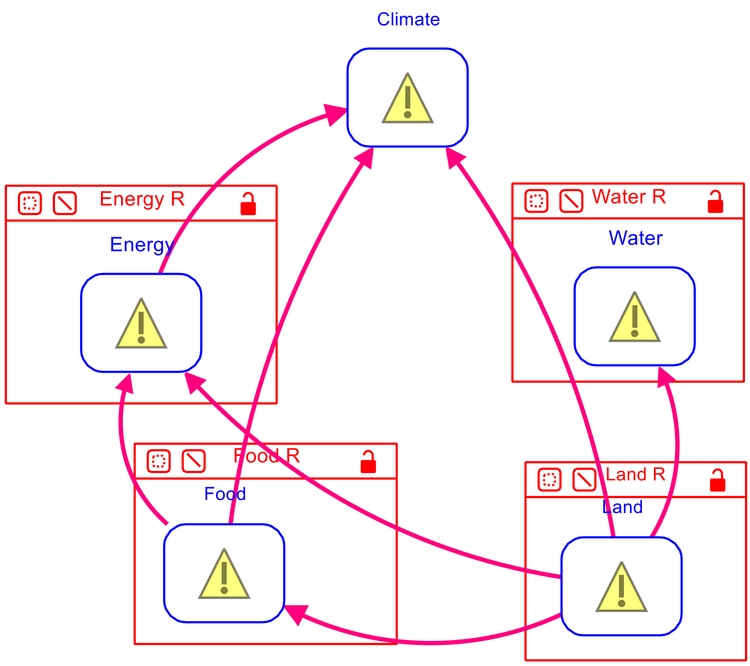

Figure 125 Global structure of the SDM for the Upper Rhine case study

When developing the SDM we aimed at establishing as many links as possible between the various Nexus domains in order to illustrate as comprehensively as possible the interactions triggered by sector policies among Nexus domains (see Figure 124 above). In particular, we have been able to establish the following linkages:

- Land-Food-Energy and Land-Energy: the production of biomass for energy use is determined by combining land use or herd sizes variables (for energy crops, wood and livestock) with “yield” variables (in tons/ha x year or tons/head x year). The amount of energy produced from this biomass is determined thanks to conversion coefficients that take into account the calorific power of each type of resource.
- Energy-Climate: Greenhouse gas emissions are determined by combining the demand variables for the different primary energy types (either for secondary energy production or consumption as fuel) and the associated emission factors.
- Food-Climate: here, livestock greenhouse gas emissions are considered through the combination of herd sizes variables and associated methane outputs.

- Land-climate: this link allows us to capture greenhouse gas emissions or sequestration from land use. This is made possible by combining land use variables (in hectares) with sequestration coefficients specific to each type of land-use.
- Land-Water: here we determine the total water demand for irrigation by combining the variables of cultivated area with water demand variables in m3/ha x year (these variables are crop specific).

Finally, we had to overcome the following challenges when developing the SDM:
- As mentioned previously, a large part of the variables included in the SDM were populated based on local data, displaying a high degree of heterogeneity between the Grand Est and Baden-Württemberg. This heterogeneity had to be taken into account when developing the structure of the model.
- It was also necessary to consider the transboundary issues in the development of the SDM, in particular those related to the Rhine system and the shared nature of water resources (ground and surface water resource) between the two case-study regions.
- The introduction of the policy scenarios/policy cards required several successive iterations in order to adjust the structure of the SDM and to integrate the associated variables. These adjustments were required due to both the selected public policies/policy cards and data availability.
- Finally, the SDM was developed in collaboration with UN-IHE. Partners. This represented both an asset and a challenge. Indeed, we were able to benefit from our partners' knowledge of this type of modelling tools as well as from the experience acquired through the development of the SDMs for five other case studies. However, this co-construction process required close dialogue (see Annex 10.9.2 for an illustration of co-construction meetings) and numerous iterations to reach the final structure of the model.

10.4.5 Addressing Nexus challenges

The Nexus challenges defined for the case study strongly conditioned the development of the SDM.
We have developed the energy sector so as to consider the composition of the energy mix and its evolution (taking into account renewable and non-renewable energy types individually) in as much detail as possible. We have also developed as much as possible the consideration of energy production from biomass, which has influenced the development of the energy sector but also the Land sector and the Food sector.
The development of the water sector also allows us to monitor the sustainability of water resource management/use by combining hydrological variables with water use variables. It is possible to influence the latter variables by simulating the implementation of innovations in irrigation systems, herd sizes, cooling systems for energy installations and water networks.
Finally, considering a large number of land-use variables allows us to monitor and influence the evolution of areas for different types of land use (in particular natural areas, forests and wetlands).

Finally, as no simulation has been carried out with the SDM and the serious game was not developed for our case-study, we could not investigate and “solve” the Nexus challenges based on the latter tools.

10.5 From the System Dynamic Modelling to the Serious Game

10.5.1 Case studies learning goals

A demonstration of Serious Game was proposed during the 1st stakeholders’ workshop (June 2018), presented by DHI. The feedback from participants during the workshop, as well as opinions or expectations collected during the stakeholders’ interviews (March-April 2018) were summarised into a note and shared with DHI. The note offers suggestions regarding the one-player vs multi-player mode, the introduction of currencies (fictional or real), possible extreme events that could threaten the implementation of policies (social rejection, floods, nuclear incidents, …) and policy cards (or measures) to be played.

The learning goals were adapted following the stakeholders workshop to reflect better the concerns related to the impacts of energy transition (see D4.8) : the Serious Game shall help the player learn about the impacts of different energy transition strategies.
In addition to the stakeholders' inputs, we introduced a learning goal on the transboundary cooperation, in order to test different national / regional policy settings through the Game and demonstrate the added-value of joint implementation by the two neighbour countries. The player should be able to choose between different play modes : a/ Consider the Upper Rhine as one entity with common policy goals and instruments, or b/ Consider the Upper Rhine as two separate entities (France vs Germany) with different policy goals and instruments, as it is today. The development of the SDM reflected this second learning goal by individualising Grand Est and Baden Wurttemberg.

The learning goals remained broad as discussions were still on-going with EURECAT and DHI on the play mode options :

- Option 1 : the Game is for awareness raising. The policies are fully implemented and it is assumed the policy goal is reached. One question remains on the reversibility of policies from one run to another. If a policy is chosen with consequences on biodiversity loss / loss of land (urbanization) / water pollution / … it should not be possible to reverse the situation on the next run (or be very costly).
- Option 2 : the Game is for decision-making. To be more realistic, policies are assumed to be never fully implemented. There are several reasons a policy goal may not be reached : - No money to implement the policy - No operators or lack of coordination among operators - Inefficient instrument promoted by the policy - Misuse of the policy instruments.

Option 1 is finally favored as it is simpler to implement, both at SDM and Serious Game stages.

10.5.2 From generic to specific use cases

The development of use cases for the Upper Rhine case study relied heavily on the methodological framework and illustrations of the latter provided by the WP1 partners in November 2019 (D1.2).

This deliverable provides precise recommendations for the development of quality use cases. In particular, it insists on the need to develop use-cases allowing the player to become aware of the links between the different Nexus sectors by observing the impacts of the different measures implemented as part of the use-case on the other sectors of the Nexus.
We have developed three specific use cases. Two of them are developed based on the Nexus challenges defined for our case study: the first aims to highlight the links between climate, water and energy production (in particular based on thermal energy, hydroelectricity and nuclear power); the second aims to highlight the Land-Food-Energy-Water trade-offs triggered by the development of renewable energies, especially of bioenergy. Finally, the third case study explores the potential of multifunctional measures for climate change mitigation: this type of measure was the subject of a special session during the second stakeholders workshop and its interest was highlighted by the latter.

The full description of the use-cases is provided in appendix 10.9.8.

10.5.3 Policy cards

As mentioned previously, the development of policy cards was a direct result of the policy scenarios: we developed a policy card for each public policy intervention/instrument constituting a "brick" of the scenarios described in section 10.4.2.1.

Different “policy elements” therefore constituted the basis for the definition of the policy cards. We considered (see section 10.4.2.1 for further detail):

- Identified policy documents/instruments and goals identified during the policy analysis and that we wished to implement within the SDM and the SG to investigate their impact/coherence
- Highlights from the workshops and interviews. For instance, the second stakeholders workshop made us consider behavioral changes to be implemented as policy cards (e.g., dietary shits, energy savings triggered by the provision of information)
- Strong policies that do not yet exist and that also we wished to implement within the SDM and the SG to investigate their impact/coherence

The complete list of policy cards considered for the Upper Rhine case study is available in Appendix 10.9.8.

We determined the impacts of each policy card in the SDM by combining elements from the literature and "isolated" simulation runs performed by thematic models for specific policy cards. In particular, we benefited from the support of Cambridge Econometrics partners to determine the impact of the policy cards related to energy policy. Partners from the University of Madrid provided us with additional CAPRI results to determine the impact of dietary shifts.
The impacts of the implementation of the policy cards in terms of cost, economic value and social capital were determined by combining elements from the design of policy cards, literature, knowledge of ACTeon experts and stakeholder participation. Indeed, the second stakeholders workshop was an opportunity for us to validate the policy cards that we had developed and to determine their impacts in terms of cost, economic value and social capital in small working groups.

10.5.4 Serious Game interface

The Serious Game for the France-Germany case study has not been developed as of today. The ideas were to display two entities: Grand Est region on the French side and Baden Wurttemberg region on the German side.

10.6 Short-term and long-term policy recommendations

10.6.1 Summary of the Nexus issues in the case study

The main Nexus challenge identified corresponds to the implementation of a "Nexus-compatible" energy transition. Indeed, we have observed that the energy transition and the associated evolution of the energy mix in the Upper Rhine seems to result in the emergence of several trade-offs between Nexus domains, with in particular negative impacts on water and land resources. More specifically, we have identified the following trade-offs:

- Transition to a low-carbon economy in the case-study area is translated – among others – into the development of bioenergy (especially biofuel production and energy generation based on methanation) through the implementation of support mechanisms. This development has significant implications in terms of land use change and possibly in terms of pressure on water resources both in qualitative and quantitative terms, not forgetting competition with food production. The existing legislative framework aims at minimizing the impact of biofuel development in terms of energy-food trade-offs and competition for land use. However, the safeguards defined by this legislative framework seem insufficient (Strosser et al., 2018, p95) and does not consider the possible negative impacts on water resources.

- This transition has also resulted in a significant development of solar energy (which is expected to further develop), encouraged by public policy instruments[26]. The legislative framework provided for the development of solar energy already defines safeguards to minimize land take and direct it towards "low value" land. However, it appears that the existing framework does not allow for the minimization of impacts on biodiversity and ecosystems (Strosser et al., 2018, p95).
- Despite the significant development of other renewable energy generation technologies in the CS region (wind-power in Grand Est and PV-Solar in Baden-Württemberg) hydroelectricity still plays a key role. Moreover, a significant share of electricity generation in Grand Est and Baden-Württemberg regions is based on nuclear and thermal power, displaying substantial water requirements for cooling. This raises the question of energy security in a climate change context, characterized by a high degree of uncertainty about future water availability and the expected increase in the frequency of extreme weather events (droughts and floods).

10.6.2 Description of the policies targeted for recommendations

We developed 14 policy recommendations. Public stakeholders represent the target group for the great majority of these recommendations:

- 13 recommendations target policy makers/decision-makers
- 5 recommendations target "technical public stakeholders being responsible for policy implementation
- Only two recommendations primarily target private actors.

Our recommendations are directly linked to the main nexus challenges defined for our case-study : six recommendations aim at defining safeguards for the implementation of the energy transition/transition to a low-carbon economy while ensuring a sustainable use of natural resources. These recommendations are very specific to the case study and defined based on the local context.

We have also developed six recommendations that are not specific to the case study but linked to the necessary implementation of a Nexus approach in the development, implementation and evaluation of public policies. Each of these recommendations concerns a lever to be activated to implement the Nexus approach.

Finally, we develop on recommendation dealing with transboundary cooperation.

10.6.3 Policy recommendations

E3ME model offers some policy recommendations from the baseline scenario and some policy runs. CAPRI results also enable the development of policy recommendations. Some policy recommendations

[26] Especially in Germany where tenders have been implemented following the revision of the national electricity law in 2017 (Strosser et al., 2018).

also result from the recent workshop. The recent stakeholders workshop allowed to critically examine thematic model results (E3ME and CAPRI combined) and confront them with CS challenges. We could draw two interesting results: 1) implications of energy transition and choices (denuclearization vs. stick to nuclear) in terms of emissions and nature of the energy mix (CLIMATE – ENERGY) 2) implications of the development of biomass and especially methanation in terms of land and water use (we underlined the issue of water quantity but participants stressed the importance of the quality issue rather than quantity).

10.6.3.1 Changes in policy outputs

Policy recommendation background: E3ME shows an increase in the share of hydropower in France and Germany for both the Baseline and the 2°C scenarios (especially in the 2°C scenario). This national trend indicates that the level of dependence on water resources for energy production will be at least maintained at the regional level (already important share of electricity generation based on hydropower nowadays). Such a result is of concern in a climate change context characterized by uncertainties regarding the availability of water resources.

In short	Decrease reliance on hydropower in the Upper Rhine
Recommendation type	Change in policy output (goal in terms of share/quantity of energy produced based on hydropower)
Nexus sectors involved	Energy, Water
Target group	Policy-makers
Target policy goal	Low carbon economy, Energy security
Target policy instrument	- GE : Regional plans for energy policy (Schéma Régional D'aménagement, De Développement Durable Et d'Egalité Des Territoires and its objective to foster the development of hydroelectricity in Grand Est, - BW : Regional adjustment of the Erneuerbare-Energien-Gesetz
Target policy process phase	Agenda setting (water related extreme water events have to be considered when developing the energy mix)
Administrative level	Region
Time scale	Medium term

Policy recommendation background: This policy recommendation is based on the outcome of the second stakeholders workshop: stakeholders had the feeling that energy transition focuses too much on its "technological dimension (composition of the energy mix, innovation for energy/electricity storage, etc.) and that there is not enough emphasis on energy efficiency and decrease in energy consumption. According to them there is need for a change in policy focus : energy efficiency gains and especially energy savings (decrease in energy consumption) should be prioritized

In short	Aim at energy efficiency
Recommendation type	Change in policy output (goal in terms of energy consumption, improvement of energy efficiency)
Nexus sectors involved	Energy (water)
Target group	Policy makers
Target policy goal	Efficient use of resources

Target policy instrument	GE : French strategy for energy and climate – multi-annual energy plans and its regional adjustment (Schéma Régional D'aménagement, De Développement Durable Et D'égalité Des Territoires) BW : Erneuerbare-Energien-Gesetz and its regional adjustment,
Target policy process phase	Policy formation
Administrative level	National to regional
Time scale	Medium term

In short	Aim at identifying and prioritizing multifunctional measures (e.g., nature-based measures)
Recommendation type	Change in policy output (declare multifunctionality as a priority)
Nexus sectors involved	Water, climate, land
Target group	Public policy-/decision-makers
Target policy goal	Low carbon economy
Target policy instrument	GE: Schéma Régional D'aménagement, De Développement Durable Et D'égalité Des Territoires
Target policy process phase	Agenda setting and policy formation
Administrative level	National to local
Time scale	Short term
Comments	**Pre-conditions for successful implementation:** - If implemented at the local level, prioritizing multifunctional measures should be allowed (at least not hampered) by the national law - Requires the implementation of many changes: in particular in the way of thinking and values, but also in implementation tools and practices (financing, research, training in multifunctional measures in a "monofunctional world").

10.6.3.2 Changes in policy contents

Policy recommendation background: interviews conducted as part of the policy analysis underlined that PV on land installations, may impact biodiversity through direct and indirect effects such as fragmentation, soil and habitat disturbance, depending on the chosen site. A group of NGOs have expressed their concern about this because they do not consider the law strict enough.

In short	Control the development of PV fields in the Upper Rhine
Recommendation type	Change in policy content (way of implementation: optimize establishment, prioritize shared use of land such as PV-farming projects, make the law/its implementation stricter)
Nexus sectors involved	Energy, Land
Target group	Politicians/decision-makers and public stakeholders responsible for implementation in the field
Target policy goal	Low carbon economy, efficient use of resources

Target policy instrument	- BW : Implementation of the "Freiflächenöffnungsverordnung" - GE : Legislation related to environmental impact assessment, the agricultural modernization law and the Climaxion program (conditionality of funds for the latter) in Grand Est
Target policy process phase	Policy formulation and implementation
Administrative level	Region
Time scale	Short term

Policy recommendation background: CAPRI and IMAGE results suggest an increase in cultivated area dedicated to energy crops. This would lead to an increased pressure on water resources both in qualitative and quantitative terms (as underlined by participants during the second stakeholders workshop).

In short	Set a maximum cultivated area and spatial establishment rules for energy crops (especially for maize) in the Upper Rhine to minimize the quantitative and qualitative pressure on water resources
Recommendation type	Change in policy content
Nexus sectors involved	Energy, Land, water
Target group	Policy/decision makers
Target policy goal	Low carbon economy, efficient use of resources
Target policy instrument	- GE : Environmental law - Decree n°2016-92, 7th July 2016 setting a 15% cap on the annual amount of crops that can be used in biogas installations, French (Code de l'Energie and related decrees and orders) - BW : German (EEG) support mechanisms (feeding tariffs/premium) for biogas and electricity based on biogas
Target policy process phase	Policy formation and implementation
Administrative level	National to regional
Time scale	Short term

Policy recommendation background: the use of organic waste produced by households and companies for energy production would allow to increase the efficiency of resource use. The implementation of such a circular economy measure would allow to build synergies within the Nexus. However this would require the separate collection of organic waste: energy production based on mixed waste is not feasible for technical and sociological reasons.

In short	Command separate collection of households' organic waste
Recommendation type	Change in policy content
Nexus sectors involved	Energy, Food
Target group	Politicians/decision-makers
Target policy goal	Low carbon economy, efficient use of resources
Target policy instrument	French Law for energy transition and green growth (2015) EU Circular Economy package

Target policy process phase	Policy formation and policy implementation
Administrative level	European and national
Time scale	Short term
Comments	Using organic waste for energy generation is sustainable if organic waste is minimize. Such a policy has to be combined with another policy aiming at the minimization of organic waste. **Pre-conditions for successful implementation :** - Social acceptance for methanation projects based on households' organic waste should be improved - Feasible in urban areas based on companies and households' organic waste, where collection costs is low (not feasible in rural areas)

Policy recommendation background: discussions during the second stakeholders workshop underlined that "Increasing coherence requires decompartmentalizing policy-making and implementation – shift from a sectoral to a transversal logic - at different levels of legislation and at all levels of policy making (from research to implementation). This decompartmentalization represents both an organizational and sociological challenge." We defined the following two policy recommendations from this key message.

In short	**Change education system to enable transdisciplinary and cross-sectoral cooperation and "eliminate" silo-thinking**
Recommandation type	Change in policy content
Nexus sectors involved	all
Target group	Stakeholders of the education system (politician/decision-makers, Universities, etc.)
Target policy goal	Efficient use of resources
Target policy instrument	French and German strategies for higher education
Target policy process phase	Agenda setting, Policy formation policy implementation
Administrative level	National
Time scale	Short/Medium term

In short	**Change governance at all levels of policy making (from research to implementation) to enable transdisciplinary and cross-sectoral cooperation and "eliminate" silo-thinking**
Recommendation type	Change in policy content
Nexus sectors involved	all
Target group	Public stakeholders at all levels of policy making (Ministries, research, local State services, etc.)
Target policy goal	Efficient use of resources
Target policy instrument	French and German strategies for higher education
Target policy process phase	Policy implementation
Administrative level	National

Time scale	Short/Medium term
Comments	*One possible lever is to set up cross-cutting missions within organizations*

Policy recommendation background: discussions during the second stakeholders workshop underlined that "Increasing coherence" implies defining shared objectives and knowledge; it therefore also requires tools to understand and measure coherence challenges.

In short	Make evaluation and implementation processes cross-sectoral/Nexus-proof *So as to make impacts of (implemented and considered) projects on other nexus sectors clear and use this information as an eligibility/prioritization criterion for funding/implementation permission*
Recommendation type	Change in policy content
Nexus sectors involved	all
Target group	Public stakeholders involved in policymaking and implementation
Target policy goal	Efficient use of resources
Target policy instrument	/
Target policy process phase	Policy formation, implementation and evaluation
Administrative level	National
Time scale	Short/Medium term

10.6.3.3 Innovations

Policy recommendation background: E3ME results show that it is not possible to pursue both an objective of decarbonization of the energy mix and a nuclear phase-out. However, reliance of water for cooling is of concern in a climate change context characterized by uncertainties regarding the availability of water resources (and considering recent droughts).

In short	Command the improvement the efficiency of cooling systems for nuclear power plants
Recommendation type	Innovation
Nexus sectors involved	Energy, water
Target group	Energy companies
Target policy goal	Low carbon economy, efficient use of resources
Target policy instrument	Dimension to be included in the official periodic check-ups by the national agency for nuclear safety?
Target policy process phase	/
Administrative level	Local
Time scale	Short term
Cost-effectivity	
Social implications	
Comment	Already implemented by some stakeholders

Policy recommendation background : CAPRI results show an increase in irrigated areas in Baden-Württemberg (stability in Grand Est) as well as a net increase in water use for irrigation in the two case study regions, despite an overall decrease in gross irrigation requirements in m3/ha.

In short	Improve efficiency of irrigation systems in the Upper Rhine
Recommendation type	Innovation
Nexus sectors involved	Water, Food, Energy
Target group	Chambers of Agriculture, farmers, agricultural and technical (research institutes)
Target policy goal	Low carbon economy, efficient use of resources
Target policy instrument	CAP, European Agricultural Fund for Rural Development
Target policy process phase	/
Administrative level	Local
Time scale	Short term
Comment	Valid if we "stick" to the same target for the development of bioenergy Other optimization measures have to be implemented in parallel (varietal selection, etc.)

10.6.3.4 Changes in the policy process

In short	Strengthen and develop transboundary cooperation on energy policy
Recommendation type	Changes in the policy process: push territorial/local formal arrangements further, widen their prerogatives
Nexus sectors involved	Energy, climate
Target group	Public and private stakeholders of the energy sector
Target policy goal	Low carbon economy, energy security
Target policy instrument	Upper Rhine conference
Target policy process phase	all
Administrative level	Local
Time scale	Short to long term
Comment	**Pre-conditions for success:** - physical energy networks and facilities required (already existing in the upper Rhine) - strong cooperation required (important transaction costs, dedicated positions required)

10.6.3.5 Changes in the science-policy interface

In short	Establish a closer dialogue between decision-makers/stakeholders and researchers to improve the dissemination and use of research results in policy making/evaluation
Recommendation type	Changes in the science-policy interface
Nexus sectors involved	All
Target group	Researchers, policy-makers
Target policy goal	All
Target policy instrument	Eligibility rules for funding – research projects
Target policy process phase	Policy making, policy evaluation
Administrative level	From EU to local
Time scale	Short term

Policy recommendation background: during the second case-study workshop we could observe on the one hand that stakeholders could be quite critical about the modelling tools, related assumptions and their results. On the other hand, researchers underlined that the dissemination of research results can be very heterogenous : sometimes stakeholders and decision makers have high expectations regarding model results and the potential policy recommendations that could be derived from these models, sometimes research results do not reach the policy sphere.

In short	Involve stakeholders in the development of scenarios and assumptions underlying the models
Recommendation type	Changes in the science-policy interface
Nexus sectors involved	All
Target group	Researchers, policy-makers, field experts
Target policy goal	All
Target policy instrument	Eligibility rules for funding – research projects
Target policy process phase	Agenda setting, policy formation
Administrative level	From EU to local
Time scale	Short term

10.7 Conclusion

The France-Germany transboundary case study applied the SIM4Nexus approach on the Upper-Rhine river basin.

The France-Germany transboundary case study focuses on the links and synergies between energy policy and the transition to a low-carbon economy on one side, and the management of natural resources (in particular water) on the other side.
Our investigations focused on the development of bioenergy (especially biofuel production and energy generation based on methanation) as substitutes of fuel products. We demonstrated this has significant

implications in terms of land use change and pressure on water resources both in qualitative and quantitative terms. As a result, stronger conditions should be set for the development of energy crops. We also examined how energy transition leads to a significant development of solar energy with trade-offs on land-use and food production. We therefore conclude on safeguard measures to minimize land take and direct it towards "low value" land.
As regards other renewable energy sources – hydropower, wind power – and low-carbon energy sources – nuclear power - the negative impacts on the other Nexus sectors can be mitigated by jointly reducing the overall energy demand and improving the efficiencies of technologies used.

Because of its transboundary character, the France-Germany case study investigated also the links between policy development and implementation on both sides of the Rhine, and whether there would be opportunities for enhancing cooperation and policy coherence between France and Germany for achieving jointly set policy objectives in a more cost-effective manner.
As a result of interactions with the stakeholders, a wide panel of policy recommendations are made to enhance transboundary governance, cross-sectoral cooperation and science-policy dialogue. These recommendations become pre-conditions to ensure that energy transition is Nexus-compliant and takes into account the constraints and opportunities stemming from the other sectors.

The Nexus analysis performed on the Upper-Rhine strongly relies on tools and methods made accessible through the SIM4Nexus partnership : the thematic models CAPRI, E3ME, SWIM and MAGNET, the methodologies to score policies' coherence and identify innovations, the production of an SDM, ….

About 30 people from France and Germany, covering the 5 Nexus domains (water, energy, land, food and climate) and representing a diversity of public or private stakeholders, engaged in the case study's activities. Through SIM4Nexus, they gained a better understanding of the Nexus issues on their territory, a stronger awareness of the constraints their activities put on other sectors and a joint analysis of possible evolutions over the next decades. The frequency of interactions with the stakeholders was quite low but highly valuable in terms of contents. The contributions from participants fed the policy coherence analysis, the conceptual model development, the selection of policy scenarios and the critical review of modelling results. The mobilization of local stakeholders knowledge was therefore complementary to the development of SIM4Nexus tools and helped to prioritize and guide our work.

10.8 References

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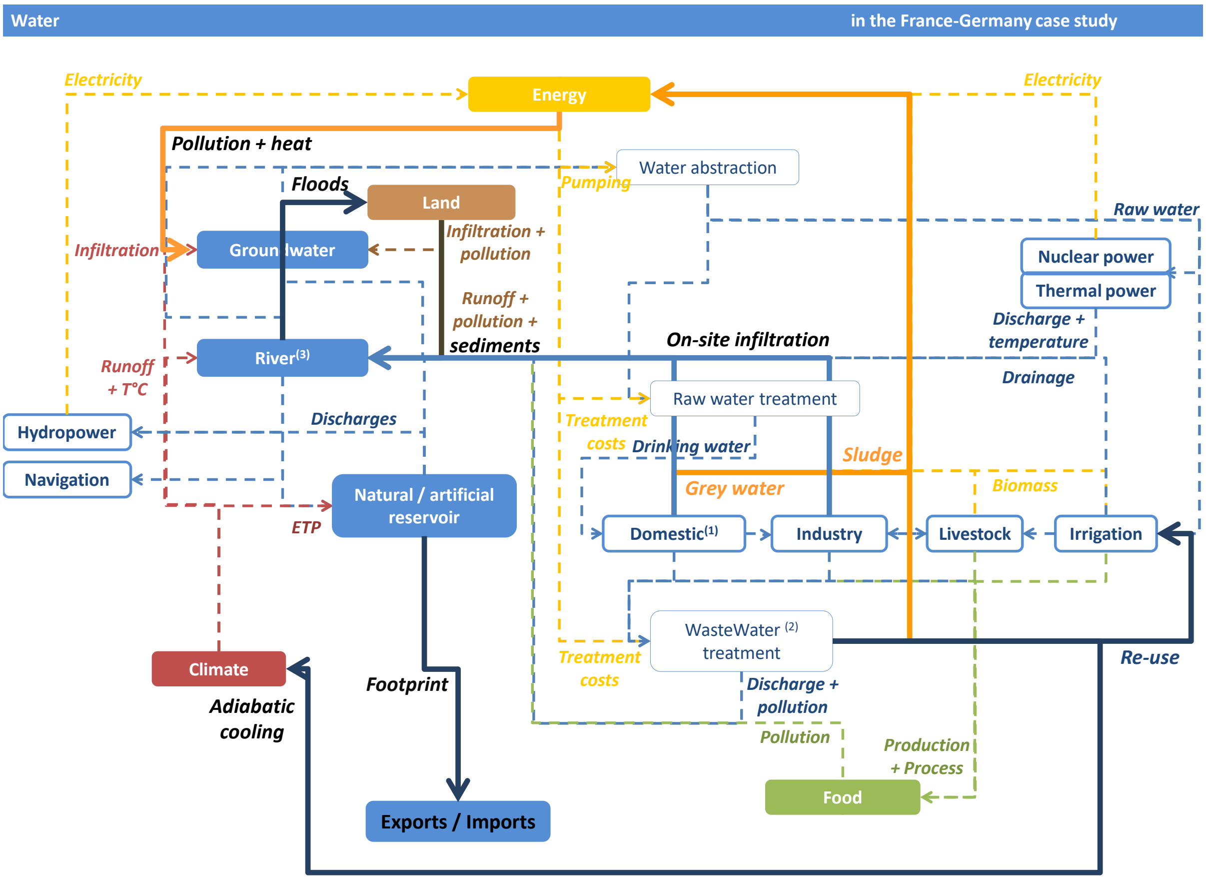
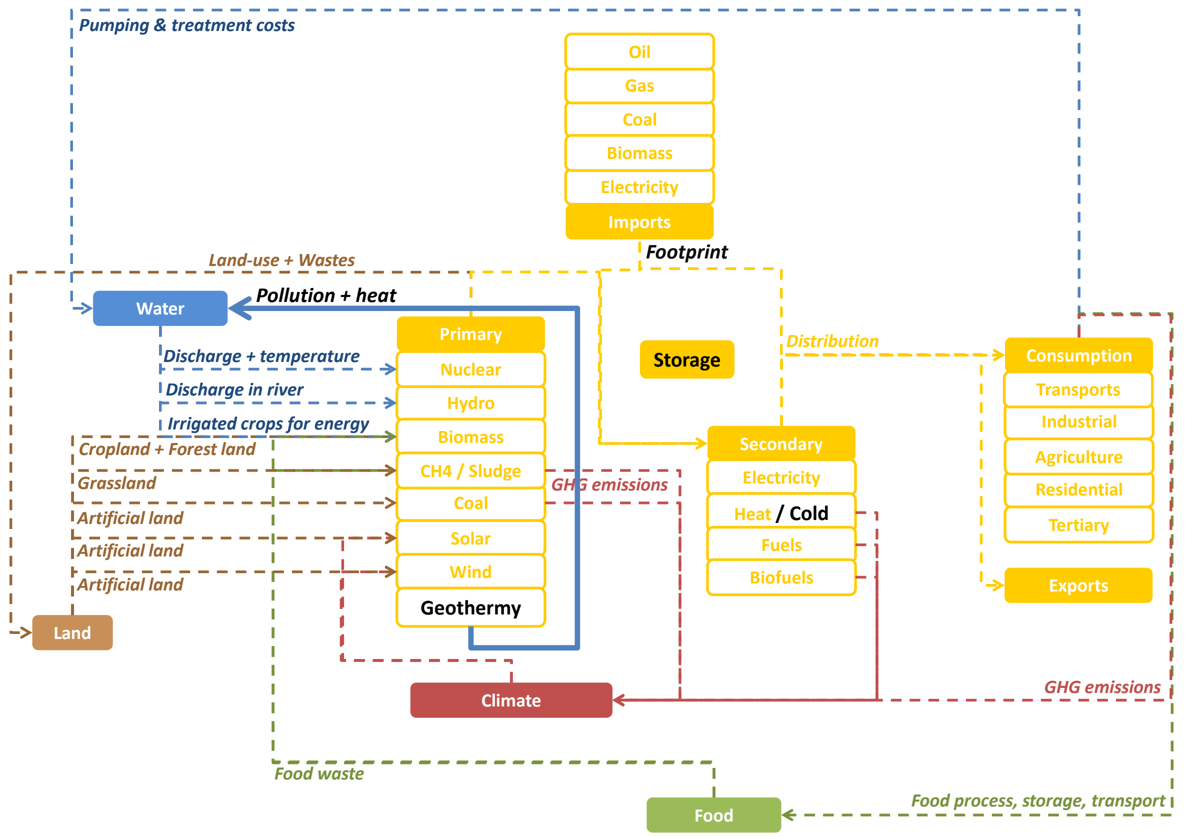
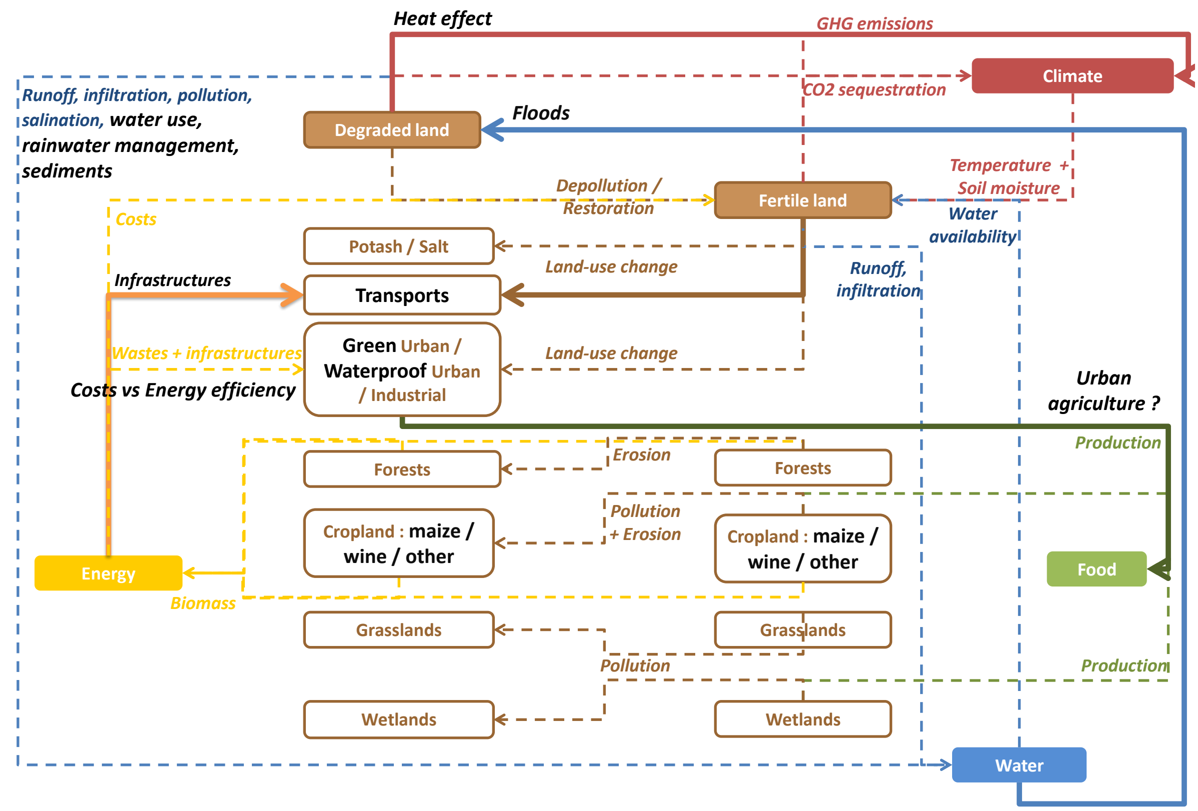
10.9 Appendix

10.9.1 Conceptual model

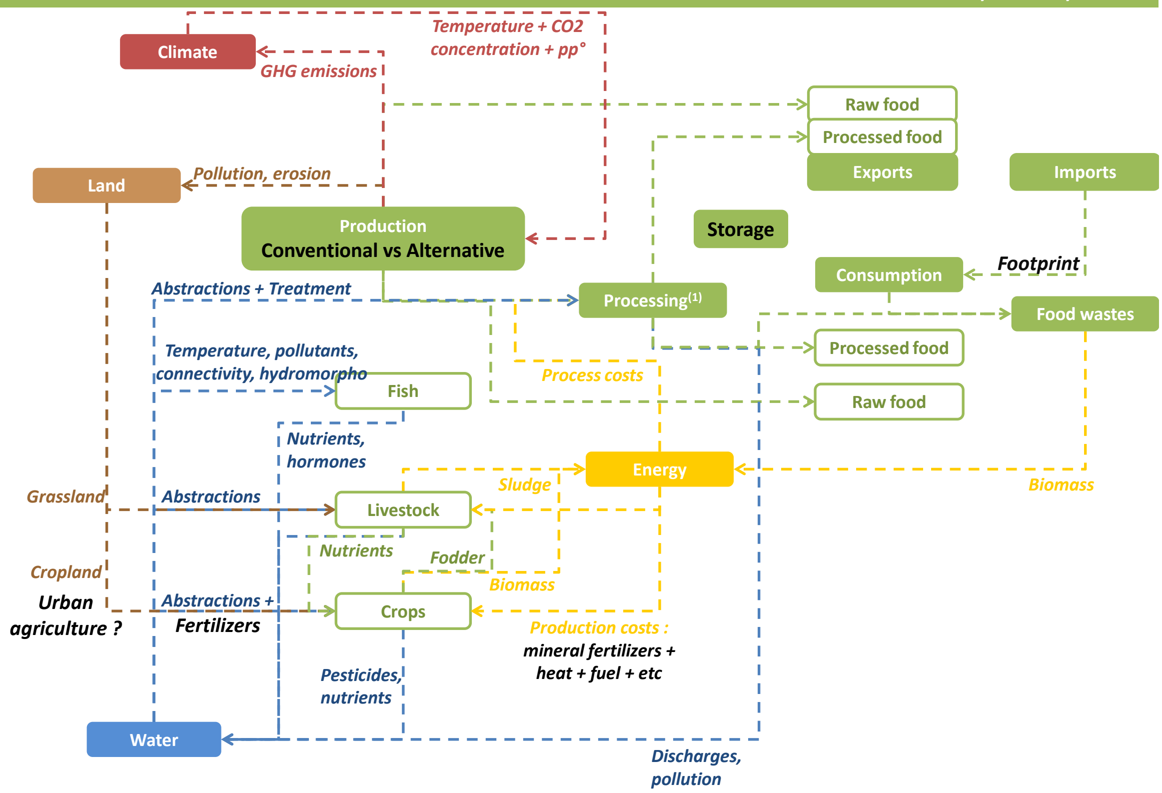



Pumping & treatment costs
Oil
Gas
Coal
Biomass
Electricity
Imports
Footprint
Land-use + Wastes
Water
Pollution + heat
Primary
Storage
Distribution
Consumption
Discharge + temperature
Nuclear
Transports
Discharge in river
Hydro
Industrial
Irrigated crops for energy
Biomass
Secondary
Cropland + Forest land
Agriculture
CH4 / Sludge
Electricity
Grassland
GHG emissions
Residential
Coal
Heat / Cold
Artificial land
Tertiary
Solar
Fuels
Artificial land
Wind
Exports
Biofuels
Artificial land
Geothermy
Land
GHG emissions
Climate
Food waste
Food process, storage, transport
Food

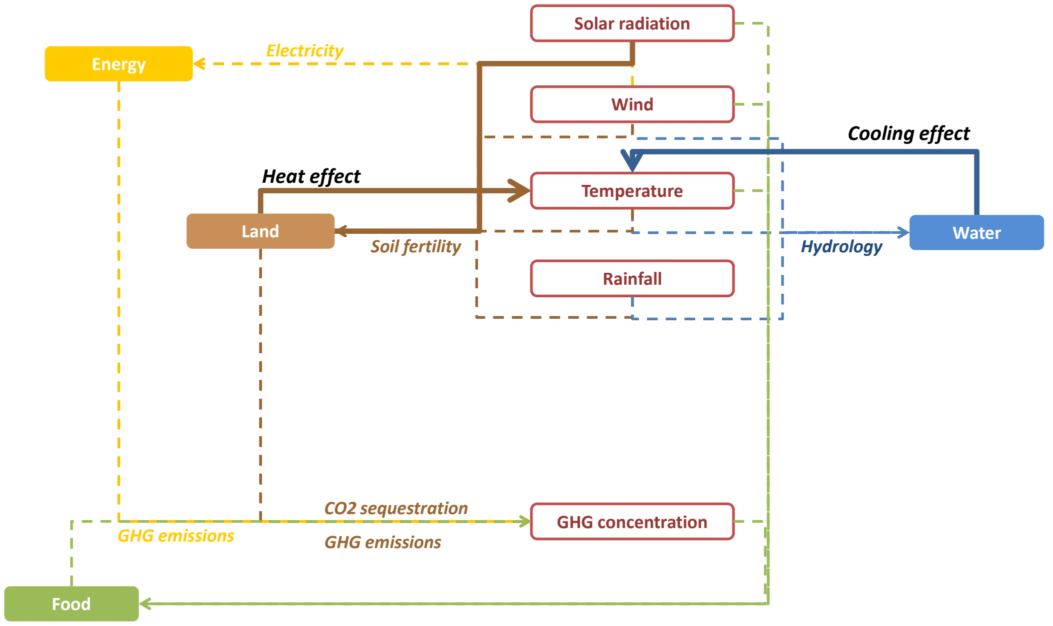
Land in the France-Germany case study



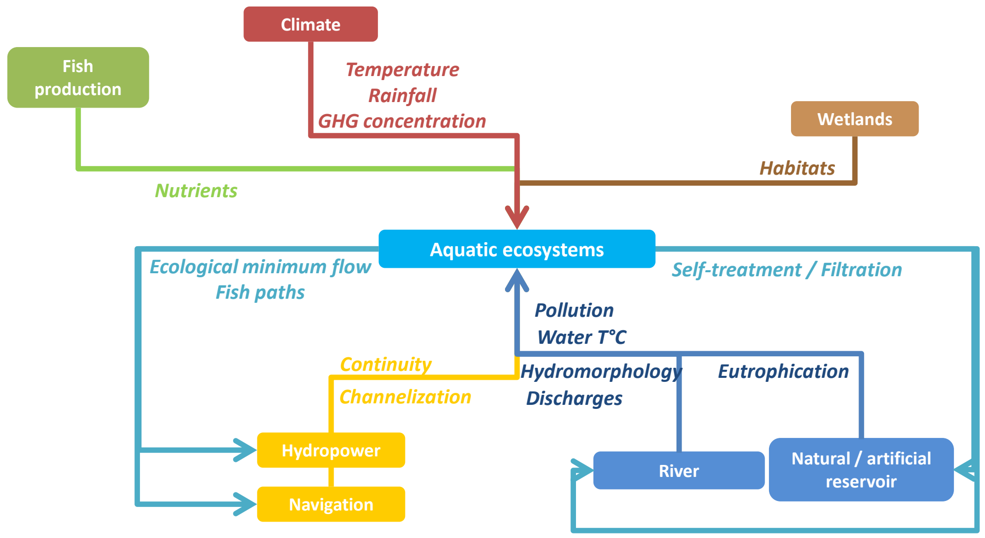
Food in the France-Germany case study



Climate in the France-Germany case study



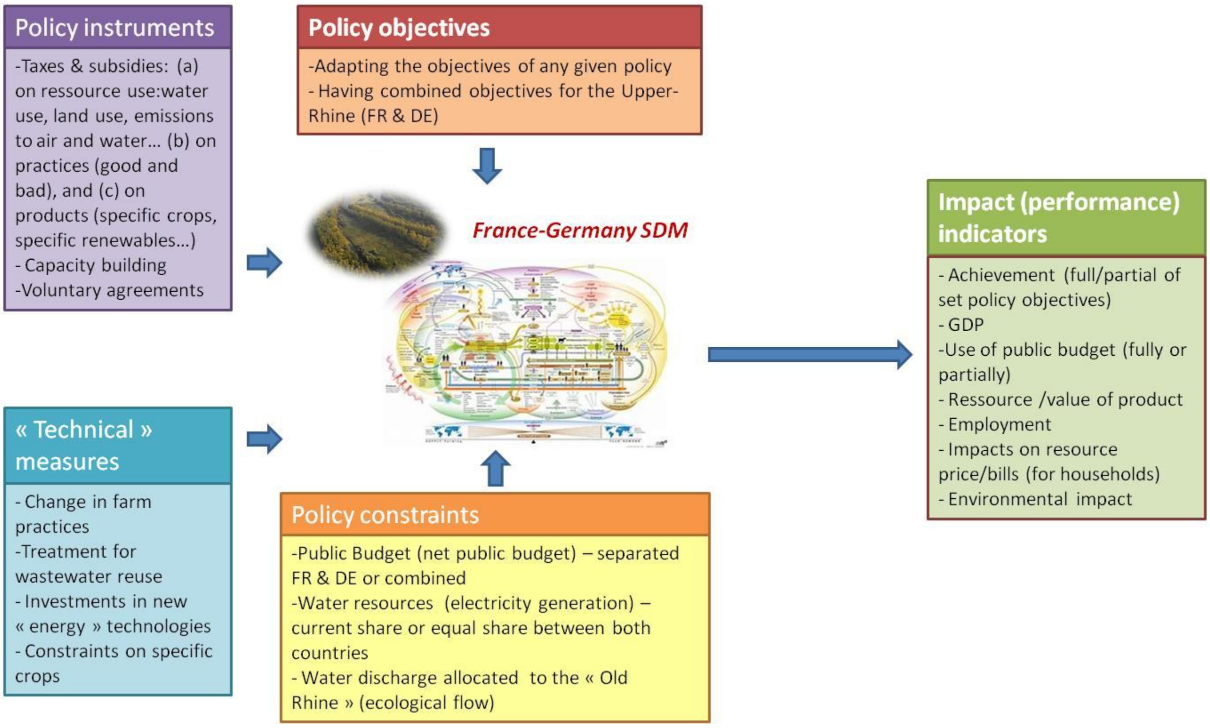
Aquatic Ecosystems in the France-Germany case study



10.9.2 Note on remaining issues regarding the SDM

Issues on the integration of thematic models' results in the SDM for SIM4NEXUS case studies
First draft following meeting between Maïté, Pierre, Sara and Janez (12/09/2018)

This has implications for WP2 (policy setting), 3 (implementation in the SDM, thematic model simulations), 4 (game design) and 5 (case studies).



This graphic is an illustration of the situation from the Case Study point of view:

- CS provide the policy inputs (objectives, instruments, measures, constraints)
- CS expect output indicators relevant to our stakeholders
- The middle part is a black box, from CS perception. The "conceptual model" focused on physical links between the Nexus domains but *how do we account for socio-economic parameters ? how do we translate policies into the thematics ? how do we translate policies into the SDM ? how policies will be computed (is it through the thematic models or the SDM) ? how do thematic models communicate (with the SDM and with other models) to account for feedback loops ? what are the missing input data for the SDM to run ? how many policies can we test / run ?*

There are two primary issues here, which are related.

- For policies related only to the 'physical' systems: these can largely be implemented in the SDMs through sets of parameters. Example = % water savings in irrigation, ban on pesticides.
- For those policies capturing the functioning of the 'human part', this is essential to provide sound understanding of the basis for playing/thinking. Example = reaction to taxation, food habits, housing, holiday choices, etc. Those behaviours are embedded into the thematic models – or at least the socio-economic ones. There is therefore a difference (potentially) in *how 'policies' are simulated and where (is it through the SDM or the thematic models?).*

Option 1 – Soft-linking thematic models

You interface the SDM directly with existing thematic models, and you run them interconnected. Problems: *this not possible as part of the serious game, and problems with time for simulation?* This seems not really feasible / practical.

Option 2 – Directly include "computational modules" of thematic models into the SDM

However, this would require that *all computational modules for all thematic models are integrated to keep the coherence within each thematic model?* And it does not solve the question how to run policies in the SDM. For physical-system related policies, this seems most appropriate. But for economic-driven policies like above this would mean trying to recreate and simplify the computations carried out in the thematic models within the SDM in order to 'replicate' thematic output directly in the SDMs. Discussions with Eva have indicated this is not really feasible regarding E3ME, and there are questions around extra workload in WP3. *Feasibility?* Or try to define how e.g. tax credits work within the SDM. *Difficult? How realistic?* Changes are by default reflected throughout the SDM through the connections between all sectors.

Option 3 – Running the thematic models for developing input-output relationships that are then integrated into the SDM

The challenge here is:

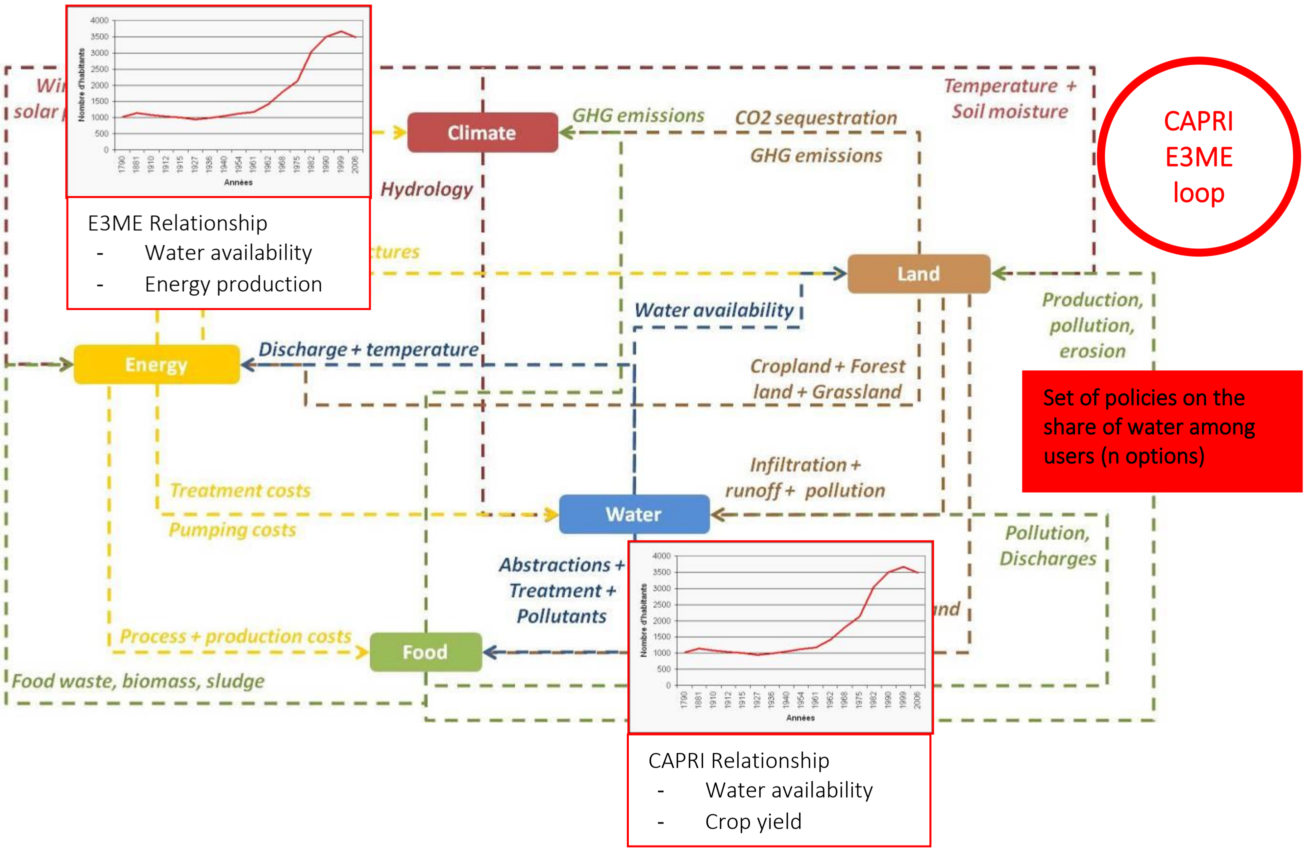
(a) the number of thematic model simulations to be carried out for establishing such relationships

(b) how to account for thematic models interdependencies/complementarities (carrying out x simulations with thematic model 1 while accounting for the intermediary results of y simulations carried out in thematic model 2 that partially encompass some of the processes considered in model 1....).

In turn, **this would imply joint development of some input-output relationships** (e.g. f(x) = function of variables that are embedded into the two different thematic models) between 2 thematic models for areas that are overlapping between them. *To what extent is this feasible in Sim4Nexus?*

Process would be the following – as far as we understand it:

1. Policies (including measures, etc.), especially economically-driven policies (e.g. taxes, subsidies, etc. – the 'human' related issues alluded to above) are defined by the Case study. Example is a tax incentive on e.g. maize.
2. The case study requests the thematic(s) to run this policy (run a new tax scheme in CAPRI). and produce a new set of outputs. It means pre-defining and pre-running in the thematics all the policy scenarios in good time.
3. These outputs are used as SDM input for that particular policy scenario. Maize area is altered in CAPRI and this is input to the SDM.
4. In turn, water, land, climate, etc., are impacted in the SDM via the interconnections. In this idea, there could be the possibility to run the same policy scenario in two thematics (e.g. CAPRI and E3Me) to compare outputs. Again, feasibility/desirability of this?
5. This would create a 'library' of new thematic model results that can be looked up during SDM runs and playing the serious game. The library is called, used as input and the nexus-wide impacts are assessed via the connections in the SDM.



Introduction of water policies (several options of water sharing among users) implies a set of runs for CAPRI and a set of runs for E3ME. But modifications in crops yields and surfaces as impacts on energy demand from agriculture as well as impacts on biomass available for energy production, thus impacting E3ME. In turn, E3ME results on energy being produced impacts energy prices for agriculture sector, to be accounted for in CAPRI.

How will this be solved?

Understanding on the **types of measures/policies that can be captured by thematic models** or what would be the outcome of the current conceptual (biophysical) model needs to be strengthened:

→Policies that aim at imposing regulatory constraints on resource use - their implication on resource use can be partially captured in the "physical flows" - however optimality and assessment of socio-economic impacts requires socio-economic information/elements that are in the thematic models.

→Policies that aim at providing incentives (+ or minus, via product price, tariffs, subsidies and charges...) - first addressed via the socio-economic system (thematic models) which outcome can then be integrated into the biophysical model (current conceptual model), including for assessing impacts on overall "resource use".

→Soft measures (like voluntary agreement, capacity building, governance) - not adequately considered so far =>would need to better account for the "knowledge" system and connections between actors so as to capture the added value of collective action. This is likely not to be considered in detailed in the modelling platform, apart via simple simplification (e.g. in the Rhine model - collaboration implies agreeing on common objectives, or sharing resources for carrying out policy, or building on each other comparative advantages for achieving goals).

Maybe then economic/human policies must go through thematic models, while physical system policies can be interpreted in the SDMs?

With regards to Option 3, the issue then is to distinguish between:

- a number of policy scenarios that need to be simulated by thematic models for developing relationships between different policy instruments (e.g. different levels of tax on natural resources or subsidy for renewable energy)

- variables that are integrated into the "physical flow" modelling component of the SDM (e.g. cropping patterns that will be directly translated into resource use for different levels of taxes or subsidies for crops, or water abstraction for a given sector on the basis of the water price level).

For each case study, the main thematic models that are to be mobilised are few – with specific "coherence/consistency" work to be carried out between the thematic models applied in a given case study area for assessing coherence or complementarity in "overlapping issues".

Questions are raised on **what the thematic models can reasonably provide** in the framework of SIM4Nexus.
→*Which policy scenarios will require 'optimising' of several models?* e.g. cash (re-)distribution among sectors from say tax income. It is probable that several case studies would like to test similar policies (taxes, subsidies, regulations, …) which the thematic models could run only once and for all case studies (like this was performed for the Baseline). But this would require coordination of the case study demands and maybe adjustments of policy scenarios to be tested.
→Here, an issue of "computational macros", running models for different levels of 2-3 policy variables and storing the results into a given file, then performing statistical/econometrics for developing functions that capture relationships (with a certain statistical significance level*). Possible if all collected in some central database for each Case Study?*
→We also discussed the issue to timesteps. Aggregating up from daily data to month/year is OK. Going the other way is trickier. It would be good to be able to base this on home historical patterns or proxy data. It requires the establishment of "transformation rules" that capture some "intra-temporal" variability (e.g. water supply always 50% higher on Saturdays and Sundays... on the basis of observed data). The same applies for changes in spatial scales, i.e. developing regional relationships/functions on the basis of national data + some understanding of the different characteristics/behaviours of individual regions. *What would be the part of the Case Study teams in this downscaling work?*

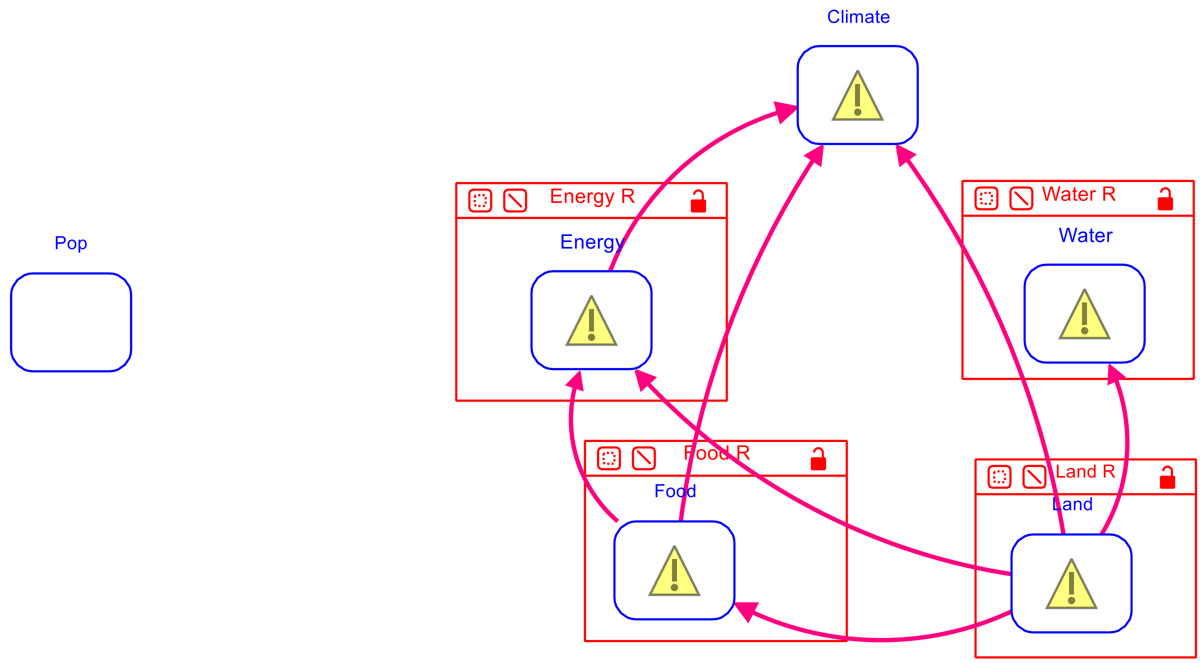
10.9.3 Implementation of policy scenarios in the SDM

Policy "brick"	SDM variables triggered	Corresponding policy scenarios
Energy efficiency gains/energy savings (e.g., building renovation works, smart meters)	Energy demand variables	Baseline 2°C Improve resource efficiency
Incentive energy pricing	Energy demand variables (through price elasticity)	Improve resource efficiency
Development of renewables (French law on energy, German energy package)	Secondary energy production variables	Baseline 2°C Improve resource efficiency
Support and development of bioenergy	Primary and secondary energy production variables	Baseline 2°C Improve resource efficiency
Ban on fossil fuel	Primary and secondary energy production variables	2°C

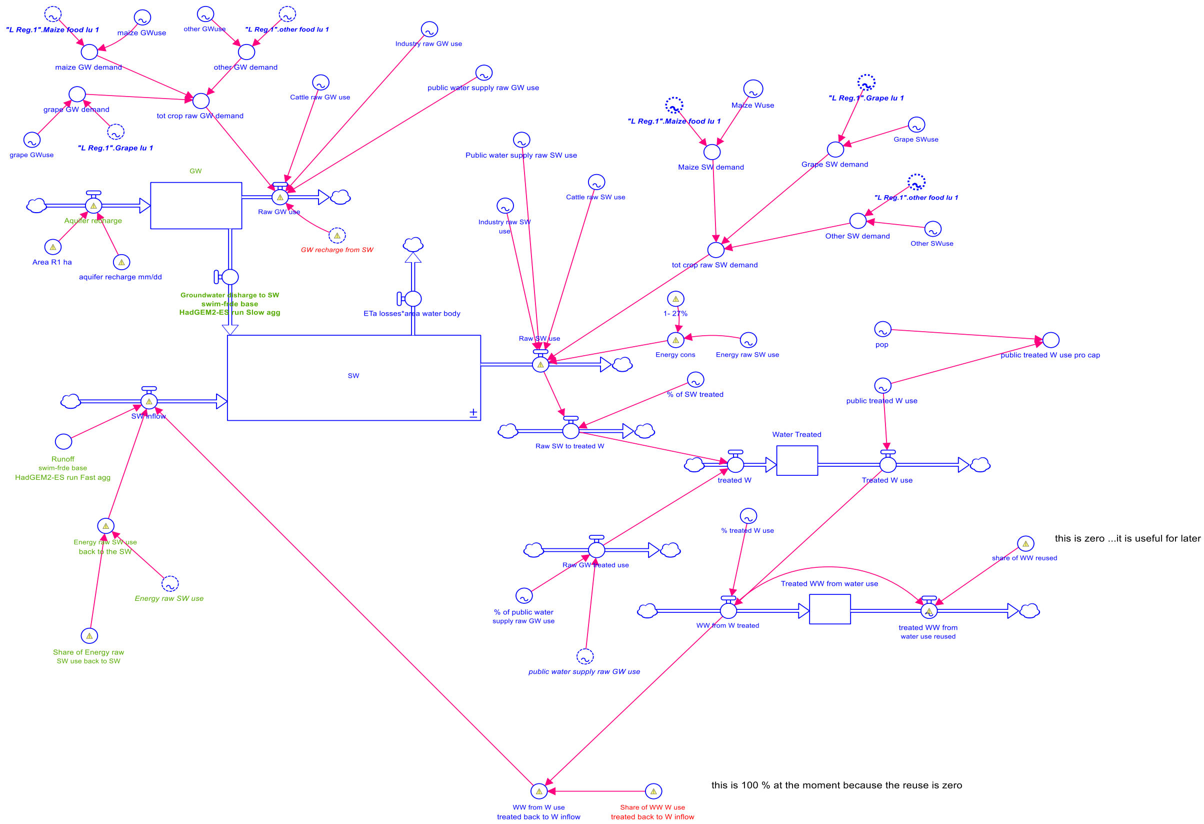
Denuclarization/Ban on nuclear	Secondary **energy** production variables	Reduce vulnerability to risks
Limit to the development of energy crops (energy crop rights, EU legislation on biofuels)	**Land** use variables Primary and secondary **energy** production variables	Baseline 2°C Improve resource efficiency
Innovation in water technologies (water for cooling for the energy sector, water for irrigation, increase in the efficiency of water networks)	**water** demand from the energy sector, the agricultural sector (for specific crops through water use/ha), for public water supply services	Improve resource efficiency
Irrigation cap	**Share of irrigated area** for each crop type **Water** demand for irrigation	Improve resource efficiency
Legislation to better use food waste	**Amount of food waste** **Energy** yield of food waste	Improve resource efficiency
Natural flood mitigation	**Surface areas** for waterproof urban areas, green urban areas and wetlands	Reduce vulnerability to risks
Soil conservation in agriculture and forestry	Cultivated/forest **surface areas** under soil conservation management practices Carbon **sequestration factors**	Restore functional ecosystems
The color code used allows to determine the corresponding Nexus domain for each triggered variable: **Energy**, **Water**, **Land**, **Climate** and **Food**		

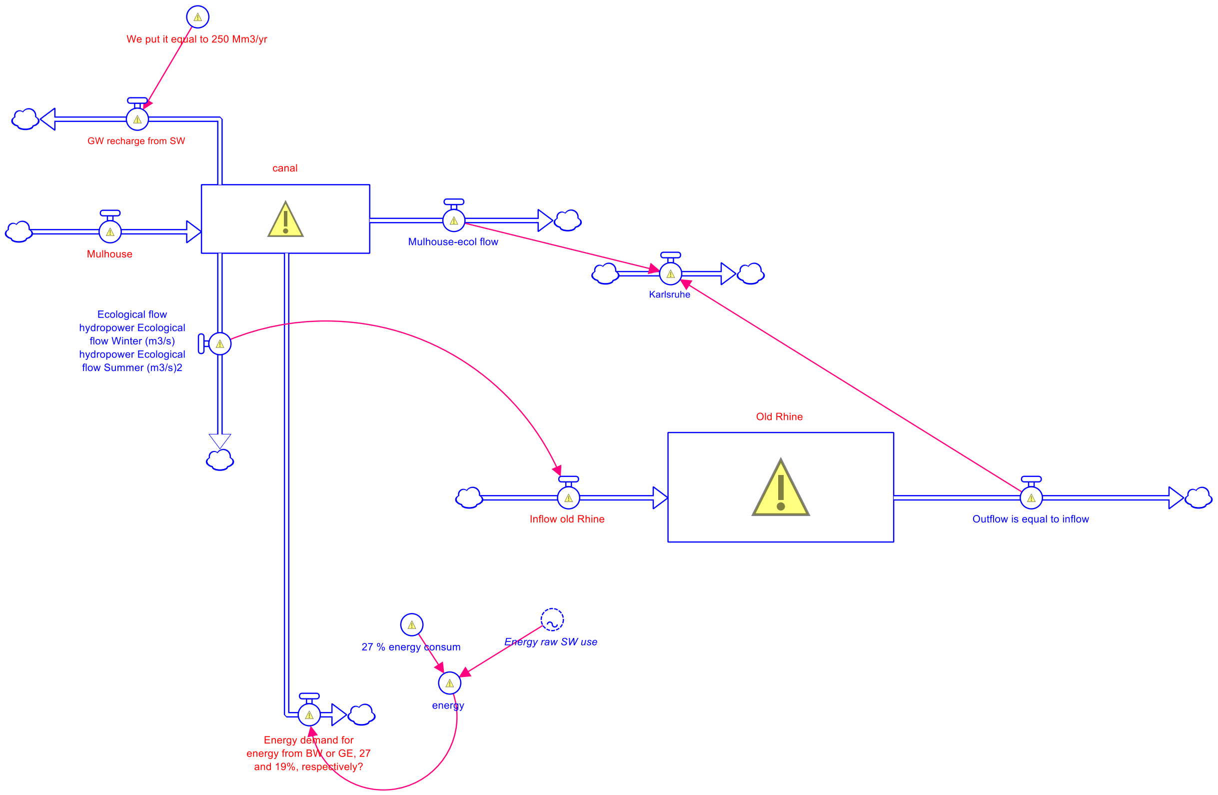
10.9.4 SDM screenshots

10.9.4.1 Global structure of the SDM

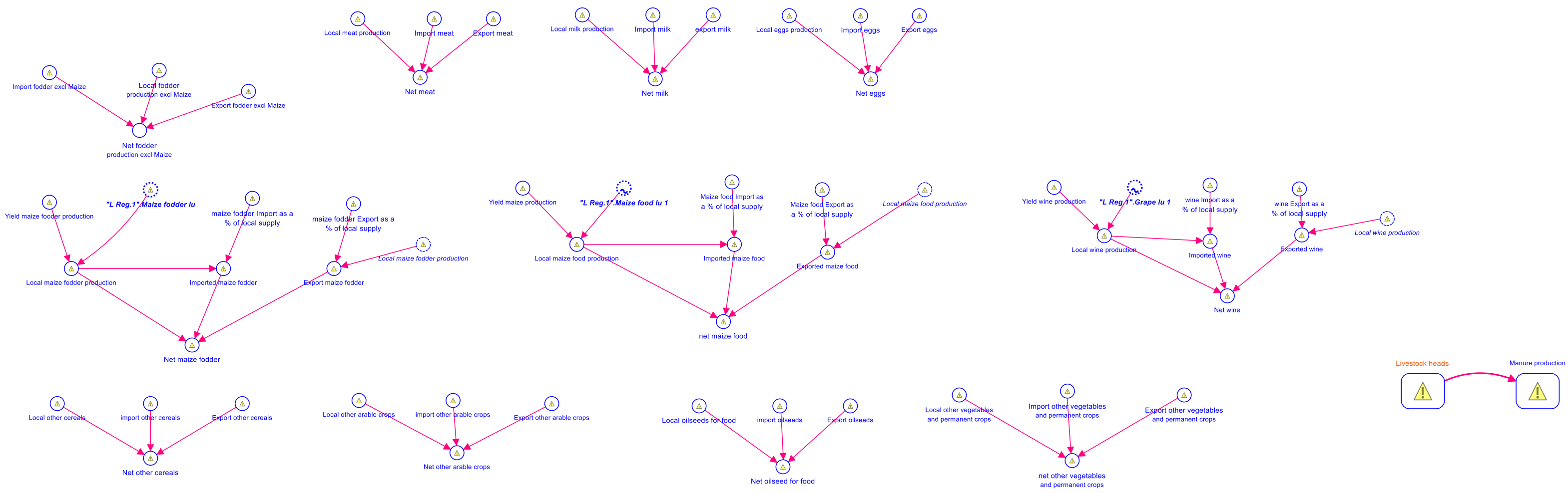


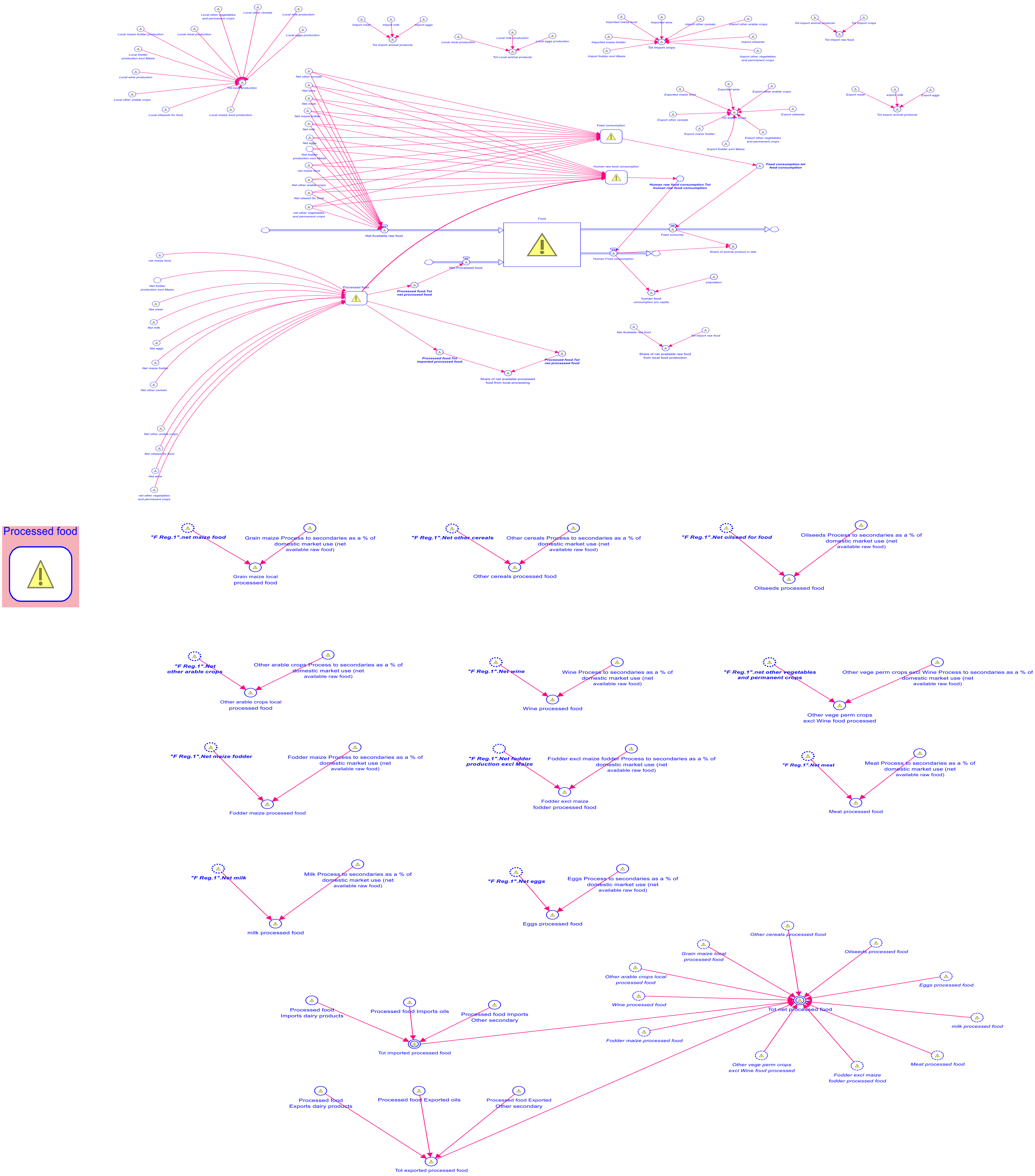
10.9.4.2 Water sector



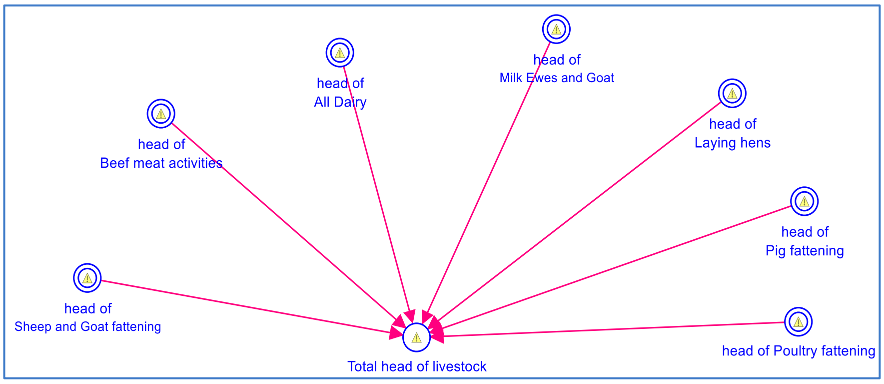


10.9.4.3 Food sector

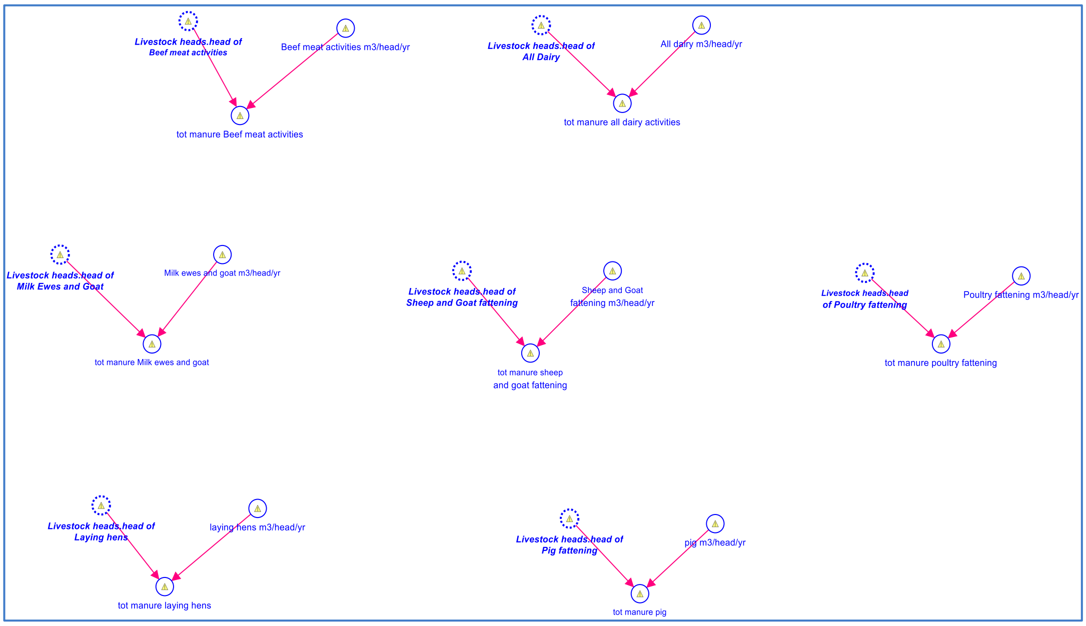



Processed food
"F Reg.1".net maize food
Grain maize Process to secondaries as a % of domestic market use (net available raw food)
Grain maize local processed food
"F Reg.1".Net other cereals
Other cereals Process to secondaries as a % of domestic market use (net available raw food)
Other cereals processed food
"F Reg.1".Net oilseed for food
Oilseeds Process to secondaries as a % of domestic market use (net available raw food)
Oilseeds processed food
"F Reg.1".Net other arable crops
Other arable crops Process to secondaries as a % of domestic market use (net available raw food)
Other arable crops local processed food
"F Reg.1".Net wine
Wine Process to secondaries as a % of domestic market use (net available raw food)
Wine processed food
"F Reg.1".net other vegetables and permanent crops
Other vege perm crops excl Wine Process to secondaries as a % of domestic market use (net available raw food)
Other vege perm crops excl Wine food processed
"F Reg.1".Net maize fodder
Fodder maize Process to secondaries as a % of domestic market use (net available raw food)
Fodder maize processed food
"F Reg.1".Net fodder production excl Maize
Fodder excl maize fodder Process to secondaries as a % of domestic market use (net available raw food)
Fodder excl maize fodder processed food
"F Reg.1".Net meat
Meat Process to secondaries as a % of domestic market use (net available raw food)
Meat processed food
"F Reg.1".Net milk
Milk Process to secondaries as a % of domestic market use (net available raw food)
milk processed food
"F Reg.1".Net eggs
Eggs Process to secondaries as a % of domestic market use (net available raw food)
Eggs processed food
Other cereals processed food
Grain maize local processed food
Oilseeds processed food
Other arable crops local processed food
Eggs processed food
Wine processed food
Tot net processed food
milk processed food
Fodder maize processed food
Other vege perm crops excl Wine food processed
Fodder excl maize fodder processed food
Meat processed food
Processed food Imports dairy products
Processed food Imports oils
Processed food Imports Other secondary
Tot imported processed food
Processed food Exports dairy products
Processed food Exported oils
Processed food Exported Other secondary
Tot exported processed food

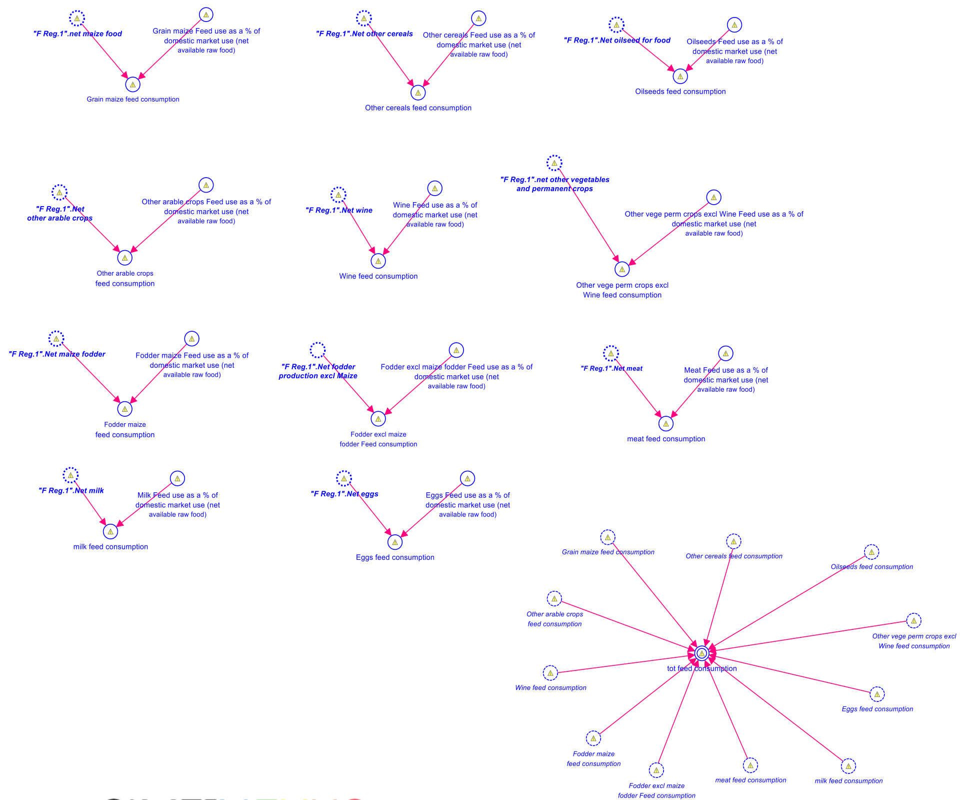
Livestock heads

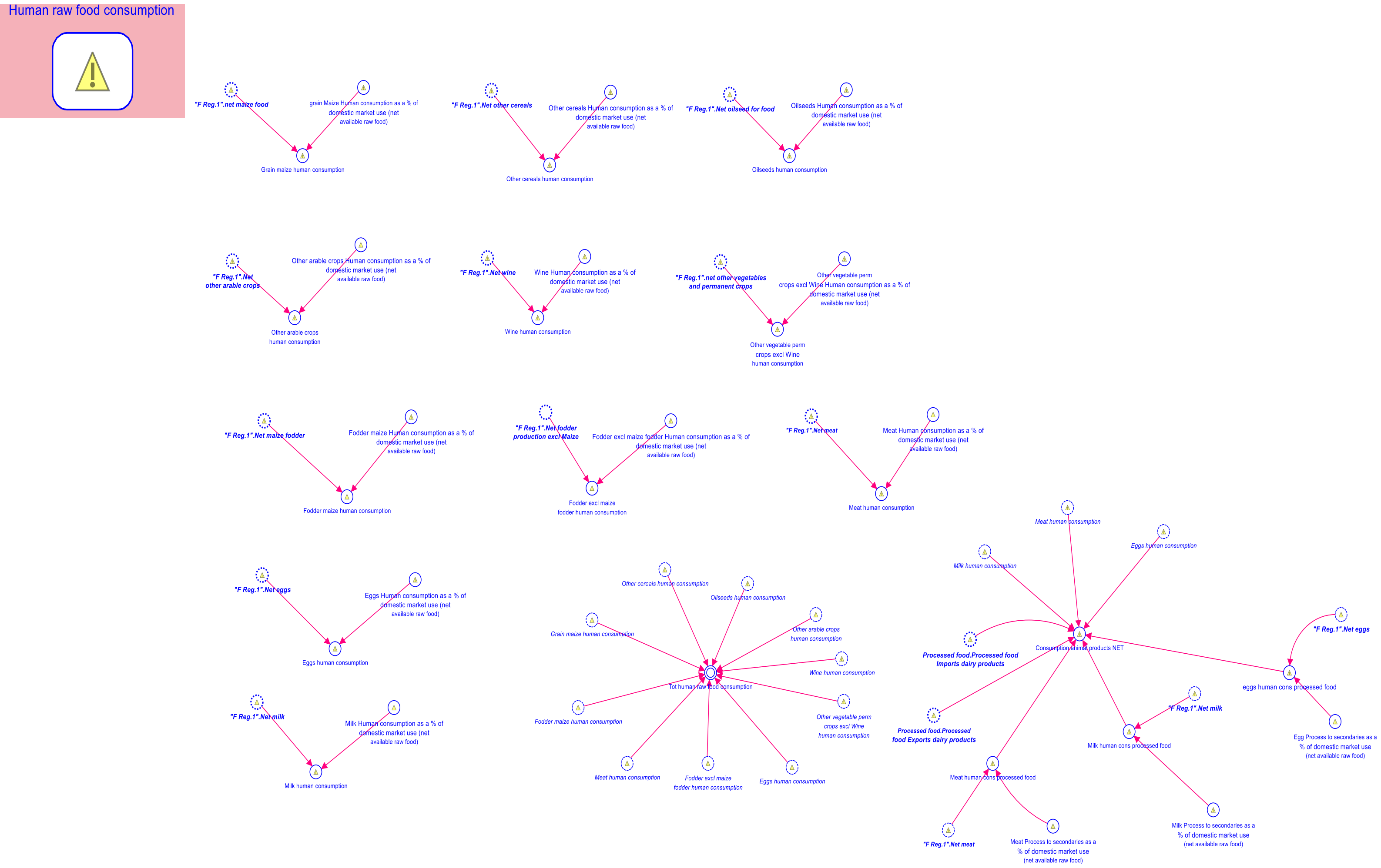


Manure production

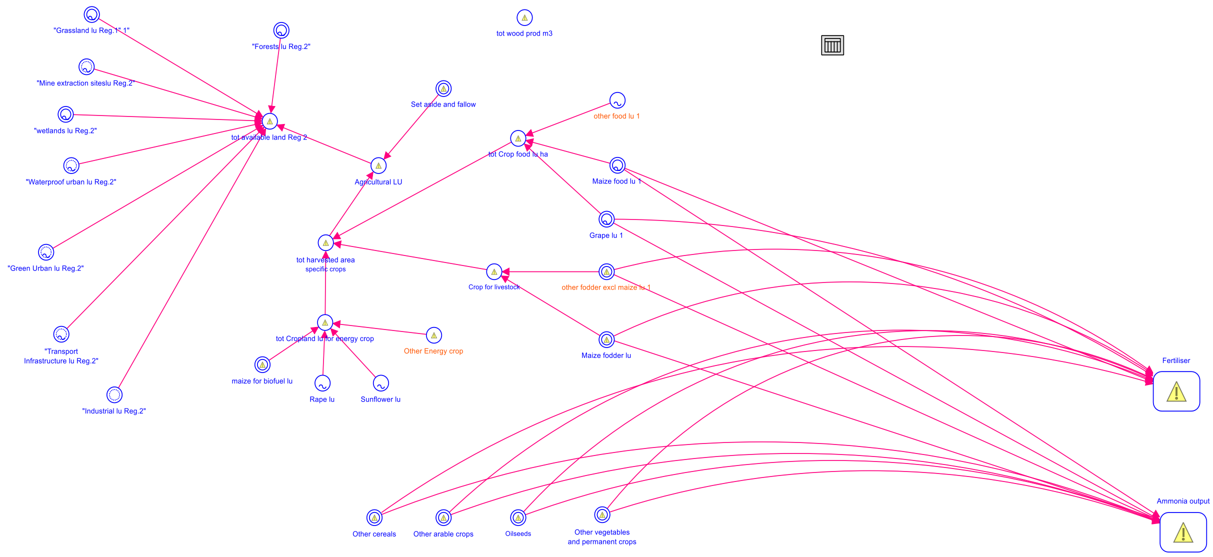


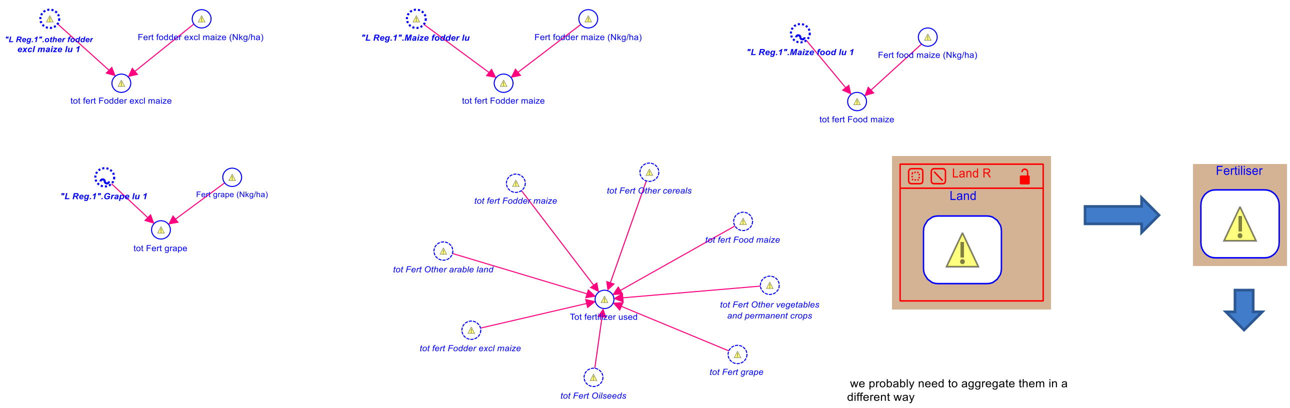
Feed consumption





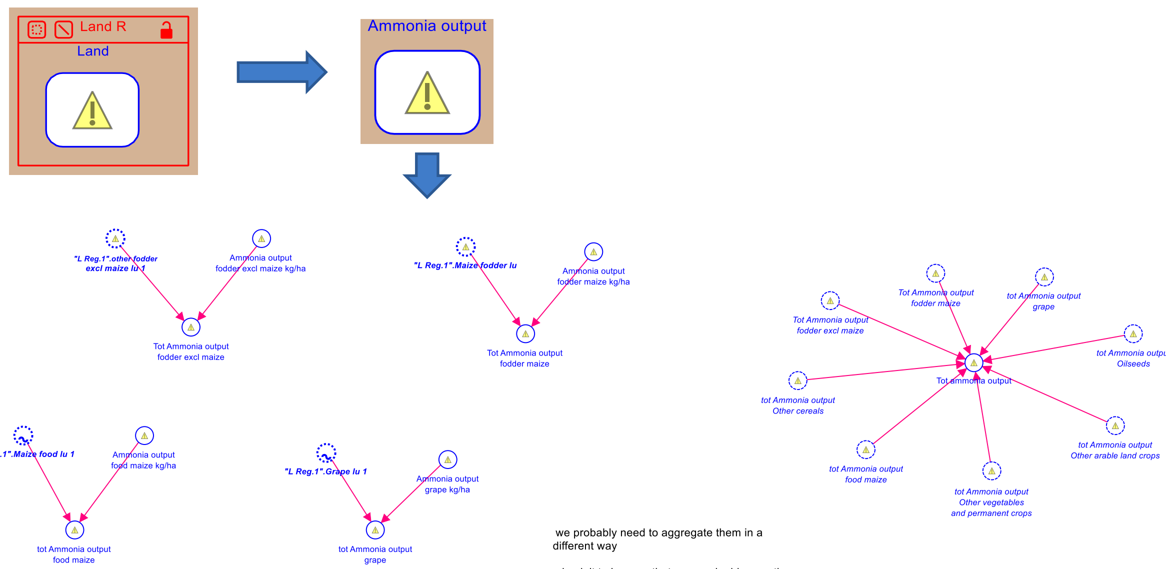
10.9.4.4 Land sector





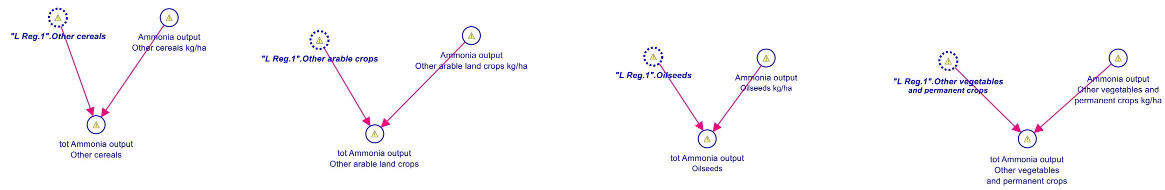
we probably need to aggregate them in a different way

check it to be sure that we are double counting

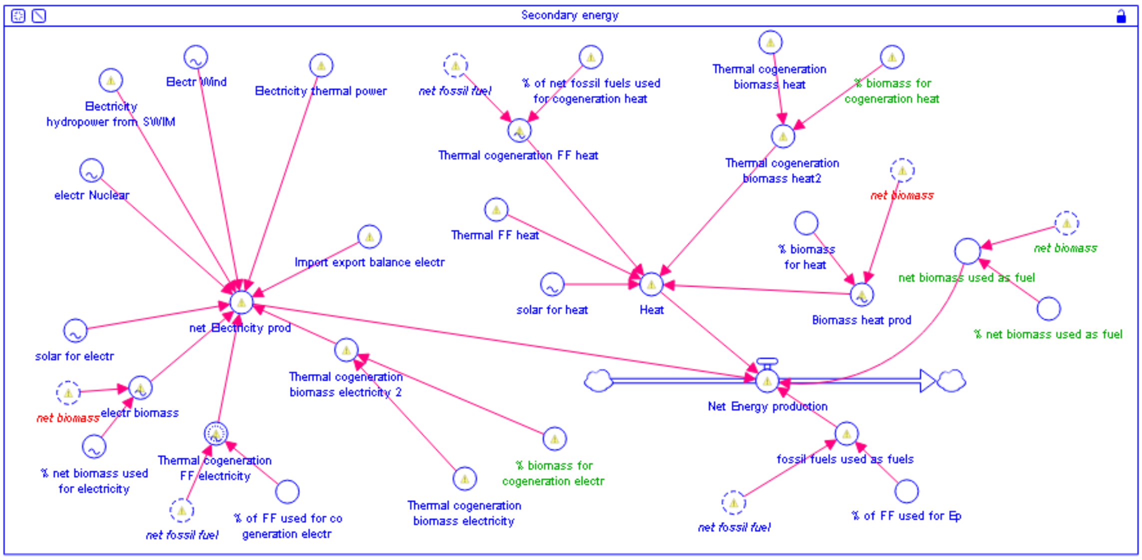


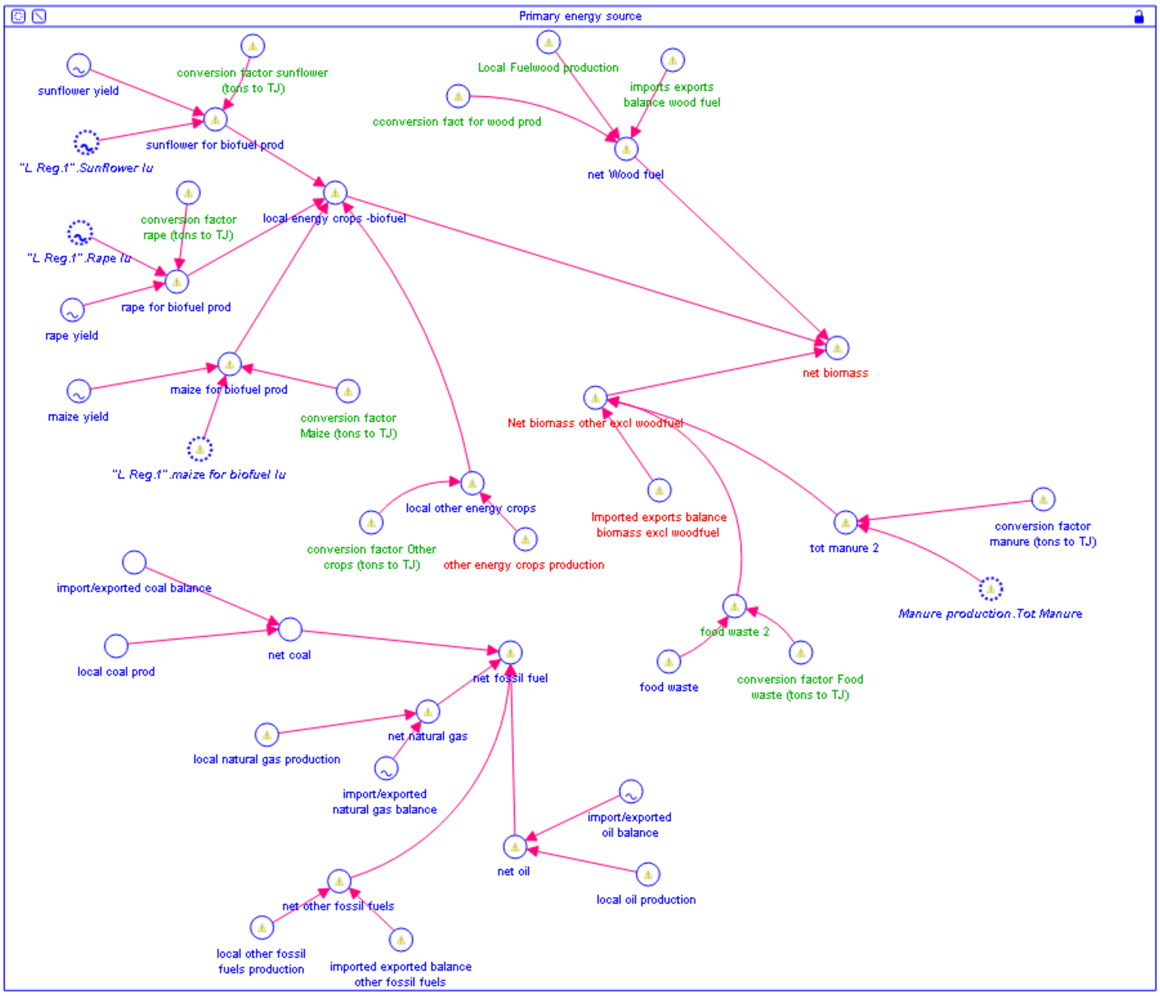
we probably need to aggregate them in a different way

check it to be sure that we are double counting



10.9.4.5 Energy sector


Secondary energy
Electricity hydropower from SWIM
Electr Wind
Electricity thermal power
net fossil fuel
% of net fossil fuels used for cogeneration heat
Thermal cogeneration FF heat
Thermal cogeneration biomass heat
% biomass for cogeneration heat
Thermal cogeneration biomass heat2
net biomass
electr Nuclear
Import export balance electr
Thermal FF heat
% biomass for heat
net biomass
net biomass used as fuel
solar for heat
Heat
Biomass heat prod
% net biomass used as fuel
solar for electr
net Electricity prod
Thermal cogeneration biomass electricity 2
Net Energy production
net biomass
electr biomass
% net biomass used for electricity
Thermal cogeneration FF electricity
% biomass for cogeneration electr
fossil fuels used as fuels
Thermal cogeneration biomass electricity
net fossil fuel
% of FF used for co generation electr
net fossil fuel
% of FF used for Ep


Primary energy source
sunflower yield
conversion factor sunflower (tons to TJ)
Local Fuelwood production
imports exports balance wood fuel
cconversion fact for wood prod
"L Reg.1".Sunflower lu
sunflower for biofuel prod
net Wood fuel
conversion factor rape (tons to TJ)
local energy crops -biofuel
"L Reg.1".Rape lu
rape for biofuel prod
rape yield
net biomass
maize yield
maize for biofuel prod
conversion factor Maize (tons to TJ)
Net biomass other excl woodfuel
"L Reg.1".maize for biofuel lu
local other energy crops
Imported exports balance biomass excl woodfuel
tot manure 2
conversion factor manure (tons to TJ)
conversion factor Other crops (tons to TJ)
other energy crops production
Manure production.Tot Manure
import/exported coal balance
food waste 2
local coal prod
net coal
net fossil fuel
food waste
conversion factor Food waste (tons to TJ)
net natural gas
local natural gas production
import/exported natural gas balance
import/exported oil balance
net oil
local oil production
net other fossil fuels
local other fossil fuels production
imported exported balance other fossil fuels

10.9.5 List of SDM variables provided by the thematic models

10.9.5.1 Food sector

Data source	Unit	Crop and livestock
CAPRI	ktons	Local fodder production excl. Maize
CAPRI	kg/ha	Yield Fodder Maize **(to be combined with area from land module of the SDM)**
CAPRI	ktons	Local meat production
CAPRI	ktons	Local milk production
CAPRI	ktons	Local eggs production
CAPRI	kg/ha	Yield maize production **(to be combined with area from land module of the SDM)**
CAPRI	kg/ha	Yield wine production **(to be combined with area from land module of the SDM)**
CAPRI	ktons	Local other cereals
CAPRI	ktons	Local other arable crops
CAPRI	ktons	Local oilseeds for food
CAPRI	ktons	Local other vegetables and permanent crops

Data source	Unit	Raw food
CAPRI	ktons	Import fodder excl. Maize
CAPRI	share	Fodder Maize - Import as a share of local supply
CAPRI	ktons	Import Fodder Maïze
CAPRI	ktons	Import meat
CAPRI	ktons	Import milk
CAPRI	ktons	Import eggs
CAPRI	ktons	Import animal products
CAPRI	share	Grain/food Maize - Import as a share of local supply
CAPRI	ktons	Import maize
CAPRI	share	Wine - Import as a share of local supply

CAPRI	ktons	import wine
CAPRI	ktons	import other cereals
CAPRI	ktons	import other arable crops
CAPRI	ktons	import oilseeds
CAPRI	ktons	import other vegetables and permanent crops
CAPRI	ktons	Import crops
CAPRI	ktons	Export fodder excl. Maize
CAPRI		Fodder Maize - Export as a share of local supply
CAPRI	ktons	Export Fodder Maïze
CAPRI	ktons	Export meat
CAPRI	ktons	Export milk
CAPRI	ktons	Export eggs
CAPRI	ktons	Export animal products
CAPRI	share	Grain/food Maize - Export as a share of local supply
CAPRI	ktons	Export maize
CAPRI	share	Wine - Export as a share of local supply
CAPRI	ktons	Export wine
CAPRI	ktons	Export other cereals
CAPRI	ktons	Export other arable crops
CAPRI	ktons	Export oilseeds

CAPRI	ktons	Export other vegetables and permanent crops
CAPRI	ktons	Export crops
Data source	**Unit**	**Processed food**
CAPRI	ktons	Importations dairy products
CAPRI	ktons	Importations oils
CAPRI	ktons	Importations Other secondary
CAPRI	ktons	Exportations dairy products
CAPRI	ktons	Exportations oils
CAPRI	ktons	Exportations Other secondary

Livestock heads	Data source	Unit
Beef meat activities	CAPRI	k heads
All Dairy	CAPRI	k heads
Milk Ewes and Goat	CAPRI	k heads
Sheep and Goat fattening	CAPRI	k heads
Pig fattening	CAPRI	k heads
Laying hens	CAPRI	k heads
Poultry fattening	CAPRI	k heads

10.9.5.2 Land sector

Agricultural Land use	Source	Unit
maize for biofuel	CAPRI combined with For BW : https://www.foederal-erneuerbar.de/landesinfo/bundesland/BW/kategorie/alle/auswahl/604-anteil_der_flaeche_f/#goto_604 For GE : Agrex consulting, FranceAgrimer 2013	hectares
Rape for biofuel	CAPRI	hectares
Sunflower for bioduel	CAPRI	hectares
Other energy crops	CAPRI	hectares

tot cropland lu for energy crops	Summation of Total maize biofuel, rape biofuel, sunflower biofuel and other biofuel	hectares
Maize food	CAPRI	hectares
Grape	CAPRI	hectares
Other food	**CAPRI**	**hectares**
Tot crop food	**Summation of Maize food, Grape and Other food**	**hectares**
Maize fodder	CAPRI	hectares
Other fodder excl. Fodder maize	CAPRI	hectares
Fodder (crop for livestock)		hectares
Harvested area	Summation of tot cropland lu for energy crops, tot crop food and fodder (should be equal to Utilized agricultural area from CAPRI)	hectares
set aside and fallow	CAPRI	hectares
Agricultural lu	Summation of Harvested area and set aside and fallow	hectares

Additional land-use variables for fertiliser use and ammonia output	**Source**	**Unit**
Other cereals	CAPRI	hectares
Other arable crops	CAPRI	hectares
Oilseeds	CAPRI	hectares
Other vegetables and permanent crops	CAPRI	hectares

Fertilizer use	**Source**	**Unit**
Other cereals	CAPRI	N kg/ha
Other arable crops	CAPRI	N kg/ha
Oilseeds	CAPRI	N kg/ha
Other vegetables and permanent crops	CAPRI	N kg/ha
Fodder Maize	CAPRI	N kg/ha
Fodder excl. Fodder maize	CAPRI	N kg/ha
Food Maize	CAPRI	N kg/ha
Grape	CAPRI	N kg/ha

Ammonia output	**Data Source**	**Unit**

Other cereals	CAPRI	kg/ha
Other arable crops	CAPRI	kg/ha
Oilseeds	CAPRI	kg/ha
Other vegetables and permanent crops	CAPRI	kg/ha
Fodder Maize	CAPRI	kg/ha
Fodder excl. Fodder maize	CAPRI	kg/ha
Food Maize	CAPRI	kg/ha
Grape	CAPRI	kg/ha

10.9.5.3 Water sector

Data source	**Unit**	**Assumptions**	
			Inflows (cubic meter/year)
SWIM	cubic meter/year		Aquifer recharge
			Discharge
SWIM	cubic meter/year		GW discharge to SW (Runoff_slow)
			Rhine surface water sub-module (SW)
SWIM	cubic meter/year		**ETa losses (actual evapotranspiration)**
			Inflows (cubic meter/year)
SWIM	cubic meter/year		Runoff (run_fast)

10.9.5.4 Climate sector

Data source	**Unit**	**Methan output from cattle**
CAPRI	kg/head	**Beef meat activities**
CAPRI	kg/head	**All Dairy**
CAPRI	kg/head	**Milk Ewes and Goat**
CAPRI	kg/head	**Sheep and Goat fattening**
CAPRI	kg/head	**Pig fattening**
CAPRI	kg/head	**Laying hens**
CAPRI	kg/head	**Poultry fattening**

10.9.5.5 Energy sector

Data source	**Unit**	**Secondary energy**
SWIM	GWh/year	Electricity - hydropower

10.9.6 List of SDM variables developed based on local data

10.9.6.1 Land

NON-Agricultural Land use

Name	Source	Unit	Assumption
Forests lu	CORINE Land Cover	hectares	IMAGE-GLOBIO trends applied to Corine Land Cover data
tot wood prod m3	AGRESTE local data for Grand Est	k cubic meter	10% increase per year, production doubled by 2030 and no further increase
Grassland	CORINE Land Cover	hectares	IMAGE-GLOBIO trends applied to Corine Land Cover data
Mine extration sites	CORINE Land Cover	hectares	IMAGE-GLOBIO trends applied to Corine Land Cover data
wetlands	CORINE Land Cover	hectares	IMAGE-GLOBIO trends applied to Corine Land Cover data
Waterproof urban	CORINE Land Cover	hectares	IMAGE-GLOBIO trends applied to Corine Land Cover data
Green urban	CORINE Land Cover	hectares	IMAGE-GLOBIO trends applied to Corine Land Cover data
Transport infrastructure	CORINE Land Cover	hectares	IMAGE-GLOBIO trends applied to Corine Land Cover data
Industrial	CORINE Land Cover	hectares	IMAGE-GLOBIO trends applied to Corine Land Cover data

10.9.6.2 Water

Data source	Unit	Water abstraction from GW per sector/use - use of raw GW
SDAGE Rhin-Meuse (2011) Statisches Monatsheft Baden-Württemberg 5/2012. https://www.statistik-bw.de/Service/Veroeff/Monatshefte/PDF/Beitrag12_05_06.pdf	cubic meter/year	Industry raw GW demand
SDAGE Rhin-Meuse (2011) Statistisches Monatsheft Baden-Württemberg 5/2012. https://www.statistik-bw.de/Service/Veroeff/Monatshefte/PDF/Beitrag12_05_06.pdf	cubic meter/year	Public water supply raw GW demand
Basis for the assumption in: French Ministry of Environment (2017) Les prélèvements d'eau douce en France: les grands usages en 2013 et leur évolution depuis 20 ans. http://www.lafranceagricole.fr/r/Publie/FA/p1/Infographies/Web/2017-01-31/Eau_rapport_31012017.pdf Statistisches Monatsheft Baden-Württemberg 5/2012. https://www.statistik-bw.de/Service/Veroeff/Monatshefte/PDF/Beitrag12_05_06.pdf	cubic meter/year	Cattle raw GW demand
No irrgation of vines in the Grand Est region Statistisches Monatsheft Baden-Württemberg 5/2012. https://www.statistik-bw.de/Service/Veroeff/Monatshefte/PDF/Beitrag12_05_06.pdf; "Landwirtschaft in Baden-Württemberg" (2014) https://www.statistik-bw.de/Service/Veroeff/Faltblatt/803814014.pdf	cubic meter/year	Vines GW demand

bnpe (2019) - https://bnpe.eaufrance.fr/acces-donnees/codeRegion/44/annee/2016/usage/2; Statistisches Monatsheft Baden-Württemberg 5/2012. https://www.statistik-bw.de/Service/Veroeff/Monatshefte/PDF/Beitrag12_05_06.pdf	cubic meter/year	maize Gw demand
bnpe (2019) - https://bnpe.eaufrance.fr/acces-donnees/codeRegion/44/annee/2016/usage/2; Statistisches Monatsheft Baden-Württemberg 5/2012. https://www.statistik-bw.de/Service/Veroeff/Monatshefte/PDF/Beitrag12_05_06.pdf	cubic meter/year	other GW demand
Data source	**Unit**	**Water abstraction per sector/use - use of raw SW (cubic meter/year)**
SDAGE Rhin-Meuse (2011) Statistisches Monatsheft Baden-Württemberg 5/2012. https://www.statistik-bw.de/Service/Veroeff/Monatshefte/PDF/Beitrag12_05_06.pdf	cubic meter/year	Industry raw SW use
SDAGE Rhin-Meuse (2011) Statistisches Monatsheft Baden-Württemberg 5/2012. https://www.statistik-bw.de/Service/Veroeff/Monatshefte/PDF/Beitrag12_05_06.pdf	cubic meter/year	Public water supply raw SW use
SDAGE Rhin-Meuse (2011) Statistisches Bundesamt Baden-Württemberg (2019) https://www.statistik-bw.de/Umwelt/Wasser/Wasserwirtschaft.jsp	cubic meter/year	Energy raw SW use
https://www.statistik-bw.de/Service/Veroeff/Statistik_AKTUELL/803409006.pdf	%	Share of Energy raw SW use back to SW
Basis for the assumption in: French Ministry of Environment (2017) Les prélèvements d'eau douce en France: les grands usages en 2013 et leur évolution depuis 20 ans. http://www.lafranceagricole.fr/r/Publie/FA/p1/Infographies/Web/2017-01-31/Eau_rapport_31012017.pdf Statistisches Monatsheft Baden-Württemberg 5/2012. https://www.statistik-bw.de/Service/Veroeff/Monatshefte/PDF/Beitrag12_05_06.pdf	cubic meter/year	Cattle raw SW demand
No irrgation of vines in the Grand Est region Statistisches Monatsheft Baden-Württemberg 5/2012. https://www.statistik-bw.de/Service/Veroeff/Monatshefte/PDF/Beitrag12_05_06.pdf; "Landwirtschaft in Baden-Württemberg" (2014) https://www.statistik-bw.de/Service/Veroeff/Faltblatt/803814014.pdf	cubic meter/year	vines SW demand
bnpe (2019) - https://bnpe.eaufrance.fr/acces-donnees/codeRegion/44/annee/2016/usage/2; Statistisches Monatsheft Baden-Württemberg 5/2012. https://www.statistik-bw.de/Service/Veroeff/Monatshefte/PDF/Beitrag12_05_06.pdf	cubic meter/year	maize SW demand
bnpe (2019) - https://bnpe.eaufrance.fr/acces-donnees/codeRegion/44/annee/2016/usage/2; *Statistisches Monatsheft Baden-Württemberg 5/2012. https://www.statistik-bw.de/Service/Veroeff/Monatshefte/PDF/Beitrag12_05_06.pdf*	*cubic meter/year*	*other SW demand*
Data source	***Unit***	**Treated waste water (WW)**
Assuming that all waste water which goes to the public sewer network is treated.	%	% treated water use

https://www.umweltbundesamt.de/sites/default/files/medien/378/publikationen /texte_34_2016_rahmenbedingungen_fuer_ die_umweltgerechte_nutzung_von_behandeltem_abwasser_0.pdf	m3/year	Treated WW from water use reused
https://www.euwid-wasser.de/news/wirtschaft/einzelansicht/Artikel/behandelte-abwassermenge-in-baden-wuerttembergischen-klaeranlagen-wieder-ruecklaeufig.html	m3/year	treated WW from W use back to water inflow
Data source	***Unit***	**Rhine system**
EDF (2013) Les aménagements hydroélectriques du Rhin franco-allemand. https://www.edf.fr/sites/default/files/Hydraulique/Alsace-Vosges/documents/les_amenagements_hydroelectriques_du_rhin_franco-allemand.pdf **One single value for France and Germany (shared Rhine system)** -The assumption is made that the values for the ecological flow defined since 2010 will not change.	m3/year	Ecological flow

10.9.6.3 Food

Data source	**Unit**	**Manure production**
http://idele.fr/?eID=cmis_download&oID=workspace://SpacesStore/e43824b5-22da-4885-852b-d2abdc2ea245	m3/kheads/year	Beef meat activities
http://idele.fr/?eID=cmis_download&oID=workspace://SpacesStore/e43824b5-22da-4885-852b-d2abdc2ea245	m3/kheads/year	All Dairy
http://idele.fr/?eID=cmis_download&oID=workspace://SpacesStore/e43824b5-22da-4885-852b-d2abdc2ea245	m3/kheads/year	Milk Ewes and Goat
http://idele.fr/?eID=cmis_download&oID=workspace://SpacesStore/e43824b5-22da-4885-852b-d2abdc2ea245	m3/kheads/year	Sheep and Goat fattening
Levasseur (1998), « Composition et volume de lisier produit par le porc, Données bibliographiques »	m3/kheads/year	Pig fattening
http://idele.fr/?eID=cmis_download&oID=workspace://SpacesStore/e43824b5-22da-4885-852b-d2abdc2ea245	m3/kheads/year	Laying hens
http://idele.fr/?eID=cmis_download&oID=workspace://SpacesStore/e43824b5-22da-4885-852b-d2abdc2ea245	m3/kheads/year	Poultry fattening

Data source	**Unit**	**Food consumption and waste**
ADEME Le Mag n°96 https://mlr.baden-wuerttemberg.de/de/unser-service/presse-und-oeffentlichkeitsarbeit/pressemitteilung/pid/aktuelle-verbrauch	**kg/in hab**	Food waste - **(kg/inhabitant)**

10.9.6.4 Energy

10.9.6.5 Climate

Emissions from secondary energy sources

Data source	**Assumption/comment**	**Unit**	**Non-renewables**	
ADEME	constant for the whole period	kgCO2e/kWh	**nuclear**	0,006

ADEME	constant for the whole period ; mean of emission factors for off-shore and terrestrial wind farms	kgCO2e/kWh	**wind**	0,013 75
ADEME	constant for the whole period	kgCO2e/kWh	**hydro**	0,006
ADEME	constant for the whole period	kgCO2e/kWh	**solar**	0,055

Emissions from primary energy sources

Data source	Assumption/comment (same values for FR and GER)	Unit	Fuel_type	
ADEME	average for various coal types, does not account for peat and shale oil	kg CO2e/GJ (PCI)	**Coal**	107,7 27273
ADEME	only natural gas considered here	kg CO2e/GJ (PCI)	**Natural_gas**	66
ADEME	average of emission factors of the main three "wood-fuel products" (logs, wood pieces and "granulés")	kg CO2e/kWh	**Fuelwood**	0,028 1
ADEME	Only methane considered here (marginal market share of biopropane, started in 2018 in France, no specific figure)	kg CO2e/kWh	**Biogas**	0,016 4
ADEME	mean of emission factors of fuel oil, gasoline, diesel and LPG	kg CO2e/GJ (PCI)	**Oil**	86,53 75
ADEME	Value for biodiesel	kg CO2e/L	**Biofuel**	3

Sequestration factors

Agriculture

Data source	Assumption/comment	Unit		
EFESE	constant for the whole period ; **same values considered for France and Germany**	tCO2/ha/year	**Cropland** (no sequestration measures)	0
EFESE	constant for the whole period ; **same values considered for France and Germany**	tCO2/ha/year	**Perennial crops** (no sequestration measures)	0
EFESE results and results of the following report give similar figures (same order of magnitude) http://inra.dam.front.pad.brainsonic.com/ressources/afile/225455-e2ffa-resource-synthese-en-francais.html	constant for the whole period ; **same values considered for France and Germany**	**tC/ha/year**	**Grassland**	0,23

Urban land use

Data source	Assumption/comment	Unit		

used in EFESE, from Mitsch et al., 2013	constant for the whole period ; **same values considered for France and Germany**	tCO2/ha/year	**Waterproof urban areas**	0
used in EFESE, from Mitsch et al., 2013	constant for the whole period ; **same values considered for France and Germany**	tCO2/ha/year	**Green urban areas**	0

Forest

Data source	Assumption/comment	Unit		
IGN data https://www.ademe.fr/contribution-lign-a-letablissement-bilans-carbone-forets-territoires-pcaet	constant for the whole period	tCO2/ha/year	**Forest Grand Est**	4,61507789
https://www.bmel.de/SharedDocs/Downloads/EN/Publications/ForestsInGermany-BWI.pdf?__blob=publicationFile combined with https://www.forstwirtschaft-in-deutschland.de/waelder-entdecken/waldfunktionen/klimaschutz/ (Dunger et al. 2014)	constant for the whole period	tCO2/ha/year	**Forest Baden-Württemberg**	4,55

Wetlands

Data source	Assumption/comment	Unit		
used in EFESE, from Mitsch et al., 2013	constant for the whole period ; **same values considered for France and Germany**	**tC/ha/year**	**Wetlands**	1,29

10.9.7 Use cases - Upper Rhine Case study

10.9.7.1 Water resources and energy generation in the Upper Rhine - Need for improving climate resilience in the energy sector (Energy-Water)

Despite the significant development of other renewable energy generation technologies in the case study region (wind-power in Grand Est and PV-Solar in Baden-Württemberg) hydroelectricity still plays a key role. A great number of hydroelectricity plants are especially located along the Rhine (10 plants are located within the Case-study territory, between Kembs and Mannheim). Moreover, a significant share of electricity generation in Grand Est and Baden-Württemberg regions is based on nuclear and thermal power, displaying substantial water requirements for cooling

Besides, the Rhine itself as well as its aquatic ecosystem and adjacent alluvial plains have been designated in 2008 as a protected natural area under the Ramsar convention on wetlands. Ecological flows – corresponding to the minimal water flow required for the good functioning of Rhine water ecosystems – have been defined. The latter constrain water abstraction for energy generation in the following way: if the water flow is less or equal to the ecological flow water abstraction on energy generation purposes is forbidden and energy generation compromised.

Finally, expected impacts of climate change regarding water resources and especially summer precipitations in the Upper Rhine region are the following (Source: Clim'Ability Upper Rhine report, 2019[27]) :

- Higher occurrences of summer droughts (increased drought risk) and dry summers
- Decrease in summer precipitations up to 25%
- Intensified dry periods in summer

USE CASE 1 FR-DE	Climate
Related Learning Goals	• Learn about the impact of climate change in the specific Upper Rhine context and resulting challenges • Learn about synergies and trade-offs between policies but also test and learn about the feasibility of specific policy objectives (e.g., low carbon and no nuclear; or 100% food self-sufficiency, etc.)
Goal	Improve climate resilience in the electricity sector
User	Public Sector (e.g. Ministry of Energy Planning, Energy agency, local authorities)
Actions	• Define the foreseen reduction in hydropower production due to climate change • Diversification of the electricity generation mix (decrease the share of energy generation technologies needing water for cooling → thermal; support the development of PV and wind-power) • Power purchase agreements (electricity import agreements) must be established with neighboring countries to compensate for low production due to climate change and to reduce risk of high electricity import prices • Phase out once-through cooling systems and invest in less water intensive cooling systems
Indicator	• % energy mix based on thermal (in production) • % energy mix based on hydroelectricity (in production) • Annual hydropower production • Water used annually (abstracted / withdrawn) by cooling systems in thermal generation power plants • % cooling systems by type (e.g. 50% once-through, 45% closed-cycle / cooling tower, 5% dry-air cooling) • Annual electricity imports

1. Identify resilience indicators:
    - % energy mix based on thermal (in production) (E3ME, SDM)
    - % energy mix based on hydroelectricity (in production) (E3ME, SDM)
    - Annual hydropower production (SWIM, SDM)
    - Annual electricity generation based on thermal (E3ME, SDM)
    - Water used annually (abstracted / withdrawn) by cooling systems in thermal generation power plants (SDM)
    - % cooling systems by type (e.g. 50% once-through, 45% closed-cycle / cooling tower, 5% dry-air cooling)

[27] Riach et al. (2019) available at : http://www.clim-ability.eu/actualites/les-precipitations-estivales-les-periodes-seches-et-le-risque-de-secheresse

- Annual electricity imports (SDM)

2. Set a forecast of reduction in hydropower generation (SWIM, SDM), -x% of base year generation; and a decrease in surface water availability for cooling systems (SWIM, SDM), -y% of water used for cooling in the base year (e.g. 100%).
3. Select measures from a pool of options that decrease the dependence of the electricity generation mix to water quantity to be applied over the period of the game:
   - Increase deployment of RET in electricity generation (e.g. solar, wind, biomass)
   - Phase out of once-through or upgrade cooling systems to less water intensive options (e.g. closed-cycle, dry-air cooling)
   - Set a minimum of electricity imports correspondent to, for example, to the decrease in annual hydropower generation;
4. Run model / game. Indicators presented in 1) are displayed.
5. Re-start game acting over the elements manipulated in 2).

10.9.7.2 Ensure a sustainable energy transition (Energy-Water-Land)

The Upper-Rhine is considered as a model region regarding energy transition however the deployment of renewables in this region resulted – among others – in a significant development of bioenergy. This development has significant implications especially in terms of competition for land use between food production and biomass production but also for the efficient and sustainable use of water resources, both in terms of quality and quantity.

For instance, in Baden-Württemberg biogas production based on cultivated crops underwent a significant development starting in the early 2000s. Between 2001 and 2019, a 100% increase in cultivated area dedicated to silage maize, one of the main resources used to produce biogas (around 40% in mass) could be observed, along with a decline in cultivated area especially for pulses and root crops.

USE CASE 2 FR-DE	Land (but also water)
Related Learning Goals	• Learn about the trade-offs linked with energy transition choices in the Upper Rhine • Learn about synergies and trade-offs between policies but also test and learn about the feasibility of specific policy objectives (e.g., low carbon and no nuclear; or 100% food self-sufficiency, etc.)
Goal	Ensure a sustainable energy transition
User	Public Sector (Ministry of Energy Planning, Energy Agency, Local authorities)
Actions	• Increase deployment of “non-biomass” RET in electricity and heat generation (especially of PV and “wind-power on “low-value lands”) • Increase/support deployment of electric cars • Increase/support deployment of the use of manure and food waste for biogas production • Control the deployment of energy crops (set a cap in terms of total utilized agricultural area (UAA) dedicated to energy crops) • Decrease the use of agricultural inputs for energy crops

Indicator	• Share of energy crops in primary energy production/generation • Quantity and share of total resource available of manure used for biogas production • Quantity and share of total resource available of food waste used for biogas production • Share of primary energy production based on manure (from total primary energy production and primary energy production from renewables) • Share of primary energy production based on food waste (from total primary energy production and primary energy production from renewables) • Cultivated area dedicated to energy crops • Share of cultivated area dedicated to energy crops with respect to total utilized agricultural area • Water demand from energy crops • Fertilizer use for energy crops • Ammonia output for energy crop

1. Identify sustainability indicators:
    - Share of energy crops in primary energy production/generation (SDM, E3ME)
    - Quantity and share of total resource available of manure used for biogas production (SDM)
    - Quantity and share of total resource available of food waste used for biogas production (SDM)
    - Share of primary energy production based on manure (from total primary energy production and primary energy production from renewables) (SDM)
    - Share of primary energy production based on food waste (from total primary energy production and primary energy production from renewables) (SDM)
    - Cultivated area dedicated to energy crops (SDM)
    - Share of cultivated area dedicated to energy crops with respect to total utilized agricultural area (SDM)
    - Water demand from energy crops (CAPRI, SDM)
    - Fertilizer use for energy crops (CAPRI, SDM)
    - Ammonia output for energy crop (CAPRI, SDM)
2. Determine the sustainable upper limit/cap for the UAA dedicated to energy crops. Determine the aimed for decrease in the use of agricultural inputs (for this maximum area dedicated to energy crops) and determine the corresponding agricultural production and primary energy production (and the corresponding “energy gap” to be bridged in terms of primary energy production).
3. Select measures from a pool of options that increase the sustainability of energy transition with regards to land and/or water resources to be applied over the period of the game:
    - Increase deployment of “non-biomass” RET in electricity and heat generation
    - Increase/support deployment of electric cars (decrease dependence on gasoline even bio-based)
    - Increase/support deployment of the use of manure and food waste for biogas production
4. Run model / game. Indicators presented in 1) are displayed.
5. Re-start game acting over the elements manipulated in 2).

10.9.7.3 Climate-proofing agriculture in the Upper Rhine through multifunctional measures

USE CASE 3 FR-DE	Climate
Related Learning Goals	• Learn about synergies and trade-offs between policies but also test and learn about the feasibility of specific policy objectives (e.g., low carbon and no nuclear; or 100% food self-sufficiency, etc.) • Learn about the impact of climate change in the specific Upper Rhine context and resulting challenges
Goal	Climate-proofing agriculture in the Upper Rhine
User	Public Sector (Local authorities), Private sector (farmers and Chambers of agriculture)
Actions	• Implement payment or environmental services/agri-environmental (PES/AES) schemes to incentivize the implementation of soil conservation measures by farmers (increase carbon storage) • Establishing sustainable water management policies (incentives to invest in more water-efficient irrigation systems, define a cap for water use in agriculture) • Cultivate drought-resistant crop varieties • Establish flood prevention policies (establish water retention areas/flood meadows)
Indicator	• Annual water use for irrigation in agriculture • Share of water use for irrigation in agriculture as a % of total water demand/use • % irrigation systems by type • Area of flood meadows established on rivers with frequent flooding (wetlands) • Total annual carbon storage in wetlands • Total annual carbon storage in agricultural soils • Total agricultural production (feed + food) • Agricultural output/person (compared to a threshold value which could be the initial value of this indicator or a target value with a nutritional meaning?) • Cost of inaction

Possibility to play either in the baseline scenario or the +2°C scenario → the player gets to choose the scenario she wants to play with (but no possible endogenous relationship between actions and climate can be modelled in our SDM).

1. Identify resilience indicators:
    - Annual water use for irrigation in agriculture
    - Share of water use for irrigation in agriculture as a % of total water demand/use
    - % irrigation systems by type
    - Area of flood meadows established on rivers with frequent flooding (wetlands)
    - Total annual carbon storage in wetlands
    - Total annual carbon storage in agricultural soils
    - Total agricultural production (feed + food)
    - Agricultural output (food)/person (in kg/pers * yr, compared to a threshold value which could be the initial value of this indicator or a target value with a nutritional meaning?)

- Cost of inaction

2. Determine the resilient upper limit/cap in terms of water use in agriculture and the lower limit in terms of agricultural production (total feed and food production and food/person)
3. Select measures from a pool of options that increase the resilience of agricultural production to climate change in an attempt to meet these targets:
   - Implement PES/AES schemes to incentivize the implementation of soil conservation measures by farmers (increase carbon storage)
   - Provide incentives/funding to invest in more water-efficient irrigation systems
   - Cultivate drought-resistant crop varieties
   - Establish flood prevention policies (establish water retention areas/flood meadows)
4. Run model / game. Indicators presented in 1) are displayed.
5. Re-start game acting over the elements manipulated in 2).

10.9.8 Policy cards

PolicyId	Nexus Sector	Name	Very short policy card name	Description of intervention as captured by the policy card
1	Energy	Improve energy efficiency of dwellings	EE - Subsidy 5	Incentive targeting landlords carrying out energy renovation work
2	Energy	Next generation smart metering energy	Smart-meters	Smart metering designed to give the householder more detailed information on their energy use
3	Energy	Deployment of electric vehicles	E-Car	Rebate for the purchase of an electric vehicle aiming at decarbonizing the fleet
4	Energy	Support the deployment of wind-energy -100% increase	Support-Wind	Strong policy and financial support for wind energy
5	Energy	Support the deployment of PV - 100% increase	Support-Solar	Strong policy and financial support for solar energy
6	Land	Increase forest area by 5%	FOR 5	Implement reforestation/conservation programs to increase forest areas
7	Land	Increase wetlands area by 5%	WET 5	Implement restoration/conservation programs to increase wetlands area
8	Climate	Implement soil conservation measures in agriculture through PES/AES schemes : 20% of agricultural areas	AGR-Soil 20	Provide incentive for the implementation of soil conservation measures
9	Climate	Implement soil conservation measures in agriculture through PES/AES schemes : 50% of agricultural areas	AGR-Soil 50	Provide incentive for the implementation of soil conservation measures
10	Water	Improve the efficiency of water distribution networks in urban areas	W-Net urban	Reducing leakage within the drinking water distribution network
11	Water	Improve the efficiency of water distribution networks in rural areas	W-Net rural	Reducing leakage within the drinking water distribution network

12	Water	Domestic water reuse	Water reuse	Deployment of grey water recycling devices in the home to reduce domestic water consumption
13	Energy	Ban on nuclear power	Ban nuclear	No nuclear production in this region (but imported electricity can still be made from nuclear power plants) ; the aim here is to reduce exposure to nuclear risk
14	Land	100% Compensation of destroyed forest areas and wetland	PRC principle	Prevent - Reduce - Compensate principle : 100% compensation of destroyed natural land
15	Land	Ban on decrease in agricultural areas	Preserve agri	Prevent the decrease in agricultural land to secure food production
16	Water	Next generation smart metering water	Smart-Water	Smart metering designed to give the householder more detailed information on their water use
12	Energy	Support the development of electricity generation from biogas	Support-Biogas	Strong policy and financial support for electricty cogenerated by methanisation plants to ensure economic viability and foster the development of this technology
13	Energy	Support heat production from renewables	Heat-R	Strong policy and financial support for heat production from renewables
14	Energy	Command 50% of biofuels in total energy use in the transport sector	BioTransport 50	Increase the use of biofuels in the transport sector to decarbonize the latter
15	Energy	Ban on fossil fuels for electricity generation	No FF	Decarbonization of the energy sector
16	Food	Decrease the share of animal products in food consumption by 25%	ToVeg 25	Reduce consumption of animal product in order to decrease GHG emissions from food consumption
17	Food	Decrease the share of animal products in food consumption by 50%	ToVeg 50	Reduce consumption of animal product in order to decrease GHG emissions from food consumption
18	Food	Command 50% of total food consumption from local production	Local food 50	Increase food security by commanding 50% of total food consumption from local production
19	Food	Command 100% of total food consumption from local production	Local food 100	Ensure food security by commanding 100% of total food consumption from local production
20	Water	Improve the efficiency of irrigation systems for 50% of irrigated cropland areas	EE-Irri 50	Decrease water consumption from irrigation by investing in more efficient irrigation techniques
21	Water	Improve the efficiency of irrigation systems maize for 100% of irrigated cropland areas	EE-Irri 100	Decrease water consumption from irrigation by investing in more efficient irrigation techniques
17	Energy	Decrease the share of nuclear in the energy mix by 25%	D-Nuclear 25	Diversification of the energy generation portfolio in order to decrease reliance on nuclear energy and exposure to nuclear risk
18	Water	Increase in the price of water	Water price	Increase in the water price to decrease water consumption from agriculture

16	**Energy**	Command 100% of total primary energy consumption from local production	E-Self-sufficiency	Ensure energy security by commanding 100% of total primary energy consumption from local energy production
17	**Land**	Upper limit on areas for energy crops : 5% of total utlized agricultural area	Energy crops 5	5% maximum of utilized agricultural area dedicated to energy production
18	**Land**	Increase green urban areas by 15%	Green-urban 15	Increase in green urban areas to increase water infiltration and improve resilience to flood risk
19	**Land**	Ban on land-use change	No LUC	Ban on land use change to maintain functioning ecosystems
20	**Land**	Decrease the use of agricultural inputs by 25%	Less-input 25	Decrease in the use of pesticides/agricultural inputs in order to increase water quality and restore ecosystems
21	**Land**	Decrease the use of agricultural inputs by 50%	Less input 50	Decrease in the use of pesticides/agricultural inputs in order to increase water quality and restore ecosystems
22	**Energy**	5% Increase price of electricty	P-Elec 5	
23	**Energy**	10% Increase price of electricty	P-Elec 10	
24	**Energy**	5% increase price of natural gas	P-Gas 5	
25	**Energy**	10% increase price of natural gas	P-Gas 10	
26	**Energy**	5% tax on fossil fuels	FF tax 5	Implementation of a 5% tax on all fossil fuels
27	**Energy**	10 tax on fossil fuels	FF tax 10	Implementation of a 10% tax on all fossil fuels

11 Eastern Germany–Czech Republic–Slovakia

11.1 Introduction

Case study lead organizations: PIK, ENKI, People and Water

The nexus context for the transboundary study was set up as a relationship of land-water-climate-energy, with crucial representation of agriculture activities that put a pressure on all four components. The study covers the whole territories of the Czech Republic (78,871 km2) and Slovakia (49,035km2). The German part of the transboundary case study covers the federal states Mecklenburg-Western Pomerania, Saxony-Anhalt, Brandenburg, Berlin, Thuringia, and Saxony (108,944 km2).

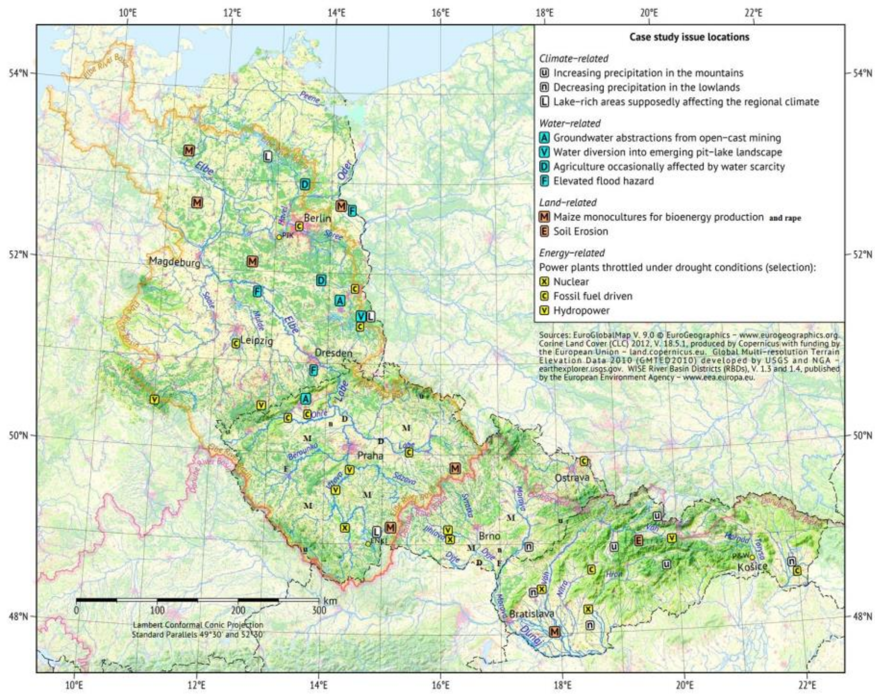


Figure 126 Map of the case study area (saturated land use colours) with major river basin boundaries and locations of selected nexus issues

The problems which are common to all three case studies states result from common history. For all three states there are typical changes in the structure of the agricultural landscape, i.e. the creation of large soil/field blocks and the removal of small landscape features, as well as complicated ownership relations. These factors are also related to extensive drainage of agricultural land (by technological drainage systems in soil, drying wetlands, etc.), and directly affect water retention ability of the landscape and local climate. The map locates also most of the nexus-related problems we are addressing with the study. Agricultural landscape fundamentally influences the hydrological cycle and the climate, is experiencing deterioration in soil quality (erosion, sealing, nutrient losses, acidification), water scarcity and drying – despite the EU's efforts to introduce various agro-environmental measures and measures to mitigate climate change. It is necessary to look at the main causes for the failure of these efforts. In the past thirty years, there was no significant landscape structure change in the case study states, which would improve the retention and accumulation of water, reduce nutrient losses and decrease the surface temperature of the landscape. Associated phenomena include losses in agricultural yields and both quantitative (floods and droughts) and qualitative (high nutrient and matter losses from catchments) water-related problems.

There is also a special focus to be set on future electricity supply for the German part of the case study area. In recent years there was regularly more electricity produced in the federal states of Mecklenburg-Western Pomerania, Brandenburg, Saxony-Anhalt, and Saxony than was consumed within their borders. Another pressure on the German electricity supply is the immediate shutdown of all nuclear power plants in Germany before the end of 2022. Recently, 72 TWh of electrical energy were generated per year from nuclear heat, a supply that will have to be replaced largely from other (renewable) sources. However, renewables in Eastern Germany mean principally wind power and photovoltaics, highly volatile sources. Last but not least, shutdowns under heat waves are expected to be more frequent for thermal power plants relying on cooling water; studies suggest increasing problems due to climate change within the next decades, especially in Germany (Koch et al. 2014, 2015). The big question is to what degree of increasing renewables shares the power grid can be kept stable given the additional challenge of coal and nuclear plants leaving the system for good. What could be sustainable solutions?

One path already taken in the course towards higher shares of renewables are bioenergy plants, largely fuelled by silage maize, other crop residues, and animal faeces – often with methane gas as intermediate product, but the agricultural areas required for these sources are already quite extensive and further growth is very limited. Two key elements to tackle the problem are: more transnational, high-capacity power lines to flexibly divert the electricity from windy and sunny spots across Europe, and a system of storage facilities. The transformation of the energy system has already started, shutdowns of nuclear and fossil-fuelled power plants are urgently needed to limit the generation of ultra-toxic radioactive waste and dangerous greenhouse gases. The EU and national policy makers need however to make sure that there is always enough buffer potential in the electricity system challenged by growing shares of discontinuous renewable power sources. Despite CZ and SK have a lower share of renewables, this problem is transboundary one, especially in days with strong winds causing high electricity production by wind mills. The requirement for more pumped storage power stations situated in Krušné hory/Erzgebirge region between Czech Republic and Germany should be solved in a transnational effort. Such transnational, EU-wide, and international approaches to the problem are in any case the only way to move forward as the current "solution" is to balance the electricity demands and supplies through significant cross-boundary transitions frequently exposing the European power grid architecture to serious stress.

The principal conditions for improvements in the landscape and regional climate are restoration of permanent vegetation, water retention measures (realized mainly on agriculture land), and changes of landscape management and land cover. The nexus context for the transboundary study was set up as a relationship of land-water-climate-energy, with crucial representation of agriculture activities that put a pressure on all four components. The study tries to find the answers for following questions (Figure 127):

- How can we encourage/achieve the complex and extensive changes of landscape structure and land cover, in national scale, in terms of increasing its water retention ability and decreasing surface temperature?
- What effect could be achieved by water retention measures which also stimulate sequestration of carbon and reduce water and nutrient losses?
- How can landscape restoration (change of landcover) be embedded into policy for climate change mitigation?
- How to increase an understanding of basic principles of the NEXUS: incoming solar energy – water/absence of water – plants (biomass, food) – local climate. This is justified by landscape

management (land cover) being the most important boundary condition for regional climate, water availability, and food production.

- How threatened is the electricity supply in the area given the increasing amount of unstable renewable sources under climate change?
- What would be the consequences of an immediate shutdown of the lignite mining activities in Lusatia?
- How much agricultural area dedicated to food production is and will be sacrificed to biomass generation? What are the environmental consequences of this “green” energy in the area, especially regarding the water balance? It means taking into consideration the negative effects of higher maize and rape dominance in the crop mix on soil quality and runoff.

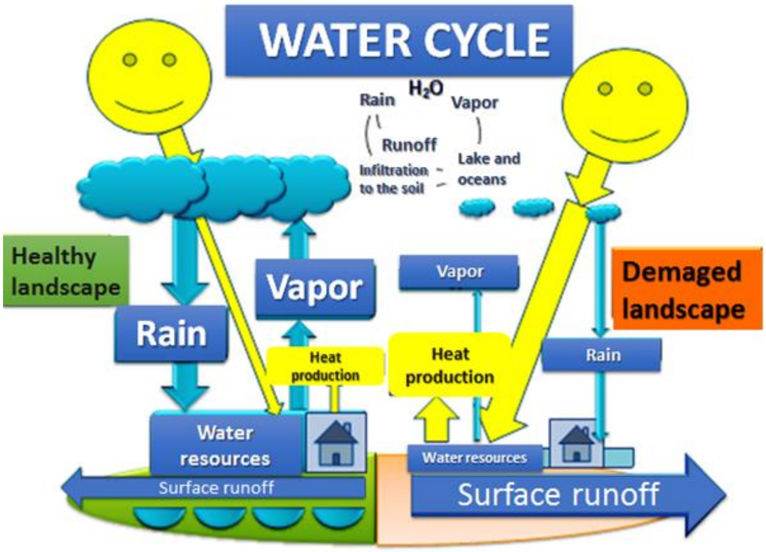


Figure 127 The water cycle in a healthy and in a damaged landscape

Representatives of several public and private organizations have been addressed in order to be actively engaged as stakeholders. Many of them have attended the stakeholder workshops listed in Tab. 2.1. There were only two major workshops in this case study due to limited financial resources and the long-distance travelling necessary for most participants. Stakeholder activities are reported in detail in Section 2.3.An active cooperation was established with:

- DE - Federal Institute for Research on Building, Urban Affairs and Spatial Development; Brandenburg State Authority for the Environment; Vattenfall GmbH
- CZ - Regional Office of South Bohemia region, Local Action Group (MAS) Třeboňsko; Ministry of Environment, Czech Republic (Department of Landscape and forest protection); Dačice town
- SK - Agency for Regional Development, Regional Government, Košice; KREAPROJEKT, Research and Development of systems for environmental monitoring.

Table 64 Transboundary case study meetings

When and where	Who	Why
6 October 2016 Třeboň (CZ)	J. Pokorný, T. Conradt, M. Kováč	Preliminary discussion on transboundary case study issues; launching the case study process
28 and 29 November 2017, Potsdam (DE)	T. Conradt, J. Pokorný, M. Kravčík	Finalization of deliverable D. 2.1.

7 – 9 April 2018, Třeboň (CZ)	Transboundary team + stakeholders + WP2 (S. Munaretto)	First stakeholders workshop followed by discussion with WP2 representative S. Munaretto – policy analysis and recommendations
26 – 27 February 2019, Třeboň (CZ)	T. Conradt, J. Pokorný, m. Kravčík, P. Hesslerová + WP 3 (S. Masia, J. Susnik)	Finalization of SDM
29 – 31 May 2019, Starý Smokovec (SK)	Transboundary team + stakeholders + WP 3 (S. Masia)	First stakeholders workshop followed by discussion with WP 3 representative S. Masia (fixing SDM bugs)

11.2 Overview of tasks performed

11.2.1 Organisation to carry-out Task 5.2

The organizational structure of Task 5.2. was created with respect to individual sub-tasks and followed by step-wise approaches in order to answer all addressed questions. The team of transboundary DE-CZ-SK study consists of four actively cooperating persons with the same share of responsibilities and competence to solve the tasks. The internal team communication has been realized mainly by e-mail communication or phone calls. Important project outputs (deliverables, SDM, etc.) have been achieved and physical meetings have been organized, not only among case study partners, however also with other project partners (see above, Table 64). The internal project communication was targeted not only to WP5 leaders (M. Fournier, F. Brouwer) but also to the WP 3 team where the development of SDM have been elaborated with L. Vamvakeridou-Lyroudia (WP3 leader) and with S. Masia and J. Susnik (responsible for the actual implementation of the SDM).

ENKI and People and Water mainly worked out the nexus challenges with the emphasis on water-land-climate aspects supplemented by the issues of energy addressed mainly by PIK. The nexus of land cover and climate is not considered in models dealing with climate change. Therefore its implementation into the SDM was a challenging task for the case study and WP3 teams. The transboundary approach appeared to be a special challenge as it has to interface the scientific background with the different legislations and policy-making frameworks of three countries, followed by implementation activities via interaction with local/regional/state administrations, even disregarding additional language issues.

11.2.2 Schedule of Task 5.2

October 2016 – January 2017 Identification and description of land – water – climate – energy nexus, draft of key research questions.
January – September 2017 case study policy review as a background for stakeholders' involvement and negotiations
December 2017 – description of nexus challenges, pathways, first development of conceptual model, analysis of thematic models.
Review on thematic models and data availability related to transboundary case study. Our specific Nexus questions about the land and water sectors are largely covered by SWIM, a spatially distributed eco-hydrological model. Other thematic models do not contain full data range needed for this case study. The problem is the charging of most data sources in the CZ and SK, which represents a significant limitation for the subsequent development of the conceptual model and SDM.

Selection of relevant parameters for conceptual model processing and suitable territorial units based on NUTS-2 units.

April 2018 - organization of the first workshop where the whole concept of case study was discussed, especially the retention of water in the landscape, its consequences on the climate and issues of energy sector involvement. Possibilities to change strategic concepts and documents with regard to water retention measures and climate improvement.

May 2018 – finalization of policy coherence and analysis as starting points for policy scenarios and cards development

August 2018 - Policy scenarios development

...till March 2019 – free available data analysis and arrangement for SWIM model and CAPRI

January 2019 – policy cards development

February 2019 - meeting of the whole transboundary case study team with S. Masia and J. Susnik (WP3) in order to finalize SDM model in Třeboň

March 2019 – design of policy goals

May 2019 – new data from CAPRI thematic model available

May 2019 - Second stakeholders workshop followed by discussion with WP 3 representative S. Masia (fixing SDM bugs); setting up intensive cooperation with stakeholders from CZ (South Bohemia Regional Office) and SK (Košice regional office) in terms of climate and water retention issues; final SDM structure

June 2019 – finalization of model description for Landcover – climate submodel (part of SDM)

July 2019 – corrected baseline data available

July - August 2019 – finalization of new version of policy cards; final version made available in September

August 2019 – E3ME – 2 degrees scenario data available

Continuous cooperation with stakeholders, discussion of Serious Game potential use. Active engagement in water management concept of South Bohemia Region (CZ), Košice Region (SK). Ongoing cooperation with Ministry of Environment on climate and adaptation strategies.

11.3 Engagement of stakeholders in the process

11.3.1 Overview of stakeholders' engagement in the case study

Stakeholders' engagement is important in almost any case where policy strategies and decisions are created, approved and adopted. Representatives of several public and private organizations have been addressed in order to offer their knowledge, experience and expertise with respect to the nexus-related policies. The issue of water retention in the landscape and drought mitigation connects many subjects, however their interest and power may differ significantly, as well as their ability/readiness to adopt significant policy changes and adaptations that can really contribute to the complex problem solving. The main constrains dwell in poor cooperation between ministries; despite the objectives (water retention, soil quality improvement, climate change mitigation, etc.) are often joint interests. The unwillingness to make fundamental changes to help solve the problem often involves fears of taking responsibility. All these facts make the process of establishing active cooperation with the crucial stakeholders very difficult. In the course of the project, continuous, active and fruitful cooperation was established primarily with the following entities:

- <u>Czech Republic</u>: town Dačice and Třeboň, South Bohemia Region, Local action group Třeboňsko, Ministry of Environment – Department of Landscape and forests protection
- Eastern Germany: Federal Institute for Research on Building, Urban Affairs and Spatial Development; Brandenburg State Authority for the Environment; Vattenfall GmbH
- Slovakia: - Agency for Regional Development, Regional Government, Košice; KREAPROJEKT, Research and Development of systems for environmental monitoring

Table 65 Selected examples of transboundary stakeholders activities

Interactions with stakeholders	Date Location	Number of participants and indicative distribution by nexus sector	Topics discussed	Outcomes / Achievements
Conference	26. March 2019 Dačice (CZ)	60 participants Nexus of water – land – climate	Water retention program in agricultural landscape	Water retention measures in landscape – practical advices
Conference	12 November 2019 Dačice (CZ)	80 participants Nexus of water – land – climate	Strategy for landscape water management	Criteria and sustainable landscape management strategies in terms of functional landscape
Conference	17 October 2019 Třeboň (CZ)	200 participants Nexus of water – land – climate	Climate change – challenge for cities and rural areas	Active approach to climate change mitigation, positive examples of landscape restoration and management, inspiration for subjects managing the landscape
"Round table"	8. October 2019 Dačice (CZ)	30 participants Nexus of water – land – climate	Strategy for landscape water management	Active discussion on criteria and sustainable landscape management strategies in terms of functional landscape
Survey	2018 – 2019 Dačice (CZ)	Nexus of water – land – climate	Sustainable management of landscape	How changes in land cover directly influence energy fluxes in landscape and climate – expert activity for Ministry of Environment Audit of the Dačice landscape – carbon footprint assessment in contrast to application of water retention measures in landscape and vegetation restoration as active climate change mitigation tools
workshop n°1	7 – 9 April 2018, Třeboň (CZ)	28 participants All nexus domains	Nexus concept and policy analysis	Setting up stakeholders process
workshop n°2	29 – 31 May 2019, Starý Smokovec (SK)	25 participants All nexus domains	Conceptual model discussion, policy scenarios, data availability, serious game	Introduction to modelling and serious game potential

11.3.2 Feedback on stakeholders' engagement in the case study

The first stakeholder interaction was established within the 1st Workshop (April 2018), which took place with the participation of various stakeholders, covering all nexus domains. In the introduction, the principle of the whole project was introduced - especially research and leading questions, tasks for achieving research goals. The main interest was focused on policy goals, analysis and instruments for serious game that had been discussed within national working groups under supervision of S. Munaretto (WP2). The second workshop followed in May 2019. The main objectives covered the conceptual model issues, as well as the potentials of modelling and serious game which was introduced by S. Masia from WP3.

The main involvement of stakeholders cooperating with ENKI is based on the interest in nexus water-land - climate and its practical implementation and respect for climate mitigation strategies and landscape management. In the course of the project, it became apparent that there was a great interest in the practical implementation of nexus, especially at the local and regional level. Intensive cooperation was established with the City of Dačice with the involvement of the Ministry of the Environment within the framework of research and evaluation landscape functioning. ENKI also cooperates with the Ministry of the Environment, especially with the Department of Landscape and Forest Protection in the role of an expert for the project "Agricultural Landscape of the Future" and within other advisory activities in the field of sustainable landscape management.

South Bohemia Regional Office accompanied by Local action groups represents stakeholders with the deep interest in consultation and preparation of a plan for water retention / drought mitigation. The inspiration provides the East-Slovak Region. The cooperation of these subjects was established within the second stakeholders' workshop in the High Tatras (SK).

Stakeholder involvement in the project is an ongoing process. During the project, it turned out that the greatest interest have been in the nexus concept of water - land - and climate and its transdisciplinary approach. This issue was introduced not only within the individual project workshops, but there is a long-standing interest in lectures and expert activities. These are dozens of events per year. The interest rises mainly from individuals and regional offices, which are willing to adopt and enforce the approach in the implementation of measures in the landscape or in the development of strategic regional concepts. We managed to bring together stakeholders from the Eastern Slovakia and South Bohemia Regions, the Local Action Groups and the Voluntary Union of Municipalities (CZ) within the preparation of a strategic plan and pilot studies for water retention in landscape. It shows efficiency and willingness to implement measures and nexus concept within the bottom-up approach. For the time being, top-level enforcement within the ministries and strategic documents on climate protection and drought prevention is only possible from the expert consulting point of view, not the implementation one. Based on the requirements of the City of Dačice and the Ministry of Environment (CZ), an elaboration of functional state and landscape audit was elaborated by ENKI), with the aim to use water-land/vegetation-climate nexus versus carbon footprint of the City of Dačice. On the top level ENKI participated on the conference on "The future of European Agriculture – 11.12.2019 in Prague", with the attendance of minister of agriculture (CZ), members of EU parliament, secretary of the agricultural sector of the European Federation of Food, Agriculture and Tourism Trade Unions (EFFAT) from Brussels and many others, where the water-land-climate nexus was introduced in order to be respected in sustainable agriculture and land management and climate issues.

After many interviews with stakeholders, it seems to be rather ineffective to reduce carbon emissions to mitigate climate change. Bottom up approach is starting to give priority to the implementation of water retention measures in the landscape, which will synergistically result in improved climate, improved hydrological situation in the territory and ultimately the desired carbon sequestration.

Unfortunately, stakeholders are not interested in modelling, policy scenarios and serious game use. We come across the limits of models that depend on available data sources and the possibility to mathematically describe the phenomenon or context. From interviews with stakeholders (mainly from the energy sector), we opened up questions about the possibility of using serious game, but for the above reasons it was not possible to implement their requirements into the conceptual model. The main disadvantage of presenting serious game outputs and potential is that the results will only be available

at the end of the project. Therefore, it was not possible to present the possibilities of serious game application and potential use in the course of ongoing meetings.
From the communication point of view, the most effective were the operational meetings (organized as needed) and discussion workshops and seminars. We expected to benefit from the expertise of some stakeholders in the field of policy analysis. However, during common discussions it turned out that the links between policies and policy coherence are the weakness of all participants and the stakeholders´ knowledge cannot contribute to raising our awareness significantly. A general problem that we were unable to solve was to directly engage high-ranked full-time policy makers as their schedules are always very tight, and SIM4NEXUS might appear to them to be just another research project among thousands equally (un)important to their daily business, an impression we could not get rid of.

11.4 From conceptual models to System Dynamic Modelling

11.4.1 Case study conceptual model

There are two focus parts of the conceptual model. The first one is related to the water–land–climate nexus based on the long-term expertise of the CZ and SK team in the field of landscape energetics. The aim is to assert the active role of different types of vegetation in the distribution of solar energy, the quantification of energy flows and the associated water cycle. At a time when climate change is mainly linked to the increase in greenhouse gases, taking into account knowledge of the direct role of vegetation in regional climate protection strategies and water management is an effective tool. This part was guided by principles of landscape effects for the local climate and water regime, which should be taken into account in mitigating and preventing the impacts of climate change. In terms of local climate, it addresses the issue of the relationship between vegetation and surface temperature, which is one of the key characteristics of the solar-driven energy balance of the landscape. The hydrological aspect is not conceived solely in terms of precipitation-runoff processes, but focuses on the importance of the evapotranspiration, which is not interpreted as a mere loss of water, but as an important process of closing the water cycle and cooling the landscape. We distinguish between evapotranspiration as a cooling process of stands and the upward flow of heated air from overheated drained surfaces, which causes rapid landscape drainage.

The other focus is set on the energy sector, more specifically the reliability of the electricity supply. Germany decided to completely shut down their nuclear power plants before 2022, at the time of writing still supplying about 72 TWh of electricity per year. In order to drastically reduce CO_2 emissions (in line with the EU climate protection plan) coal-fuelled power stations are to be phased out until 2038. In Eastern Germany, part of the case study region, lignite still plays a major role for mining and electricity generation, but one of the largest lignite power plants of the region, Jänschwalde, will shut down operation already in 2028 which implies a production loss of 19.5 TWh per year alone. These supplies will have to be replaced largely from other sources. Among these sources will of course be renewables. According to eurostat, their contribution to the German electricity mix emerged from virtually zero in the 1990s to currently about 40% and still appears to be slowly growing – for comparison, Slovakia reports 22% renewables share and the Czech Republic only 14% with growth stalling in both countries since 2014. However, renewables in Eastern Germany mean principally wind power and photovoltaics, highly volatile sources. In 2019, there have been a couple of sunny hours with enough wind to exceed the demand – negative prices in the electricity market between the providers were one of the results. There have also been a few instances in which windstills, darkness, and outages of fossil-fueled power plants appeared together and required transnational electricity purchases at high price levels. In general, there is a light and wind-induced daily oscillation between over- and under-supply which quite often requires buffering by highly adaptive gas turbines and pumped storage power stations. The challenge for keeping the power grid in a stable state is growing and so is the probability for a large-scale blackout as our stakeholders from a large energy provider operating in Germany confirmed. And that was a big motivation to also concentrate on the electricity sources and demands in the conceptualisation of the case study model.

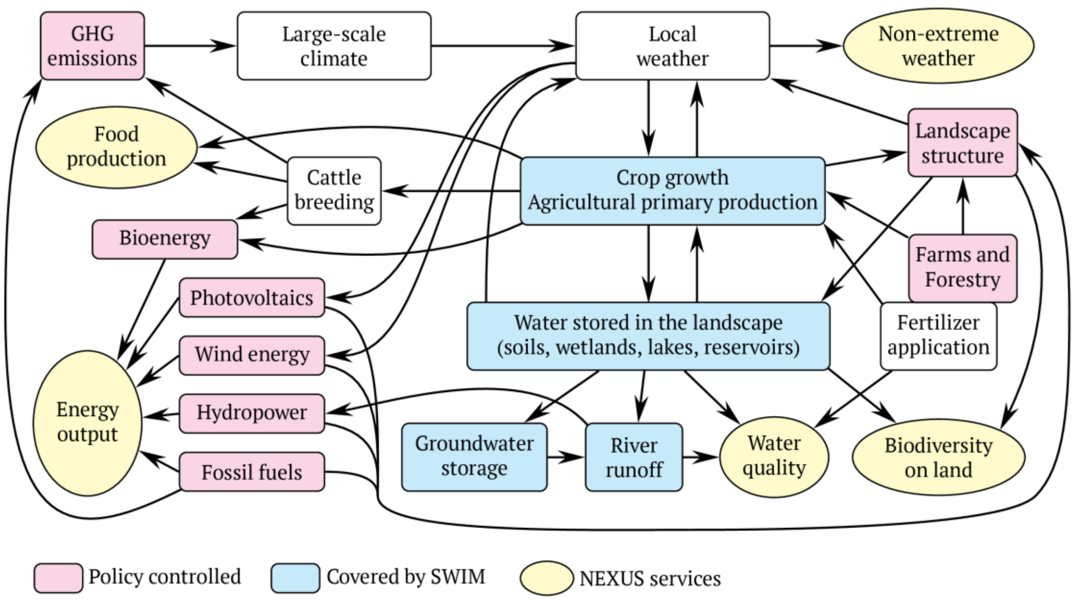


Figure 128 The initial conceptual model sketch for the DE-CZ-SK transboundary case study

It was clear from the beginning that the SDM modelling in this case study would mainly be based on the thematic models SWIM (eco-hydrology) and CAPRI (agriculture); furthermore E3ME (energy) could not be missed. The dominating role of SWIM, developed by PIK and set-up in SIM4NEXUS in a special version customised for the case study domain, can be seen in the first concept for the SDM (Figure 129). The parts covered by SWIM are indicated in blue tint and take a central position on the canvas. Another early idea was to concretise "Nexus services" for each sector (here ovals in yellow tint), an early representation of what would later become the sector-differentiated, but otherwise more general "nexus health status" in the serious game. For example, energy output was seen as the service of the energy sector. This did not take into account the demand side – it's quite simply missing in this concept –, and especially with energy "the more the better" cannot be a sustainable goal. What we can however already see here are five sources for the energy (read: electricity) output. Their shares are important for greenhouse gas emissions and did indeed make it into the SDM.

The energy sources, together with farms and forestry (enterprises, stakeholders), the landscape structure and remarkably also greenhouse gases are tinted red to indicate them as objects of policy control. Of course there was the idea of control through policy scenarios to be chosen in the serious game. But it was also not clear at this point of development that E3ME, part of the thematic model portfolio, is a dedicated energy sector model to be utilized, and what CAPRI actually contained. The idea of greenhouse gases being policy controlled was however chosen to be generally implemented in SIM4NEXUS by two climate scenarios to be considered, baseline (RCP 6.0) and 2-degrees (RCP 2.6) – respective variants of scenario runs from the thematic models had been made but finally the 2-degrees scenarios could not be fully mirrored by the SDM due to time constraints.

To summarise, the early conceptual model in Figure 128 could not serve as template for the SDM as many details (clear definition of terms, variables to consider, distinction of fluxes and controls, etc.) were unclear or simply lacking, but it helped in shaping the general idea about some nexus subsystems and how to put them into the modelling focus. A big leap towards the structure and common graphical notation of systems dynamics modelling was made by a separation into sector-specific modules whose final – but still conceptual – versions are shown in Figure 129 - Figure 131.

Our focus nexus sectors of water and energy received modules of their own, and there is a combined land-food module. Climate was still treated as some external input, not something that can actively be modified, at least on a regional scale. The regional climate, termed "local weather" in Figure 128, became completely internalised to modifications of precipitation and evapotranspiration in the water module

(Figure 129). As the local climate effects of landscapes, especially the water and vegetation therein, are of high importance in our case study area the actual SDM was developed further in this respect and also received the climate module still missing here. In general, a lot of modifications and adaptations to data actually available from the thematic models had been made in the transition process from conceptual drawings of hypothetic models to the "real" SDM. There is neither any use in commenting on all of these changes nor in elaborating single components of the conceptual model in detail; comparing the figures of the conceptual and the finally realised SDM (Figure 129 - Figure 131 in Section 11.4.3 below) illustrates however the wealth of changes and the long way of development. This development was not the work of the case study team alone but depended strongly on the devotion of the SDM modellers Sara Masia and Janez Sušnik (IHE Delft) who effectively implemented the better parts of the concept and continuously helped detailing, improving and altering it wherever necessary.

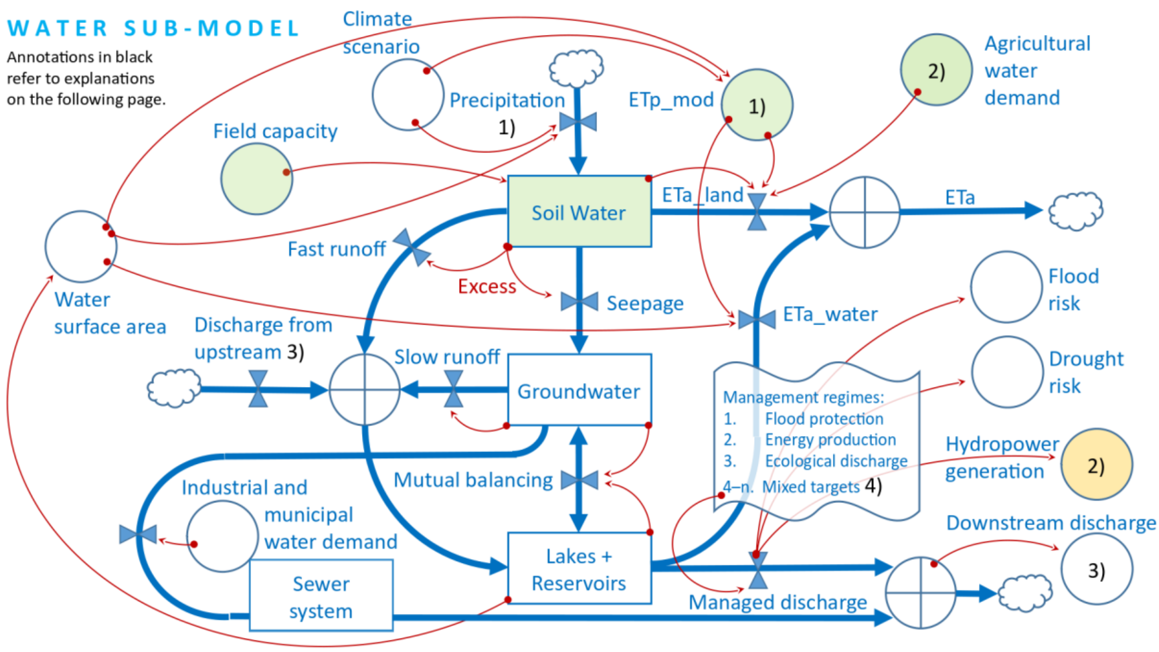


Figure 129 The water module of the conceptual model

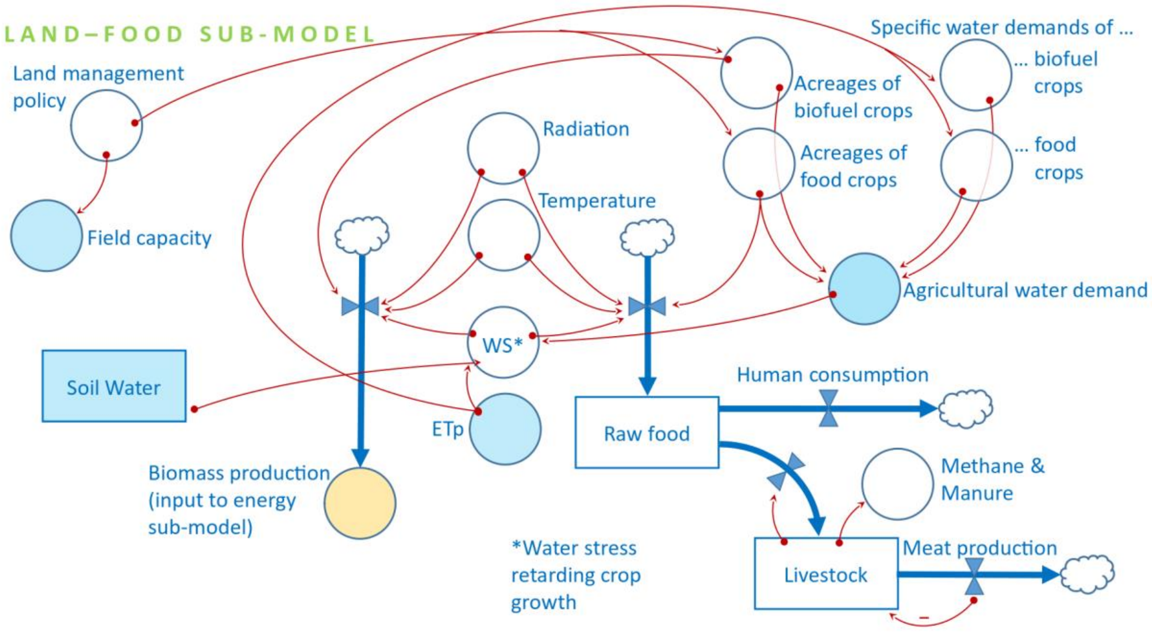


Figure 130 The combined land and food module

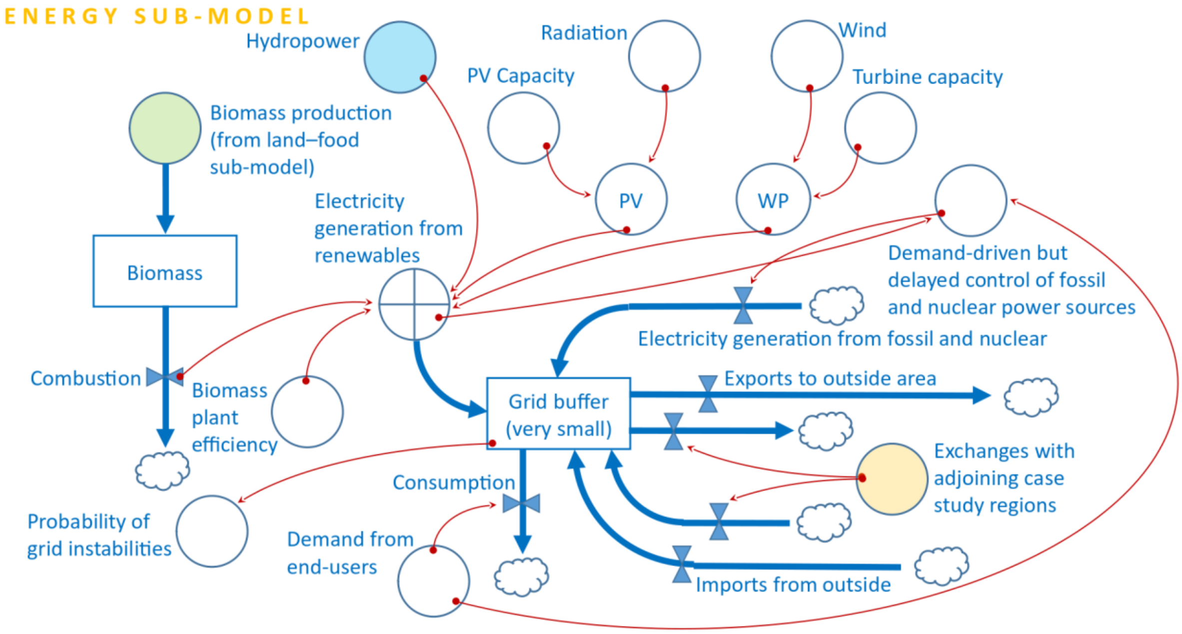
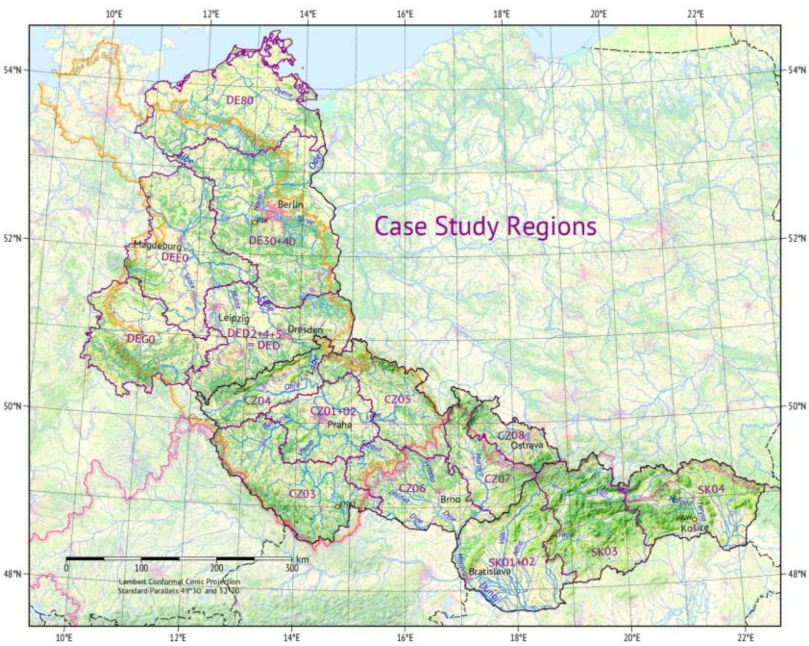


Figure 131 The module about electrical energy

Owing to the size of the case study domain – two and a half national states, 236'850 km² – it was necessary to separate it into regions following the example of Greece. As most regional data within the EU are available for NUTS regions and CAPRI operates on NUTS-2 level we decided to follow the NUTS-2 structure with three alterations: (1) The German capital Berlin, NUTS-2 code DE30, was united with the surrounding federal state of Brandenburg (DE40); (2) The German federal state of Saxony, split into three subregions by the NUTS-2 system, was treated as one unit (DED in NUTS-1); and (3) the Slovak capital region Bratislavský kraj (NUTS-2: SK01) was united with the western region of Slovakia (SK02). The resulting 15 case study sub-regions are listed in Table 66 and shown on the map in Figure 132. This spatial disaggregation had direct consequences for the SDM modelling: There are 15 respective sub-models for the 15 regions to be built. This was however already anticipated in the conceptual planning phase, it is the tinted circle elements in Figure 129 - Figure 131 which indicate connections to neighbouring sub-models like symbols of wall sockets or sink holes for fluxes to be received or sent. It was however not well understood from the beginning how this would multiply the number of variables with the same content but separated for different regions or relations.

Table 66 Correspondence of SDM sub-models and regions by name

SDM	Name of the region
01	Mecklenburg-Western Pomerania
02	Berlin and Brandenburg
03	Saxony-Anhalt
04	Thuringia
05	Saxony
06	Northwest (Ústecký and Karlovarský kraj)
07	Northeast (Liberecký, Královéhradecký, and Pardubický kr.)
08	Prague and Central Bohemia
09	Southwest (Plzeňský and Jihočesky kraj)
10	Southeast (Kraj Vysočina and Jihomoravsky kraj)
11	Central Moravia (Olomoucký and Zlínský kraj)
12	Moravian-Silesian Region
13	Bratislava and West Slovakia
14	Central Slovakia (Žilinský and Banskobystrický kraj)
15	East Slovakia (Prešovský and Košický kraj)



NUTS Codes and Model №s

DE80	01
DE30+DE40	02
DEE0	03
DEG0	04
DED	05
CZ04	06
CZ05	07
CZ01+CZ02	08
CZ03	09
CZ06	10
CZ07	11
CZ08	12
SK01+SK02	13
SK03	14
SK04	15

Figure 132 Map showing the separation of the DE-CZ-SK transboundary case study domain into 15 sub-model units. These are based on NUTS-2 regions in accordance with the CAPRI disaggregation and regional statistics from EUROSTAT

The conceptual model had been designed on the basis of internal case study discussion and supported by the long term expertise of the teams. There is scientific evidence on the role of land use and land cover change in the distribution of solar energy, the water cycle, temperature dynamics, local and regional climate and carbon sequestration or emissions (Pielke, 2005; Pielke et al., 2011). Links between vegetation-cover and climate with a focus on forests and precipitation were reviewed by Sheil (2018). He appealed for a more intense study of the biology of evaporation, aerosols and atmospheric motion and introduced the biotic pump theory (formulated by Makarieva and Gorshkov 2007) which explains how high rainfall can be maintained within those continental landmasses that are sufficiently forested. However much remains unknown and multiple research disciplines are needed to address this issue and to improve the understanding. Monitoring techniques have improved in the last decades and allow detailed studies and evaluation of the effects of land cover on temperature dynamics (Hesslerová et al. 2019), evapotranspiration and fluxes of sensible heat from different types of land cover. Such studies show that evapotranspiration is a powerful process to equalize the temperature and air pressure potentials, whereas sensible heat produced on drained overheated surfaces transports moisture high into the atmosphere and blocks the input of wet air from the ocean (Pokorný, 2019). The knowledge of small water cycle (Kravčík et al. 2007) is actively transformed into landscape restoration actions in Slovakia (Kravčíková et al. 2020a,b).

11.4.2 Modifications introduced to model policy scenarios

11.4.2.1 Development of policy scenarios for the case study

The principal policy scenarios are covered by the policy goals defined in the process of making policy options for the serious game. These include:

- Achievement of a high water availability and higher landscape water contents (water quantity)
- Quality improvement of all water bodies until the good ecological status as defined by the EU Water Framework Directive is reached (water quality)
- Decarbonisation and Denuclearisation of the energy sector
- Maintaining power grid stability under supply variability pressure from renewable energies
- Achievement of higher production quantities of food
- A smaller environmental footprint of the food sector
- Protection of naturally grown soils and maintenance of their ecosystem services
- Increase of the diversity of cultural landscapes
- Enhancement of flood protection
- Mitigation of large-scale climate change by utilizing landscape climate effects

The first scenario – high water availability in the landscape – would mean the reversal of the structural drought generation process by the currently common land management. This process is one of the two major challenges identified for our entire case study region. It is the dominance of “empty” agricultural landscapes, monocultures, in the lowlands that generates dry surfaces, especially after harvest, leading to high surface temperatures and convection of dry, hot air which in turn negatively affects the regional climate. Policies for a new landscape design bringing back the water and its evaporative cooling could break this vicious cycle.

Quality improvement of water bodies means more or less making the process of the EU Water Framework Directive (WFD) effective. The challenge is clearly defined and iterated by numerous WFD monitoring reports: Water quality is generally not sufficient in any water body of our case study area. The WFD management process implemented to raise quality levels to a good ecological status however appears to be ineffective, many targets are not only regularly missed but not even approached. Despite the availability of potable water (from designated reservoirs or protected zones of ground water) generally not yet being an issue in this case study area, even during summer drought events, stronger policies are required prioritising environmental obligations over profit interests.

Decarbonisation of the energy sector responds of course to the global nexus challenge of keeping the CO_2 level of the atmosphere below 450 ppm in order to reach the 2-degrees target of climate change mitigation. Denuclearisation is recommended to maintain the health of the population inside and around the Czech and Slovak parts of the case study equipped with two nuclear power plants each. Especially the nuclear power stations of Dukovany (CZ), Bohunice and Mochovce (SK) pose high risks as their reactors are old Soviet models without containment. The nuclear plant Temelín (not far away from Třeboň, CZ) is notoriously known for a high number of smaller incidents and outages.

Maintaining power grid stability is a continuous challenge in electricity supply as demand and supply have always to be exactly balanced. This challenge has grown a lot with the boom of renewables, especially in Germany, because wind power and solar energy are highly volatile sources and cannot easily be regulated according to the demand. It is therefore the second special focus of our case study, see above.

Achievement of higher production quantities of food can also be understood as maintaining the current production level. Major challenges of food production are soil degradation (loss of organic carbon, compression by machinery, wind and water erosion) and the concurrence of biomass production for bioenergy generation (mainly rape for biodiesel and maize for biogas). Policies have therefore to be oriented towards soil protection – formulated as a policy scenario of its own – and balancing of land use, an example already in force are maximum allowed shares of maize in biogas plants.

The food sector has a substantial environmental foodprint which shall be minimized. There are several contributions to it, the most prominent from meat production. Animals require much more energy in their fodder than is retained in their meat; their faeces are used as manure, releasing too much nutrients for the environment; ruminants produce methane, one of the most potent greenhouse gases; etc. Other environmental stresses come from food processing (canning, smoking, freezing etc.) and long-distance transport (e.g. of non-seasonal fruits or vegetables).

Increasing the diversity of cultural landscapes means a number of measures including making the field blocks smaller following the historical standard, interspersing hedges, shelterbelts, and other woody structures, plus a lot of watercourses, ponds, and wetlands. Respective measures support both the efforts for high water contents in the landscape and maintain the structures for biodiversity. High biodiversity is a value in its own right, stabilising agricultural and other ecosystems.

Flood protection is needed in several lowlands along the bigger rivers of our case study area. There have been centennial flood events in the Elbe River in the years 2002 and 2013, possibly triggered by climate change effects. Recent flood protection usually meant building dikes, but in the extreme floods dike breaches occurred and consequently severe damages the settlement areas that should have been protected. There are at least three sub-strategies to be followed: (1) More money and efforts can be put into the building and maintenance of dikes, (2) Dike lines can be partly relocated to the hinterland, leaving space for a quasi-natural floodplain forest (a habitat nearly completely lost in Central Europe), and (3) the original glacial floodplains can be abandoned at all, this means no costs for dikes and no flood risk for humans any more but requires infrastructure, homes and working places to be rebuilt in other places, disregarding the emotional distress of the relocated population.

Finally, there is the goal of climate enhancement on the landscape level. The challenge here is both the global climate change and, as elaborated above, the structural drought from the current land use governed by practices of industrial agriculture. Respective countermeasures are closely interlinked with the water availability and the landscape diversity scenarios; they can for instance include the choice of plant species used for new woody structures enhancing evapotranspiration.

The policy scenarios were chosen and developed by the team of project partners responsible for the DE-CZ-SK transboundary case study, i.e. ENKI (CZ), P&W (SK), and PIK (DE) using their scientific knowledge and societal and political experience. Stakeholders of different professions and backgrounds from the three countries helped in the definition process through several exchanges at and alongside the dedicated stakeholder workshops that were organized in Třeboň (CZ) and at the foot of the High Tatras (SK), the final decisions remained however exclusively with the project partners. The selection made certainly reflects the specific problem consciousness of the people involved in the process and should not be interpreted as a list of the most important challenges in the case study domain or mixed up with eventual policy recommendations.

There are some other issues stressed than in the baseline description (D1.8), because these policy scenarios were not oriented along the common SSP2 narrative. This might be an advantage because any downscaling of the general (global or continental) SSP narratives and scenarios runs the risk of remaining in the general categories applied on the larger scales. There is also not much direct overlap with the policy coherence analysis (D2.2) in which a high number of actors and interests could be identified, their individual interests and fields of governance are however largely distinct from the landscape perspective we focus on. This holds even for the agricultural sector which is basically bound by the EU funded system of subsidies, world market prices, and the economies of scale – if a single farm enterprise dare to experiment with long-term sustainable landscape cultivation they will simply be out of business. Another example is the energy sector: As we learned from our stakeholders, the electricity providers are well aware of the increasing blackout risk, but there is not much they can do about it as long as EU and national energy policies are focusing solely on annual production figures when it comes to increasing the share of renewables. The arising challenge of supply volatility and limited buffer elements is not reflected at all in current policy making: Operators of pumped power storage stations are invariantly taxed for their situational trade of electricity stabilising the grid.

11.4.2.2 Introduction of policy scenarios in the SDM

At the time of writing, the introduction of policies into the SDM had not become operational. This SDM had been chosen to be one of the last to be set up among the SIM4NEXUS case study models, probably because the sheer amount of data with all variables parallelised for 15 sub-region models promised a long implementation time, and this should not defer the finalisation of a couple of probably easier-to-handle case study models within the project.

However the general approach will follow along the lines for the policy cards designed for the serious game: Policy scenarios, defined by objectives, are first subset and substantiated by one or more policy objectives. Then single interventions are derived from the objectives which will be represented by policy cards in the serious game. To apply them to the SDM will basically mean altering variables or parameters by well-defined amounts and analyse the reaction of the system. Which variables to choose and in what directions they should be shifted to what extent has at least been sketched for the 33 interventions (policy cards) defined in the process. This was detailed in an Excel sheet of 141 rows; the final implementation will however very probably differ from that as the conceptual model differs from the actual SDM. Table 67 lists some examples of these interventions and how they might be adopted into the SDM.

Table 67 Policy interventions and their probable representations in the SDM

Policy intervention	**Drafted alterations applied to SDM parameters or variables**
Building of new reservoirs	Land use changes (adjustment of two variables each): Water surface area increases, respective reduction of forest (-75%) and agriculture (-25%). Hydropower generation increases.
Complex land consolidation	Increase of evapotranspiration from agricultural areas. Water retention increases, direct runoff reduces, aquifer recharge increases accordingly. Changes for direct runoff and aquifer recharge stronger on agricultural land. Strong reductions of water erosion, slight reduction of agricultural yields.
New buildings with mandatory eco-tech	Electricity demand for heat reduces by 50%, oil heating drops to zero. General electricity demand reduces by 10%. Evapotranspiration from urban areas is increased by 10%. Changes will kick in gradually over time.
Turning agriculture into energy forests	Land use for biofuel crops (ligneous) increases, land use devoted to food production decreases accordingly. Electricity production from biomass increases slightly.
Shutdown of all nuclear power plants	Electricity production from nuclear drops to zero. Stability indicator of the power grid reduces.
Subsidies for organic farming	Food and fodder crop yields reduce (one variable per species), biofuels production reduces even stronger. Evapotranspiration from agricultural land increases slightly. Water erosion decreases.

The examples given in Table 67 do not reveal the modelled effects of the direct interventions the SDM should illustrate, e.g. landscape temperature modifications based on altered land use patterns, but they do not illustrate the limitations of the SDM approach either: Whatever cannot be calculated in form of a variable is easily wiped off the picture, e.g. biodiversity, which will for sure benefit from a furthering of organic farming.

11.4.2.3 Data available from the thematic models

The following parameters from the thematic models were considered in the SDM. With the exception of E3ME they were spatially discretised for NUTS-2 regions or directly for the 15 SDM sub-model areas; only E3ME results were available for national aggregates alone and needed disaggregation to the SDM regions:

- From the model SWIM – for the baseline and the 2-degrees scenario, times five forcing models (GCMs), for 15 sub-model areas. These are monthly data with the exception of annual agricultural yields.
  - Aquifer recharge
  - Aquifer recharge under agriculture
  - Water erosion
  - Actual evapotranspiration (ETa)
  - ETa of agricultural areas
  - ETa of clover (per year in the three-year crop cycle)
  - ETa of corn maize
  - ETa of fodder crops

- ETa of oats
- ETa of pasture
- ETa of potatoes
- ETa of rape
- ETa of rye
- ETa of summer barley
- ETa of sugarbeets
- ETa of silage maize
- ETa of triticale
- ETa of vegetables
- ETa of winter barley
- ETa of winter wheat
- Potential evapotranspiration
- Groundwater height (relative)
- Hydropower generation
- Precipitation (effective)
- Precipitation on agricultural areas (effective)
- Total runoff, in mm/d
- Total runoff, in m^3/s
- Groundwater runoff
- Runoff from agriculture
- Direct runoff from agriculture
- Direct runoff
- Subsurface runoff from Agriculture
- Subsurface runoff
- Soil water equivalent
- Soil water equivalent under agriculture
- Lateral water exchanges with neighbouring units or outside areas
- Water balance
- Water balance of agricultural areas
- Seepage to aquifer
- Crop yields, per species

• From the model CAPRI – for the baseline and the 2-degrees scenario, decadal data (2010, 2020, 2030, 2040, and 2050) of the 15 submodel areas for agricultural areas and yields of
  - Pasture
  - Oilseeds
  - Oats
  - Potatoes
  - Other cereals
  - Rape
  - Fodder activities
  - Barley
  - Vegetables and permanent crops
  - Sugar beet
  - Rye and meslin
  - Soft wheat
  - Arable land

    - Utilized agricultural area
    - Grass and grazings extensive
    - Gras and grazings intensive
    - Fodder maize
    - Fallow land
    - Soya
    - Durum wheat
    - Pulses
    - Grain maize
- From the model E3ME – Baseline, 2-degrees, and five action scenarios (Phase out of fossil fuel plants a.s.a.p./Introduction of carbon tax, low and high/Complete nuclear phase out a.s.a.p./Reduction of household energy consumption by 10% over 5 years). Annual *national* data for 2003–2050.
    - Energy demands by sector (23 sectors, e.g. 'iron & steel', 'food', 'Households', etc.) for
        - Coal
        - Oil
        - Gas
        - Electricity
        - Heat
        - Biomass and combustible waste
    - Electricity generation by technology
        - Nuclear
        - Coal
        - Oil
        - Gas
        - Biomass
        - Hydro
        - Solar
        - Wind
        - Other

As the E3ME data were only available on national scale they had to be disaggregated to the SDM submodel regions. For the demand, this was done according to the number of inhabitants (on 1st January 2018, according to EUROSTAT): For instance, Germany as a whole had a population of 82.792 million, and the German federal states of Berlin Brandenburg, represented by SDM 02, together counted 6.117 million which is 7.4% of the national value. The energy demands of SDM 02 are then assumed to be likewise 7.4% of the national energy demand according to E3ME. For the production figures, recent sub-national energy balances were assessed for the production shares of the different sources within the countries where available. In the Czech Republic, and even more in Slovakia, the officially published data contain gaps that had to be filled using auxiliary sources. An example for these was an online map with locations of biogas plants in the Czech Republic; we counted the biogas plant numbers per SDM region on-screen and worked out the relative distribution shares for biomass usage in electricity generation; cf. the remarks on local data sources below.

Furthermore, data generated by SWIM on the model's daily timestep had to be aggregated to monthly values. This postprocessing step had been implemented to the SWIM code to obtain a special model version customized to the needs of the SDM modelling. Another peculiarity solved within this special version was the output of spatial averages for the politically divided sub-model regions from a model based on the natural catchment-based routing structure.

The NUTS-2 discretisation of CAPRI and many EUROSTAT tables led to the decision for shaping the SDM sub-model areas accordingly, this was probably the most important impact of data availability on the SDM definition. Regarding the only national availability of E3ME data and SWIM calculations of much higher resolution (with a daily timestep and basic spatial units typically less than 5 km²) this seemed to be the most practical balance between direct transfer, simplification and complexification.

Any SDM representation of geographical regions will however remain a strong simplification of the nexus sectors and their interlinkages in the real landscape. Important features not traceable by this kind of modelling are for instance the contrasts between mountainous and lowland areas, both are present in most sub-model areas but all their individual characteristics are completely averaged out, so that drought situations in the agriculturally dominated lowlands will not show up in the water balances nor will erosion events concentrating on hill slides or any other effect bound to a smaller part of the sub-model area.

11.4.2.4 Local data to be collected

Local data were generally not needed or used directly in the SDM generation with one exception: a table of landscape climatic effects represented by degrees of cooling and air velocities typically induced by different types of land cover. This table was prepared by the Czech and Slovak teams and delivered the parameter set for the landscape-climate module of the model.

The role of local data was very prominent in the set-up and calibration of the SWIM model. These include e.g. a complete soil map with profile characteristics for each mapping unit, measured river runoff time series, spatially discretized data on hydropower generation, or the knowledge on the sowing, fertilising and harvesting dates for the different crops grown in the region. For more information Deliverable 3.5 on thematic modelling should be consulted, because these sources were not utilized directly in the SDM modelling.

A third group of local data are auxiliary data that had to be collected for making use of the thematic model outputs through postprocessing. This refers especially to the information used for downscaling the E3ME-results for electricity generation from the national to the sub-model regional level. The parameters collected from regional energy balances (as far as available) were:

- Electricity generation from fossil fuels
    - hard coal
    - lignite
    - mineral oil
    - natural gas
- Electricity generation from nuclear heat
- Electricity generation from renewables
    - Hydropower
    - Solar
    - Wind
    - Biomass
- Electricity generation from waste

While regional energy balances exist for the federal states of Germany and, in form of regional statistics, for the Czech kraj, the political sub-units of their NUTS-2 regions, the regional statistical data for the Slovak part is rather patchy. Proxy information was used to fill data gaps as good as possible, e.g. the electricity generation from biofuels in the Czech regions was distributed according to the distribution of the 569 Czech biogas plants published in form of a web application.

As already stated, local data were generally of much lesser importance for the SDM creation than the thematic model outputs. Therefore regular processing (e.g. upscaling/downscaling) was not applied at this point; this was only an issue in the SWIM setup, see D3.5. Likewise, local data availability had no impact on the SDM – the final gaps which occurred with the distribution of energy sources in Slovakia were filled by educated guesses.

One of the major problems faced by this case study is the different national data policies. While in Germany most data are freely available, in the Czech Republic and Slovakia, the situation is quite the opposite. With the exception of data on the hydrological network, land cover (CORINE LC database), all data is charged for more or less. This was a fundamental and limiting factor that had to be taken into account when creating SDMs. The model had to be adapted to the available data. For this reason, the model could not be designed to provide relevant answers to questions about the importance of water vapor in the local climate. The data for the climate sub-model is thus based on long-term monitoring of temperature effects of different types of land cover (20-year research and monitoring of ENKI) under certain meteorological conditions and at different parts of the year, with emphasis on the growing season. On this data base it was possible to create a generalized database of climate sub-model input data.

11.4.3 Case Study SDM in Stella/R

For the remainder of this chapter, the term "module" refers to a thematically distinct part of the SDM structure, while each of the 15 sub-regions of the DE-CZ-SK case study will be represented by a regional "sub-model" of the SDM sharing an identical structure as defined by the modules. Distinct dynamic structures within the modules with their stocks, fluxes, and control parameters detailed in the following figures often form "sub-modules"; these parts are addressed accordingly.

The five nexus components are represented by SDM modules with principal interlinkages as shown in Figure 133. Already on this level it is obvious that the use of land is decisive for the functions in the other sectors: Climate, water and food are directly dependent, and there are two secondary links towards energy.

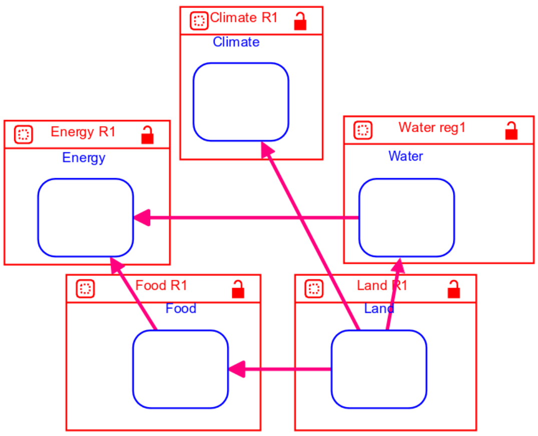


Figure 133 The SDM nexus component modules and their principal connections

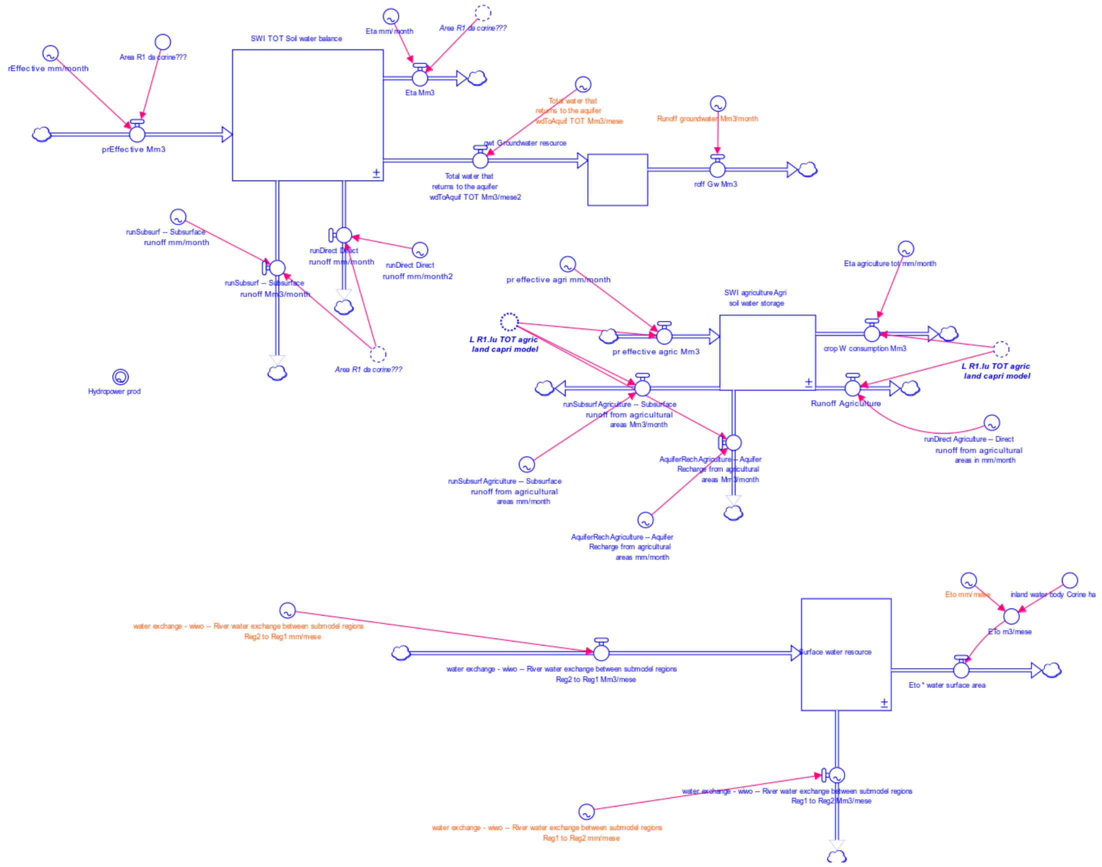


Figure 134 Hydrological systems representation in the water module. Concepts and core variables selected according to the thematic model SWIM, the main data source for this part

Going into the details of the modules reveals a higher order of complexity. We start with the water module. The hydrological storage elements of the landscape and the flows between these are shown in Figure 134. In the top-left quarter, there is the general structure for the entire landscape. Precipitation (here coming from the left) is the first-order input to the soil water storage, the big box with two flows each leaving to the right and downwards. The outputs to the right are actual evapotranspiration, water going back to the atmosphere, and groundwater recharge. The flows leaving downward are more or less direct contributions to river runoff (surface and subsurface flows), while groundwater runoff is released from an extra groundwater storage, the small box to the right, which is receiving the groundwater recharge component from the soil.

In the middle part of the figure, somewhat shifted to the right, a similar set-up is shown to be applied for the agricultural areas. It contains principally the same variables but subset to the agricultural areas of the respective sub-model. Finally, the lateral water exchange between sub-model regions has to be considered: rivers crossing the administrative boundaries between them; the respective sub-module is depicted in the bottom-right part of Figure 134. Not every region has an active incoming part of the water exchange, for example SDM12, the mountainous Moravskoslezko region in the Czech Republic, and there are shares of outgoing flows from many regions which do not enter another modelling region but leave the case study domain. An important input from outside the case study area had to be largely disregarded because the modelling was confined to political boundaries rather than river basins: the Danube river runoff, utilized for approximately 98% of Slovakia's total hydroelectric power generation.

Land use structures do not change very rapidly, thus the general land use accounting shown in Figure 136 will be characterised of rather stable figures, however there are different patterns for the different SDM regions. And there will be some fluctuations between the different crop activities for food, fodder and biofuel covering the agricultural land. Their developments are fed in from the CAPRI thematic modelling.

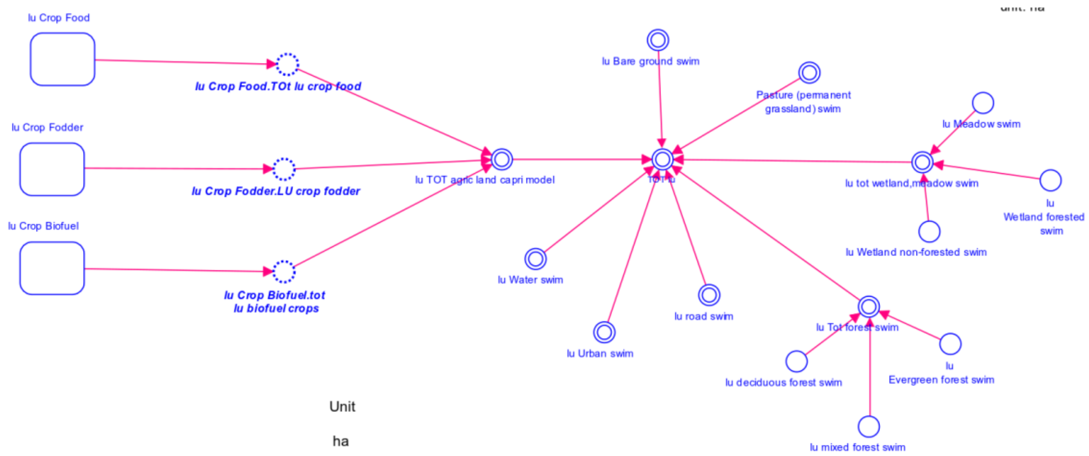


Figure 135 Principal land use categories in the land module

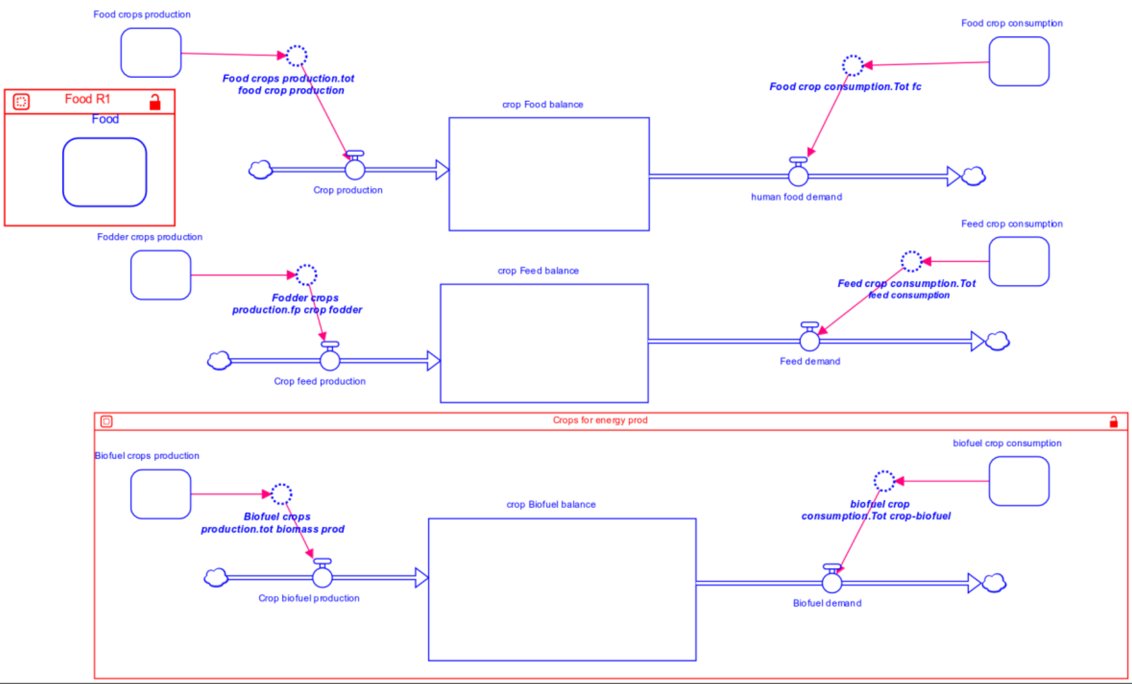


Figure 136 Basis of the food and bioenergy module

Crop produce is usually stored before consumption, be it food, fodder, or biofuel. Figure 136 shows that these stocks are considered in a simple and straightforward way, they should have been amended by diverting flows representing imports, exports, processing, and losses (spoilage). However, a more elaborate food modelling would also require separated views on carbohydrates, protein, and fat as well as on dietary scenarios etc. This is deliberately left well alone here – food is not a focus sector of this case study, because the food consumption in the case study regions is hardly connected to what is actually grown and harvested there.

However, the link between crop species and their specific products is still maintained: See Figure 137 - Figure 139 for the individual contributions adding up to aggregated production values for food, feed, and biomass, controlled by agricultural yields and cropping areas.

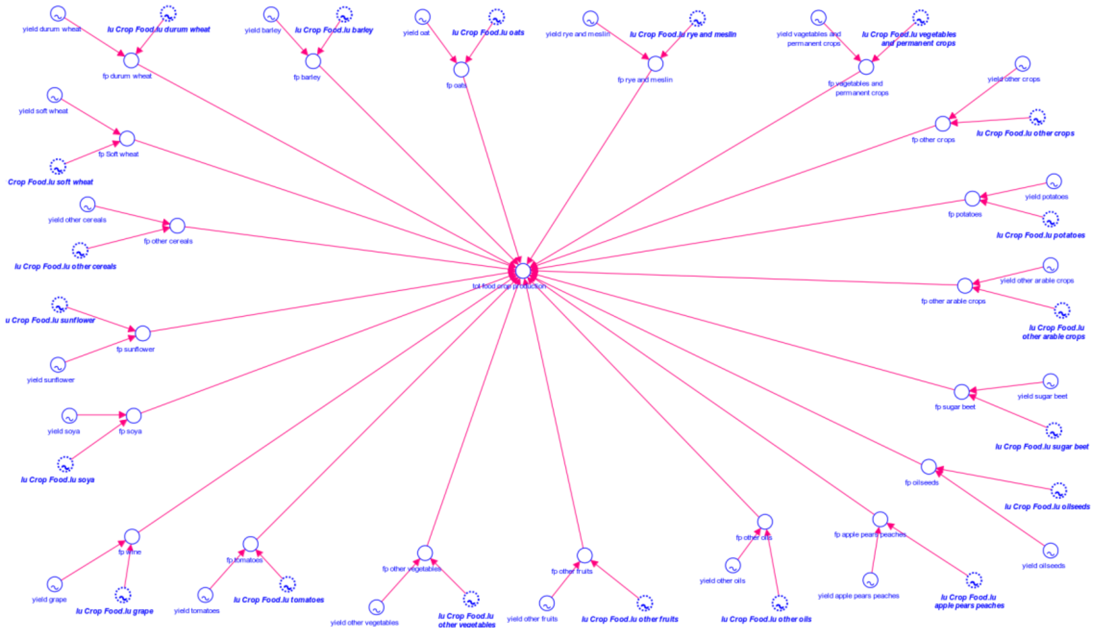


Figure 137 Food production from crops, separated by crop species

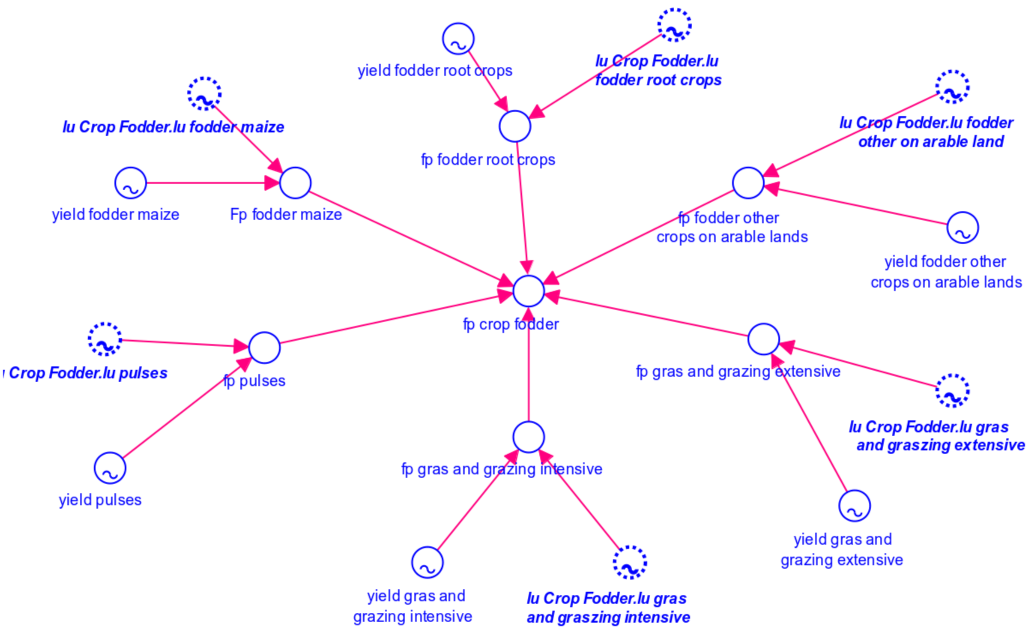


Figure 138 Fodder production, separated by crop species

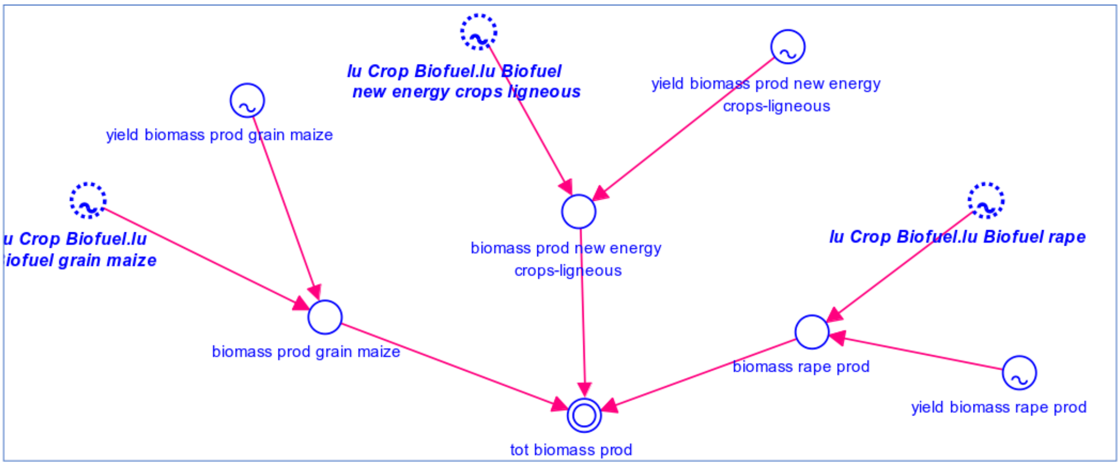


Figure 139 Production of biofuel crops

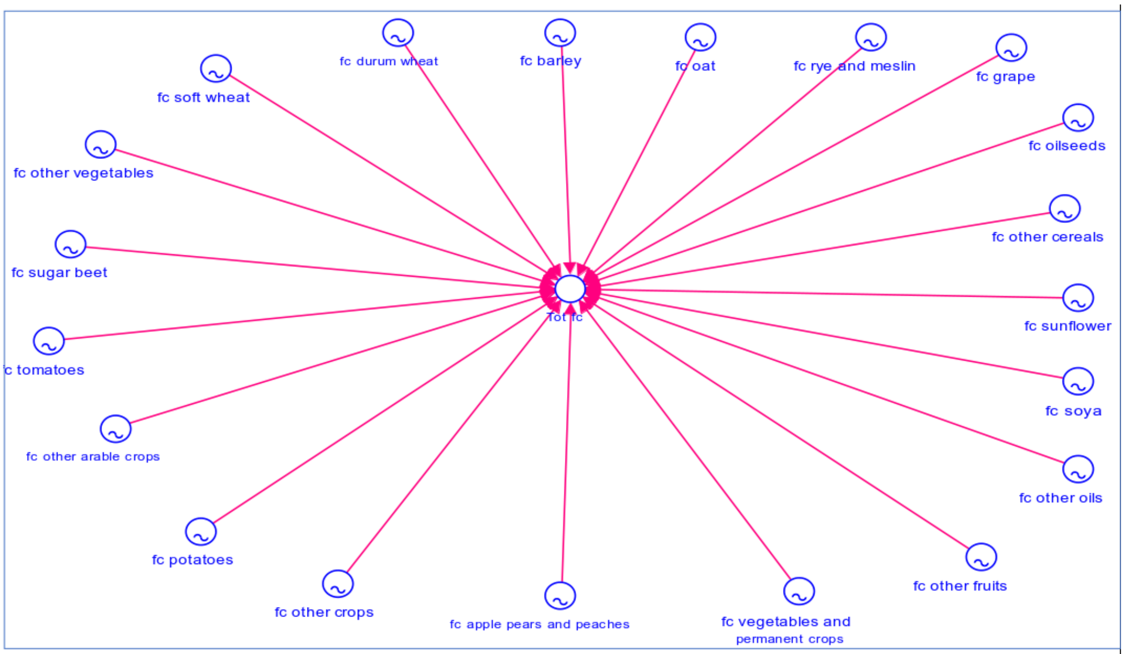


Figure 140 Consumption of food

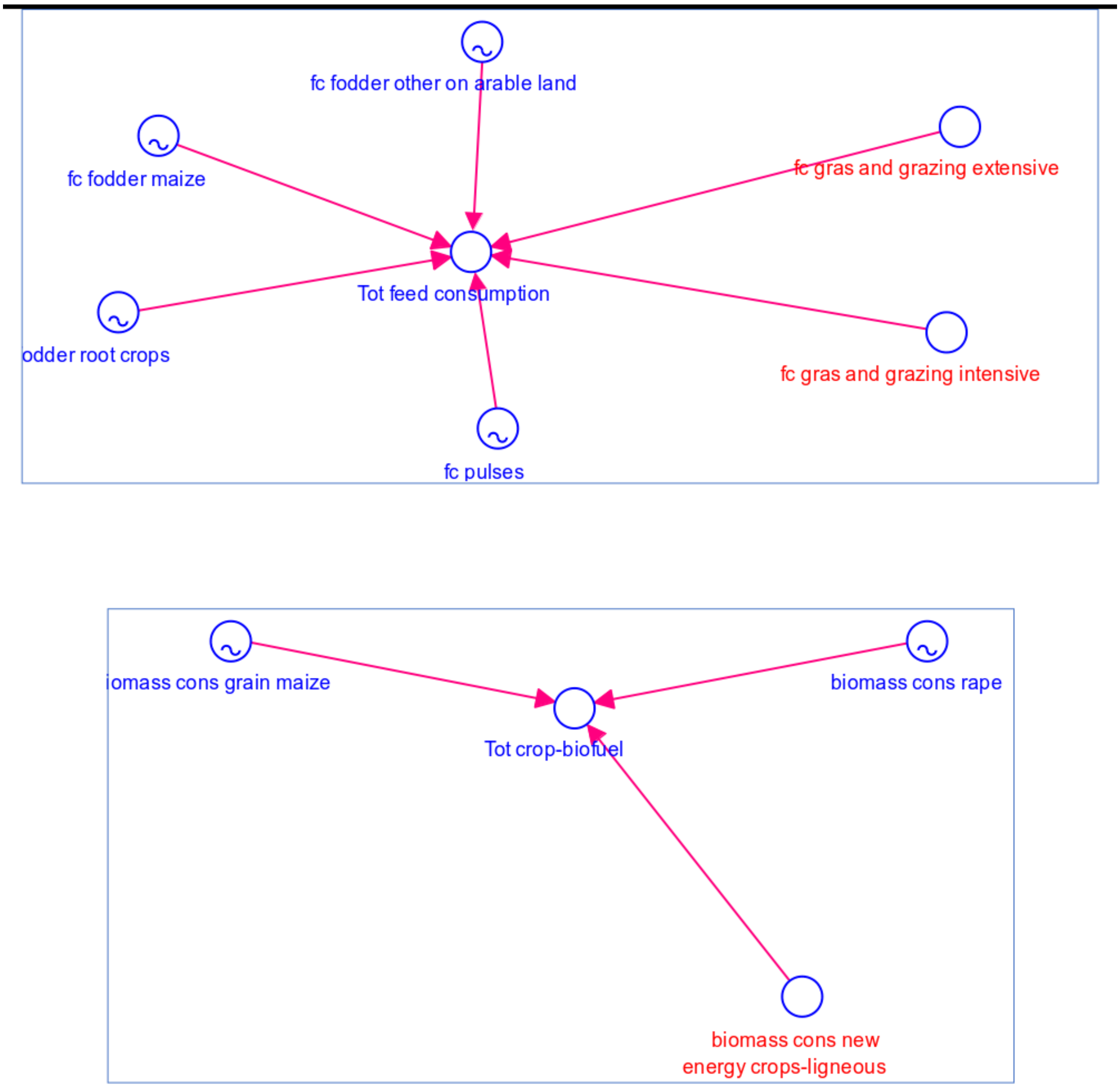


Figure 141 Consumption of fodder and biofuels

Figure 141 and Figure 142 differentiate the respective consumptions for individual crops. Again, complex intra-regional trade patterns, mutual substitution potentials, processing (e.g. fermentation for biogas) or accidental losses between production and consumption are not considered in the modelling applied for this sector.

Cropland allocation to crop species is in principle a precondition for the individual production shares considered above and finally determines the relative importance of vegetarian food vs meat vs biofuel production in the landscape. We present the dedicated area allocation control just here in because it is likewise decisive for the evapotranspiration pattern of the landscape – again linking to water and climate which are, together with land, the major foci of the DE-CZ-SK transboundary case study.

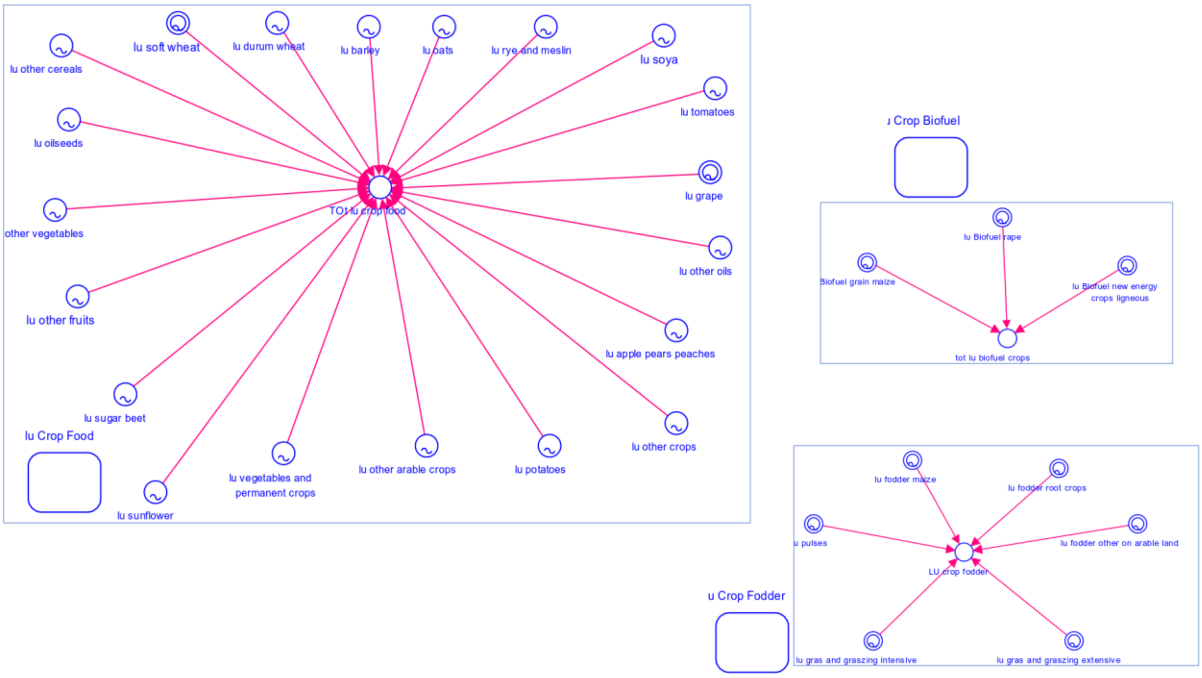


Figure 142 Cropland area extents, separated for individual crop species. The relevant data source is the CAPRI thematic model

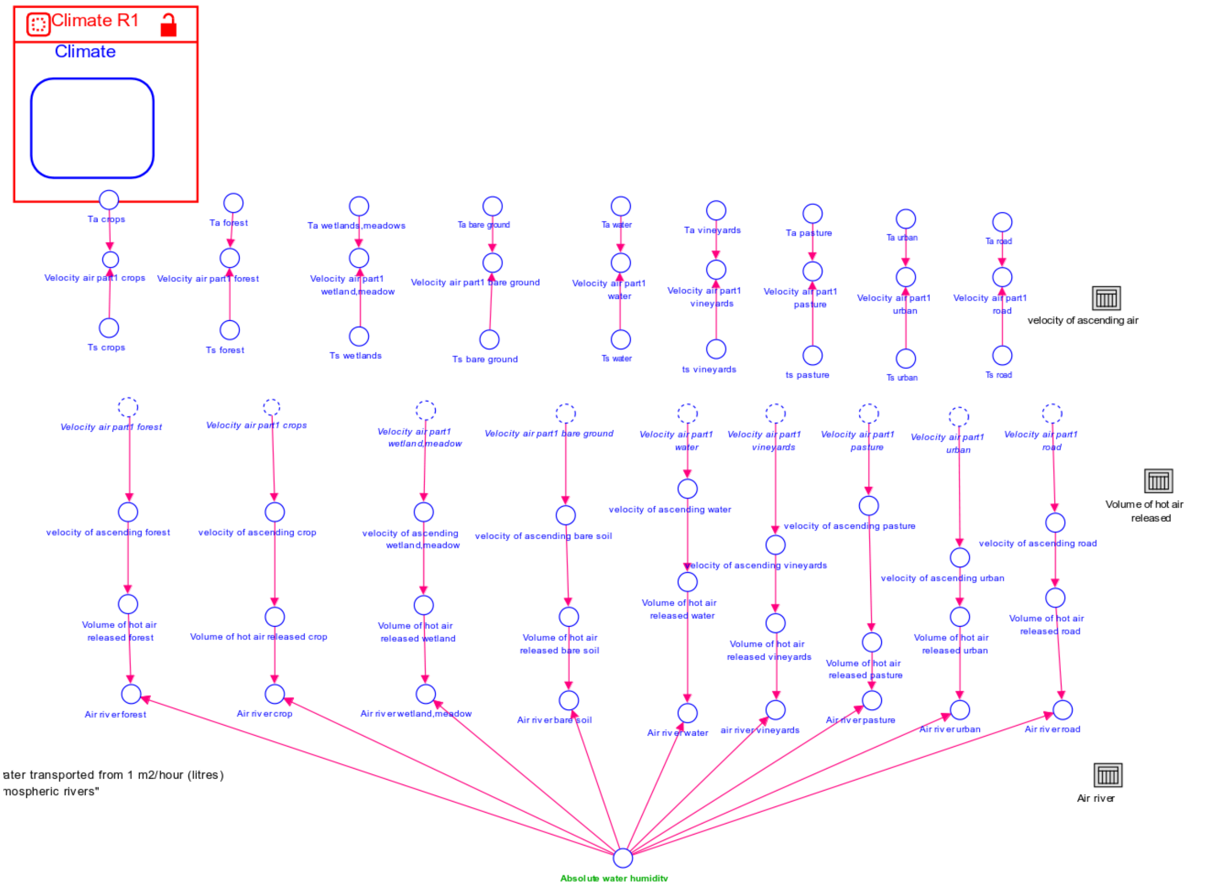


Figure 143 The climate module

These are calculated by the climate module shown in Figure 143: For each land use there are distinct air temperatures (Ta) and temperatures of the soil or canopy surface (Ts). Together with the respective actual evapotranspiration rates the velocities of the thermal convection, atmospheric water fluxes, and cooling effects are determined. Figure **144** details the submodule calculating the temperature reductions (cooling). It is assumed that a part of the warming trend observed in recent decades is not caused by the CO_2-induced global climate change but is a consequence of the systemic drought of contemporary agriculture on huge, well-drained field blocks. In former times, this effect was suppressed by higher evapotranspiration rates from a multitude of small natural water surfaces and vegetation patches interspersed between the fields which were also much smaller and cultivated more diversely compared to today.

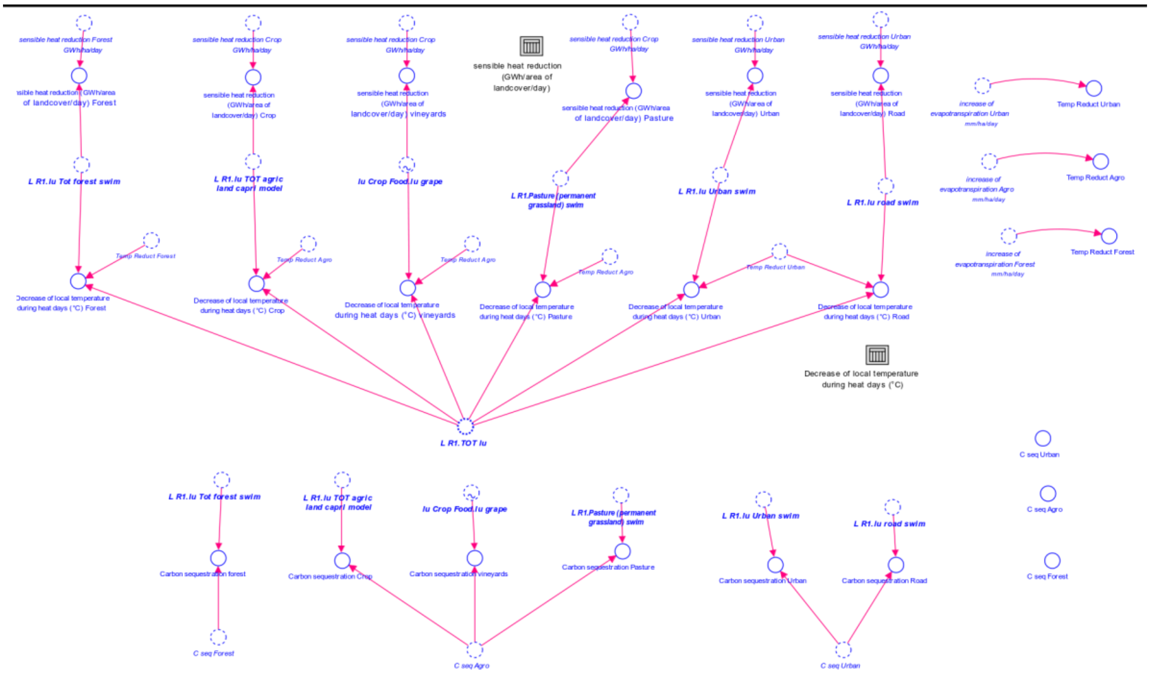


Figure 144 Calculation of landscape temperature reductions depending on evapotranspiration and land cover types. This is the main output of the climate module

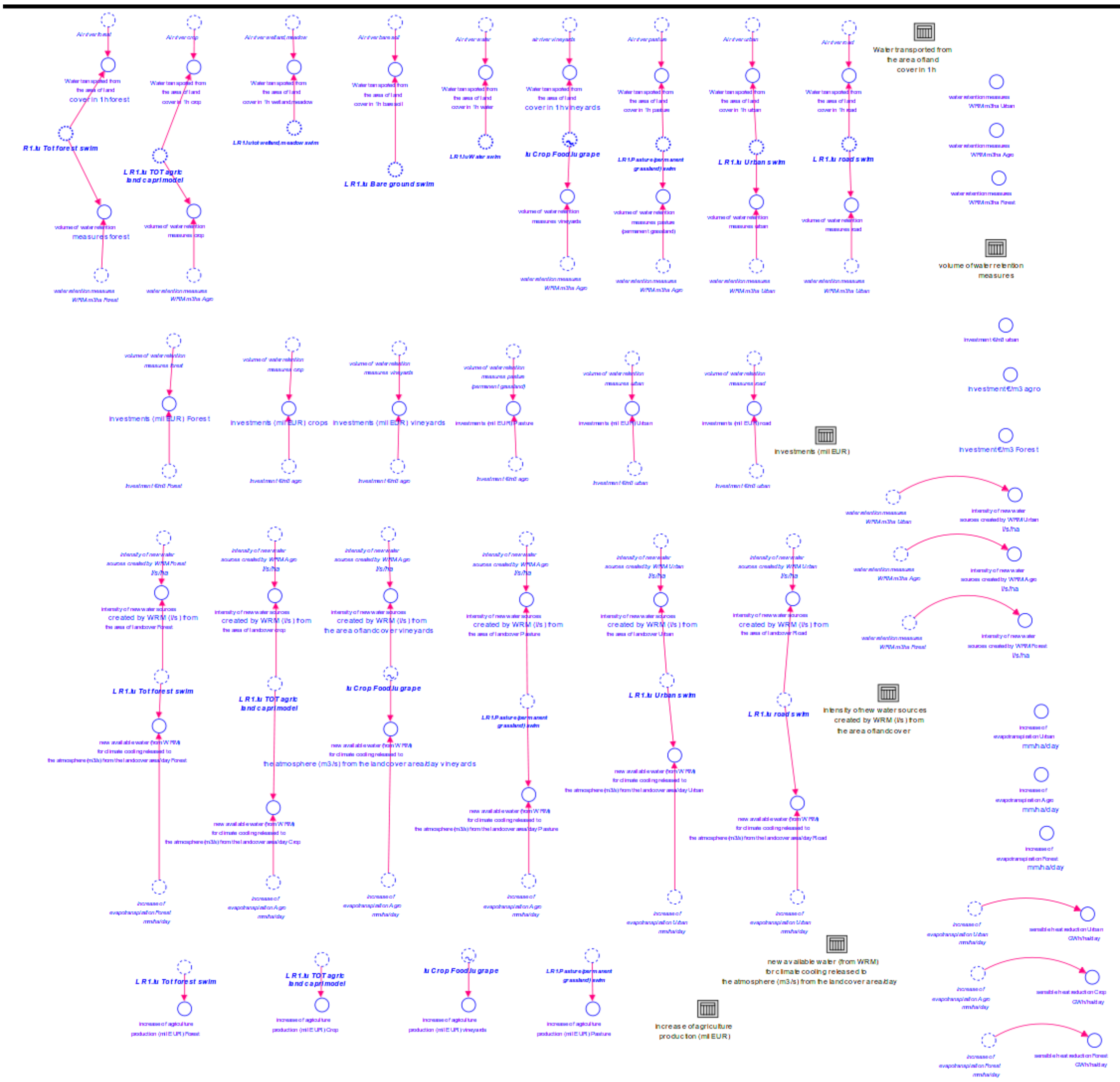


Figure 145 Interlinkages within the climate module

Figure 145 illustrates the links between climate variables and the control parameters of landscape restoration investments and water retention measures. The idea is to calculate the climate and agricultural yield effects that could be utilized by shaping the landscape towards the water storage and distribution function it had had in former times. Of course, not every parameter of this submodule can be exactly estimated, and there is an ongoing discussion to which extent a water particle that was used for landscape cooling by evaporation can maintain the surface water storage of a water retention project in the same landscape at the same time. On the other hand, crop production is probably hampered most by heat and drought, so any effort in favour of water storage and cooling would help increasing the yields. Although the model parameters can only be educated guesses, system reactions may be calibrated in a way that cause-effect relationships can still be discovered correctly in a qualitative manner through the serious game.

Finally, there is the energy module shown in Figure **146**. It is confined to the electricity sector, because the stability of the electrical power grid is challenged by severe changes on the supply side, already made and upcoming, in order to decarbonise the power sector. A nice feature – from the mathematical point of view – is that there is virtually no storage element (as shown in the graph) in the grid, supply must equal demand at any point in time. With all nuclear power stations of Germany to be shut down until 2022 and further shutdowns of fossil fuel plants planned in the next decade the probability for large and sustained blackouts is high. The idea here is to deliberately simulate this system instability, but still leave a little maneuvering space for a successful energiewende, a feature to be played with in the serious game illustrating the high sensitivity for decisions in this sector.

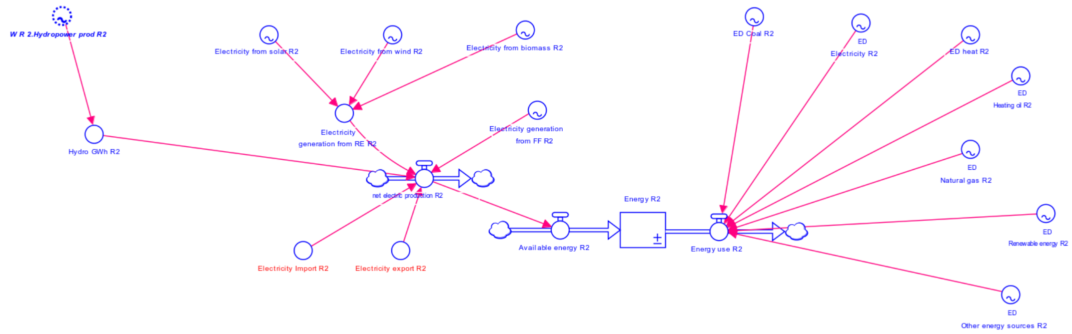


Figure 146 The energy module

11.5 From the System Dynamic Modelling to the Serious Game

11.5.1 Case studies learnings goals

The transboundary Germany- Czech Republic-Slovakian case study focuses on the effects of land use management and water retention policies on two water related indicators under stress - water quantity and quality and climate. Agro-urban zones (intensive agriculture and non-permeable urban surface) are areas with higher temperatures (heat islands). The heat is a contributor to unstable air that concentrates as clouds over areas with lower temperatures. As a result, there is less rain over the agro-urban zones, and too much rain over the mountain zones. Retention in ecosystems will lead to decrease of run-off decrease and avoid sensible heat production through evaporation. Instead of high-rising convective clouds horizontal cloud layers with rainfall across wider landscape area can be formed which do not lead to torrential rains causing local and downstream floods.

The Czech Republic transfers water to Germany through the Elbe river. Slovakia is not physically connected but faces similar issues. The greater fluctuation of water supply in downstream Germany leads to seasonal flooding, as well as a shortage of water for agriculture during dry periods, lower water quality, and sedimentation in the Elbe estuary.

Rainwater is the driving force of ecosystem recovery, atmospheric CO_2 reduction and thermoregulation of the landscape. This rainwater is currently flowing into rivers and oceans, causing peak flows without benefit for the land. Measures to retain rainwater in the landscape are based on the principle of slowing down the flow of rainwater from higher to lower places, to give it the opportunity to infiltrate and replenish the groundwater. In this way it can form a water buffer that feeds the base flow of rivers and streams during dry seasons. Measures include restoring natural courses of streams, wetlands, patches of forest and rows of trees, and constructing terraces, ponds, small dams in streams, gullies and balks perpendicular to the slopes. By retaining rainwater in damaged ecosystems, the renewal of vegetation begins, carbon sequestration, soil and groundwater reserves improve, springs are renewed, water vapour is increased and solar energy is transformed into latent heat that is transferred to higher, cooler layers of the atmosphere. There, at the dew point, this latent energy is transformed into sensible heat. The generated rainfall returns to the ground and feeds the ecosystems, stimulates vegetation growth, carbon sequestration and thermoregulation in the landscape (Figure 147). Clouds reduce the entering of solar radiation. This functional model can be quantified and implemented at individual, local, regional and global levels.

The Serious game players will therefore learn about:
1) The interrelations between effects of upstream land use and water retention policies and downstream stability of flow that may prevent floods and sedimentation, and water availability for irrigation in the Elbe/Labe basin.
2) Land use policies that increase retention of rainwater in forested, agricultural, and urban landscapes; retention in ecosystems will lead to decrease of temperature (local climate improvement), run-off, and reduce vertical cloud formation that leads to heavy local rainfall and flooding in other areas. The water retention measures will also positively affect water accumulation and thus agriculture production, carbon sequestration.

Details of the game design will however still to be defined; at the time of writing (March 2020) the serious game building for this case study had not been started due to delays in the SDM setup.

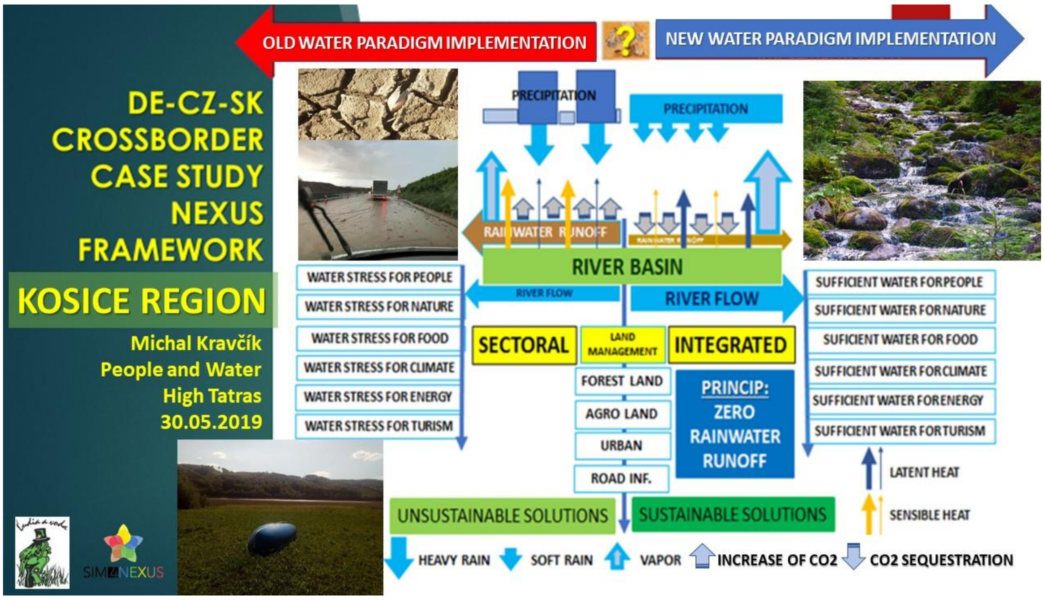


Figure 147 A New Water Paradigm for the Košice Region (SK). Schemes of unsustainable and sustainable landscape management show the principal approaches (Kravčíková, 2020a)

11.5.2 From generic to specific use cases

The specific use cases were made explicit in the framework of Deliverable D4.8 where a full listing of them is given. For illustrative purposes, we present here three of these use cases about the sectors water, energy, and climate; it should be obvious that these are highly customized to our case study and do not have very much in common any more with their generic templates.

USE CASE W.1	Water
Related Learning Goals	Sustainable management of water resources
Goal	Increase water retention in the landscape
User	Public Sector: Ministries for Agriculture and Environment
Actions	22. Building of new reservoirs 23. Restoration of natural wetlands 24. Construction of artificial bio-wetlands 25. Transform huge field blocks into small structures

	26. River restorations towards longer stream channels 27. Soil quality improvement (higher organic content, decrease of compaction) 28. Small water cycle restoration via permanent vegetation
Indicator	29. Water volume stored in the landscape 30. Share of water surface areas in the landscape 31. Balanced runoff

Step in the SG:
1. Take any of the actions, alone or combined.
2a. Observe the positive changes in the water-in-landscape indicators.
2b. Observe drawbacks with other nexus components, e.g. losses in agricultural productivity due to crop areas converted to wetlands
3. Re-consider taking actions in the next time step and loop over with 2a+b…
4. …until an acceptable trade-off between indicators is achieved

USE CASE E.2	Energy
Related Learning Goals	32. Reduction of electricity demand 33. Reduction of GHG emissions 34. Improvements for urban climate
Goal	Transformation of the building sector towards environmentally sustainable architecture and engineering
User	Governments, Ministries of Building, Energy and Infrastructure
Actions	35. Eco-technology mandatory for new buildings 36. Subsidise eco-tech for existing buildings
Indicator	37. Electricity demand 38. Volatility/stability indicator of the power grid 39. Surface-dependent temperature surplus of settlement areas (urban heat island effect)

Step in the SG:
1. Implement the measures listed under actions.
2. Observe the entirely positive shifts in all the indicators
3. Learn that the actions are effectively no-regret measures that should be taken in the framework of our serious game
4. Be aware of the bias to reality where such transformation needs decades to be accepted by the public: If you were politician in a democracy, you wouldn't be re-elected after implementing these confinements for architects and house owners.

USE CASE C.1	Climate
Related Learning Goals	Cooling the agricultural landscape, increasing precipitation and hence agricultural productivity and carbon sequestration
Goal	Reduce surface-near air temperatures by at least 2 K.
User	Regional policy makers and rural communities
Actions	40. Technical measures to cool the agricultural landscape (e.g. distribution of white pigments)

	41. Natural measures to cool the agricultural landscape (Integrated land and water management)
Indicator	42. Temperature surplus of agricultural areas 43. Agricultural productivity: food 44. Agricultural productivity: bioenergy 45. Land cover heterogeneity

Step in the SG:
1. Identify current temperature, yield and production levels.
2. Calculate costs and benefits:
   - If technical measures are chosen, increased productivity lasts only the first time step; every application of technical measures incurs however high costs
   - If natural measures are chosen, costs diminish with renewed application while productivity is sustainably increased
3. Learn that only natural measures lead to sustainable benefits in the long run.

11.5.3 Policy cards

The policy cards design was based on the concrete actions, measures and instruments that result from climate adaptation and mitigation strategies, energy policy, water acts and directives, as well as agriculture policy issued mainly by state authorities. Currently, the issues in the strategic documents are named, as well as the tools how the issue should be addressed. In some cases demands, costs, efficiency, acceptance and time horizons are also mentioned in these documents. The disadvantage is the non-binding nature and non-enforceability of these documents. The other information for policy cards development is based on the expertise and experience of the case study team with implementation of concrete actions of landscape restoration.

11.5.4 Serious Game interface

As already stated above, the serious game design for this case study had not been started at the time of writing (March 2020) due to delays in the SDM development.

11.6 From the SDM and SG to policy recommendations

11.6.1 Supporting policy coherence

The overview of Strategies and Action plans for adaptation and mitigation of climate change and water retention in landscape showed that recommendations of EU were considered and included in the national documents. However the text stays on declaration level namely in terms of water retention in landscape and aiming of agriculture subsidies to functioning landscape. Large drained fields are exceptionally modified for higher water retention and increase of permanent vegetation which accumulates carbon. The Strategies and Action plans are written from the holistic point of view however real policy is realised via individual ministries, regional offices, water boards and the main lasting obstacle are property rights. Mostly, there is high number of small owners of the land who do not agree or do not act towards restoration measures. Critical point is aiming of incentives and subsidies towards improvement of landscape structure i.e. towards real implementation of Strategies. Briefly saying needed action and measures are formulated in Strategies and Action plans in reality only small changes take place like restoration of segments of small streams, ecological farming, agroforestry which is based more on enthusiasm of individuals than on system subsidies.

Nexus approach is disseminated by the participants of the S4N transboundary study Germany – Czech Republic – Slovakia, namely by ENKI and People and Water who act in relatively smaller countries on regional level with direct contact to decision makers and politicians. They are invited to dozens of lectures and discussions on role of land cover and management measures in local/regional climate and water regime namely in last several years when drought gets stronger.

The nexus approach explains how the intensification of agriculture and urbanization interfere with the fluxes and distribution of solar energy in the landscape. Drainage and removal of permanent and functional vegetation (not only forest stands, but also wetlands, wet meadows), preference for xerophyllic and thermophilic crops leads to overheating and degradation of the landscape, resulting in increased erosion, loss of matter and nutrients. The temperature of the agricultural landscape at the peak of the ripening and post-harvest period is the same as the temperature of the industrial and urban landscape. Therefore, the land management entities deciding on its use and management (i.e. landowners, farmers, foresters, fishermen, etc.) should be considered as important "controllers" of solar energy distribution and consequently creators of the local climate. Examples from different parts of the world show that the return of functional vegetation to the landscape can help maintain water in the landscape. As examples of landscape restoration based on rainwater retention, increasing the water retention capacity of the soil and promoting permanent vegetation show, these measures lead to moderation of climatic extremes and restoration of low water circulation and closed nutrient cycles. Higher evapotranspiration leads to lowering of surface temperature, lowering of temperature gradients and thus minimizing loss of matter, nutrients and water. Simultaneously carbon dioxide is sequestrated into growing plant biomass. Pointing out, for each molecule of carbon dioxide fixed during photosynthesis, several hundred molecules of water vapour is released via transpiration of plants. The nexus approach dealing with the close relationship among: sun shine – water – plants – local climate accentuate role of land managers in local climate, water supply and carbon sequestration.

The innovative part of the nexus approach consists in an active role of landscape managers in local climate and their important role in steering of fluxes of solar energy, water and carbon dioxide. Both landscape managers and vegetation are not taken as a passive object of climate change however as an active players.

Landscape degradation in the Czech Republic, Slovakia and Eastern Germany can be considered a 'WLEFC nexus' problem. It was caused by historical developments in agricultural practices and land ownership, leading to large farms and plots. This situation has been established and enhanced by actual European and national agriculture and energy policies, with effects on land, water, climate mitigation and adaptation. The Czech Republic and Slovakia are among the countries with a high percentage of large farms or firms which receive direct payments under the Common Agricultural Policy (CAP) (https://www.europarl.europa.eu/factsheets/en/sheet/106/financing-of-the-cap). Farm sizes are also large in Eastern Germany. European and national renewable energy policies stimulate the large-scale cultivation of bioenergy crops, such as maize and rape. Good Agricultural and Environmental Conditions (GEAC) and Greening measures that are part of the CAP first pillar have only been partially implemented and did not lead to the expected results. Only a few farmers signed up for voluntary measures for sustainable agricultural land use under the second pillar of the CAP because of the administrative burden.

The case Eastern Germany-Czech Republic-Slovakia has been focusing on the impact of large drained agricultural fields and large sealed urban areas on the water regime and on the air temperature, looking at the distribution of solar energy. This resulted in a passionate plea for paying attention to the role of land cover changes in the local and regional climate change and in carbon sequestration. Water retention and support of permanent vegetation may cool down the land relatively soon, with higher primary production and carbon accumulation in the recovering soil. The European Green Deal communication (EC, 2019) addresses the Commission's proposal for the EU Common Agricultural Policy

2021 to 2027, stipulating that at least 40% of its budget would contribute to climate action. Also, the Green Deal communication mentions that ecosystems help regulate the climate and it promotes nature-based solutions. These two policy intentions mentioned in the European Green Deal communication may become reality in landscape restoration as proposed by the transboundary SIM4NEXUS case Eastern Germany-Czech Republic-Slovakia. Where feasible and useful, landscape restoration could become part of obligatory conditions for direct funding or voluntary measures in Rural Development Programmes of the new CAP. Also, the EU Renewable Energy Directive could pay attention to landscape degradation caused by the cultivation of bioenergy crops.

11.6.2 Testing policy scenarios

Due to the delays in SDM setup and SG creation we could not yet test different policy scenarios within these tools (state of March 2020). We think it will be unlikely that SDM and SG can support actual policy decision making in our case study, at least for the remaining run-time of SIM4NEXUS. The onset of the COVID-19 crisis in Europe will finally block any possibility to present the tools to any decision maker for the time being.

11.6.3 Addressing Nexus challenges

Since the beginning of the S4N project we point out the negative effect of drained areas on the regional climate and we wonder whether it can be modelled how water retention, restoration of permanent vegetation will affect the regional climate. We provided rough experimental data and expert estimates of such an effect. During the duration of the S4N project, the drought has deepened considerably, the lack of water in the landscape has increased and temperatures have risen. It is obvious and measurable that this is a consequence of drainage and changes in land cover, so we focus on the return of water and vegetation, which will also bring CO_2 sequestration. On the basis of communication with stakeholders, we have found interest in landscape revitalization, especially at local and regional level, so we follow the bottom-up approach. Unable to wait for up-bottom activities. Unfortunately there is no high interest in the results of modelling and Serious Game. In essence, Serious Games are unable to explain the principles of the direct role of vegetation and water in the distribution of solar radiation and climate. It is only considered using the Climate (SDM) submodel for educational purposes such as how changing the land cover will affect the temperature distribution and what effect water-retaining measures will have on the climate. In other words we are using SDM as a supporting tool for understanding the nexus based on exact data and principles. Improving the knowledge base, understanding, respecting and then using the basic principles of nature's functioning is a way to improve the environment in which we live.

Despite the SDM and SG cannot provide sufficient results in order to design solutions, we are using the “WLEFC nexus” in process “from water retention programmes to concrete action”. Several conferences and meetings about landscape restoration were organised in which representatives from regional governments, municipalities, research institutes and stakeholders -environmental NGOs, farmers and land owners- participated from the Czech Republic, Slovakia and Eastern Germany. Here, a programme was discussed to support pilot studies that aim at water retention in the landscape for climate change mitigation and adaptation. Since then, a concrete programme of landscape restoration has been elaborated and approved in Eastern Slovakia and a similar one is being prepared for Southern Bohemia in the Czech Republic. Ideas and approaches were presented at several conferences and dealt with local communities and politicians (cf. Figure 147). The ‘Landscape Recovery Programme’ for the Košice Region is being implemented (Košice self - government Region, 2018). Forest owners, agricultural and urban landscape managers, and local and regional authorities have been motivated to realize spatial rainwater retention. Figure 148 shows the quantified expected positive effects of the Landscape Recovery

Programme in the Košice Region in Eastern Slovakia on natural resources and carbon sequestration via primary production and retention in the soil. The return on invested money is expected to be less than 3 years. This is a concrete contribution of regional policy to climate change mitigation and adaptation in Slovakia Region Košice and its principles and calculations have also been involved into SDM (climate submodel). After implementing the whole programme, it is expected that:

- production of sensible heat will be reduced by increasing latent heat,
- temperature in summer heats will be reduced,
- 1.3 million tons of carbon will be stored in soil and vegetation,
- food production will increase,
- new water resources will be created,
- employment in rural areas will increase,
- biodiversity will increase.

Impact of landscape restoration on the water cycle, agricultural production, temperature and carbon sequestration on the case of Slovakian region Kosice

Decreasing	Area of territory	Volume of rainwater retention measures in the landscape	Investment to rainwater retention measures	The yield of new water resources in the springs	Increase of water vapour from the lands to the atmosphere	Increase of agricultural and wood production	Sensible heat reduction to the air	Expected decrease current temperature on heat days	Increasing carbon sequestration
	km3	mil. m3	mil. €	m3/s	mil. m3/year	mil. €/year	GWh/year	celsius	tons/year
Agricultural land	2 040,34	20,6	102,813	4,113	13,718	30,605	9 596	- 2,4	408 070
Vineyard	29,58	0,3	1,490	0,060	0,189	0	139	- 2,4	5 920
Gardens	154,64	1,6	7,792	0,312	1,041	0	727	- 3,2	30 930
Permanent grassland	1109,44	11,2	55,905	2,236	7,442	10,650	5 218	- 4,0	221 890
Forest lands	2691,38	10,8	54,000	2,160	7,190	26,913	5 040	- 1,6	538 280
Water lands	163,76	0	0	0	0,000	0	0	0	0
Built-up areass	344,58	9,5	47,554	1,902	6,339	0	4 438	- 7,3	68 920
Road infrastruc.	220,61	6,1	30,446	1,218	4,068	0	2 842	- 7,3	44 120
KOSICE REGION	6754,32	60,0	300,000	12,000	39,988	68,168	28 000	- 2,7	1 350 870
NOTES		To build waterholdings for rainwater harvesting	Total investment	New water sources	Increased average vapour		Minimum reduction		

Figure 148 Expected changes in several quantities caused by landscape restoration in the Košice Region on heat days (Kravčíková, 2020b). The quantification have been involved into climate submodel of SDM

Regarding the electricity supply-and-demand balancing problem under increasing contributions from renewables we are preparing a policy recommendation, also independently from potential SDM or SG outcomes:

In recent years there was regularly more electricity produced in the federal states of Eastern Germany. This picture will however change in the near future, because hard coal and lignite-fueled power plants are still the major part of Eastern Germany's electricity production, and Germany intends to phase out all sorts of coal combustion before 2038. One of the largest lignite power plants, Jänschwalde, will shut down operation already in 2028 which implies a production loss of 19.5 TWh per year alone, and there are more production decreases in sight.

Another pressure on the transnational electricity grid is the immediate shutdown of all nuclear power plants in Germany before the end of 2022. Recently, 72 TWh of electrical energy were generated per year from nuclear heat, a supply that will have to be replaced largely from other sources. Among these sources will of course be renewables. According to eurostat, their contribution to the German electricity mix emerged from virtually zero in the 1990s to currently about 40% and still appears to be slowly growing – for comparison, Slovakia reports 22% renewables share and the Czech Republic only 14% with growth stalling in both countries since 2014.

However, renewables in Eastern Germany mean principally wind power and photovoltaics, highly volatile sources. In 2019, there have been a couple of sunny hours with enough wind to exceed the demand – negative prices in the electricity market between the providers were one of the results. There have also been a few instances in which windstills, darkness, and outages of fossil-fueled power plants appeared together and required transnational electricity purchases at high price levels. In general, there is a light and wind-induced daily oscillation between over- and under-supply which quite often requires buffering by highly adaptive gas turbines and pumped storage power stations. The big question is to what degree of increasing renewables shares the power grid can be kept stable given the additional challenge of coal and nuclear plants leaving the system for good. That the problem is real is not only confirmed by our stakeholders from the energy sector but also mirrored in recent publications and a current competition of the German Federal Office of Civil Protection and Disaster Assistance (BBK 2019a,b) about recommendations for a long-term blackout.

What could be sustainable solutions? One path already taken in the course towards higher shares of renewables in electricity generation are bioenergy plants, largely fueled by silage maize, other crop residues, and animal faeces – often with methane gas as intermediate product. In contrast to other renewables, electricity from biomass could be generated demand-driven (usually it is not). However, in our eyes it is still a dead end because of the enormous demand for agricultural land.

Photosynthesis has only about 5% of the energetic efficiency of photovoltaics, even before considering the conversion losses of methane generation and biogas engines. Monocultures of maize and other energy plants negatively affect biodiversity and the regional climate (see the other parts of this policy brief) and they occupy land which could be used for food production. Another problem with biogas stations are inevitable losses of methane, one of the most potent greenhouse gases, into the atmosphere.

As the production shares of volatile renewables will and shall rise further even in other countries, two key elements to tackle the problem are:

- More transnational, high-capacity power lines to flexibly divert the electricity from actual supply areas (depending on meteorological conditions) over long distances and
- A system of storage facilities.

The erection of new power lines is often deferred or even inhibited by exhaustive approval procedures. Building and operation of any storage facilities, e.g. pumped storage power stations, should be furthered, e.g. by tax exemptions. Dedicated battery parks are however no viable solution for the time being as the environmental loads associated with battery production are tremendous.

Only a non-foreseeable development of a high-capacity battery technology without the need for toxic compounds would change this. But a lot of problematic batteries will soon be produced in any case – for electric cars. This is also the direction in which the demand for electricity, very stable across the EU over the past two decades, will grow again in the future. And here the fact that battery charging and driving are decoupled over time (disregarding outlier experiments with overhead lines on a German motorway and inductive transmission systems in city streets for local buses) must be used for flexible take-up of the renewables' supply peaks.

An empty tank requires only a short stop at the petrol station, an empty battery demands hours of charging – a problem that can only be overcome by rapid exchange of battery blocks. The massive deployment of public recharging points, one of the currently intended measures of the EU Green Deal (COM(2019)640/F1), does neither solve the hour-long stop problem nor makes it supply-driven peak charging easy (if implemented, charging would take variable amounts of time depending on the actual state of the power grid). One of the policies needed here is:

46. An obligatory technical standard for exchangeable batteries.

With that, an e-car of any model can be refilled with fresh batteries at any recharging station in a minute, and a perpetual, distributed reserve of charging batteries can buffer the grid in any region at any time of the day. There is the counter-argument that for each car at least two of the standardised batteries would have to be produced instead of a single built-in one, increasing the environmental footprint. But this neglects the fact that all batteries have a certain lifetime which can be measured in load cycles, and each standard battery produced will for sure be used until it is fully degraded and probably also serve more than one car; an individual battery might on the contrary not last for the car's lifetime or be phased out unnecessarily early.

The transformation of the energy system has already started, shutdowns of nuclear and fossil-fueled power plants are urgently needed to limit the generation of ultra-toxic radioactive waste and dangerous greenhouse gases. The EU, inter- and transnational cooperations need however to make sure that there is always enough buffer potential in the electricity system challenged by growing shares of discontinuous renewable power sources.

11.7 Conclusion

The major lessons learnt in the process of dealing with stakeholders, data, models, and scenarios can be summarised as follows: The increase of the average temperatures in the Czech Republic, Slovakia and Eastern Germany has been higher than the global average and in some regions it increased by 3.5 K between 2000 and 2020. Local climate change have been more serious than the change of the average temperature indicates. Mismanagement of the landscape has caused overheating, water losses and carbon emissions from degraded soils. The landscape has been drying out. In the last decade, production of feed crops decreased, fishponds repeatedly did not fill up and deeper wells were drilled both legally and illegally. Shortage of water has become a serious problem in agriculture, forestry, inland fishery and rural areas. Big cities were supplied with water from large water reservoirs. There was a shortage of water in rivers, minimal flow rates could not be kept, the water consumption by the industry was limited during the summer in some regions and navigation on the river Elbe was interrupted both in Germany and the Czech Republic.

While the negative consequences of recent land management become more and more obvious, the other big issue we identified has not yet caused the expected consequences: instabilities in the electrical power grid and eventually long-term blackouts affecting large parts of Central Europe. The stability of the electricity supply is challenged by the highly welcomed transition from nuclear and fossil-fuelled power generation to renewable sources. In contrast to the classical, dirty ways of electricity generation which can be operated in line with the volatile demand, the principal renewables solar energy (photovoltaics) and wind produce according to the meteorological conditions, also highly volatile but completely disconnected from actual electricity demands.

In recent years, there was a massive surge in renewables on the German side which is still ongoing while this development stalled on low levels a few years ago in the Czech Republic and Slovakia. Accordingly, the net energy transfers between the countries changed their dominant direction (currently Eastern Germany is exporting excess power, ten years ago it was a net consumer), but the challenges are the intra-daily oscillations between day and night that need to be instantly buffered, and the decision to completely phase out nuclear plants on the German side in 2021 with coal plants to follow in the subsequent years. A few pumped hydroelectric power stations are already working at their limits to maintain grid stability, but more measures are needed to make the energiewende feasible on European level.

Links between the electricity sector and land use/food production exist through bioenergy and large-scale photovoltaic installations, both requiring and transforming parts of the landscape. Currently, there are still large parts of agricultural areas (20–30% in many parts of the case study domain) reserved for silage maize and rape to be fermented to biogas or used for biodiesel. Their energy yield per hectare is much lower than in photovoltaic plants, but gas generators are a much more stable source of electricity. This Gordian knot in the Nexus towards a green and carbon-neutral energy sector makes it in principle very attractive for simulation studies and serious games offering a couple of decision-making options, the Trans-European power grid itself is however such a specialized and complex object that directly modelling its management dynamics was not feasible.

We also got aware of the current limits of modelling about the impact of landscape cover and the importance of evapotranspiration on local climate. The SDM representation of these effects is instead based on accurately measured data to describe the nexus relations between land, water, and climate.

Completely independent from the issues with modelling and entirely helpful for our system understanding were the stakeholder interactions with local stakeholders. Be it the experts from the (green) architecture/engineering, the energy providers, communal administrations, NGOs, or whoever else: We could and did learn from everyone. It is often not easy and takes some time to deepen a contact to a point where detailed insights from one's field of experience are freely shared. In a couple of cases, we could cross this margin of personal trust, and these became the most interesting and valuable exchanges with stakeholders.

The use of scenarios would probably have been bigger if we would have been able to actually simulate and compare them in the SDM/SG environment, but as already noted several times, these tools did not get to the point to be played with. Another drawback was the project-wide decision to drop the 2-degrees-scenario due to time constraints; this would have been the most independent trajectory considering the dedicated simulations on the thematic models level. Finally, scenarios were considered at least through narratives and their consequences derived in more qualitative ways.

A similarly non-enthusiastic bottom line has to be drawn for the use of SDM and SG in our case. In essence, neither SDM nor SG became tools for providing support for decision makers and sectoral policies and plans. That these could not be developed into presentable states during the final phase of the project is however only one reason. We doubt that some sector health percentages (the most prominent result of the finalized SGs) would have been able to convey the complexity of the nexus trade-offs and landscapes of the region despite our effort to divide the case study domain into 15 sub-regions – mountain and lowland landscapes with their specific peculiarities are lumped together more often than not.

However, the nexus approach itself shapes learning and thinking towards being constantly aware of the cross-connections between sectors. It automatically enhances discussion processes and urges everyone involved to take a step back and look at the situation from a broader perspective. Actions of the DE-CZ-SK case study team probably incentivised by nexus thinking included practical support for the Landscape Recovery Program in the Košice Region in Eastern Slovakia or an engagement against a planned barrage in the Elbe River near the Czech–German boundary.

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12 European

12.1 Introduction

The Continental European case study examines the impact of a transition to a low carbon economy in Europe on the five elements of the Nexus: Climate, Energy, Land, Water and Food. The case study focuses on the entire European continent which has been further divided into 6 regions, four regions within the European Union and 2 regions outside. See Figure 149 for regional definition. The time frame for the analysis is from 2010 until 2050, with future projections reported in 10 year periods.

The case study examines economic incentives, such as carbon prices and renewable energy subsidies, as well as regulatory policies on, for example, land use or transport emissions, as possible pathways for the transition to a low carbon economy in Europe as a mitigation strategy to combat climate change.

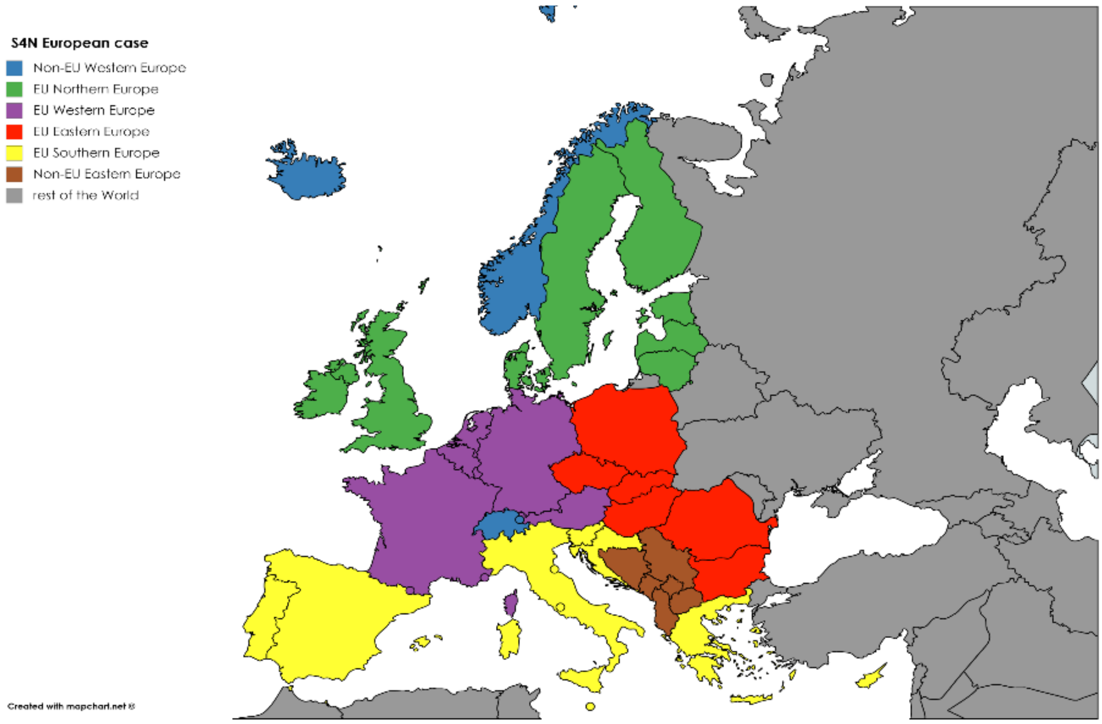

Figure 149 Spatial scale and regional definition of the European Case Study, not pictured, Greenland which is included in Non-EU Western Europe

The main focus of the European case study is to identify the synergies and trade-offs between the transition to a low carbon economy in Europe and the development of the other Nexus elements of Water, Land, Energy and Food. For example the transition to an energy system less dependent on fossil fuels may result in increased demand for bio-energy which may put increased pressure on scarce land resources and increase food prices. A clear trade-off between fewer greenhouse gas emissions from energy and food security. An example of synergies among the nexus policy goals on the other hand would be a push to more healthy diets in Europe which reduces the demand for meat and livestock herds and in turn reduces the greenhouse gas emissions from agriculture.

Unlike the national and regional case studies which engage directly with stakeholders in the form of external workshops and interviews, the Continental European case study is driven by the expertise and modelling capacity of the contributing institutes behind the thematic models involved in the project. These thematic models used to explore the nexus interactions in the European case study and supply data necessary to instantiate the system dynamics model are: MAGNET from Wageningen Economic

Research (WEcR) which is also coordinating the case study, E3ME-FTT from Cambridge Econometrics (CE), CAPRI from the Technical University of Madrid (UPM), IMAGE-GLOBIO from the Netherlands Environmental Assessment Agency (PBL), and MAgPIE from the Potsdam Institute for Climate Impact Research (PIK). The analysis of European Union nexus policies in work package 2 particularly deliverable 2.1 was also an important input for the European Case study and helped to inform the focus of the analysis.

It is hoped that the insight into the nexus synergies and trade-offs provided in this case study would then help to inform the stakeholders in developing integrated Europe wide energy, climate, water and agricultural policies.

12.2 Overview of tasks performed

12.2.1 Organisation to carry-out Task 5.2

Wageningen Economic Research (WEcR) was the lead of the European case study. The two main researchers involved were Jason Levin-Koopman and Andrzej Tabeau. Several other researchers from WEcR contributed as well in various forms. The contributions of the various researched from WEcR are summarized in Table 24.

Table 68 People from Wageningen Economic Research involved in the European case study

NAME	MAIN RESPONSIBILITIES
JASON LEVIN-KOOPMAN	CASE STUDY LEAD, CONCEPTUAL MODEL OF THE SDM, POLICY CARDS PREPARATION, ANALYSIS OF THE RESULTS FROM THE MAGNET MODEL, INTERPRETATION AND INTEGRATION OF RESULTS FROM ALL CONTRIBUTING THEMATIC MODELS, CONTRIBUTION TO SIM4NEXUS PROJECT MEETINGS, COORDINATION OF INTERNAL CASE STUDY WORKSHOPS WITH CONTRIBUTING INSTITUTES
ANDRZEJ TABEAU	IMPLEMENTATION OF SCENARIOS IN THE MAGNET MODEL, ANALYSIS OF THE RESULTS FROM THE MAGNET MODEL
HANS VAN MEIJL	SUPPORT FOR CASE STUDY LEAD, ANALYSIS OF THE RESULTS FROM THE MAGNET MODEL, INTERNAL CASE STUDY WORKSHOPS WITH CONTRIBUTING INSTITUTES.
TROND SELNES	POLICY ANALYSIS AND CASE STUDY POLICY RECOMENDATIONS
DAVID CU	SCENARIO SUPPORT FOR THE MAGNET MODEL AND SDM

While WEcR was the lead of the European case study there was close collaboration with the institutes behind the many thematic models involved in the case study as well. Further Delft-IHE was responsible for the creation and implementation of the SDM and policy cards from the conceptual model and policies developed by WEcR. PBL provided the policy analysis of the nexus policies in the European Union. Table 25 shows the contributions of the people and participating institutions outside of WEcR.

Table 69 People from partners involved in the European case study

ORGANIZATION	NAME	CONTRIBUTION TO CASE STUDY
NETHERLANDS ENVIRONMENTAL	JONATHAN DOELMAN	DATA AND ANAYSIS FROM THE IMAGE-GLOBIO THEMATIC MODEL, CONCEPTUAL MODEL, CONTRIBUTION TO INTERNAL WORKSHOPS

PLANNING AGENVCY (PBL)	JAN JANSE	DATA AND ANAYSIS FROM THE IMAGE-GLOBIO THEMATIC MODEL, CONTRIBUTION TO INTERNAL WORKSHOPS
	ELKE STEHFEST	ANAYSIS FROM THE IMAGE-GLOBIO THEMATIC MODEL, CONTRIBUTION TO INTERNAL WORKSHOPS
	MARIA WITMER	POLICY COHERENCE ANALYSIS, POLICY CARDS
	STEFANIA MUNARETTO	POLICY COHERENCY ANALYSIS
CAMBRIDGE ECONOMETRICS (CE)	EVA ALEXANDRI	DATA AND ANAYSIS FROM THE E3ME THEMATIC MODEL, CONTRIBUTION TO INTERNAL WORKSHOPS
TECHNICAL UNIVERSITY OF MADRID (UPM)	MARIA BLANCO	DATA AND ANAYSIS FROM THE CAPRI THEMATIC MODEL, CONTRIBUTION TO INTERNAL WORKSHOPS
	PILAR MARTINEZ	DATA AND ANAYSIS FROM THE CAPRI THEMATIC MODEL, CONTRIBUTION TO INTERNAL WORKSHOPS
POTSDAM INSTITUTE FOR CLIMATE IMPACT RESEARCH (PIK)	BENJAMIN BODIRSKY	DATA AND ANAYSIS FROM THE MAGPIE THEMATIC MODEL, CONTRIBUTION TO INTERNAL WORKSHOPS
IHE DELFT	JANEZ SUSNIK	SDM CONSTRUCTION, IMPLEMENTATION OF POLICY CARDS IN THE SDM
	SARA MASIA	SDM CONSTRUCTION, IMPLEMENTATION OF BASELINE IN SDM

Collaboration between the various partners involved in the thematic models occurred mostly through group skype meetings as well as several in person workshops. Coordination and planning of these workshops and skype meeting was done together with the Global case study lead by PBL as the Thematic models that were involved in the European Case study were also involved in the Global Case study as well. Discussions on the policy coherence and the implementation of the SDM were done mostly using in person meetings.

Even though of the involved participants were involved with thematic models and therefore were also familiar with possibilities for quantitative representation of the nexus interactions, the interdisciplinarity of the European case study was still a challenge because each institute and model had their own focus and simplifying assumptions of the nexus. Therefore it was still quite a challenge to understand each other's perspective. This challenge was also quite enriching on the other hand as it forced the participants to critically examine their own inherent assumptions and biases on what the important nexus interactions were and how they influenced the system as a whole. The involvement of the policy experts and the system dynamic modelers included yet another perspective on the key components of coherent nexus policy implementation which helped to sharpen the focus and give clear limits to the European cases study.

In sum we conclude that the transdisciplinary character of the work to achieve results benefits the analysis but it is also clear that it takes time for the various disciplines involved to understand each other and by that take the analysis up to a new level.

12.2.2 Schedule of Task 5.2

Table 26 presents the general list of activities conducted by in the European case study. The activities include the modelling, data collection, policy analysis, stakeholder interaction, reporting and project meetings. In addition, additional activities have been undertaken such as contributions to conferences, papers and other projects.

Table 70 Overview of tasks performed in the European case study

TASKS	DESCRIPTION
THEMATIC MODELS AND DATA	
THEMATIC MODEL REPORTING TEMPLATE	DESIGNING THE COMMON VARIABLES, UNITS AND SPATIAL DETAIL REQUIRED FOR THE THEMATIC MODELS TO DELIVER TO THE EUROPEAN CASE STUDY (DONE TOGETHER WITH THE GLOBAL CASE STUDY)
SCENARIOS	DESIGNING THE POLICY SCEARIOS TO BE RUN BY THE THEMATIC MODELS
ANAYSIS AND INTERPRETATION OF MODEL RESULTS	INTEGRATION AND INTERPRETATION OF MODEL RESULTS FOR A COHERENT UNDERSANDING OF THE NEXUS CHALLENGES AT THE EUROPEAN LEVEL
DATA TRANSLATION FOR SDM	ADAPTING AND INTEGRATING THEMATIC MODEL RESULTS FOR USE IN THE SDM
POLICY	
POLICY COHERENCE	DISCUSSIONS WITH WP2 ON THE RELAVENT POLICY FOCUS/LESSONS
SDM	
CONCEPTUAL MODEL	PREPARATION OF THE CONCEPTUAL MODEL IN PPT
SDM	TRANSLATION OF CONCEPTUAL MODEL INTO FULL SDM
BASELINE DATA	POPULATING SDM WITH BASELINE DATA
POLICY CARDS	PREPARATION OF POLICY CARDS TO BE INCLUDED IN THE SDM/SG
STAKEHOLDER INTERACTION	
INTERNAL WORKSHOP 1	1ST INTERNAL WORKSHOP WITH THEMATIC MODEL EXPERTS, THE HAGUE, OCTOBER 2-3 2017
INTERNAL WORKSHOP 2	2ND INTERNAL WORKSHOP WITH THEMATIC MODEL EXPERTS, ATHENS, MARCH 13TH 2018
INTERNAL WORKSHOP 3	3RD INTERNAL WORKSHOP WITH THEMATIC MODEL EXPERTS, THE HAGUE, FEB 12-14, 2019
GREEN WEEK	PRESENTATION AND DISCUSSION AT THE GREEN WEEK, BRUSSELS, MAY 16TH 2019
INTERNAL WORKSHOP 4	4TH INTERNAL WORKSHOP WITH THEMATIC MODEL EXPERTS, RIGA, JULY 2ND 2019
REPORTING	
D1.6	USE CASES
D2.1	NEXUS POLICY COHERENCE AT THE EUROPEAN SCALE
D3.5	THEMTIC MODELS IN THE EUROPEAN CASE STUDY
D4.1	LEARNING GOALS OF EUROPEAN CASE STUDY
D4.8	UPDATE ON LEARNING GOALS OF EUROPEAN CASE STUDY
D5.2	INTERMEDIATE REPORT ON THE CASE STUDY PROGRESS

D5.5	FINAL REPORT ON THE CASE STUDY
MS18	CONCEPTUAL MODEL FOR THE SDM
PROJECT MEETINGS	
JULY 12-13, 2016	SIM4NEXUS PROJECT MEETING IN SCHEVENINGEN
NOVEMBER 15-17, 2016	SIM4NEXUS PROJECT MEETING IN BARCELONA
MAY 31ST-JUNE 2ND 2017	SIM4NEXUS PROJECT MEETING IN TREBON
MARCH 12-14, 2018	SIM4NEXUS PROJECT MEETING IN ATHENS
NOVEMBER 14-16, 2018	SIM4NEXUS PROJECT MEETING IN EXETER
JULY 3-5, 2019	SIM4NEXUS PROJECT MEETING IN RIGA
MARCH 25-27, 2020	SIM4NEXUS PROJECT MEETING IN VIENNA
OTHER ACTIVITIES	
COP 23	PRESENTATION AT THE COP SIDE EVENT BONN, NOVEMBER 8, 2017
MAGIC-SIM4NEXUS MEETING	PRESENTATION AT NEXUS SYMPOSIUM IN BRUSSELS, NOVEMBER 27, 2018
COP 24	PRESENTATION AT THE COP SIDE EVENT KATOWICE DECEMBER 13 2018
CONFERENCE CONTRIBUTION	PRESENTATION AT THE SCENARIOS FORUM 2019 CONFERENCE IN DENVER, MARCH 11-13, 2019

The main steps include:

- Understanding the different perspectives of the thematic models and integrating multiple thematic model narratives on disparate elements of the nexus into a coherent narrative for the European case study.
- Linking the nexus policy challenges and synergies found in WP2 to the nexus links and policy options in the thematic models.
- Selecting the nexus challenges identified by the thematic models and policy analysis and designing the System Dynamics Model that can capture many of these synergies and trade-offs.

Bottlenecks included:

- Many of the nexus interactions at the European level that were captured by the thematic models involve economics and economic incentives. However the system dynamics model is built for the purpose of tracking physical flows, and so could not always directly capture the dynamics we are interested in.
- While other cases studies were much more centralized, the policy analysis of the European case study was done in WP2 while the data gathering and modelling was done in WP5. Without direct contact with stakeholders we relied on discussions with WP2 to focus the analysis of the modelling results.

12.3 Engagement of stakeholders in the process

12.3.1 Overview of stakeholders' engagement in the case study

In contrast to the national and regional case studies which engage directly with stakeholders in the form of external workshops and interviews, the European case study is driven by the expertise and modelling capacity of the contributing institutes behind the thematic models involved in the project. The researchers who implement these models in the European case study bring particular expertise in a nexus element or set of nexus interactions. The stake-holder interactions in the European case study primarily took the form of frequent skype meetings and several in person workshops with the experts behind the thematic models, in often in combination with Maria Witmer or Stefania Munaretto from work package 2 who were responsible for the analysis of European Nexus policy.

The expertise behind the thematic models can roughly be categorized as follows. The MAGNET model from Wageningen Economic Research (WEcR) is an economic model which covers all Nexus interactions but with particular institutional expertise in agriculture, food and rest of bio-economy (bio-based chemicals\materials, bioenergy). E3ME-FTT from Cambridge Econometrics (CE) is an economic model with significant technical detail in energy systems. E3ME-FTT has particular institutional expertise in Energy and Climate. The CAPRI from the Technical University of Madrid (UPM), is an agro-economic model with particular expertise in agriculture and water. IMAGE-GLOBIO from the Netherlands Environmental planning agency(PBL) is an integrated assessment model with particular expertise in agriculture and land and water quality. The MAgPIE model from the Potsdam Institute for Climate Impact Research (PIK) is an agro-economic model with a focus on agriculture land and water.

In addition to the internal workshops we presented our results in Brussels at the Green Week and received feedback from audience particulate on the presentation and framing of our results. Excluding the audience in the Green week there were approximately 20 distinct individuals involved in the workshops for the European cases study. Table 71 gives an overview of the stakeholder interactions.

Table 71 Overview of the stakeholder interactions in the European Caste study

Interactions with stakeholders	Date Location	Number of participants and indicative distribution by nexus sector	Topics discussed	Outcomes / Achievements
Workshop 1	The Hague, October 2-3 2017	8 total 3 focused on Energy 4 focused on Food and Land. 1 focused on Water	Strategy for Model comparison (relevant variables, baseline and 2 degree scenarios, regional aggregation) Structure of SDM	Initial template for data comparison Initial descriptions of core scenarios. 1st structure of SDM, and regional aggregation for European Case study
Workshop 2	Athens, march 13th 2018	7 total 3 Agriculture and Food 1 Energy 1 Water 2 European Nexus policy	Links with policy work of WP2. Serious Game.	Agreed to initiate a series of 1 on 1 skype discussions between WP2 and the thematic models to ensure the policy work of WP2 is included in the baseline and 2 degree scenarios of the thematic models.

				Initial sketch of serious game goals and player perspective.
Workshop 3	The Hague, Feb 12-14, 2019	14 total 1 European Nexus policy 2 System Dynamics modelling 2 Water 2 Energy 4 land and food 3 Other	How to integrate different thematic models into the same SDM. Further harmonization of data reporting and scenario assumptions. European Nexus policy objectives.	First run of the Policy Cards for the European Case study. General structure of how the thematic models representing different elements of the Nexus will contribute to the SDM Additional variables added to the reporting template to explore key Nexus interactions for the European Cases Study
Green Week	Brussels, May 16th 2019		Results from the European Case story were presented. With feedback from the room.	Feedback on framing of results.
Workshop 4	Riga, July 2nd 2019	8 total 4 Land and Food 2 Energy 1 Water 1 Other	Thematic model results and policy recommendations. Policy Cards for the Serious Game.	Initial Policy recommendations for the case study. Consensus on the initial policy cards.

In total approximately 20 unique persons have been involved in the case study.

12.3.2 Feedback on stakeholders' engagement in the case study

All of the workshop attendees were members of the SIM4NEXUS project and therefore the commitment and intrinsic motivation was high. Most of the involved participants were also involved with a thematic model and therefore were also familiar with possibilities for quantitative representation of the nexus interactions that the other workshop participants could deliver. However because each institute and model had their own focus and simplifying assumptions of the nexus it was still quite a task to understand each other's perspective. Once we fully understood the view on the nexus that each institute brought to the workshop we realized that we agreed on the qualitative development of the nexus interactions and development until the year 2050. We must still be very careful in attempting to integrate the quantitative model results into a single system, i.e. the system dynamics model.

The interactions with the policy experts from work package 2 helped to bring necessary focus for the nexus goals and objective for the analysis and the serious game. Here too there were challenges as the obstacles to coherent nexus policies identified in work package 2 such as trust and commitment, common goals, perspectives and interests of the organizations implementing the policies were not possible to capture in either the thematic models or system dynamics model. However the nexus synergies and trade-offs identified by the policy experts could be examined by the thematic models and system dynamics model which could then further inform our policy recommendations.

This process could be made smoother in the future if more time were spent initially on understanding the nexus perspective of the participants as early as possible in the process before the jump is made to solutions in identifying synergies and trade-offs. However it is also understood that this approach requires more commitment than participation in a single workshop for most case studies. The European cases study is an exception here because of the nature of the participant being in the project.

12.4 From conceptual models to System Dynamic Modelling

12.4.1 Case study conceptual model

The Continental European case study examines the impact of a transition to a low carbon economy in Europe on all five elements of the Nexus: Climate, Energy, Land, Water and Food. To this extent the conceptual model of the SDM needed to include all nexus elements to the extent these elements contribute to greenhouse gas emissions or are impacted, directly or indirectly, by mitigation policy.

The conceptual model was built in consultation with the experts from the thematic models so we could be sure to include the key interactions between the nexus interactions and also be certain that there would be quantitative data from the thematic models to implement the actual system dynamics model when it came time to do so.

The key challenge was that several of the nexus policies implemented in the thematic models were economic incentives such as carbon prices and renewable energy subsidies as possible pathways for the transition to a low carbon economy in Europe as a mitigation strategy to combat climate change. The structure of the system dynamics model, as well as the modeling capacity within the project, however is focused on tracing physical flows and not on simulating economic behavior. The very first iteration of the conceptual model in deliverable 5.2 included many economic linkages and feedbacks. However these were eliminated from the model in consultation with Delft-IHE who was responsible for building the actual SDM. It was decided then to include only the physical nexus flows and feedbacks in the SDM. Then for the policy cards related to economic incentives to first calculate impact of the policy on the physical nexus elements using the thematic models and then to implement the change the physical nexus elements directly in the SDM. For example a carbon price on electricity generation would directly change the electricity generation mix of fossil fuels and renewables in the SDM rather than directly modeling the economic response to a carbon price in electricity sector.

The spatial coverage of the case study is the European continent, however there is a particular focus on the European Union (EU) as there are clear EU polices defined for this region. It is proposed that the system dynamics model be divided roughly into 6 regions, southern, middle and northern areas of the EU, non-EU member states that are members of the European Economic Area (EEA) and non-EU member states that are not members of the EEA.

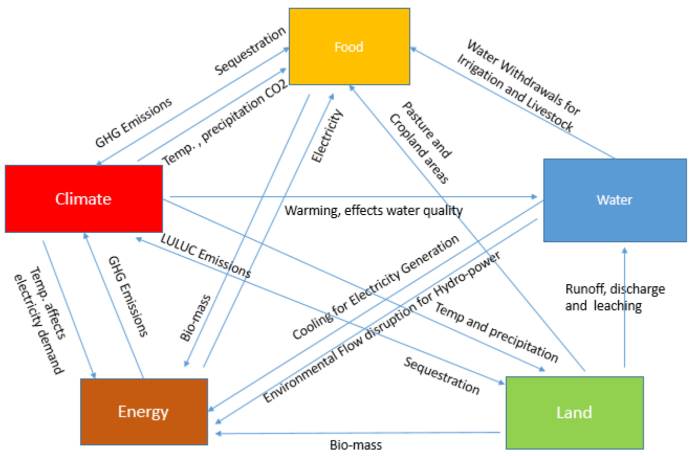

Figure 150 Main relationships between all elements of the Nexus in the European case study

Figure 150 shows the main relationships between all elements of the Nexus. The remaining figures of the conceptual models are shown in Annex 12.10.1. All relationships shown in Figure 150 can be found in the corresponding figures in the annex in more detail.

12.4.2 Modifications introduced to model policy scenarios

12.4.2.1 Development of policy scenarios for the case study

The policy scenarios for the European case study were developed in consultation with the experts from the thematic models during the workshops mentioned in section 12.3.1 and further refined during the many teleconference meetings in between. The policy scenarios were developed to provide data and insight into the main nexus interactions arising from the policy cards developed for the case study. As we had 5 thematic models exploring these scenarios we often had insights from multiple perspectives from different modeling coming from the same general policy scenario.

All scenarios were developed around the main theme of the case study: exploring alternative pathways to a low carbon economy in Europe and the impact of these pathways on all 5 elements of the Nexus.

12.4.2.1.1 Baseline

In the European case study we first analyse a baseline scenario, which is run by all thematic models participating in the case study. This baseline is informed by the 2nd Shared Socio-economic Pathway (SSP2) which is the "business as usual" future projection scenario for the period 2010-2050 O'Neill et al. (2017). The results from the other policy scenarios described in this deliverable on the Water, Land, Energy, Food and Climate (WLEFC) nexus are then compared to the baseline results to explore the Nexus impacts of various transition pathways to a low carbon economy. This study has a particular focus on Europe but connects the future projections of the nexus related developments in Europe with larger SSP2 trends and developments related to the nexus around the globe. For more detail on the exact implementation of the baseline scenario in all participating models see Milestone 17.

12.4.2.1.2 2 degree scenario

Mindful of international commitments to reduce greenhouse gas emissions this case study has a particular focus on the large scale mitigation possibilities of, for example, carbon taxes, renewable energy subsidies or increasing designated nature areas as a carbon sink. To explore this, all participating thematic models ran a “2 degree” scenario where various mitigation policies were enacted to alter the global greenhouse gas emission pathway from the baseline to an emission pathway consistent with restricting global warming by 2 degrees by the end of the century. The baseline emission pathway follows the representative concentration pathway (RCP) 6.0, while the 2 degree scenario follows the RCP2.6 (van Vuuren et al. 2011a,b). Each participating thematic model was given the freedom to choose the mitigation policies that best suit the logic of their model. An overview of the mitigation policies implemented in each model is given in Table 72. A detailed overview is given in Milestone 17.

Results from an additional European 2 degree scenario are presented by the MAGNET model. This scenario explores the possibility that Europe completes the transition to the RCP2.6 emission pathway but the rest of the world remains in the baseline business as usual scenario. The MAGNET model implements the mitigation policies in the Global 2 degree scenario primarily via a carbon tax and restrictions on agricultural land expansion. In the European 2 degree scenario this same tax is applied only to Europe.

Table 72 An overview of the climate mitigation policies for the thematic models

Models	Model type	Economic Coverage	Nexus focus	Main Climate Policies
MAGNET	General Equilibrium	Full Economy	Energy and Agriculture	Carbon Tax on all emissions; Land Based mitigation from IMAGE
IMAGE	Integrated Assessment	Linked to MAGNET	Land, Agriculture, Energy	Carbon tax on energy and industry, protection of all forests with carbon storage of >10 tC/ha, mitigation in agriculture based MAC from Lucas et al. (2007)
CAPRI	Partial Equilibrium	Agriculture	Agriculture	Price on non-CO2 emissions in Agriculture
E3ME	Econometric	Full Economy	Energy and Climate	Carbon tax, investments in energy efficiency and renewable energy, regulations on energy efficiency, vehicle emission etc…
MAgPIE	Partial Equilibrium	Agriculture	Agriculture	Increase in Bio-energy demand consistent with Popp et al. (2018); Land based mitigation reforestation based on NDCs;mitigation in agriculture based MAC from Lucas et al. (2007)

12.4.2.1.3 2 degree scenario with increased technology

The “2 degree with increased technology” scenario is based on the initial 2-degree scenario but with higher learning rates for renewables in power generation, household heating and transport technologies. This scenario is run exclusively by the E3ME model, taking advantage of this models detail in the energy sector.

In power generation the learning rates for bioenergy generation, wind, solar, tidal and geothermal technologies are increased by 30 percent compared to the standard 2-degree scenario. Solar technology sees a 20 percent increase in learning rates. No changes have been made to hydro-power. For transport technologies a 10 percent increase in learning rates has been added for hybrids and electric vehicles. For household heating, a 10 percent improvement in learning rates has been added to heat pump technologies and solar thermal. The changes in learning rates have been implemented from 2020 onwards.

12.4.2.1.4 Diet transition towards eating less animal products scenario

The “Diet transition towards eating less animal products” scenario implements a dietary transition in Europe of a 35 percent reduction in meat consumption as compared to the baseline. This transition takes place gradually over the period 2020-2050 with the same percentage reduction in meat consumption per period. Total expenditure on food is fixed so the reduction in meat consumption is replaced by increased consumption of crop based food products. This diet transition is for Europe only but is similar in nature to the global diet scenario described in Frank et al. (2019).

12.4.2.2 Introduction of policy scenarios in the SDM

Unlike the national and regional case studies which engage directly with stakeholders in the form of external workshops and interviews, the Continental European case study is driven by the expertise and modelling capacity of the contributing institutes behind the thematic models involved in the project. Therefore the Conceptual model and later the System Dynamics Model was built in consultation with the experts from the thematic models to ensure that we would be able implement quantitative data coming from the thematic models into the System Dynamics Model when it came time to do so. Therefore no changes needed to be made to the structure of the System Dynamics Model to incorporate the information coming from the thematic models in the policy scenarios.

Many of the dynamics within the several of the thematic model however are driven by economic optimization, which the System Dynamics Model is to track physical flows. In the thematic models economic agents change their behavior based on the prices of goods they are producing or consuming. Prices in their turn fluctuate based on demand and supply. Further many (although not all) of the policies implemented in the thematic models are economic in nature, such as a greenhouse gas emission tax, or a subsidy for renewable energy. This caused an initial mismatch between the two modeling systems.

To overcome this difference in modeling approaches we implemented the economic policies first into the MAGNET thematic model which then showed the changes in the main physical quantities resulting from the economic policies. Then the implementation of the policy card in the system dynamics model is then a direct change to several of the variables representing the main physical quantities affected by the policy. The system dynamics model then calculates the changes to the remaining variables which are only indirectly affected and not directly specified by the policy card.

12.4.3 Modifications introduced to account for data availability

12.4.3.1 Data available from the thematic models

The following is a list of parameters in the SDM that are covered by the thematic models.

Model	**Variable**	**Unit**
MAGNET	Agricultural Demand|Crops	Mt DM/yr
MAGNET	Agricultural Demand|Livestock	Mt DM/yr
MAGNET	Agricultural Exports|Non-Energy|Crops	million t DM/yr
MAGNET	Agricultural Exports|Non-Energy|Livestock	million t DM/yr
MAGNET	Agricultural Imports|Non-Energy|Crops	million t DM/yr
MAGNET	Agricultural Imports|Non-Energy|Livestock	million t DM/yr
MAGNET	Agricultural Production|Crops	million t DM/yr
MAGNET	Agricultural Production|Livestock	million t DM/yr
MAGNET	Emission | Secondary Energy|Liquids Consumption|Agriculture	Mt CO2eq/yr
MAGNET	Emission | Secondary Energy|Liquids Consumption|Domestic	Mt CO2eq/yr

MAGNET	Emission | Secondary Energy|Liquids Consumption|Industry	Mt CO2eq/yr
MAGNET	Emission | Secondary Energy|Liquids Consumption|Transport	Mt CO2eq/yr
MAGNET	Emission |Secondary Energy|Liquids Consumption|Services	Mt CO2eq/yr
MAGNET	Emission|Coal Consumption|Agriculture	Mt CO2eq/yr
MAGNET	Emission|Coal Consumption|Domestic	Mt CO2eq/yr
MAGNET	Emission|Coal Consumption|Industry	Mt CO2eq/yr
MAGNET	Emission|Coal Consumption|Services	Mt CO2eq/yr
MAGNET	Emission|Coal Consumption|Transport	Mt CO2eq/yr
MAGNET	Emission|Gas Consumption|Agriculture	Mt CO2eq/yr
MAGNET	Emission|Gas Consumption|Domestic	Mt CO2eq/yr
MAGNET	Emission|Gas Consumption|Industry	Mt CO2eq/yr
MAGNET	Emission|Gas Consumption|Services	Mt CO2eq/yr
MAGNET	Emission|Gas Consumption|Transport	Mt CO2eq/yr
MAGNET	Emissions|CH4|Crops	Mt CO2eq/yr
MAGNET	Emissions|CH4|Livestock	Mt CO2eq/yr
MAGNET	Emissions|N2O|Crops	Mt CO2eq/yr
MAGNET	Emissions|N2O|Livestock	Mt CO2eq/yr
MAGNET	Emissions|Other|Domestic	Mt CO2eq/yr
MAGNET	Emissions|production|Industry	Mt CO2eq/yr
MAGNET	Emissions|production|Services	Mt CO2eq/yr
MAGNET	Emissions|production|Transport	Mt CO2eq/yr
MAGNET	Food Demand (cap/day)|Crops	kcal/cap/day
MAGNET	Food Demand (cap/day)|Livestock	kcal/cap/day
MAGNET	GDP|MER	million US$2010/yr
MAGNET	Land Cover|Cropland	million ha
MAgPIE	Land Cover|Cropland|Energy Crops	million ha
CAPRI	Land Cover|Cropland|Irrigated	million ha
CAPRI	Land Cover|Cropland|Rainfed	million ha
MAGNET	Land Cover|Pasture	million ha
MAGNET	Population	million
E3ME	Primary Energy Consumption|Biomass	EJ/yr
E3ME	Primary Energy Consumption|Coal	EJ/yr
E3ME	Primary Energy Consumption|Gas	EJ/yr
E3ME	Primary Energy Consumption|Oil	EJ/yr
MAGNET	Primary Energy Exports|Biomass	EJ/yr
MAGNET	Primary Energy Exports|Coal	EJ/yr
MAGNET	Primary Energy Exports|Gas	EJ/yr
MAGNET	Primary Energy Exports|oil	EJ/yr
MAGNET	Primary Energy Imports|Biomass	EJ/yr
MAGNET	Primary Energy Imports|Coal	EJ/yr
MAGNET	Primary Energy Imports|Gas	EJ/yr
MAGNET	Primary Energy Imports|oil	EJ/yr
MAGNET	Primary Energy Production|Biomass	EJ/yr
MAGNET	Primary Energy Production|Coal	EJ/yr
MAGNET	Primary Energy Production|Gas	EJ/yr
MAGNET	Primary Energy Production|oil	EJ/yr

MAGNET	Primary Energy|Biomass Consumpton |Bio-Fuel	EJ/yr
MAGNET	Primary Energy|Biomass Consumpton |Electricity	EJ/yr
MAGNET	Primary Energy|Coal Consumption|Agriculture	EJ/yr
MAGNET	Primary Energy|Coal Consumption|Domestic	EJ/yr
MAGNET	Primary Energy|Coal Consumption|Electricity Generation	EJ/yr
MAGNET	Primary Energy|Coal Consumption|Industry	EJ/yr
MAGNET	Primary Energy|Coal Consumption|Services	EJ/yr
MAGNET	Primary Energy|Coal Consumption|Transport	EJ/yr
MAGNET	Primary Energy|Gas Consumption|Agriculture	EJ/yr
MAGNET	Primary Energy|Gas Consumption|Domestic	EJ/yr
MAGNET	Primary Energy|Gas Consumption|Electricity Generation	EJ/yr
MAGNET	Primary Energy|Gas Consumption|Industry	EJ/yr
MAGNET	Primary Energy|Gas Consumption|Services	EJ/yr
MAGNET	Primary Energy|Gas Consumption|Transport	EJ/yr
MAGNET	Primary Energy|Oil|Fossil Fuel	EJ/yr
MAGNET	Secondary Energy|Bio Fuel Consumption	EJ/yr
MAGNET	Secondary Energy|Bio Fuel Exports	EJ/yr
MAGNET	Secondary Energy|Bio Fuel Imports	EJ/yr
MAGNET	Secondary Energy|Bio Fuel Production	EJ/yr
MAGNET	Secondary Energy|Electricity Consumption|Agriculture	EJ/yr
MAGNET	Secondary Energy|Electricity Consumption|Domestic	EJ/yr
MAGNET	Secondary Energy|Electricity Consumption|Industry	EJ/yr
MAGNET	Secondary Energy|Electricity Consumption|Services	EJ/yr
MAGNET	Secondary Energy|Electricity Consumption|Transport	EJ/yr
MAGNET	Secondary Energy|Electricity|Biomass	EJ/yr
MAGNET	Secondary Energy|Electricity|Coal	EJ/yr
MAGNET	Secondary Energy|Electricity|Gas	EJ/yr
MAGNET	Secondary Energy|Electricity|Hydro	EJ/yr
MAGNET	Secondary Energy|Electricity|Nuclear	EJ/yr
MAGNET	Secondary Energy|Electricity|Solar and Wind	EJ/yr
MAGNET	Secondary Energy|Fossil Fuel Consumption	EJ/yr
MAGNET	Secondary Energy|fossil Fuel Exports	EJ/yr
MAGNET	Secondary Energy|fossil Fuel Imports	EJ/yr
MAGNET	Secondary Energy|fossil Fuel Production	EJ/yr
MAGNET	Secondary Energy|Liquids Consumption|Agriculture	EJ/yr
MAGNET	Secondary Energy|Liquids Consumption|Domestic	EJ/yr
MAGNET	Secondary Energy|Liquids Consumption|Industry	EJ/yr
MAGNET	Secondary Energy|Liquids Consumption|Services	EJ/yr
MAGNET	Secondary Energy|Liquids Consumption|Transport	EJ/yr
MAGNET	Secondary Energy|Liquids Production	EJ/yr
CAPRI	Water use|Irrigation	million m3

Because the system dynamic model was built with the thematic models in mind, specifically the MAGNET model. The thematic models were able to deliver in the correct regional and sectoral detail required by the SDM and no further downscaling or post processing of the data was required.

12.4.3.2 Local data to be collected

All of the data for the System Dynamics Model was supplied by the thematic models and therefore no local data was needed or collected to supplement the data coming from the thematic models.

12.4.4 Case Study SDM in Stella/R

The system dynamics model for the European case study has 6 regions, four regions within the European Union (Northern European Union, Western European Union, Eastern European Union, Southern European Union) and 2 regions outside (Western Non-European Union, Eastern Non-European Union). See Figure 149 in section 12.1 for regional definition. Each region is divided into is divided into 5 subsystems, Energy, Climate, Food, Land and Water. Figure 151 shows this top level view of the SDM structure in the European case study.

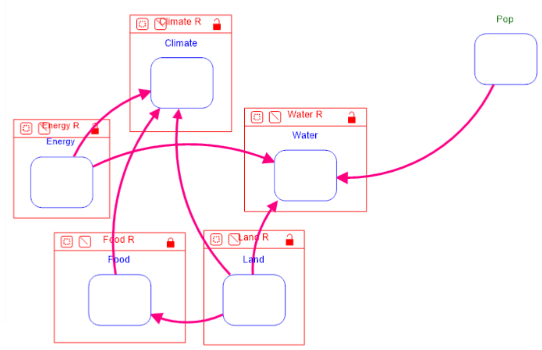

Figure 151 Top level view of the SDM in the European cases study, showing the 5 subsystems and population which is exogenously specified

The Energy subsystem of the model tracks energy production and use from primary energy to final users. Primary energy can come from fossil sources, coal, gas, oil, or from biomass. Other renewables, wind, solar and hydropower, are used exclusively in electricity production and only enter the model in the form of secondary energy. Secondary energy refers to either electricity or petrol, electricity can be produced from fossil sources or renewables, while petrol can either be produced from oil or biomass. The final users of energy are divided into 5 groups, Transport, Industry, Agriculture, Domestic use (households) and Services. Imports and exports as well as production of primary energy and petrol are included in the model as well as production. The links between energy and the other subsystems are in domestic production of biomass which uses agricultural resources and in the emissions that come from energy use.

Similar to energy, the agricultural and food subsystem tracks food from production to final use. Primary agricultural products are divided into crops and livestock, these activities use land and water for crop irrigation. They produce emissions tied to the volume of production as well as to energy use. The model includes imports and exports of crop and livestock products as well as production. After exports have been subtracted from production and imports have been added, the remaining primary agricultural products are added into processed available food where again exports of processed food are subtracted and imports are added to the total food consumed.

The Climate subsystem of the model is exclusively focused on tracking greenhouse gas emissions. These emissions are connected to energy production and use and distinguished by type. For example there is a particular emission coefficient attached to coal use in industry which is different than the emission coefficient for fossil petrol used industry, or coal used for electricity production. Further there are emissions inherently tied to the volume of output of the economic sectors themselves, e.g. transport, services, crops and livestock all have specific emission coefficients tied to their production. The land and water subsystems are exclusively tied the agricultural demands of these nexus elements.

The main challenge in designing and conceptualizing the System Dynamics Model was that many of the nexus interactions and polices at the European level that we were interested were economic in nature, such as renewable energy subsidies or a tax on greenhouse gas emissions. We initially conceived of exploring the interactions of these polices in the SDM, however this proved beyond the scope of what we could achieve in this project and so restricted ourselves to mapping the physical nexus flows within the SDM. A future project might expand on the existing European SDMs which our allow for prices changes and the corresponding changes in the behaviour of energy and agricultural consumers. These dynamics are now calculated outside of the SDM and are specified explicitly as physical changes when the policy cards are applied.

12.5 From the System Dynamic Modelling to the Serious Game

12.5.1 Case studies learnings goals

The European case study includes all five aspects of the Nexus in examining the transition to a low carbon economy. The goal is not to focus solely on the emission mitigation transition itself, but also on the interactions with other elements of the Nexus. The case study investigates how the transition will affect each sectoral policy's objectives. It explores both the economic policy incentives to facilitate - as well as the wider economic impacts of making - the transition. The relationships between the various elements of the Nexus are approached via both technical demands and economic linkages. Examples of technical demands are fuel use in transportation, emission coefficients in livestock or coal fired power plants. Examples of economic linkages via prices for goods and resources; are the impact of climate and energy policy on land prices and how these in turn affect food prices and food accessibility.

Case study learning goals
The essence of the learning will be on how policies targeting a particular GHG emission reduction pathway might interact with EU policy objectives in the Nexus domains of Food, Water, Land and Energy as well as how policies in these other Nexus arenas might help to facilitate synergies or trade-offs with the transition to a low carbon future.

12.5.2 From generic to specific use cases

The use cases for the European cases study were developed based on the learning goals of the game and the main Nexus synergies and trade-offs the game will highlight. The use case iterated and revised with comments from the WP1 team responsible for D1.2 and D1.6.

The use cases were all related to the pathways for a transition to a low carbon economy and the trade-offs and synergies with other elements of the Nexus and represent example pathways for a player maximizing an element of the Nexus at the European level mindful of the health of the other elements of the Nexus.

Three example use cases were developed for the European cases study:

47. The first is a transition pathway to a low carbon economy with a focus on the reducing emissions focusing on the sectors included in the Emission Trading System (ETS) of the European Union (electricity generation and heavy industry).

48. The second is a transition pathway to a low carbon economy with a focus on reducing emissions in the non-ETS sectors (transport and agriculture).

49. The third use case focuses on achieving the nexus health indicator for the food system which at the European Game is represented by maintain low food prices.

12.5.3 Policy cards

The basis for the policy cards was the policy analysis done in work package 2 particularly deliverable 2.1. Table 7 on page 28 of D2.1 shows the collection of policy objectives related to the Nexus from that resulted from the survey of European Union policies. This table, served as a bases for discussions with Maria Witmer from work package 2 as well as the modelling experts from the thematic models on which set of policy objectives we would explore in the European Case study that both covered the main policy objectives interreacting with the objective of a transition to a low carbon economy and also could be explored and analysed with the system dynamics model and the 5 thematic of thematic models used in the case study.

Policy cards were further developed in discussions with the thematic models. Particularly in 3rd workshop in The Hague in February 2019 and in the 4th workshop in Riga in July 2019. The acceptance and costs were estimated qualitative based on the expert judgement of the attendees of the workshops.

12.5.4 Serious Game interface

The serious game is still to come as of the time of this writing.

12.6 From the SDM and SG to policy recommendations

12.6.1 Answering main research questions of the case study

The European case study askes the question: what are the synergies and trade-offs between the transition to a low carbon economy in Europe to meet the climate goals on the one hand and the development of the other nexus elements of Water, Land, Energy and Food on the other? Further what role does resource efficiency play in this transition?

This question is necessarily explored at higher spatial aggregation than the national and regional cases studies and examines economic incentives, such as carbon prices and renewable energy subsidies, as well as regulatory policies on, for example, land use or transport emissions, as possible pathways for the transition to a low carbon economy in Europe as a mitigation strategy to combat climate change.

In this case study we have identified several main synergies and trade-offs at play at this level of spatial and economy aggregation. These nexus interactions are largely in line with and build on the nexus policy coherence work done in D2.1 and the first report on the nexus challenges in D5.2.

While there are many interlinkages (trade-offs and synergies) between the nexus elements, the main trade-offs are between reaching the climate goals of achieving a low carbon economy in Europe and goals maintaining low food and energy prices. The main synergies that we have found can all be associated with resource efficiency.

For the energy sector the main trade-offs are between the need to feed household demand for energy and power the economy on the one hand and the need to burn fuel (such as fossil fuels or biomass) to meet these requirement on the other. Reducing emissions in the energy sector to meet the climate goals may result in higher energy prices which come from a more limited supply. Similarly a push to increase the share of renewable energy requires additional investments, if these costs are assumed to be passed on to the energy consumers than this will increases prices as well.

Further increasing the use of bio-energy as an alternative to fossil fuels has a trade off with land use and nature, as land must be allocated to grow or collect the biomass. This land can then not be used by agriculture to grown food.

The main point of synergy in the energy sector between a reduction of greenhouse gas emission on the one hand and the provision of the necessary energy at a low cost is energy efficiency and savings. This is a crucial part of the transition to a low carbon economy, it reduces the need to burn fossil fuels to feed household demand for energy and to power the economy. Assuming that reduced energy prices do not in turn greatly encourage the further purchase of energy intensive devices, this reduced energy demand due to efficiency gains will reduce greenhouse gas emissions from energy. Therefore it is important that energy efficiency gains are not simply a technical feat but are paired with societal awareness on the importance of reducing emissions from energy consumption.

Trade-offs and synergies exist between transition to a low carbon economy and the agricultural sector as well. Emissions from the agricultural sector account for approximately 10 percent of total European emissions in 2010 (25 percent if we include forestry and other land use in with agriculture). Similar to the energy sector, trade-offs exist in the agricultural sector between the provision of food and other goods for domestic and international markets on the one hand and the need to reduce emissions resulting from agricultural production on the other. Limitations on production would then increase prices and reduce the competitiveness of European agriculture in international markets.

The main synergy with respect to agriculture that we focus on in this case study is between goals for improving human health and diet and the goal of reducing greenhouse gas emissions in agriculture. A shift to a diet less focused on animal proteins change in diets reduces the demand for animal products and therefore reduces the production of livestock, livestock is responsible for a significant portion of the agricultural emissions (70 percent in Europe in 2010) and reducing livestock production through a change in food preferences reduces greenhouse gas emissions, reduces pressures on land and keeps food prices low. When examining this through the lens of resource efficiency one can see that the shift in diets leads to a more efficient use of agricultural resources with respect to producing food as well as reducing greenhouse gas emissions.

Sections 12.6.2-12.6.4 go into more detail on the synergies and trade-offs mentioned in this section.

12.6.2 Supporting policy coherence

The interactions between model builders and policy experts from WP 2 brought focus on the coherence of nexus goals and objective for the analysis and the serious game. Many obstacles to coherent nexus policies identified in WP 2, such as trust and commitment, common goals, perspectives and interests of the organizations implementing the policies, was not possible to capture in either the thematic models or system dynamics model. But many of the nexus coherence issues (synergies and trade-offs) originally branded by the policy experts were examined by the thematic models and system dynamics model. This in turn further informed us to make policy recommendations.

Among the findings in this process we present here the following:

- The importance of energy efficiency on reducing consumption.
- Energy efficiency and savings can lead to lower prices which as positive impact on Energy Security.
- Increase of biomass and hydro can reduce dependence on foreign fossil fuels.
- Renewable Energy Mandates (Increase bio and Hydro) can lead to higher prices.
- Increase production of bio-energy (not only fuels) has negative impact on forest cover and preventing land use change.
- Energy efficiency and reduced consumption on resource efficiency in agriculture and forestry.
- Energy efficiency and reduced consumption on reducing emissions and on supporting the uptake of low carbon technology
- Increase energy efficiency in transport synergistic with energy efficiency in general and reducing consumption.
- Support the development of low carbon technology is synergistic with energy efficiency.
- Incentives for climate friendly land use to ensure provision of environmental public goods in agriculture.
- Increase efficiency in transport and support the development and uptake of low carbon technology -> increase efficiency in agriculture.
- Ensuring provision of environmental goods in agriculture help to restore degraded soils and prevent soil degradation.
- Resource efficiency in agriculture -> reduces GHG emissions and supports the development and uptake of low carbon technology.
- Reducing intake of animal protein reduces GHG emissions.
- Maintaining or enhancing forest cover reduces GHG emissions
- Energy efficiency and savings can lead to lower prices which has positive impact on Energy Security.
- The importance of diet change in reducing GHG emissions, limiting land use and reducing prices of agricultural commodities.
- Increase of biomass and hydro can reduce dependence on foreign fossil fuels.

The main nexus synergies and trade-offs identified in the case study are largely in line with and build on the nexus policy coherence work done in D2.1.

Deliverable 2.1 focused on the coherence of the policy objectives for the nexus related polices of the European Union. Further work in the European case study built upon this initial analysis using several thematic models to explore the interaction of the impacts of a generalized version of several of these polices. Nothing in the further analysis of the European case study contradicted the work done in in D2.1 but we have highlighted the importance of specific nexus interactions in the transition to a low carbon economy.

Deliverable 2.1 focused on a complete survey of all nexus policy objectives in current European policy while the remainder of the work in the European case study was to explore specific pathways in the transition to a low carbon economy in Europe.

12.6.3 Testing policy scenarios

Through analysis in the European case study of the System Dynamics model and the results of the thematic models which support and inform the logic of the SDM we have come to the following lessons on the conflicts and synergies with respect to policy interventions in the Nexus at the European level.

Negative emissions from bio-electricity combined with carbon capture and storage (CCS) technology is a critical component in the transition to a low carbon economy in Europe, particularly in the Eastern Europe Union region which currently producers a significant amount of electricity from coal. However large amount of bio-electricity can have a trade-off with land use for nature and agriculture to produce the necessary biomass for the increase in bio-electricity.

Energy efficiency and energy savings are central to reduce greenhouse gas emissions in Europe while limiting the amount of renewable energy needed to replace fossil fuels. A requirement for a large increase in renewable energy can increase energy prices as well as increase the use of land and agricultural resources (in the case of bio-energy). Therefore energy efficiency policies are essential in combination with other mitigation policies which encourage a transition to renewables.

Similar to energy efficiency policies, encouraging healthy diets with less meat consumption and food waste is critical for reducing emissions from livestock in Europe without high price increases for agricultural products. A policy to encourage healthy diets combined with further demands for a reduction of greenhouse gas emissions in agriculture, such as the carbon tax, is an effective combination for a more resource-efficient and low emission agricultural sector in Europe.

As low emission policies effect livestock in Europe, crop farmers can exploit some land and other resources unused in a smaller livestock sector. However, increased crop land use might increase water withdrawals as it is often more water intensive. This is particularly true in the Southern European Union Region which has a relatively high share of irrigated cropland. Therefore a policy to encourage sustainable irrigation water withdrawals is important in combination mitigation policies which might indirectly encourage expanded land use for crops by reducing livestock herds.

12.6.4 Addressing Nexus challenges

The main challenge explored by the European case study is how can Europe transition to a low carbon economy without putting undue pressure on the Energy and Food systems as well as on nature including Water and Land.

Climate:
Assuming a business as usual trajectory with respect to socio-economic trends and greenhouse gas emissions the world will be on target to achieve approximately 3 degrees of warming above pre-industrial levels by 2100[28]. Europe will also have to play a significant part in reducing greenhouse emissions to change the change the global emission trajectory to keep the world below 2 degrees of warming above pre-industrial levels by 2100.

[28] The business as usual trajectory with respect to socio economic trends is known as the second shared socio economic pathway (SSP2) (O'Neill et al., 2017).
The business as usual trajectory with respect to greenhouse gas emissions is the Representative concertation pathway RCP 6.0 (van Vuuren et al. 2011a)

The European Cases study primarily worked with the 5 thematic models, MAGNET, IMAGE-GLOBIO, MAgPIE, CAPRI, E3ME to explore the various pathways for Europe to reduce its greenhouse Gas emissions consistent with a global emission trajectory which results in 2 degrees of warming by 2100. Each participating thematic model independently developed their own "2 degree mitigation scenario" and was given the freedom to choose the mitigation policies that best suit the logic of their model. The results of the mitigation scenarios were then compared in order to gain an understanding of the variation of the possible impacts on the Nexus elements.

For the sake of consistency however the MAGNET thematic model was primarily responsible for providing the data for the systems dynamic model, however this was supplemented where appropriate with data from the other models and all thematic models contributed to the analysis of the Nexus.

The mitigation pathways will impact the various regions of the case study differently as each of the 6 regions as a different share of emissions coming different sources. Figure 152 show the sources of emissions from the 6 regions of the case study, normalized to 1.

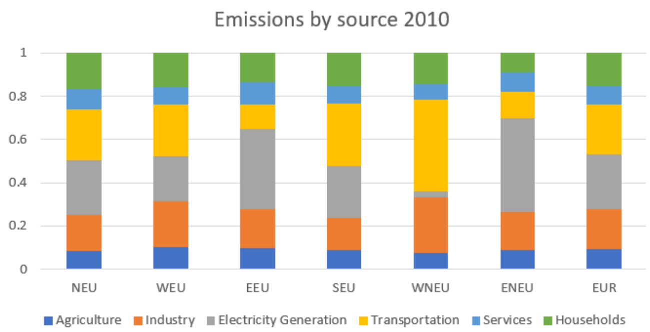

Figure 152 Emissions by final user source in the 6 regions of the European case study (Northern European Union (NEU), Western European Union (WEU), Eastern European Union (EEU), Southern European Union (SEU), Western Non-EU (WNEU), Eastern Non-EU (ENEU) as well as the total Europe (EUR)

Energy:

Greenhouse gas emissions from energy make up the lion's share of total emissions in Europe approximately 80 percent of the emissions considered in the case study. Therefore mitigation policy with respect to Energy will have the greatest impact on reaching the climate goals.

Figure 153 summarizes the total primary energy demand results for the baseline for the E3ME, IMAGE and MAGNET models. Both IMAGE and E3ME are reporting similar primary energy demand levels for coal, oil, gas and biomass in 2010. MAGNET and IMAGE forecast and increase in primary energy demand by 2050, while E3ME project a decrease in primary energy demand. The E3ME results are mainly driven by policies implemented in the EU, such as the EU-ETS, the Energy Efficiency Directive and the Renewables Directive. These policies are expected to lead both to lower energy-intensity in the economic sectors targeted as well as a decrease in demand for coal in the power generation sector in the EU. On the other hand, the IMAGE model results highlight an increase in primary energy demand for coal in the baseline. The MAGNET model projects a significant increase in the use of oil and primary energy over all, as the MAGNET model assumed very little energy efficiency growth and therefore demand incases with economic activity.

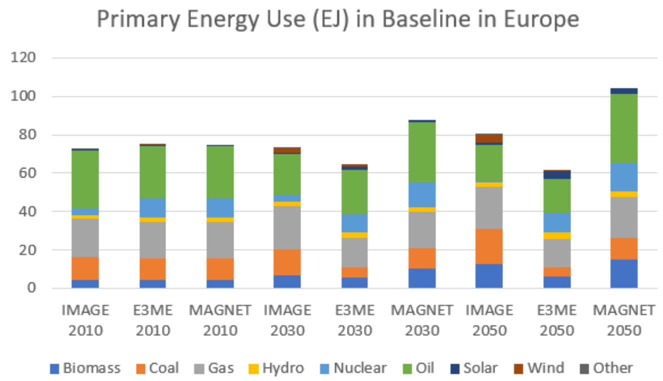

Figure 153 Primary energy consumption in the baseline SSP2 scenario in Europe from three different thematic models

These differences between the thematic models in the baseline highlight the various mitigation options with respect to energy available to the player of the serious game. The mitigation pathways explored in this case study with respect to emissions from energy use can be broadly classified into three categories. The first is energy efficiency and savings. This is a crucial part of the transition to a low carbon economy, it reduces the need to burn fossil fuels to feed household demand for energy and to power the economy. High energy efficiency and savings also reduces the need for the other two transition pathways in the energy sector, namely structural transformation and negative emissions.

The second avenue for mitigation from energy use is a structural change in energy production and use, in particular we explore a structural change in electricity generation (i.e. a transition from coal and gas to renewable sources of electricity) as well as the possibility of using biofuels for transport. This energy mitigation pathway is available to the player of the serious game in the form of renewable electricity and biofuel mandates as well as a greenhouse gas emission tax on non-agricultural emissions.

The greenhouse gas emission tax pathway reduces the overall demand for energy substantially and induces a shift from fossil based to renewables. Within the fossil mix the more GHG intensive coal and oil decline quicker than gas as these are more emission intensive.

The third avenue for mitigation within the energy system is negative emissions from the use of bio-electricity with carbon capture and storage (BECCS). BECCS is a developing technology where bio-mass is grown for bio-electricity. When bio-mass is grown it absorbs CO2 from the atmosphere and when it is burned for energy the CO2 emissions are captures and put back into the ground. Large scale use of this technology would reduce the need for the other two pathways of the energy transition (energy efficiency and structural change) however it would require a significant amount of biomass, which in turn uses land and other agricultural resources.

Food

Europe has already in 2010 reached a food supply of more than 3000 kcal per capita per day, which indicates sufficient food availability and a substantial share of food being wasted in households. The food supply in calories consists approximately of one quarter of animal-based products and three quarters of plant-based products.

In the business as usual baseline projection emissions from the agricultural sector account for approximately 10 percent of total European emissions in 2010, not including emissions from forestry and other land use. Of the agricultural emissions livestock accounts for 70 percent and 75 of those emissions in 2010 and 2050 respectively.

Some of the mitigation pathways explored in this case study aim at a reduction in the amount of greenhouse gas emissions in agriculture. One of the pathways is through a tax on all greenhouse gas emissions in agriculture (both crops and livestock) and the other is through a change in consumer diets.

The 2 degree mitigation scenario explored by the thematic models achieved by a carbon price, raises food prices and especially meat prices relatively to crop prices. Therefore, there will be a little drop in the overall food demanded and food availability. Also food access (food purchasing power) will be under pressure for lower income groups. This trade-off between mitigation and food security is conform the findings of Hasegawa et al. 2018, van Meijl et al. 2018 and Frank et al. 2019. Compensating measures, like investments in yields or additional shifts in diets are needed to avoid trade-offs between mitigation measures and food security (Doelman et al. 2019).

The GHG emission taxes induce relatively higher prices in the emission intensive meat products relative to crop products. Meat consumption will go down relative to crop consumption (Frank et al. 2019, Hasegawa et al. 2018, van Meijl et al. 2018). In general livestock production will also decline along with consumption unless a country increases its exports (or decreases imports). In Europe livestock production is much less GHG intensive than other countries and therefore it gains a competitive advantage. Livestock production is less likely to decline with a tax on GHG emissions if there is a low price elasticity of demand, the higher its GHG intensity relative to other countries, the higher the share and price sensitivity of foreign versus to domestic demand. In the MAGNET results European livestock production contracts but in the Magpie production EU livestock production expands as demand for meat is less responses to price changes and European livestock competitors achieve an advantage over other countries as their production is less emission intensive. This does mean however that prices for agricultural products in MAgPIE are much higher than in MAGNET and CAPRI.

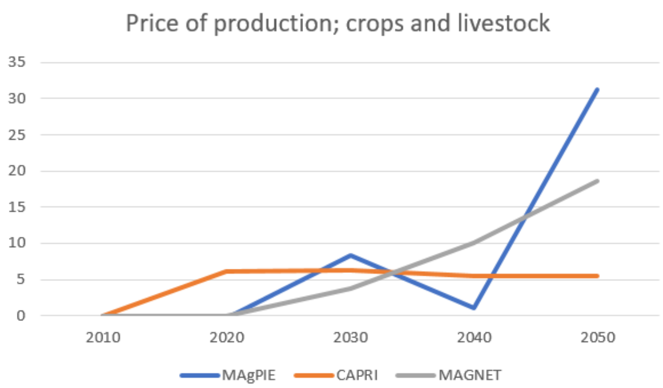

Figure 154 Average price of production of crops and livestock in Europe in the 2 degree mitigation scenario as a percent difference with the baseline

In this case study we also examined the impact of a unilateral GHG tax in Europe to explore the implications if Europe as a leader in climate mitigation. If this were the case then the adjustments in demand are softened as prices of imported meat do no not increase so much. However, production of meat within Europe will be significantly lower as Europe loses competitiveness relative to other countries. This is shown in figure Figure 155 below.

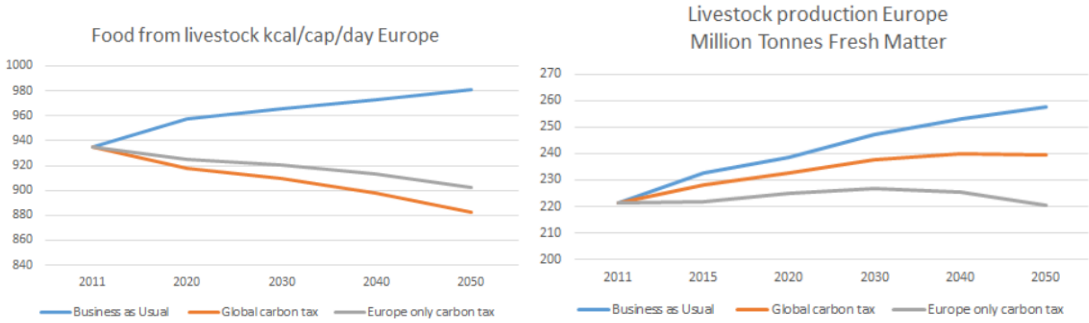

Figure 155 Food consumption (left) and production (right) from livestock products with the same tax on GHG emissions imposed globally on only on European agriculture. Results from the MAGNET model

An alternative pathway to reducing GHG emissions in agriculture is through a change in diets. That is through a change in consumer preference to more demand for plant based products and less demand for meat. This pathway has the added benefit of lowering food prices, as livestock production declines not because of higher consumer prices (which in turn reduces demand) but because of intrinsic less consumer demand. Lower food prices then has a positive impact on food security (accessibility). The increase in crop prices is minimal due the higher demand from consumers as at the same time the demand from feed diminishes.

Figure 156 shows the percent change in the price of production of crops and livestock when there is a shift in European diets from livestock products to crop based products. This diet shift is analysed for both the baseline and the 2 degree mitigation scenario. The diet shift in the baseline reduces the price of both crop and livestock outputs. The reduction in price for livestock products is due the reduction in demand, while the reduction of price of crop products, despite the increased demand for crops for food, is due to the availability of land from the shrinking livestock sector and shrinking demand of the livestock sector for feed. Similarly, a diet shift in the 2 degree scenario reduces the prices of crops and livestock compared to the 2 degree scenario without the diet shift. These reduced prices help consumers and also the crop sector which see increased demand and can expand into new land. However livestock farmers see both a reduction in demand for their products and also an increase in costs because of the mitigation measure in the 2 degree scenario.

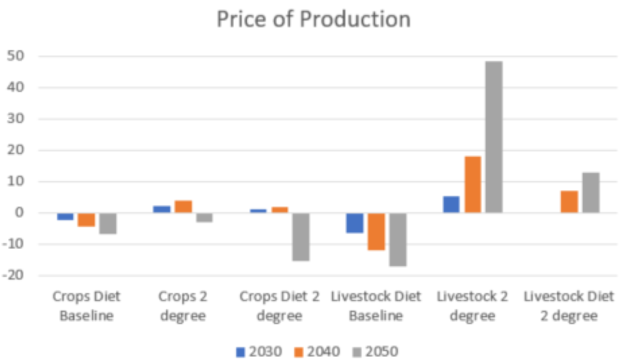

Figure 156 The price of production of crops and livestock in Europe for the three scenarios from the MAGNET model: Diet shift away from consumption animal products in the baseline, standard 2 degree scenario, and diet shift away from consumption of animal products in the 2 degree scenario. Prices are presented as percent changes from the standard baseline scenario

Both agricultural mitigation pathways result in less livestock production in Europe. If in addition to the mitigation policy there is a flexible land policy, this allows some farmers to change from livestock to crop production or alternatively allows some crop farmers to expand into areas that were previously used for livestock. This repurposing of agricultural land from livestock to crops helps to further decrease the cost crop production and keep crop prices lower that they would be otherwise.

Bioenergy production remains marginal if no climate policy is implemented. In case of a 2° policy target, the cultivation of bioenergy makes up a larger share of agricultural production, ranging up to 30% in the year 2050 in MAgPIE. With regard to the impact of bioenergy on food there are two general impacts depending on the source of the biomass. In case where biomass is sourced from residues from agricultural and forestry production, then agricultural production becomes a bit more profitable as residues get a higher price and agricultural production will expand a bit. Given the strong competition within agriculture this might induce lower food prices. When dedicated bioenergy crops have to be produced, this needs land that competes with agriculture resulting in higher land price and therefore higher food prices. This effect is larger for first generation (made of crops) then second generation (woody biomass) bioenergy\fuels is produced. From a food security (access) perspective, it is good to produce bioenergy from residues and there are trade-offs with second generation energy crops and especially first generation crops.

Land

Figure 157 shows the changes in agricultural land use in Europe in the 2 degree mitigation scenarios from the thematic models as compared with the baseline. There are many interacting factors and behavioural assumptions which determine the agricultural response to the mitigation measures imposed in the 2 degree scenario and these factors differ across the thematic models. In IMAGE and MAgPIE for example, dedicated energy crops for bio-energy can be grown on degraded lands which are unsuitable for other type of agriculture. This is not the case in MAGNET where dedicated energy crops must compete with other type of agriculture for land. The MAGNET model on the other hand makes more generous assumptions on the availability of crop residues for use in bio-energy. These crop residues provide additional income for crop farmers. The CAPRI model does not include bio-energy.

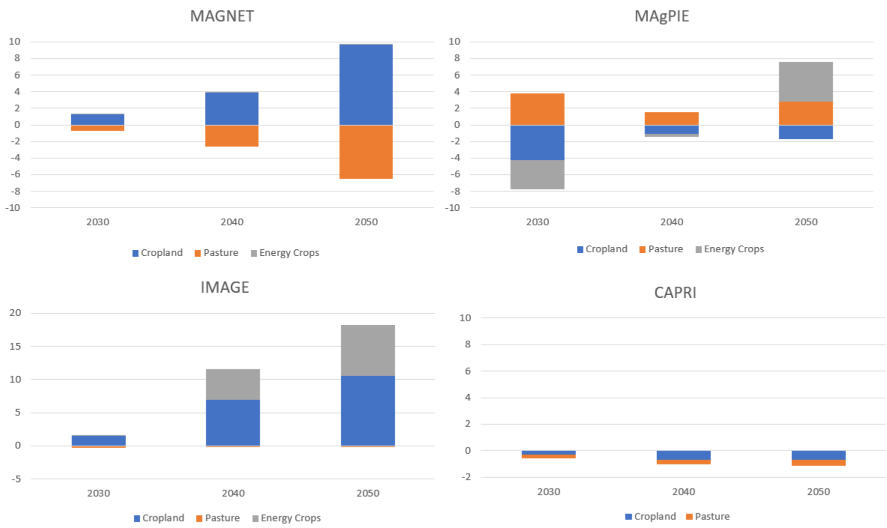

Figure 157 Changes in agricultural land use in Europe for the 2 degree scenario compared with the baseline. Unites are million square hectares

Assumptions on the competition for land between crops and livestock such as, the consumer reaction to price increases and the competitive advantage of European agriculture with compared to the rest of the world with respect to greenhouse gas emissions, also determine changing patterns in agricultural production and land use in Europe. In MAGNET higher prices for livestock products means that consumers substitute away from animal products when the prices rise. This reduced demand for livestock results in less production and the shrinking livestock sector then allows for the expansion of crop land. In MAgPIE, the demand for animal products is rather stable in the 2° scenario. Yet, pasture area is in turn increased because the ruminant sector in Europe has a low emission intensity compared to the rest of the world and therefore gains in international competitiveness under emission pricing. In 2050, bioenergy demand increases and requires additional land. Due to higher land scarcity, croplands are intensified. In IMAGE, crop and livestock production is exempted from the carbon tax. In combination with high current efficiency and further global increases in food demand this leads to an increase in cropland and continued use of existing pasture lands. In CAPRI land allocation is fixed according to the Common Agricultural Policy (CAP) and the small reductions in land use are exogenously specified. European livestock production in CAPRI increases slightly as it has a comparative advantage with non-European livestock with respect to greenhouse gas mitigation.

Similar to the impact of a GHG emission tax on agricultural production a change in diets also leads to a reduced livestock sector and, assuming a flexible land use policy, a reallocation of land from livestock to crops. Figure 158 shows this reallocation by region due from the diet change policy card coming from the MAGNET model.

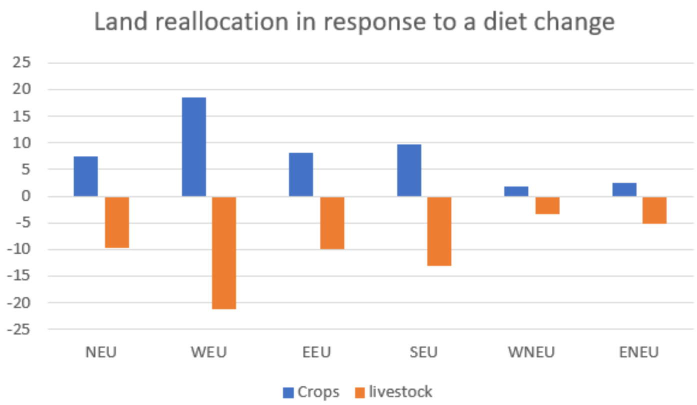

Figure 158 Change in land allocation in 2050 (in 1000 km^2) in response to the diet change policy by region in the European case study

Water

Water problems in Europe include water scarcity, water quality and flood risks. Various environmental assessments have indicated that a key environmental problem in the next decades will be increasing water scarcity (Marchal et al., 2011, Bijl et al., 2016). Water scarcity can be a threat to ecosystems, food production, rural livelihoods and electricity production. Agriculture is the dominant sector in water demand, most importantly through large-scale irrigation. In addition, the electricity, industry and municipal sectors have a substantial water demand. Especially in more arid regions, like Southern Europe, and during dry periods of the year, overall demand and competition between different sectors can cause scarcity. The occurrence of dry periods is expected to increase as a result of climate change, increasing the gap between demand and supply. Water scarcity in turn will have effects in other parts of the water-land-food-energy-climate nexus. Apart from water quantity, water quality is an important issue. While the deterioration of water quality has been stabilized or turned into some improvement especially in Western Europe, in Eastern Europe eutrophication is expected to increase due to agricultural intensification

IMAGE calculates water demand from the electricity, industry and municipal sectors. It is shown that water withdrawal for electricity generation decreases substantially in Europe due to reduced need for cooling water as the number of traditional coal-fired power plants goes down. In the mitigation scenario this process is even faster leading to much lower water withdrawal by the year 2050. In contrast, water use for hydropower (not yet included in the model calculations) is expected to increase. Water withdrawal for industry and the municipal sector is roughly stable as Europe is already at a high level and because population is projected to remain stable as well. With a global carbon tax water demand from agriculture is expected to decline as agricultural production and consumption decline (expansion effect). However it should also be said that this change in farming may change the landscape in the areas where this shift from extensive livestock to crops occurs (substitution effect). This may also have an effect on sustainable use of water resources. As crop farming expands into areas that were previously used for livestock irrigated areas may expand as well along with total water withdrawals for irrigation. With a unilateral carbon tax, water use by agriculture goes down more within the EU but will go up in other parts of the world (water leakage effect). A diet shift, does not induce the negative expansion effect, but also promotes crops versus to livestock and has similar effects. Therefore combining these policies on mitigation and dietary change with policies on irrigation withdrawals or irrigation efficiency requirements may also be needed to prevent (further) unsustainable water withdrawals.

12.7 Short-term and long-term policy recommendations

12.7.1 Summary of the Nexus issues in the case study

The Continental European case study is about how Europe can deal with the transition to a low carbon economy without putting undue pressure on the Energy and Food systems as well as on nature including Water and Land. Five elements of the Nexus are central: Climate, Energy, Land, Water and Food. The case study focuses on the European continent, divided into 6 regions, with four regions within the European Union and 2 regions outside. The case study examines economic incentives, such as carbon prices and renewable energy subsidies, as well as regulatory policies on, for example, land use or transport emissions, as possible pathways for the transition to a low carbon economy in Europe as a mitigation strategy to combat climate change.

12.7.2 Description of the policies targeted for recommendations

The policy targeted is in first instance the European Green Deal (https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en). The Green Deal focuses on better coherence and efficiency of the policy; increase synergies and deal with negative trade-offs. If trade-offs cannot be avoided or mitigated, choices must be made and negative effects mitigated or compensated. This is only possible if trade-offs were assessed and foreseen.

The European Green Deal is the current framework for dealing with climate change and environmental degradation in Europe. The EU aims to transform the EU into a modern, resource-efficient and competitive economy with no net emissions of greenhouse gases by 2050 and an economic growth that is decoupled from resource use in a social way ('no person and no place is left behind'[29]). For these purposes the European Green Deal is made as a roadmap for making the EU's economy sustainable.

[29] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

Turning climate and environmental challenges into opportunities across all policy areas and making the transition just and inclusive for all is then essential, the EU states.

12.7.3 Policy recommendations

The subtitles are indicative of the diversity of recommendations we are looking for. Please adapt with the relevant headline of your recommendations. For each policy recommendation, fill-in the "in-short" table. You can list as many recommendations as you want (not limited to 5).

12.7.3.1 Changes in policy outputs

The SIM4NEXUS European case shows that this transition to a low carbon economy might have major effects on Nexus domains as land-use and prices for energy, agriculture and food. It is therefore recommendable to be aware of major effects of changes by engaging in an early dialogue with broad parts of the society on the targets and the links to possible effects of the transition and how public and private parties could act to deal properly with the consequences. We have seen from the policy studies (Munaretto, 2018) that at a strategic level, most European and national nexus policies are coherent. However coherence issues manifest during implementation, and awareness of challenges as ambiguity, inconsistencies and conflicts are key to achieve trust and commitment from those active in the implementation stage.

We found support for this recommendation during the workshops and the GreenWeek in 2019 where the participants expressed their interest in and the importance of clarity in effects and how to achieve objectives in the nexus (SDGs, EU objectives) and see how the nexus components interact and counteract. In particular we propose a dialogue inside or between the EU-DG's on how to deal with land-use changes as a consequence of possible changes in diets or more energy-crops. This can support decision making.

In short	Conduct an early dialogue on the links between climate and resource efficiency and social effects
Target group	Initiative: EU DG Agri and DG Energy
Target policy goal	Resource efficiency: support decision making
Target policy instrument	EU Circular Economy Action Plan and the CAP Farm to Fork strategy.
Target policy process phase	EU Green Deal
Administrative level	EU
Time scale	short term
Cost-effectivity	Better view to costs and benefits
Social implications	Longer term social acceptance

12.7.3.2 Changes in policy contents

Encourage flexible land-use in agriculture

In order to reach aims for climate and food, the placing of burdens to mitigate greenhouse gas emissions on the agricultural sectors themselves (for example via a tax on GHG emissions) will result in higher food prices particularly for the livestock sector. A policy of encouraging flexible land use within agriculture can result in favourable circumstances for crop production even with increased burden of mitigation as crop farmers can take advantage of land and other resources that are not being utilized in a diminished livestock sector. This will lower food prices that would otherwise have been higher.

In short	Encourage flexible land-use in agriculture
Target group	EU DG Climate Action, DG Agri. Economic sectors
Target policy goal	Climate and food goals
Target policy instrument	Farm to Fork-strategy of CAP
Target policy process phase	EU-Green Deal
Administrative level	EU-initiative, then all levels.
Time scale	short term
Cost-effectivity	Lower food prices
Social implications	More policy support from farmers

A GHG tax on energy use will increases energy prices. Energy efficiency (in combination with a GHG tax) is an important component in reducing greenhouse gas emissions in Europe while limiting the trade-offs with other elements of the Nexus (Energy, Food, Land, Water).

In short	**More focus on energy efficiency (in combination with a GHG tax) is an important component**
Target group	EU DG Climate Action, DG Agri. Economic sectors
Target policy goal	Climate: reducing greenhouse gas emissions
Target policy instrument	EU Climate plan
Target policy process phase	EU-Green Deal
Administrative level	EU-initiative, then all levels.
Time scale	short to middle term
Cost-effectivity	Lower prices energy, possible rebound effect (more energy use.
Social implications	Support for the climate policy could be increased if the energy costs are lowered.

12.7.3.3 Innovations

In order to strengthen policy processes where stakeholders are engaged we propose that stakeholders are approached with the support of fully formed maps of the nexus interactions in their area or for their issue before asking for the stakeholder reaction and detailed opinion as opposed to coming to the stakeholders as a first step in the process, with little premade input. The European cases study can act as a example of this for further nexus related projects.

In short	Stakeholder engagement with fully formed maps of nexus interactions
Target group	EU-DG Agri (initiative). Broad participation
Target policy goal	Low-carbon and resource efficiency
Target policy instrument	EU Farm to Fork strategy and Biodiversity Strategy
Target policy process phase	EU Green Deal, process of ‘Mainstreaming sustainability in all EU policies’, in particular the sub-process ‘Stakeholders to identify and remedy incoherent legislation that reduces the effectiveness in delivering the European Green Deal’.
Administrative level	All (community, region, country, EU). Initiative EU
Time scale	Short term
Cost-effectivity	Low cost measure, but a need to use research funds

Social implications	Increase awareness and support

12.7.3.4 Changes in the policy process

Diet: stimulate less animal protein.

Encouraging healthy diets with reduced meat consumption in Europe has synergy with climate goals and will lead to a more resource efficient agriculture. The combination of this diet transition combined with further demands for a reduction greenhouse gas emissions in agriculture (for example via a carbon tax) will lead to a significant contribution to greenhouse gas reduction. However these polices have even more impact when done as part of a coalition with other countries or even globally .

In short	Diet: stimulate less animal protein.
Target group	EU DG Climate Action, DG Agri, economic sectors
Target policy goal	Low-carbon and resource efficient economy
Target policy instrument	Agriculture and food
Target policy process phase	EU Green Deal
Administrative level	EU-initiative, then all levels
Time scale	Middle to long-term
Cost-effectivity	Depends on the scale
Social implications	Mixed: resistance in the beginning is to be expected.

12.7.3.5 Changes in the science-policy interface

The recommendation 'Move the Cursor' refers to a way to use the serious game in an understandable and robust way where people have some clear causal pathways they can explore by 'moving the cursor', which means that the players actually can move the cursor over the different options to reach the different objectives in the nexus (SDGs, EU objectives) and see how the nexus components interact and counteract. This can support decision making, or be a tool for education, maybe even as a part of the training of new EU-employees. In the presentation the naming and framing should be understandable for the participants, and linked to the scenarios, and connected to the SDGs and EU goals and targets, so that people have clear associations with them. Example: food security is not associated with more or less meat consumption. Frame it as 'everybody a healthy diet and a sustainable food supply'. Also, give details about population and level of welfare in the scenarios.

One possible consequence demonstrated in the case is that changes in the diet, i.e. less meat consumption, could have great impact on the land-use. Less demand for meat would mean less animal farming and less farming in general. This in turn could be a call for compensation schemes.

In short	' Move the Cursor' Serious Game as a feeder for discussions
Target group	Policy makers EU (DG Agri), education
Target policy goal	Greening of CAP
Target policy instrument	Communication on for example the Farm to Fork strategy.
Target policy process phase	Green Deal
Administrative level	EU
Time scale	short term
Cost-effectivity	Low-cost measure
Social implications	Increasing awareness and acceptance of policy

12.8 Conclusion

The Continental European case study examines the impact of a transition to a low carbon economy in Europe on the five elements of the Nexus: Climate, Energy, Land, Water and Food. The case study examines economic incentives, such as carbon prices and renewable energy subsidies, as well as regulatory policies on, for example, land use or transport emissions, as possible pathways for the transition to a low carbon economy in Europe as a mitigation strategy to combat climate change.

In this deliverable we have identified several main synergies and trade-offs at play at this level of spatial and economy aggregation. While there are many interlinkages (trade-offs and synergies) between the nexus elements, the main trade-offs we observe are the following:

50. Reducing emissions in the energy sector to meet the climate goals may result in higher energy prices which come from a more limited supply or more costly (renewable) alternative.
51. Further increasing the use of bio-energy as an alternative to fossil fuels has a trade off with land use and nature, as land and other agricultural resources, must be allocated to grow or collect the biomass.
52. In the agricultural sector limitations on production, or additional demands for mitigation, can increase prices and reduce the competitiveness of European agriculture in international markets.
53. There is synergy in the energy sector between reducing of greenhouse gas and the promotion of energy efficiency and energy savings.
54. There is synergy between goals for improving human health and diet and the goal of reducing greenhouse gas emissions in agriculture.

Unlike the national and regional case studies which engage directly with stakeholders in the form of external workshops and interviews, the Continental European case study did not have that kind of access to the stakeholders at the European level. Therefore the many thematic models and the expertise behind them proved invaluable in assessing and quantifying the interactions between the Nexus elements.

The interdisciplinarity of the European case study was certainly a challenge as each participating institute and model had their own focus and simplifying assumptions of the nexus. Therefore it was still quite a challenge to understand each other's perspective. This challenge was also quite enriching on the other hand as it forced the participants to critically examine their own inherent assumptions and biases on what the important nexus interactions were and how they influenced the system as a whole. The involvement of the policy experts and the system dynamic modelers included yet another perspective on the key components of coherent nexus policy implementation which helped to sharpen the focus and give clear limits to the European cases study. The process of finding solutions to nexus challenges could be made smoother in the future if more time were spent initially on understanding the nexus perspective of the participants as early as possible in the process before the jump is made to solutions in identifying synergies and trade-offs.

Many of the nexus interactions at the European level that were captured by the thematic models involve economics and economic incentives. However the system dynamics model is built for the purpose of tracking physical flows, and so could not always directly capture the dynamics we are interested in. This points to the need for including economic mechanisms and feedbacks when designing a single system to represent the main nexus interactions at the European aggregation.

The main policy message of the cases study is that in addition to the stick of putting the obligation on producers of energy and food to reduce their greenhouse gas emissions in Europe which can lead to higher prices; we also recommend raising awareness with the consumers about the importance of resource efficiency, by encouraging a healthy diet and the purchases of energy saving technologies. This change in demand towards healthier cleaner products will help to reduce greenhouse gas emissions while maintaining lower energy and food prices in Europe.

The essence of the learning goals for the serious game and indeed for other communication activities of the case study are to show policies targeting a particular GHG emission reduction pathway might interact with EU policy objectives in the Nexus domains of Food, Water, Land and Energy as well as how policies in these other Nexus arenas might help to facilitate synergies or trade-offs with the transition to a low carbon future. It is hoped that the insight into the nexus synergies and trade-offs provided in this case study would then help to inform the stakeholders in developing integrated Europe wide energy, climate, water, land and agricultural policies.

12.9 References

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12.10 Annexes

12.10.1 Conceptual model

Figure 150 in section 12.4.1 shows the relationships between all elements of the Nexus. Figures 2-5 focus on the internal structures of the Food, Energy, Land and Water nexus elements. All relationships shown in Figure 150 can be found in the corresponding figures in more detail.

Unlike the other Nexus elements, Climate is not represented below by its own figure. This is because the climate element will not have internal dynamics in the systems dynamic model for the European case. That is, changes in European policies affecting emissions will not affect global temperature, weather and precipitation changes by 2050 but these will be defined by previously specified climate scenarios, along with assumed behaviour of the regions outside of Europe.

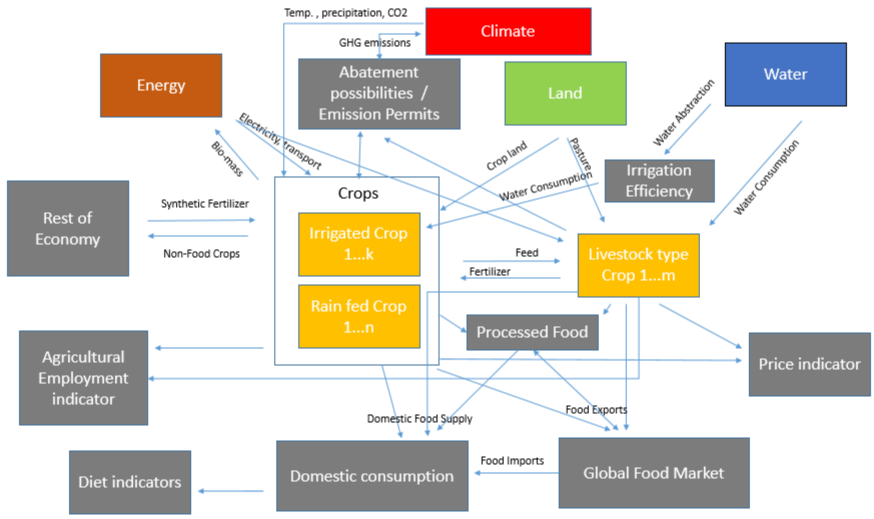


Figure 159 Conceptual model for the food system

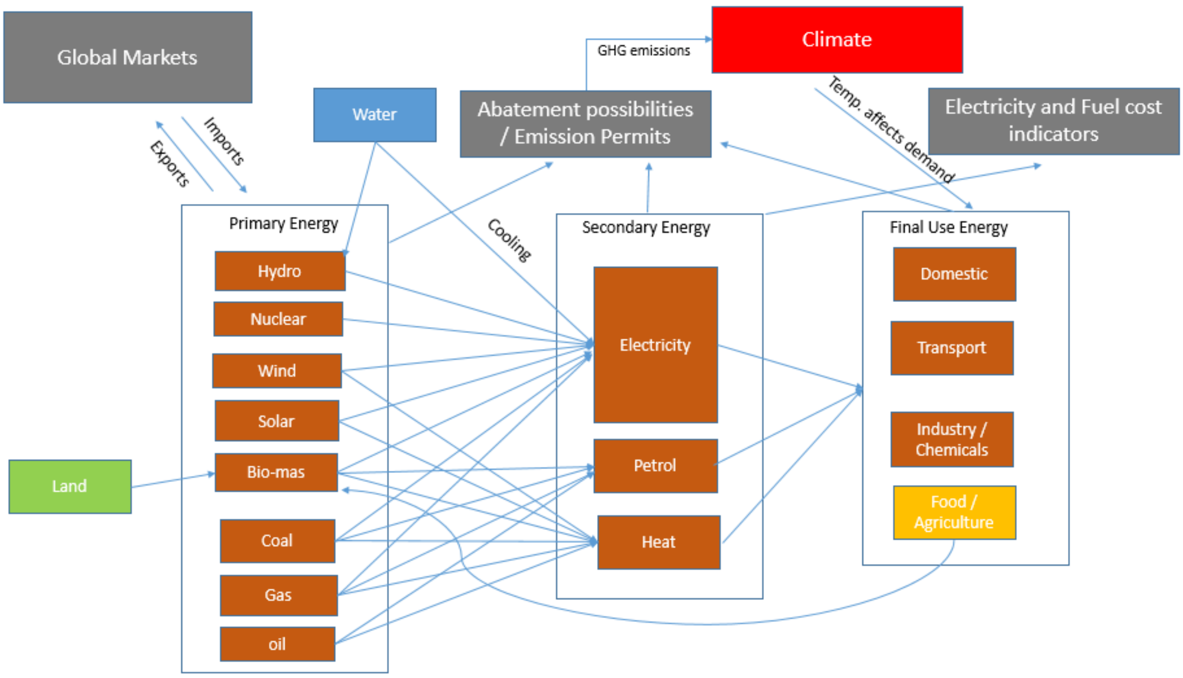


Figure 160 Conceptual model for the Energy system

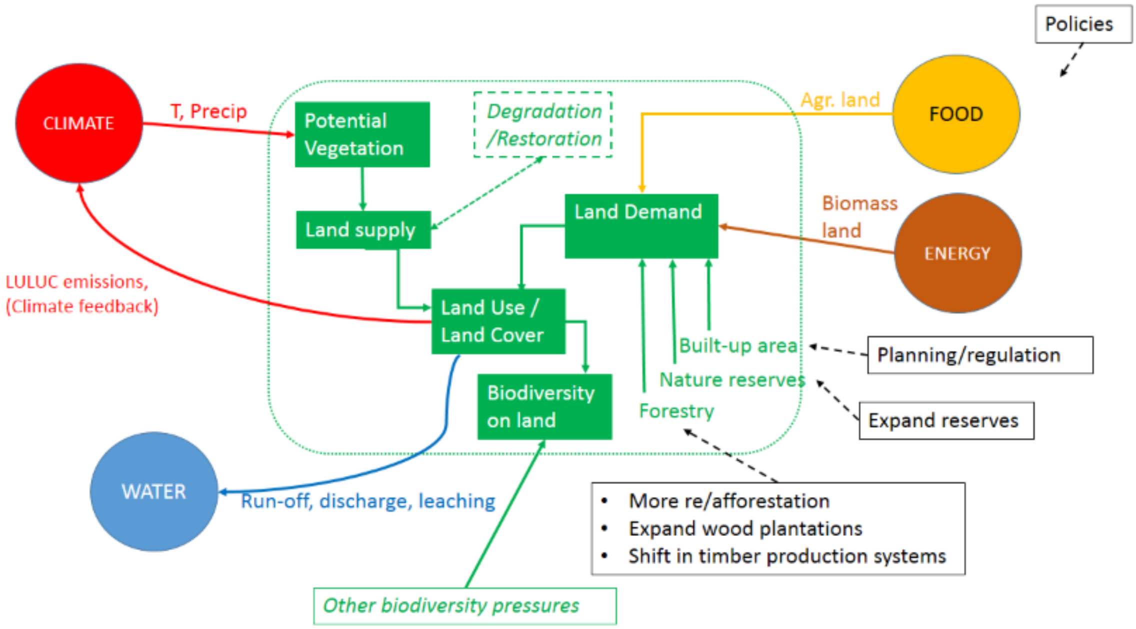
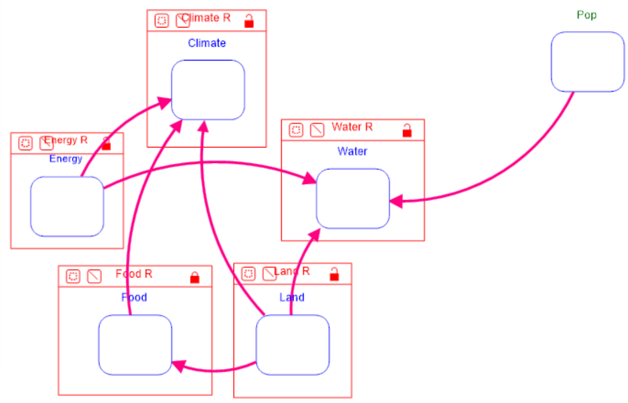


Figure 161 Conceptual model for the Land system

12.10.2 SDM screenshots



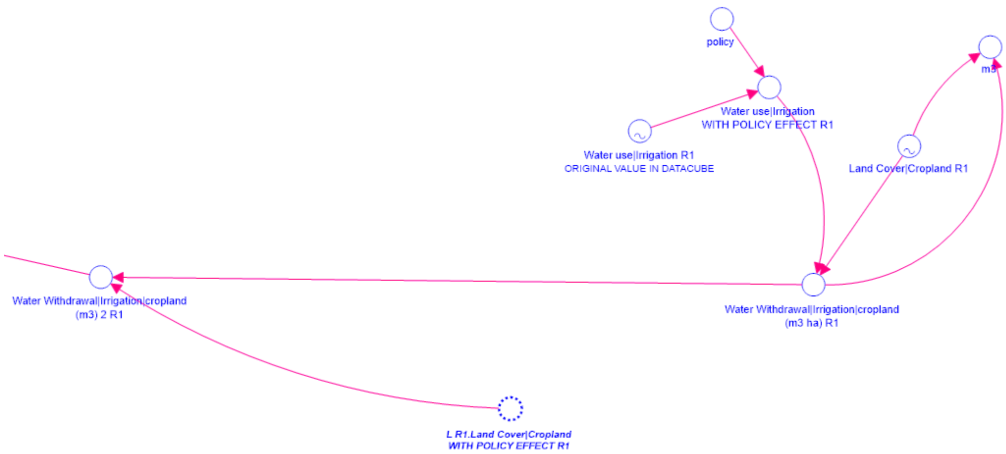


Figure 162 Water subsystem in the SDM. The model structure also allows for the possibility of an extension to include of water use in other areas, but this is not instantiated in the current version of the SDM

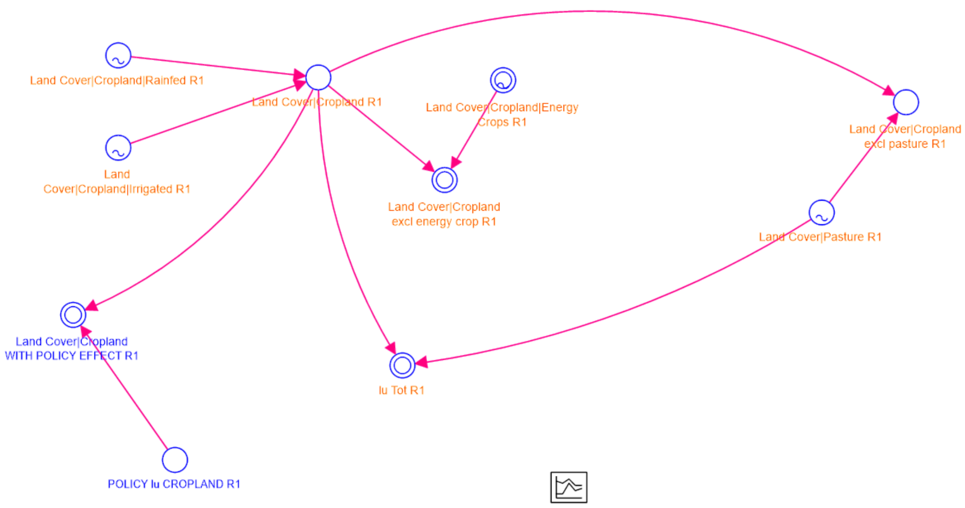


Figure 163 The Land subsystem in the SDM

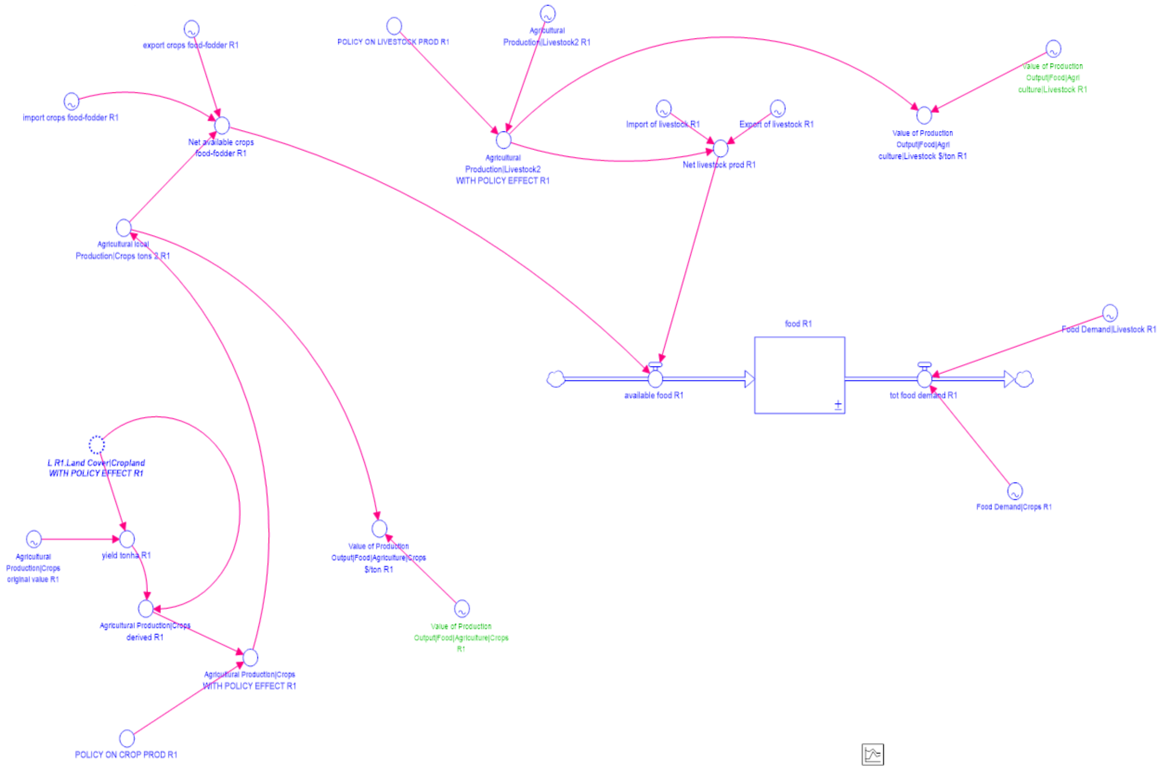


Figure 164 The Food subsystem in the European SDM

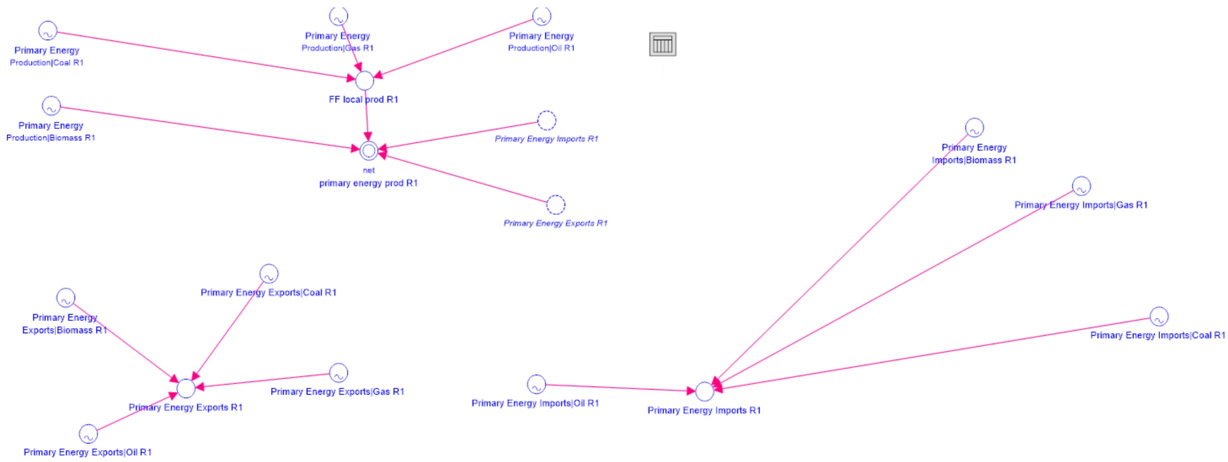


Figure 165 Primary Energy Production and trade

Figure 166 Net available primary energy of oil and biomass

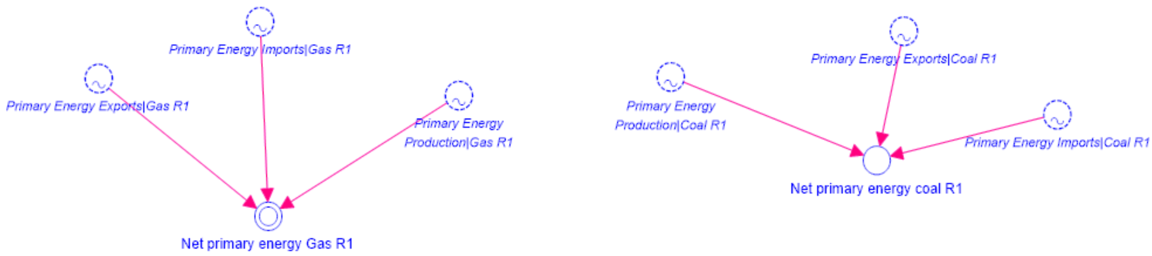


Figure 167 Net available primary energy of gas and coal

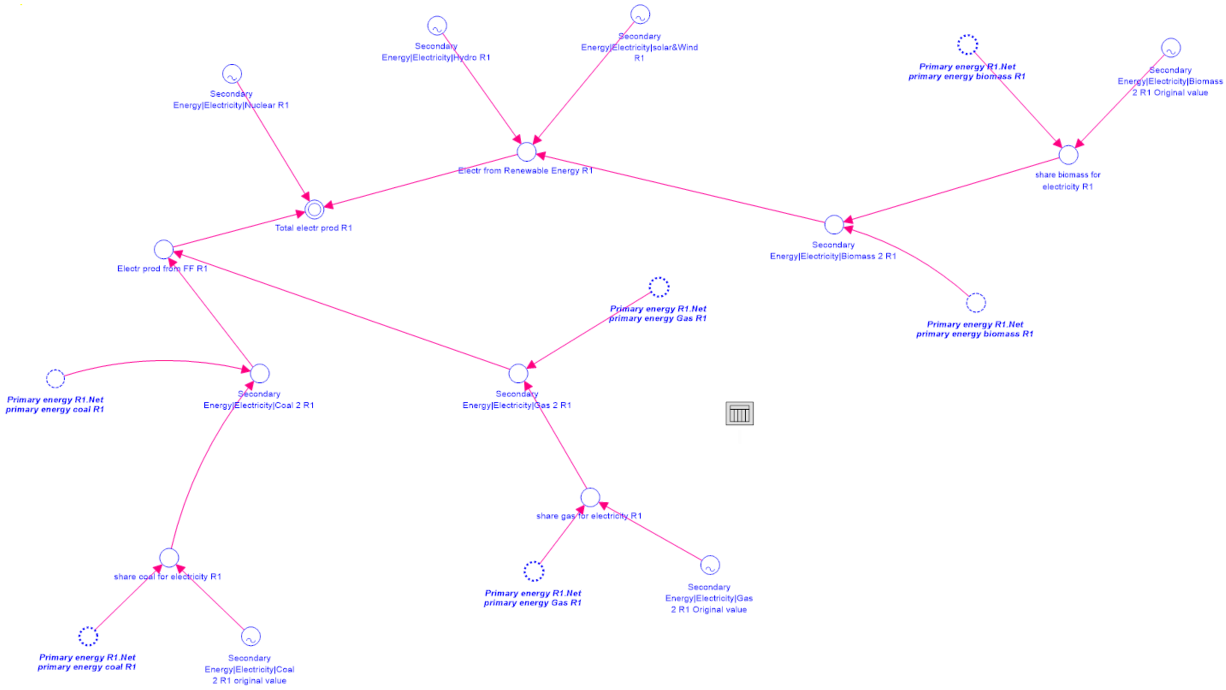


Figure 168 Electricity production

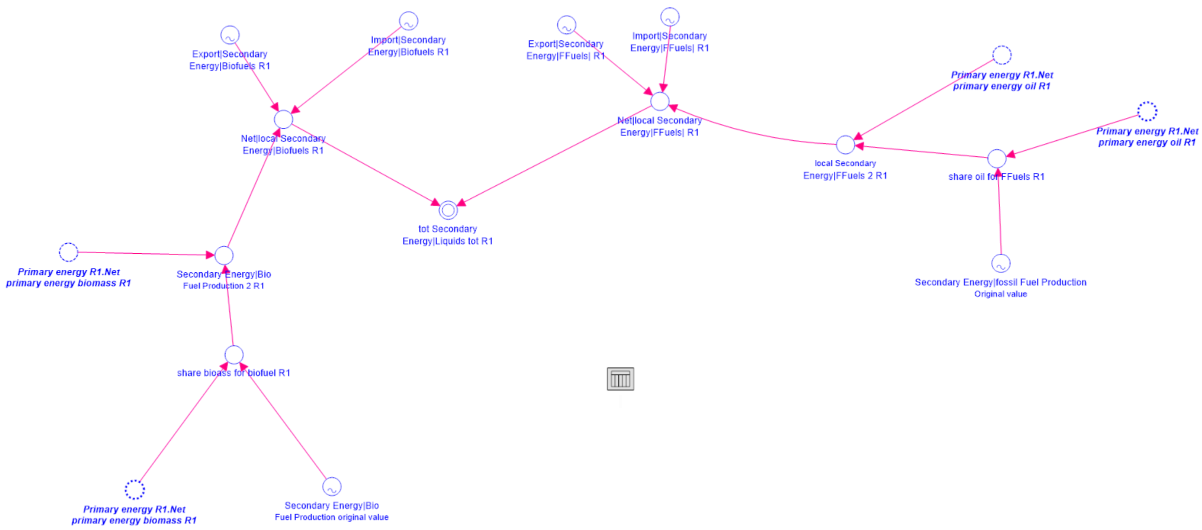


Figure 169 Production of traditional fossil fuels and biofuels

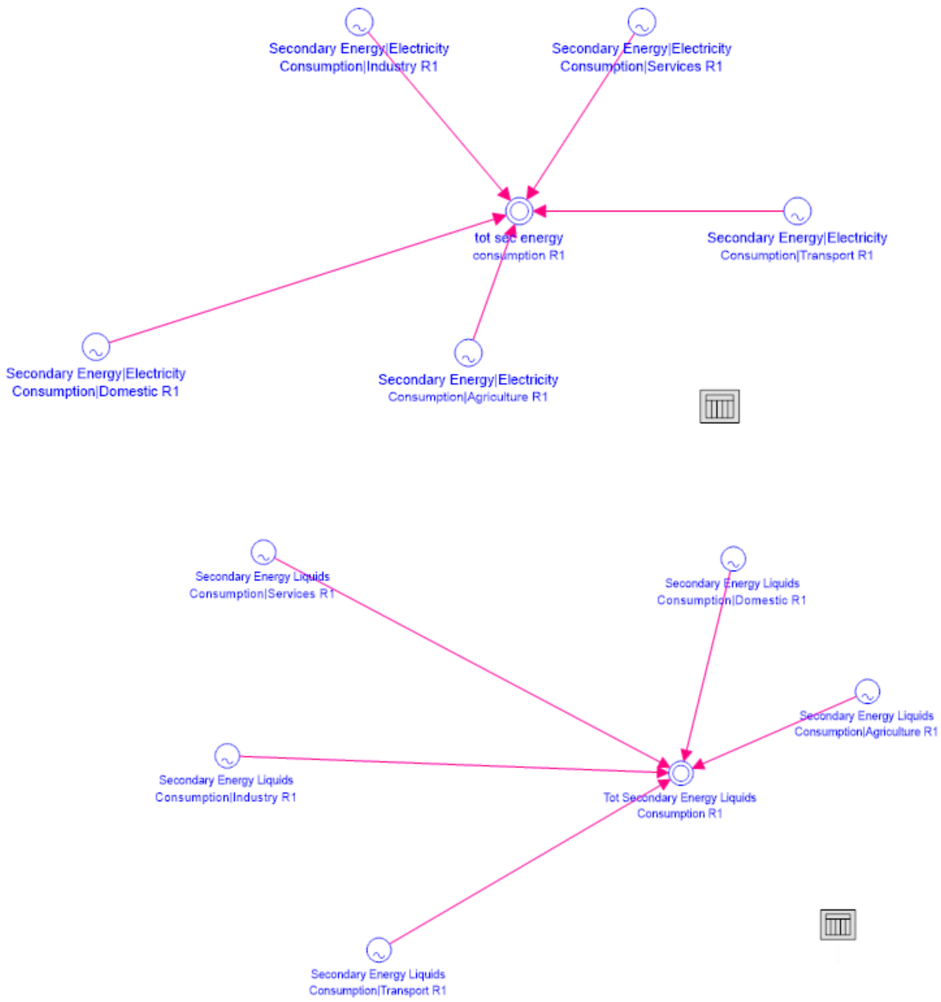


Figure 170 Secondary energy electricity and fuel consumption

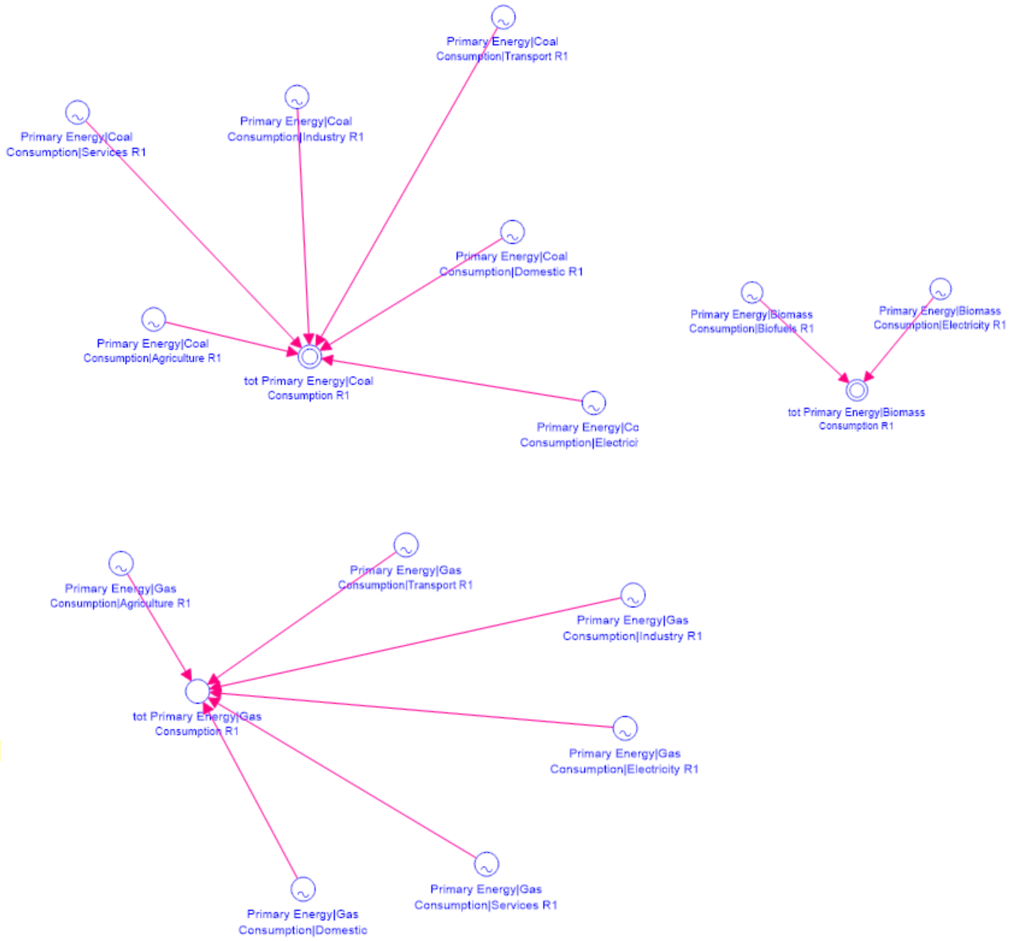


Figure 171 Primary Energy consumption of coal, gas and biomass. Primary energy from oil is only consumed by fossil fuels

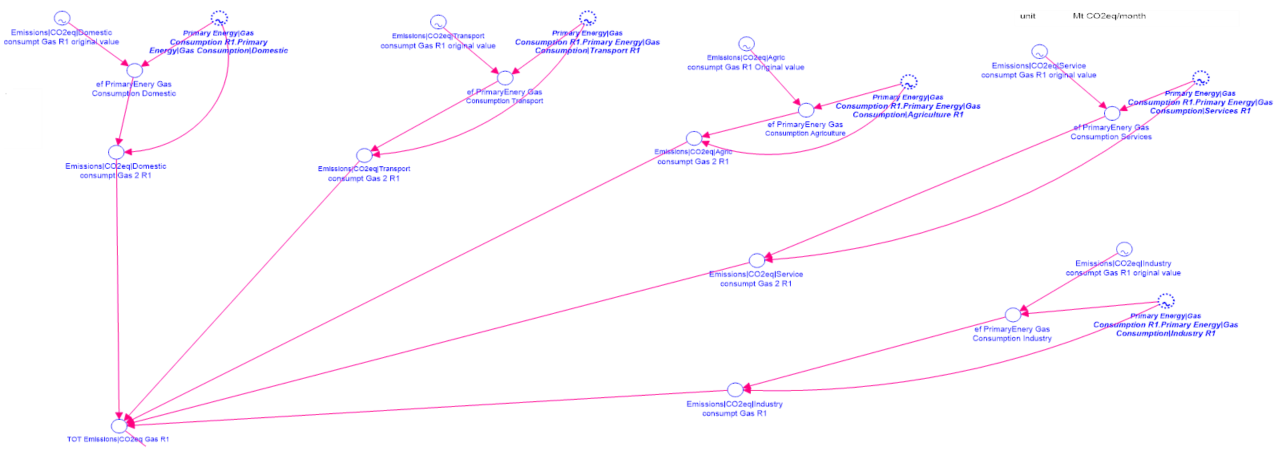


Figure 172 Greenhouse gas emissions from the use of gas

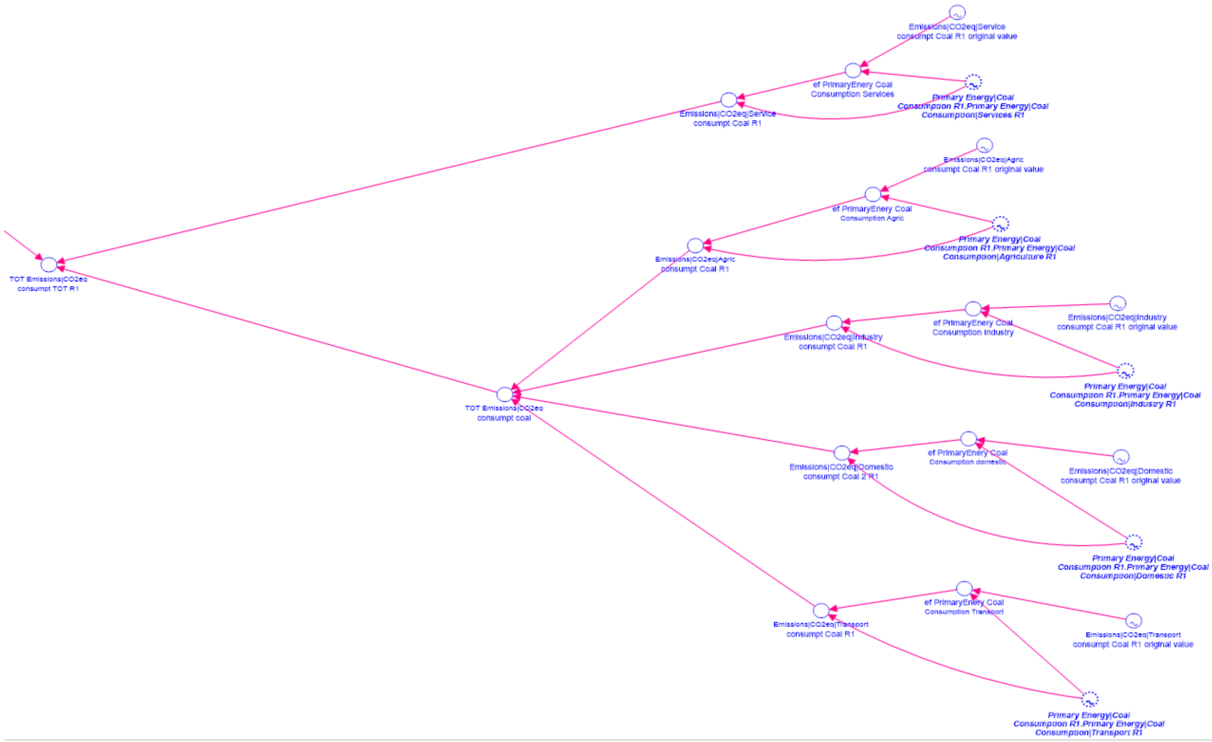


Figure 173 Greenhouse gas emissions from the use of coal

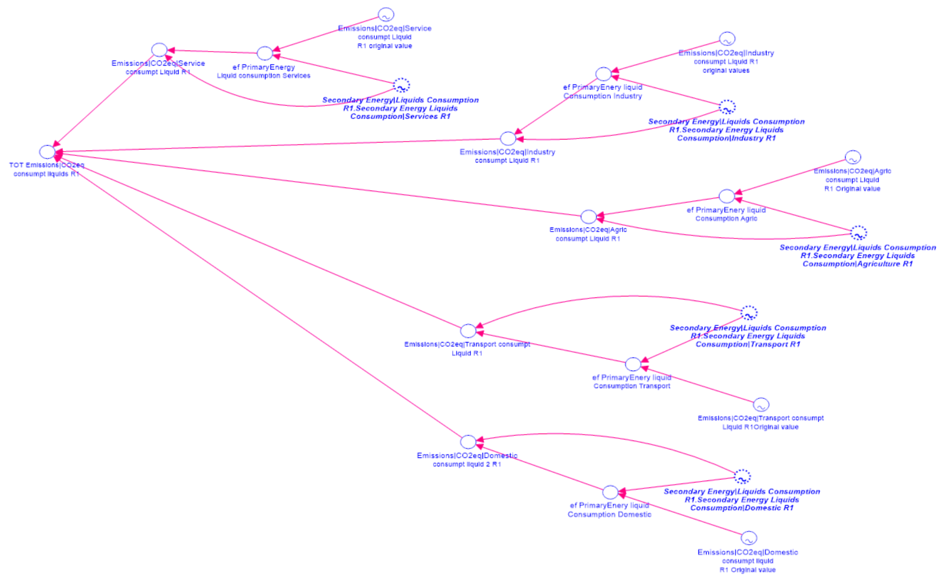


Figure 174 Greenhouse gas emissions from the consumption of fossil fuels

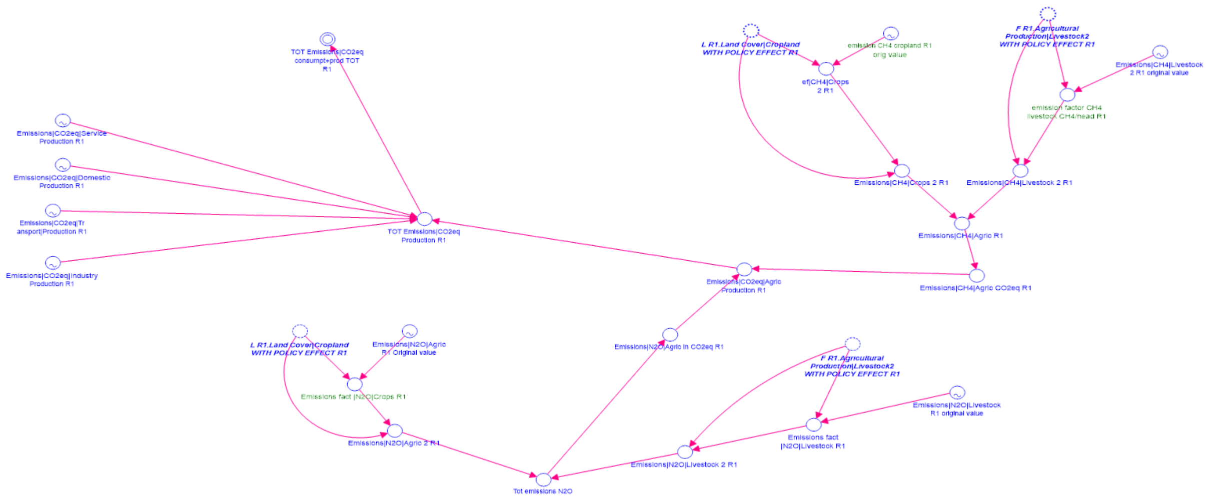


Figure 175 Greenhouse gas emissions directly connected to production volume

12.10.3 Policy cards

Nexus Sector	Name	Very short policy card name	Description of intervention as captured by the policy card
Water	Restrict Irrigation Areas	Restrict Irrigation Areas	Fix or limit growth of irrigated areas with respect to the previous period.
Water	Increase irrigation efficiency.	Increase irrigation efficiency.	Decrease the amount of water withdrawals needed to achieve irrigated crop yields.
Land	Increase Protected Nature areas	Protect area for Nature	Increase land cover of protected nature areas and decrease the growth potential of agricultural areas.
Energy	Increase energy efficiency in Transport	Energy efficiency, transport	Reduce the amount of energy needed in Transport
Energy	Increase energy efficiency in Industry	Energy efficiency, Industry	Reduce the amount of energy needed in Industry
Energy	Increase energy efficiency in Industry	Energy efficiency, Industry	Reduce the amount of energy needed in Industry
Energy	Increase energy efficiency in Agriculture	Energy efficiency, Agriculture	Reduce the amount of energy needed in Agriculture
Energy	Increase energy efficiency in Services	Energy efficiency, Services	Reduce the amount of energy needed in Services

Energy	Increase energy efficiency in Households	Energy efficiency, Domestic	Reduce the amount of energy needed in Households
Energy	Increase energy efficiency in Electricity Production	Energy efficiency, Electricity	Reduce the amount of primary energy needed in electricity production
Energy	Increase energy efficiency in Fuel Production	Energy efficiency, Fuel	Reduce the amount of primary energy needed in Fuel production
Energy	Renewable Electricity Mandate	Renewable Electricity Mandate	Increase share of renewables in electricity generation
Energy	Increase Electricity Production from Solar and Wind	Increase Solar and Wind	Increase Electricity Production of Solar and Wind
Energy	Increase Electricity Production from Biomass	Increase Bio-electricity	Increase Electricity Production from Biomass
Energy	Increase Electricity Production from Hydropower	Increase Hydro-electricity	Increase Electricity Production from Hydropower
Energy	Change Biofuel Mandates	Biofuel Mandates	Increase (or decrease) Biofuel mandate
Food	Increase irrigated areas	Increase irrigated areas	Increase growth of irrigated areas with respect to the previous period.
Food	Increase investments in crop yields	Increase crop yields	Increase crop production per hectare or land
Food	Stimulate a shift in diets, less meat consumption	Diet shift	Households reduce share of meat in total calorie consumption
Climate	Carbon price on all GHG emissions	Carbon Price All	Increase the cost of a polluting activity (e.g. electricity from coal, livestock production etc...) and therefore reduce that activity.
Climate	Carbon price on ETS sectors	Carbon Price ETS	Increase the cost of a polluting activity in the ETS sectors
Climate	Carbon price on Agriculture	Carbon Price Agriculture	Increase the cost of a polluting activity in the Agriculture
Climate	Investments in GHG emmision abatement in Agriculture	Emmision abatement in Agriculture	Reduce emission coefficient in agriculture

Climate	Invesments in CCS GHG emmision abatement in Electricity production	CCS	Investments in Carbon Capture and Storage (CCS) to reduce the GHG emmision coefficient in Electricity production (Negative for Bioelectricity)
Climate	Increase electrification in road vehicles	Promote electric vehicles	Increase electricity demand and reduce petrol demand in transport.

12.10.4 Use Cases

USE CASE EUR: C.1	Climate
Related Learning Goals	Learn what the major contributors to greenhouse emissions are in Europe and the impact on the other nexus of reducing those emissions at their source.
Goal	Reduce Greenhouse Gas Emissions in Europe Consistent with at least an RCP2.6 degree pathway
User	*Public Sector,* national and EU level (Directorate-General ENER, CLIMA)
Actions	Focus on reducing emission in ETS sector to achieve Goal. • Investments in Carbon Capture and Storage (CCS) to reduce the GHG emission coefficient in Electricity production (Negative for Bioelectricity) • Renewable Energy Mandates. • Carbon tax on ETS sectors
Indicator	• Total kg of CO_2,eq emissions • kg of CO_2,eq emissions in the electricity generation sector/ EJ of electricity generated • Total annual CO_2 eq emissions from energy use in power generation and industry. • Electricity price (Related to the learning goal)

Steps in the Serious Game:
Calculate total GHG emissions in current period for all 6 European regions.
Calculate GHG emissions from electricity, industry, and other fuels for all 6 European regions.
Compare European emissions in current period to target European emissions in current period to reach 2 degree pathway by 2050 (Policy Goal).
Calculate share of GHG emissions from ETS sectors to total GHG emissions.
If total GHG emissions are below the target for the period then do nothing.
If total GHG emissions are above the target for the period then the player can decide to implement one or more of the following actions.

    - Increase investments in Carbon Capture and Storage (CCS) to reduce the GHG emission coefficient in Electricity production (Negative for Bioelectricity).
    - Increase renewable Energy Mandates.
    - Implement a carbon tax on the ETS sectors

Display the following indicators at the end of the period.

- Total kg of CO_2,eq emissions.
- kg of CO_2,eq emissions in the electricity generation sector/ electricity generated.
- Total annual CO_2 eq emissions from energy use in power generation and industry.
- Electricity price

USE CASE EUR: C.2	Climate
Related Learning Goals	Learn what the major contributors to greenhouse emissions are in Europe and the impact on the other nexus elements of reducing those emissions at their source.
Goal	Reduce Greenhouse Gas Emissions in Europe Consistent with at least an RCP2.6 degree pathway
User	*Public Sector,* national and EU level (Directorate-General AGRI, CLIMA)
Actions	Focus on Non-ETS sectors to achieve Goal • Invest in GHG emission abatement in agriculture • Promotion of electric vehicles through regulation and investment. • (Effective) Carbon tax on Effort Sharing Decision (ESD) sectors (Agriculture, transport, ...)
Indicator	• kg of CO_2,eq emissions in the total ESD sectors. • kg CO_2,eq emissions in agriculture. • kg CO_2,eq emissions in transport. • Quantity of food production of crops and livestock (related to learning goal) • Price of production for crops and livestock (related to learning goal)

Steps in the Serious Game:
Calculate total GHG emissions in current period for all 6 European regions.
Calculate GHG emissions from Agriculture, transport, other services for all 6 European regions.
Calculate share of GHG emissions from Non-ETS sectors to total GHG emissions.

Compare European emissions in current period to target European emissions in current period to reach 2 degree pathway by 2050 (Policy Goal).
If emissions are below the target for the period then do nothing.
If emissions are above the target for the period then the player can decide to implement one or more of the following actions.

- Invest in GHG emission abatement in agriculture
    - Promotion of electric vehicles through regulation and investment.
    - Implement a Carbon tax on Effort Sharing Decision (ESD) sectors (Agriculture, transport, ...)

Display the following indicators at the end of the period.

- kg of CO_2,eq emissions in the total ESD sectors.
- kg CO_2,eq emissions in agriculture.
- kg CO_2,eq emissions in transport.
- Quantity of food production of crops and livestock (related to learning goal)
- Price of production for crops and livestock (related to learning goal)

USE CASE EUR: A&F.1	Agriculture and Food

Related Learning Goals	Explore the trade-offs between exploiting additional land-water resources and food security in the context of a transition to a low-carbon economy; Explore policies to exploit synergies between reducing greenhouse gas emissions and healthy water, land, food and energy systems.
Goal	Food security (maintain low food prices)
User	Public Sector, national and EU level (Directorate-General AGRI)
Actions	• Encourage investments in crop yields • Increase the amount of irrigated areas • Encourage a shift in diets to less meat consumption
Indicator	• Price of production of crops and livestock • Quantity of food production of crops and livestock • Volume of abstracted water for irrigation (related to 1st learning goal) • Total greenhouse gas emissions in agriculture (related to 2nd learning goal)

Steps in the Serious Game:

Compare price of production of crops and livestock in current period to price of production in the initial period (2010).
If the price of production of crops and/or livestock is at or below the price of production in the initial period then do nothing.
If the price of production of crops and/or livestock is above the price of production in the initial period then the player may take one or more of the following actions.

- Encourage investments in crop yields
- Increase the amount of irrigated areas
- Encourage a shift in diets to less meat consumption

Display the following indicators at the end of the period.

- Price of production of crops and livestock
- Quantity of food production of crops and livestock
- Volume of abstracted water for irrigation (related to 1st learning goal)
- Total greenhouse gas emissions in agriculture (related to 2nd learning goal)

13 Global

13.1 Introduction

The Global case study investigates the Nexus at the global scale. The lead for this case study is PBL Netherlands Environmental Assessment Agency. The partners in this case study are the six institutes that study Nexus issues using various modelling tools: the Swedish Royal Institute of Technology (KTH) with the OSeMOSYS model, the Polytechnic University of Madrid (UPM) with the CAPRI model, The Potsdam Institute for Climate Impact Research (PIK) with the MAgPIE model, Cambridge Economic (CE) with the E3ME model, Wageningen Economic Research (WEcR) with the MAGNET model and the Netherlands Environmental Assessment Agency (PBL) with the IMAGE-GLOBIO model. These partners were important stakeholders in the case study. In addition, a number of stakeholders from the European Commission were involved in a workshop during the Greenweek 2019 in Brussels.

The case study is explored at the level of 8 aggregated world regions (Figure 176) and at the global level. Five Nexus domains are considered: water, land, energy, food and climate. The main research goal is to quantify synergies and trade-offs when introducing policies aimed to improve one of the Nexus sectors. These synergies and trade-offs are analyzed both between the Nexus domains as between the regions. In addition, an important goal is to develop a scenario where all Nexus sectors are improved simultaneously to assess possible reinforcing effects of synergies and trade-offs. Examples of important nexus challenges at the global scale that are investigated in this case study are the following: impacts of climate change mitigation policy on food security and biodiversity; the effects of increased food production on land use, water use and quality; synergies between reduced consumption of animal products, climate policy and biodiversity and many more.

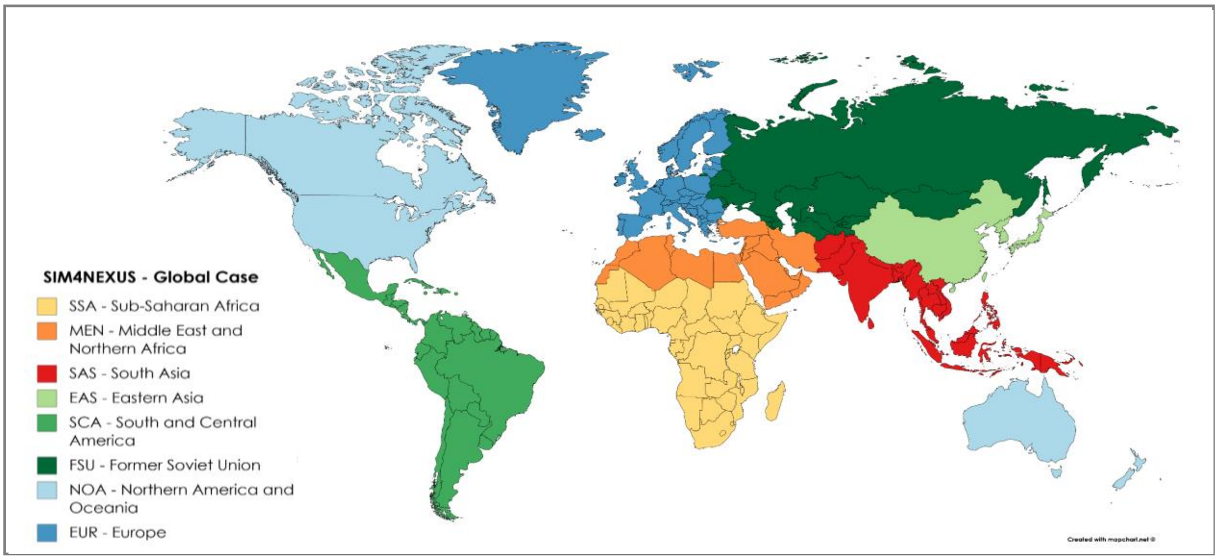


Figure 176 Regional aggregation used in the Global case study

13.2 Overview of tasks performed

13.2.1 Organisation to carry-out Task 5.2

PBL Netherlands Environmental Assessment Agency is in the lead for the global case study. At PBL, four people have been actively involved in the activities of the global case study. Responsibilities have changed between these persons over time due to illness and retirement, but all four were involved in organizing meetings with partners and stakeholders, developing the scenarios, conceptual model, interactive visualization tool, and analysing the results to formulate policy recommendations.

Five partners from SIM4NEXUS were involved in the global case study: the Swedish Royal Institute of Technology (KTH), the Polytechnic University of Madrid (UPM), The Potsdam Institute for Climate Impact Research (PIK), Cambridge Economic (CE), and Wageningen Economic Research (WEcR). All partners were involved with one or two persons. Each team used their respective thematic model to develop scenarios at the global scale. In addition, everyone was involved in brainstorming and discussions on development of the conceptual model and formulation of the policy recommendations. The set-up of the scenarios and indicators also benefitted from discussions with other SIM4NEXUS partners at dedicated sessions during the plenary workshops held in Trebon (2017), Athens (2018) and Exeter (2018).

An important challenge in the global case is the difference in types and setups of the different thematic models. For example, the coverage of the nexus differs between the models: E3ME covers the energy and climate components of the Nexus, whereas CAPRI and MAgPIE cover the land, food, water and climate components of the nexus. OSeMOSYS, MAGNET and IMAGE-GLOBIO cover the energy, land, food and climate components of the nexus, however with different levels of detail between sectors. Water quality and biodiversity impacts was only covered by IMAGE-GLOBIO, results of which could therefore not be compared to other models. The regional resolution of the models also differed: OSeMOSYS is a global model with one world region, CAPRI has high resolution in Europe but lower resolution outside of Europe and IMAGE-GLOBIO is restricted to a standard set of 26 world regions. MAgPIE and MAGNET were flexible in there model setup and therefore developed a specific model for the 8 regions of the global case.

A benefit of the different types of models involved in the case study is that the different partners could learn about each other’s modelling approaches and combine results to provide a more complete understanding of the nexus interlinkages at the macro-level. Even though everyone in the case study works with modelling tools, differences in model setup make it still an interdisciplinary exercise. For example, MAGNET and IMAGE-GLOBIO work with general global equilibrium modelling for the economic sector, while E3ME uses a different macro-economic approach that leads to very different results. Comparisons and discussions about the differences in results leads to interesting insights and improved understanding of the economic system.

13.2.2 Schedule of Task 5.2

The work on the Global Case started with discussions on the choice of global-scale Nexus topics and indicators (presented on a poster and skype session during the Barcelona meeting, 2016), and preliminary runs of the thematic models to identify coverage and gaps. In October 2017 a case study meeting was organized in The Hague. This meeting was used to brainstorm about the conceptual model that was presented in deliverable 5.2. In addition, practical decisions were made about reporting of data and the development of a standard baseline and two degrees scenario (which later formed the basis for the reference and energy and climate scenarios, respectively, of the target scenarios). These were used to identify the main Nexus challenges in our case study that were presented in deliverable 5.2.

In 2018, various telecalls were organized to discuss the development of the target scenarios and the system dynamic model. Determining how to implement the target scenarios in the different models was a challenge as the models differ in setup and coverage of the Nexus and policy interventions. The target scenarios were an important target for the global case study as these are the basis for the policy recommendations provided in this deliverable (see Section 13.2.6).

In February 2019, another case study meeting was organized in The Hague. This meeting was used to analyse the first versions of the different target scenarios, to identify remaining issues in scenario setup or reporting and to formulate first conclusions. In addition, discussions were held on how to convert the conceptual model into a systems dynamics model that would form the basis for the serious game (for more detail see deliverable 5.2). The discussions how to make this conversions showed that it was a challenge to find a way to combine the detailed and complex thematic models with a more simplified systems dynamics model.

In the summer of 2019 the first results of the target scenarios and policy recommendations were presented at a workshop during the Greenweek in Brussels, and at the project meeting in Riga. This was an important step in analysing and presenting the results of the global case, and to derive/formulate policy recommendations. At the project meeting it also became clear that the system dynamic model as planned at the beginning of the project was not in line with the expectations of the different thematic model teams. To overcome this issue it was decided to develop instead an interactive visualization tool that can graphically present the results of the target scenarios developed by the different thematic models, and in this way explain Nexus issues at the global scale to stakeholders and others.

In the fall of 2019 and early 2020 the target scenarios were finalized and reported by all partners of the global case. In addition, in cooperation with Mehdi Khoury, an interactive visualization tool is developed as a product of task 5.2 for the global case study (see Section 13.2.4). The current version shows results from IMAGE-MAGNET-GLOBIO (combination of IMAGE-GLOBIO and MAGNET), but work is ongoing to also develop versions of the tool showing results from other models starting with the OSeMOSYS model.

13.3 Engagement of stakeholders in the process

13.3.1 Overview of stakeholders' engagement in the case study

The global case is a special case study regarding stakeholders as it is difficult to identify stakeholders at the global level. For this reason, the partners of the thematic model teams are considered the most important stakeholders. The workshops for the global case are therefore the most important moments of stakeholder interactions. In addition, the global case was presented to policymakers of the European Union at a Greenweek event in Brussels in 2019.

The stakeholders of the global case were crucial for the development of the target scenarios. These target scenarios are the central result of the global case study and also form the basis of the policy recommendations that are presented later in this deliverable.

Unfortunately no stakeholders have yet been involved from the UN secretariats for the various global conventions such as the Rio convention on climate (UNFCCC), biodiversity (CBD) and land degradation (UNCCD), or the UN Sustainable Development Goals. We still plan to organize a webinar to present the visualization tool and the target scenarios, so this would be an opportunity to still involve these stakeholders.

Interactions with stakeholders	Date Location	Number of participants and indicative distribution by nexus sector	Topics discussed	Outcomes / Achievements

Workshop	October 2017, The Hague, Netherlands	10 participants: Energy-Economy: 2 Agriculture-Economy: 2 Agriculture-Climate: 1 Water: 2 General: 1	Conceptual model, baseline and 2 degree scenario, reporting format.	Draft conceptual model.
Workshop	February 2019, The Hague, Netherlands	13 participants: Energy -Economy: 2 Agriculture-Economy: 2 Agriculture-Climate: 3 Water: 2 General: 4	Draft target scenarios, system dynamics model, reporting issues.	Important step in development of target scenarios that form the basis for policy recommendations.
Presentation	June 2019, Brussels, Belgium	25 participants. From European Commission and partner institutes. Unknown what Nexus sector specializations.	Target scenarios, policy recommendations	Input on framing of policy recommendations.
Workshop	July 2019, Riga, Latvia	10 participants: Energy -Economy: 2 Agriculture-Economy: 2 Agriculture-Climate: 3 Water: 2 General: 1	Target scenarios, policy recommendations.	Interpretation of target scenarios, further development of policy recommendations.

13.3.2 Feedback on stakeholders' engagement in the case study

The cooperation with the stakeholders in the global case generally worked well. Everyone was involved throughout the project period and attended the various workshops as well as teleconferences. As described before, the modelling teams had different specializations. This ensured that all components of the Nexus were well covered. At the same time this made it sometimes difficult to pay enough attention to all different components. For example, as water quality and biodiversity was only covered by one of the models this received at times less attention as there was less necessity to discuss different approaches or compare model results.

The transdisciplinary character of the global case was educational but also at times a challenge. Stakeholders from different backgrounds learned from each other: for example, discussions between stakeholders with an economic or a more biophysical background could be very informative. However, when developing scenarios together this also at times caused miscommunications as people had different approaches to scenario development. In general such issues are inevitable in transdisciplinary research. When sufficient time for such discussions is reserved in advance, this does not need to be a major problem.

13.4 From thematic model scenarios to interactive visualization tool

The global case study is a special case as it had the possibility to use multiple complex thematic models to investigate the Nexus. For this reason, it was decided not to develop a system dynamics model and a serious game like in the other case studies, but to use the multiple models directly to investigate the implications of a set of target scenarios on the different dimensions of the Nexus. The target scenarios have a similar role as the use cases have in other case studies. In addition, an interactive visualization tool was developed to present these results and to let stakeholders explore the results in an interactive way. Here, we present the development of the different target scenarios and the interactive visualization tool.

13.4.1 Reference and target scenarios

For the global case six scenarios were developed. First, a reference scenario is developed: The reference scenarios are business-as-usual cases. In MAgPIE, MAGNET, IMAGE-GLOBIO, E3ME and CAPRI these are represented by the SSP2 scenario from the Shared Socio-economic pathway framework (Riahi et al., 2017). In OSeMOSYS, the reference scenario is built from different sources, mainly the Energy Technology Perspective (IEA, 2012) and the FAOSTAT Database (FAO, 2018), and it has been aligned as much as possible to the SSP2 scenario. This means that all models use the same population and GDP projections as agreed upon in the development of the SSP scenarios (Dellink et al., 2017, KC and Lutz, 2017). In addition, there are model-specific assumptions catered towards the specifications of each thematic model and in line with the SSP2 narrative as described by (O'Neill et al., 2013)(see Table 73).

Table 73 Scenario setup and assumptions per model for the reference scenario

Scenario setup and assumptions per model	MAgPIE	IMAGE-GLOBIO	MAGNET	OSeMOSYS	E3ME	CAPRI
Agricultural system						
Yield increase	Climate impacts from LPJml and endogenous yield increase.	Exogenous tech. increase according to FAO agricultural outlook (2012), endogenous increase following MAGNET	Endogenous model result, exogenous tech. increase according to FAO agricultural outlook (2012)	-	-	Medium - 75% of the exogenous yield growth from GLOBIOM implementation, 25% CAPRI endogenous
Irrigation	endogenous irrigation area increase	Irrigation area increases following the FAO agricultural outlook of irrigated harvested area, irrigation efficiency increases by 0.2%/yr for the share newly irrigated area	-	Irrigation requirements based on AQUASTAT (FAO, 2016)	-	-
Livestock intensification	Medium intensification	Exogenous tech. increase according to FAO agricultural outlook (2012), endogenous increase following MAGNET	Endogenous model result, exogenous tech. increase according to FAO agricultural outlook (2012)	-	-	Medium - Model endogenous adjustments emulated through a 2.5 EUR/t carbon price

Land-use change regulation	Linear increase of protected forest areas by factor 1.5 between 2010 and 2100	Medium – Protected areas are extended to achieve the Aichi target of 17% of the terrestrial area, gradually implemented from 2010-2050.	same as IMAGE	-	-	Medium - Model endogenous adjustments emulated through a 2.5 EUR/t carbon price
Nitrogen fertilzer use	Soil nitrogen uptake efficiency converges to 60% globally by 2050; constant thereafter.	Following largely the projections by FAOs agricultural outlook	endogenous model outcome	-	-	Medium - Model endogenous adjustments emulated through a 2.5 EUR/t carbon price
Land degradation	-	-	-	-	-	-
Food system						
Food demand	Endogenous, but depends on demographic and income drivers as well as storyline-dependent parametrization of the food demand system leading to medium food demand and low demand for livestock products. Additionally, livestock share in rich countries are not falling below 15%.	from MAGNET	endogenous model outcome	Exogenous data and projections based on IMAGE-GLOBIO data and SSP2 Database (IIASA, 2018)	-	Business as usual
Waste	Included in food demand (driven by demography and income)	from MAGNET	current levels of food losses	-	-	Business as usual
International trade						
Agricultural trade barriers	Agricultural trade barriers decline by 0.5% per year	from MAGNET	Current tariffs and subsidies.	-	Current tariffs and subsidies.	Business as usual

Energy system						
Energy technology specifications	-	medium assumptions from IMAGE energy model (TIMER, van Vuuren et al., 2017)	-	IEA *Energy Technology Perspectives* (2012); OECD and Nuclear Energy Agency *Projected Costs of Generating Electricity* (2010); IEA ETSAP *Energy Supply Technology Briefs* (2011).	-	-
Energy demand	exogenous bioenergy demand based on previous coupling runs with REMIND with and without mitigation target (Klein et al 2014)	medium assumptions from IMAGE energy model (TIMER, van Vuuren et al., 2017)	-	Energy consumptions and efficiency improvements data considered are based on IEA *Energy Technology Perspectives* (2012), SSP2 Database (IIASA, 2018), Outlook for Air Transport to the Year 2025 (ICAO, 2007), IEA ETSAP Technology Briefs (2011), Review on Maritime Transport (UNCTAD, 2012), Second IMO GHG Study (IMO, 2009).	-	-
Energy system policy	-	no climate change mitigation policy	-	-	All existing regulation and policies implemented by government by early 2016 (NB this includes ETS schemes and other carbon/energy pricing). EU ETS values in line with PRIMES 2015. Non EU carbon prices in line with WEO 2016 CPS.	-

The reference scenario forms the basis for 5 target scenarios. Each scenario strives for an optimization of one or two of the SDGs in the WLEFC Nexus (the goals on food, water and energy provision, land conservation and limited climate change), i.e. the ones that could be covered by the thematic models. Next, we translated these into 'packages' of measures that the main societal sectors can undertake to contribute to these goals (see Table 74). The packages were however limited to assumptions that were considered as more or less realistic within the SSP framework. This implies that the targeted SDGs will not always fully meet the defined targets. It should also be kept in mind that the targets of many SDGs are a yet only defined in broad terms. In addition, a scenario is developed that combines the policy actions of the four others:

1. The energy and climate scenario (ENERGYCLIM): this scenario aims to limit global warming to 2 degrees above pre-industrial temperatures in line with SDG 13. Additionally, the scenario aims for a strong increase in renewable energy sources in line with SDG 7. Dependent on model characteristics, a range of policy actions is taken in the energy, industry and land sectors such as increased use of renewable energy sources, phasing out of fossil fuel sources, improved energy efficiency, more use of bio-energy, carbon-capture-and-storage technological options, afforestation, pricing of greenhouse gas emissions, and more.
2. The land and biodiversity scenario (LANDBIODIV): this scenario aims to limit the loss of terrestrial biodiversity compared to the reference scenario in line with SDG 15. In order to achieve this, a major expansion of protected areas is implemented to limit the conversion of natural areas. In addition, major improvements in fertilizer efficiency are implemented in order to reduce nitrogen deposition (which is one of the additional pressures to biodiversity).
3. The water scenario: this scenario aims to optimize SDG 6, regarding the availability of enough and good-quality water for all, including aquatic biodiversity in line with SDG 14. To achieve this, it is assumed that environmental flow requirements are respected by limiting the extraction of water to a pre-defined amount to ensure water for ecosystems. (However, no restrictions on hydropower were assumed.) Next to that, assumptions are made that reduce water demand by preventing additional expansion of irrigated cropland, by improving the efficiency of existing irrigation systems and by improving the efficiency of water use in other sectors such as households, industry and energy production. In addition, policy action is implemented to improve water quality: this involves improved fertilizer use efficiency and improved waste water treatment.
4. The food scenario (FOOD): this scenario aims to implement healthy and sufficient diets for all in line with SDG 2. To achieve this goal, it is assumed that people in high- and middle-income regions will eat less animal-based products by replacing them with plant-based products, in line with the guidelines on healthy diets suggested by (Willett et al., 2019). A large share of the food intake will then be based on legumes in order to provide sufficient proteins. In addition, major improvements in the efficiency of the agricultural sector are assumed, to produce more and cheaper food per area of cropland, to be able to feed the part of the population that is currently undernourished. Moreover, levels of food waste are significantly reduced further alleviating the pressure on the food system
5. The total scenario: this scenario aims to improve all nexus sectors considered by combining all policy actions as described in the scenarios above. This allows to understand where policy actions reinforce each other (synergies) and where they counteract (trade-offs) In some cases, policy actions overlap. For example, improved fertilizer efficiency is assumed in both the land and biodiversity scenario and the water scenario. In the total scenario it is assumed that these policies are combined to achieve a double fertilizer efficiency improvement.

Table 74 Policy assumptions for the target scenarios developed for the global case

Scenario-specific assumptions	Reference	Energy and climate	Land and biodiversity	Water	Food	Total
Primary SDGs targeted	-	7, 13	15	6, 14	2	2, 6, 7, 13 ,14, 15
Climate policy action						
carbon price/emissions pathway		in line with 2 degrees				in line with 2 degrees
Land policy action						
forest protection		forest protection in line with				forest protection in line with 2deg target

		2deg target					
biodiversity protection			Increase in protected areas for terrestrial biodiversity				Increase in protected areas for terrestrial biodiversity
Nutrient policy action							
fertilizer efficiency			increased fertilizer efficiency	increased fertilizer efficiency			double increase in fertilizer efficiency
Wastewater				improved waste water treatment			improved waste water treatment
Water policy action							
environmental flow requirement				Limit water extraction ensuring sufficient water for aquatic biodiversity			Limit water extraction ensuring sufficient water for aquatic biodiversity
irrigation expansion				limit irrigation expansion			limit irrigation expansion
irrigation efficiency				improve irrigation efficiency			improve irrigation efficiency
water use efficiency				improved efficiency households, industry, energy			improved efficiency households, industry, energy
Diet policy action							
diet change					reduced meat consumption/healthy diet		reduced meat consumption/healthy diet
Food waste					Reduced food waste		Reduced food waste
Agricultural policy action							
yields					high yield improvement		high yield improvement
livestock efficiency					high livestock efficiency improvement		high livestock efficiency improvement
Climate impacts							
climate impacts	RCP 6.0	RCP 2.6	RCP 6.0	RCP 6.0	RCP 6.0		RCP 2.6

Not all thematic models were able to run all scenarios (Table 75): MAgPIE and the IMAGE-MAGNET-GLOBIO models combined developed all six scenarios. OSeMOSYS developed all scenarios except the land scenario. E3ME was limited to the reference and energy and climate scenario as the model does not have an explicit land/water sector. CAPRI was limited to the reference, food and energy and climate scenarios. Please note that due to differences in model setup not all scenario assumptions are implemented in all models.

Table 75 Simulation scenarios developed per model

Scenarios / Models	Reference	Energy and climate	Land and biodiversity	Water	Food	Total
IMAGE-MAGNET-GLOBIO	x	x	x	X	X	X
OSeMOSYS	x	x		X	X	X
MAgPIE	x	x	x	X	X	X
E3ME	x	x				
CAPRI	x	x			X	

13.4.2 Data global case

A reporting template was developed to collect output data from each thematic model (Table 76). The template was developed in such a way that sufficient data is reported for each of the Nexus sectors. In addition, steps were taken to collect indicators that could be directly linked to different SDGs (so-called SDG indicators). All data are model-specific output variables and depend on the way each model is set up and calibrated. Input data is derived from many different sources. For land use and food data, the Food and Agriculture Organization (FAO) is an important datasource at the global level that is used in many of the thematic models; for the energy sector, the International Energy Agency (IEA) is another important datasource.

Table 76 List of variables with units and definition

Category	Variable	Unit	Definition
agriculture	Agricultural Production|Energy Crops	Mt DM/yr	production for modern primary energy crops (2nd generation)
agriculture	Agricultural Production|Energy Crops|Irrigated	Mt DM/yr	
agriculture	Agricultural Production|Crops	Mt DM/yr	total production for food, non-food and feed products (crops)
agriculture	Agricultural Production|Crops|Irrigated	Mt DM/yr	
agriculture	Agricultural Production|Livestock	Mt DM/yr	total production for livestock products
agriculture	Agricultural Demand|Energy Crops	Mt DM/yr	
agriculture	Agricultural Demand|Crops	Mt DM/yr	
agriculture	Agricultural Demand|Livestock	Mt DM/yr	
agriculture	Agricultural Demand|Feed	Mt DM/yr	Total demand for feed
agriculture	Agricultural Demand|Feed|Concentrate feed	Mt DM/yr	Demand for concentrate feed (including crops and secondary products like oilcakes)
emissions (non-CO2)	Emissions|CH4	Mt CO2eq/yr	total CH4 emissions (global warming potential IPCC AR5)
emissions (non-CO2)	Emissions|CH4|AFOLU	Mt CO2eq/yr	CH4 emissions in the AFOLU sector (global warming potential IPCC AR5)
emissions (CO2)	Emissions|CO2	Mt CO2eq/yr	total CO2 emissions (IPCC category 3)
emissions (CO2)	Emissions|CO2|AFOLU	Mt CO2eq/yr	CO2 emissions from agriculture, forestry and other land use (IPCC category 3)
emissions (CO2)	Emissions|CO2|Energy	Mt CO2eq/yr	CO2 emissions from energy use on supply and demand side (IPCC category 1A, 1B)
emissions (CO2eq)	Emissions|CO2eq	Mt CO2eq/yr	CO2eq emissions total
emissions (CO2eq)	Emissions|CO2eq|AFOLU	Mt CO2eq/yr	CO2eq emissions from agriculture, forestry and other land use
emissions (CO2eq)	Emissions|CO2eq|Energy	Mt CO2eq/yr	CO2eq emissions from the energy generation on supply side
emissions (non-CO2)	Emissions|N2O	Mt CO2eq/yr	total N2O emissions

emissions (non-CO2)	Emissions|N2O|AFOLU	Mt CO2eq/yr	total N2O emissions from agriculture, forestry and other land use
climate	Temperature|Global Mean	°C	change in global mean temperature relative to pre-industrial
food	Food Demand (cap/day)	kcal/cap/day	all food demand in calories per capita per day (conversion factor: 1 kcal = 4,1868 kJ)
food	Food Demand (cap/day)|Crops	kcal/cap/day	crop related food demand in calories per capita per day
food	Food Demand (cap/day)|Livestock	kcal/cap/day	livestock related food demand in calories per capita per day
food	Food Demand	kcal	all food demand in calories (conversion factor: 1 kcal = 4.1868 kJ)
food	Food Demand|Crops	kcal	crop related food demand in calories
food	Food Demand|Livestock	kcal	livestock related food demand in calories
agriculture	Fertilizer Use|Nitrogen	Mt N/yr	Nitrogen fertilizer use
agriculture	Fertilizer Use|Phosphorus	Mt P/yr	Phosphorus fertilizer use
agriculture	Manure|Nitrogen	Mt N/yr	Nitrogen in manure used on cropland
agriculture	Manure|Phosphorus	Mt P/yr	Phosphorus in manure used on cropland
economy	GDP|MER	million US$2010/yr	GDP at market exchange rate
demography	Population	million	Total population
land cover	Land Cover|Cropland	million ha	total arable land, i.e. land in bioenergy crop, food, and feed/fodder crops, permanent crops as well as other arable land (physical area)
land cover	Land Cover|Cropland|Rainfed	million ha	rainfed arable land, i.e. land in bioenergy crop, food, and feed/fodder crops, permanent crops as well as other arable land (physical area)
land cover	Land Cover|Cropland|Irrigated	million ha	actually irrigated land, i.e. land in non-forest bioenergy crop, food, and feed/fodder crops, as well as other arable land (cultivated area)
land cover	Land Cover|Cropland|Energy Crops	million ha	land dedicated to energy crops (e.g., switchgrass, miscanthus, fast-growing wood species)
land cover	Land Cover|Forest	million ha	managed and unmanaged forest area
land cover	Land Cover|Primary Forest	million ha	unmanaged forest area
land cover	Land Cover|Pasture	million ha	pasture land. All categories of pasture land - not only high quality rangeland. Based on FAO definition of "permanent meadows and pastures"
land cover	Land Cover|Other Land	million ha	other land cover that does not fit into any other category
agriculture	Price|Agriculture|Non-Energy Crops and Livestock	Index (2010 = 1)	weighted average producer price index of non-energy crops and livestock products (real prices)
agriculture	Price|Agriculture|Non-Energy Crops	Index (2010 = 1)	weighted average producer price index of non-energy crop (real prices)
agriculture	Price|Agriculture|Livestock	Index (2010 = 1)	weighted average producer price index of non-energy livestock products (real prices)
agriculture	Price|Food|Non-Energy Crops and Livestock	Index (2010 = 1)	weighted average consumer price index of non-energy crops and livestock products (real prices)
agriculture	Price|Food|Non-Energy Crops	Index (2010 = 1)	weighted average consumer price index of non-energy crop (real prices)
agriculture	Price|Food|Livestock	Index (2010 = 1)	weighted average consumer price index of non-energy livestock products (real prices)
energy	Price|Electricity	Index (2010 = 1)	consumer price of electricity
energy (primary)	Primary Energy	EJ/yr	total primary energy consumption (direct equivalent)
energy (primary)	Primary Energy|Biomass	EJ/yr	primary energy consumption of purpose-grown bioenergy crops, crop and forestry residue bioenergy, municipal solid waste bioenergy, traditional biomass
energy (primary)	Primary Energy|Coal	EJ/yr	coal primary energy consumption

energy (primary)	Primary Energy|Gas	EJ/yr	gas primary energy consumption
energy (primary)	Primary Energy|Hydro	EJ/yr	total hydro primary energy consumption
energy (primary)	Primary Energy|Nuclear	EJ/yr	nuclear primary energy consumption (direct equivalent, includes electricity, heat and hydrogen production from nuclear energy)
energy (primary)	Primary Energy|Oil	EJ/yr	conventional & unconventional oil primary energy consumption
energy (primary)	Primary Energy|Solar	EJ/yr	total solar primary energy consumption
energy (primary)	Primary Energy|Wind	EJ/yr	total wind primary energy consumption
energy (primary)	Primary Energy|Other	EJ/yr	other energy consumption
energy (capacity)	Capacity|Electricity	GW	total electricity production capacity
energy (capacity)	Capacity|Electricity|Biomass	GW	electricity production capacity from biomass
energy (capacity)	Capacity|Electricity|Coal	GW	electricity production capacity from coal
energy (capacity)	Capacity|Electricity|Gas	GW	electricity production capacity from gas
energy (capacity)	Capacity|Electricity|Hydro	GW	electricity production capacity from hydropower
energy (capacity)	Capacity|Electricity|Nuclear	GW	electricity production capacity from nuclear
energy (capacity)	Capacity|Electricity|Oil	GW	electricity production capacity from oil
energy (capacity)	Capacity|Electricity|Solar	GW	electricity production capacity from solar
energy (capacity)	Capacity|Electricity|Wind	GW	electricity production capacity from wind
energy (capacity)	Capacity|Electricity|Other	GW	electricity production capacity from other sources
energy (secondary)	Secondary Energy	EJ/yr	total secondary energy production
energy (secondary)	Secondary Energy|Electricity	EJ/yr	total net electricity production
energy (secondary)	Secondary Energy|Electricity|Biomass	EJ/yr	net electricity production from municipal solid waste, purpose-grown biomass, crop residues, forest industry waste, biogas
energy (secondary)	Secondary Energy|Electricity|Coal	EJ/yr	net electricity production from coal
energy (secondary)	Secondary Energy|Electricity|Gas	EJ/yr	net electricity production from natural gas
energy (secondary)	Secondary Energy|Electricity|Hydro	EJ/yr	net hydroelectric production
energy (secondary)	Secondary Energy|Electricity|Nuclear	EJ/yr	net electricity production from nuclear energy
energy (secondary)	Secondary Energy|Electricity|Oil	EJ/yr	net electricity production from refined liquids
energy (secondary)	Secondary Energy|Electricity|Solar	EJ/yr	net electricity production from all sources of solar energy (e.g., PV and concentrating solar power)
energy (secondary)	Secondary Energy|Electricity|Wind	EJ/yr	net electricity production from wind energy (on- and offshore)
energy (secondary)	Secondary Energy|Electricity|Other	EJ/yr	net electricity production from other sources
energy (secondary)	Secondary Energy|Gases	EJ/yr	total production of gaseous fuels, including natural gas
energy (secondary)	Secondary Energy|Heat	EJ/yr	total centralized heat generation
energy (secondary)	Secondary Energy|Hydrogen	EJ/yr	total hydrogen production
energy (secondary)	Secondary Energy|Liquids	EJ/yr	total production of refined liquid fuels from all energy sources (incl. oil products, synthetic fossil fuels from gas and coal, biofuels)
energy (secondary)	Secondary Energy|Solids	EJ/yr	solid secondary energy carriers (e.g., briquettes, coke, wood chips, wood pellets)
energy (secondary)	Secondary Energy|Other	EJ/yr	other
water	Water Withdrawal	km3/yr	total water withdrawal
water	Water Withdrawal|Electricity	km3/yr	water withdrawal for electricity production
water	Water Withdrawal|Industrial Water	km3/yr	water withdrawal for industrial processes
water	Water Withdrawal|Municipal Water	km3/yr	water withdrawal for municipal uses
water	Water Withdrawal|Irrigation	km3/yr	water withdrawal for irrigation

water	Water Withdrawal|Electricity|Biomass	km3/yr	water withdrawal for electricity production from biomass
water	Water Withdrawal|Electricity|Fossil	km3/yr	water withdrawal for electricity production for fuels
water	Water Withdrawal|Electricity|Hydro	km3/yr	water withdrawal for electricity production from hydropower
water	Water Withdrawal|Electricity|Nuclear	km3/yr	water withdrawal for electricity production from nuclear
water	Water Withdrawal|Electricity|Solar	km3/yr	water withdrawal for electricity production from solar
biodiversity	Terrestrial biodiversity	MSA	Biodiversity intactness ('mean species abundance') on land
biodiversity	Freshwater biodiversity	MSA	Biodversity intactness ('mean species abundance') in inland waters
water quality	N Water Loading |Agriculture	Mt N/yr	Agricultural Nitrogen leaching to water
water quality	P Water Loading |Agriculture	Mt P/yr	Agricutural Phosphorus leaching to water
water quality	N Water Loading|Urban	Mt N/yr	Urban Nitrogen loading to water
water quality	P Water Loading|Urban	Mt P/yr	Urban Phosphorus loading to water

13.4.3 Interactive visualization tool

In cooperation with Mehdi Khoury an interactive visualization tool is developed. The tool consists of two graphic interfaces. The first shows the most important physical flows of the human-earth system, how they are interlinked in the Nexus and how they change between scenarios. The second shows the system dynamics of the human-earth system and the Nexus. The purpose of the tool is to present results to stakeholders and to let them explore differences between scenarios and connections in the water-land-energy-food-climate (WLEFC) nexus in the most informative way.

13.4.3.1 Technical setup of the tool

A subset of the variables from the reporting template are input to the visualization tool. The visualization consists of so-called 'nodes' and 'edges'. The nodes are points of information on sectors or resources, end the edges are the flows or dynamics between them. Table 77 shows an example of input data for nodes and Table 78 shows an example of input data of edges.

Table 77 Example of an input table for nodes, in this case for the physical flow diagram

id	title	summary	extrainfo
1	Land	Total land used	orange
2	Bio-energy Production	Production of Bio-energy on agricultural land	green
3	Crop Production	Production of Crops for Food, Feed, Other	green
4	Grass Production	Production of Grass	green
5	Forestry	Production of forest products	green
6	Water	Total water resources	blue
7	Livestock	Production of livestock products	green
8	Food Consumption	Consumption per capita	purple
9	Greenhouse gasses	Total Greenhouse gas emissions	grey
10	Fossil resources	Primary energy production	red
11	Nuclear resources	Primary energy production	red
12	Wind	Primary energy production	red
13	Solar	Primary energy production	red
14	Energy	Total secondary energy	red
15	Residential and Commercial	Consumption by the residential and commercial sectors	grey

16	Manufacturing	Consumption by the manufacturing sector	grey
17	Transport	Consumption by the transport sector	grey

Table 78 Example of an input table for edges, in this case for the physical flow diagram filled with data from the reference scenario in 2010 on the global level

source	target	flow	extrainfo	description
1	2	13.64	orange	Land for bioenergy production
1	3	1556.92	orange	Land for crop production
1	4	3200.17	orange	Land for grass production (i.e pasture)
1	5	259.39	orange	Land for wood production
1	15	62.95	orange	Land for built-up area
3	7	1089.63	green	Crop production for feed
4	7	2699.63	green	Grass production for feed
3	8	1345.70	green	Crop production for food
7	8	262.44	green	Animal product demand
2	14	11.10	red	Biomass for energy
10	14	430.60	red	Fossill fuels for energy
11	14	9.92	red	Nuclear for energy
12	14	1.23	red	Wind for energy
13	14	0.12	red	Solar for energy
5	14	7.95	red	Biomass for energy from residues
8	15	2890.88	purple	Food demand per capita
5	15	1355.48	green	forest production for human use
1	9	3833.44	grey	Emissions from land-use change
3	9	5661.83	grey	Emissions from crop production
7	9	3874.96	grey	Emissions from livestock production
14	9	14842.71	grey	Emissions from energy production
15	9	3131.66	grey	Emissions from residential and commercial sector
16	9	6485.24	grey	Emissions from industry
17	9	6031.02	grey	Emissions from transport
6	3	1759.45	blue	Water withdrawal for irrigation
6	14	551.16	blue	Water withdrawal for energy production
6	15	486.84	blue	Water withdrawal for households
6	16	358.16	blue	Water withdrawal for industry
14	15	123.08	red	final energy for residential
14	16	121.92	red	final energy for industry
14	17	89.43	red	final energy for transport

13.4.3.2 The physical flow diagram visualization

The physical flow diagram visualization shows the main flows between major resources and sectors in the global human-earth system (Figure 177). The buttons in the top show the different policy scenarios that are included. By clicking on them you see the flows between the scenarios caused by different policies. By clicking on the 'show difference' button you can show what the percentage difference between scenarios is indicating where the increases or decreases due to different policy options takes place (Figure 178).By clicking on one of the sectors, you can highlight which flows are interacting with that specific sector (Figure 180). In this way the tool is ideal to inform stakeholders and other people that are interested in an interactive exploration of the global WLEFC Nexus. A guided tour is developed to help people understand the basic principles of the tool and to highlight the main synergies and trade-offs that are present in the Nexus.

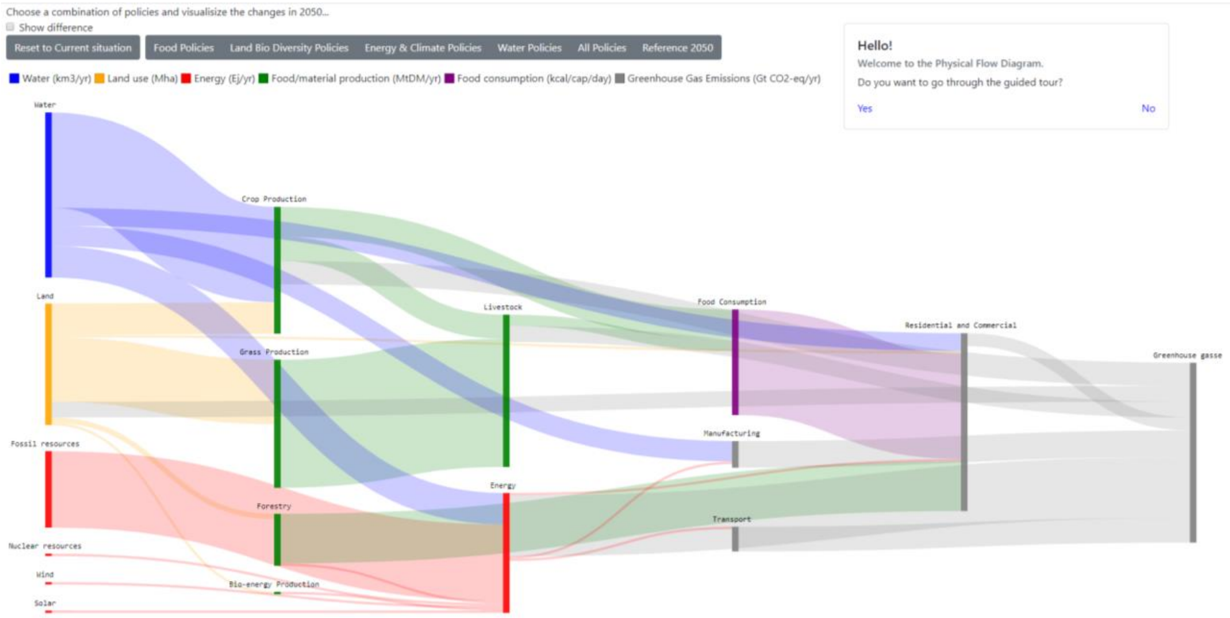


Figure 177 Screenshot of the physical flow diagram visualization for the 2010 reference situation

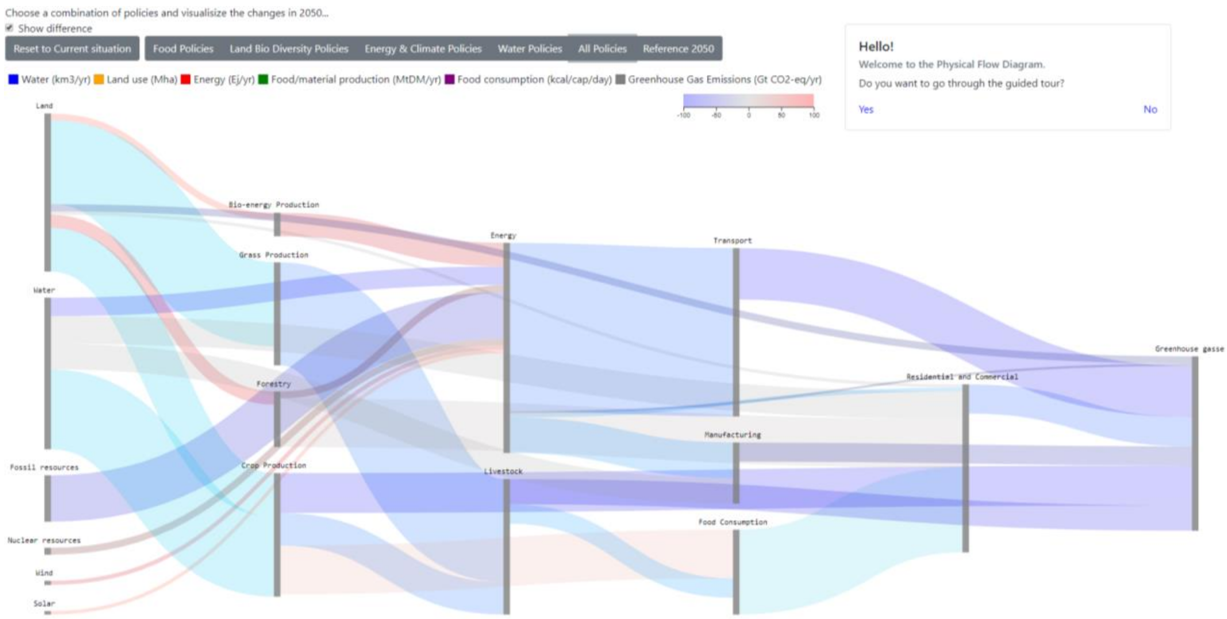


Figure 178 Screenshot of the physical flow diagram visualization for the difference between the 2050 reference scenario and the 2050 total scenarios where all policies are implemented

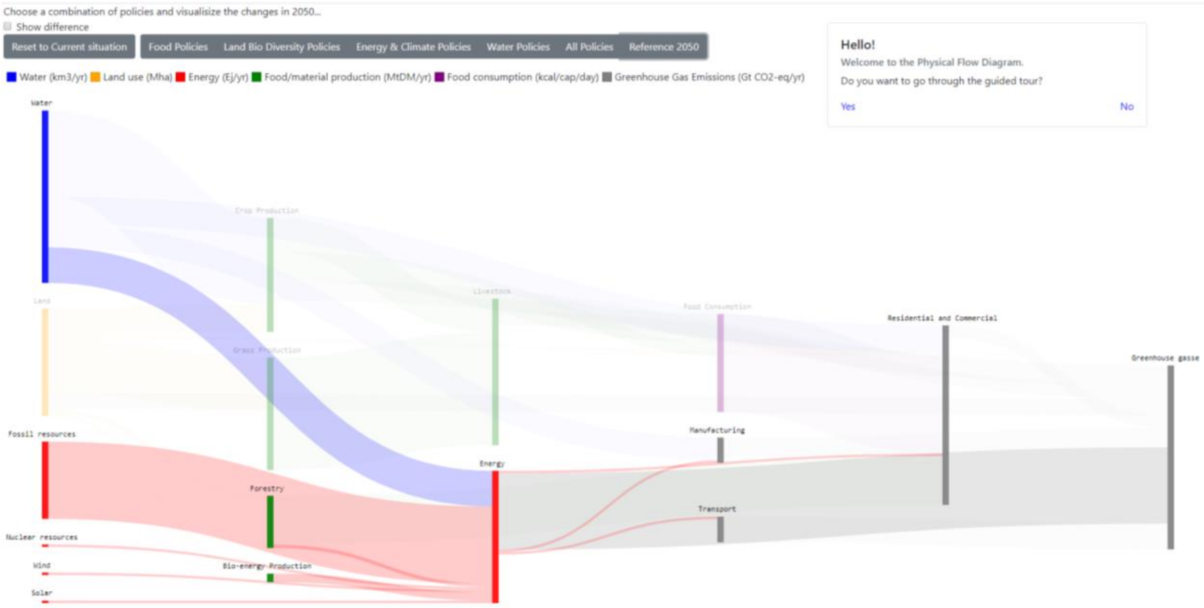


Figure 179 Screenshot of the physical flow diagram visualization for the reference scenario in 2050 - clicking on for example the energy sector highlights the flows to and from this sector

13.4.3.3 The system dynamics diagram visualization

The system dynamics diagram visualization shows connections between the sectors, resources or processes of the human-earth system (Figure 180). The purpose is to inform about the complexity of the system in a relatively simple way. The colours on the bar indicate different Nexus sectors, the circles are the different sectors, resources or processes. The lines are the connections between them. By clicking on one of the circles the specific connections are highlighted (Figure 181).

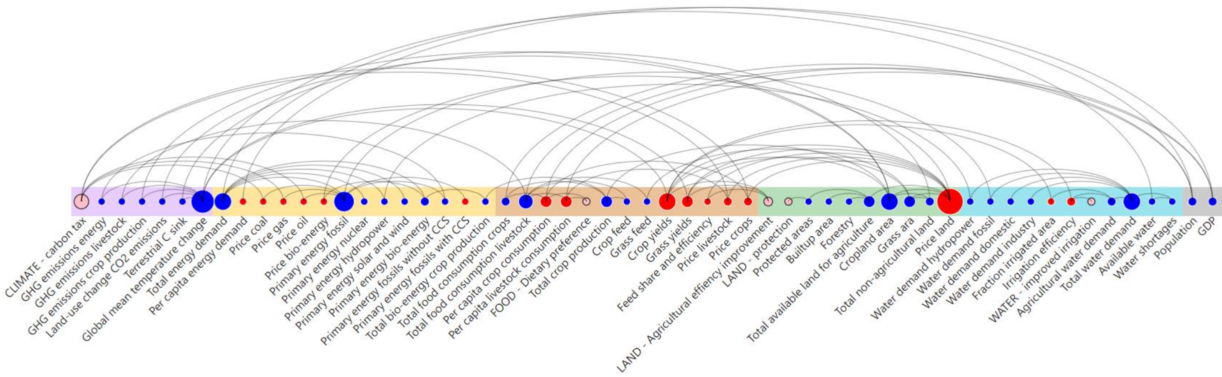


Figure 180 Screenshot of the system dynamics diagram visualization

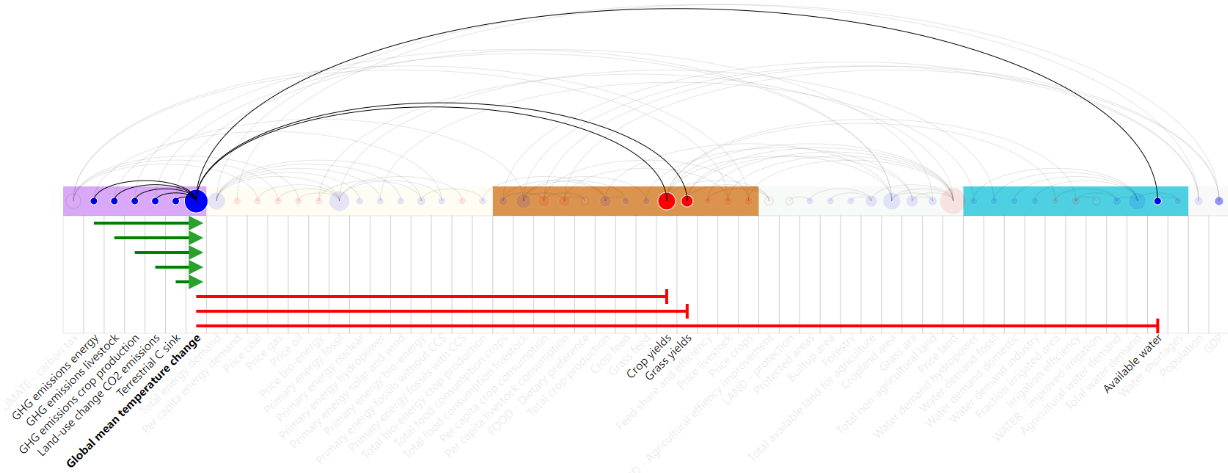


Figure 181 Screenshot of the system dynamics diagram visualization – clicking on for example the global mean temperature shows the connection and effects of this aspects of the system

13.5 From target scenarios to policy recommendations

13.5.1 Introduction

The human population has substantially grown and become wealthier over the last decades. These developments have led to major increases in the use of key natural resources such as land, food, energy and water causing increased pressure on the environment throughout the world. As these trends are projected to continue into the foreseeable future, a crucial question is how the provision of resources as well as the quality of the environment can be managed sustainably.

Environmental quality and resource provision are intricately linked. For example, food production depends on availability of water, land suitable for agriculture, and favourable climatic circumstances. In turn, food production causes climate change due to greenhouse gas emissions from land-use change, fertilizer application or livestock production, and affects biodiversity through conversion of natural vegetation to agriculture and through the effects of excessive fertilizer and use of pesticides. There are many examples of the complex interlinkages between different production systems and environmental issues. To handle this complexity the nexus concept has been introduced which recognizes that different sectors are inherently interconnected and must be investigated in an integrated, holistic manner.

Until now, the nexus literature predominantly exists of local studies or qualitative descriptions. This study presents the first quantitative, multi-model nexus study at the global scale, based on scenarios simultaneously developed with the MAgPIE land use model, the IMAGE integrated assessment model in combination with MAGNET, and the OSeMOSYS energy modelling system. In this analysis we excluded the CAPRI and E3ME models as they did not developed more than three target scenarios which made the possibility to quantify synergies and trade-offs very limited. The goal of the study is to quantify synergies and trade-offs between different sectors of the water-land-energy-food-climate nexus in the context of sustainable development goals (SDGs). Each scenario is designed to substantially improve one of the nexus sectors water, land, energy, food or climate (for more detail see section 13.4.1). A number of indicators that capture important aspects of both the nexus sectors and related SDGs is selected to assess whether these scenarios provide synergies or trade-offs with other nexus sectors, and to quantify the effects. Additionally, a scenario is developed that aims to combines policy action across nexus sectors providing an example of a holistic approach that achieves multiple sustainable development goals.

13.5.2 Results

For each of the three models a number of SDG indicators are selected that represent different Nexus sectors. We calculate the difference in these indicators between the reference scenario and the respective target scenario in the year 2050 (Figure 182 - Figure 184). This shows the effect of policies implemented in these scenarios (see Table 73) on the different Nexus sectors. For MAgPIE and IMAGE-MAGNET-GLOBIO we display boxplot where the underlying data points represent the 8 world regions to show the spread in values between the regions.

The indicator "food price" reflects the estimated change in agricultural commodity prices. Please note that it excludes the often substantial value-added in retail and processing, so it does not reflect the change in final consumer prices. Agricultural commodity prices rise under a climate mitigation scenario (ENERGYCLIM) for various reasons. Firstly, agricultural emissions are taxed, and the tax burden of the residual emissions is rolled over to consumers. Secondly, carbon pricing for forests lead to reduced land expansion and increases land scarcity and therefore land rents, which are also rolled over to consumers. Thirdly, mitigation measures are implemented and add to production costs. The combined effect explains the substantial rise in agricultural commodity prices. This indicates a trade-off between food security for net food-buyers and climate mitigation; this trade-off could however be softened if tax income would be redistributed to consumers. The effect of land protection for biodiversity protection on food prices is much smaller. This is because here only land scarcity is increased, while emissions are not priced. Moreover, the protected areas are smaller than the land areas affected by a carbon tax, where in principle all areas with vegetation carbon are taxed. The FOOD scenario, shifting to sustainable diets with less waste, result in a strong reduction of food prices. The reduced demand allows to cultivate crops only in the most productive areas, and requires less investments into land-sparing technological change. Implementing maximum water withdrawals for agriculture that respect environmental flow requirements (WATER) has only a small impact on food prices. Opportunity costs for expanding irrigation elsewhere or cultivating irrigated crops rain-fed seem to be rather low. Finally, the combination of all measures lead to a net-reduction of food prices for most regions. There are positive synergies between the measures. It seems that reducing the pressure on the agricultural system by lowering food demand also allows for a more efficient allocation of the remaining food production on areas with little environmental impacts.

The interactions of the different NEXUS scenarios on water usage are less diverse, and show clear positive synergies. Here, only the mitigation scenario ENERGYCLIM leads to a slight increase of irrigation water demand due to the additional demand for bioenergy, and due to the need to intensify the crop production to spare land from deforestation. The highest water savings are of course achieved under the water scenario where all environmental flow requirements have to be achieved, but also the food demand scenario shows a strong reduction in blue water consumption.

In the case of fertilizer use, all scenarios lead to a decline fertilizer application. The ENERGYCLIM scenario shows the lowest reductions, as two processes are opposing each other: on the one hand, additional bioenergy usage requires more fertilizers; on the other hand, pricing of N_2O emissions leads to a more efficient fertilizer management. Nitrogen fertilizers are however not only relevant for greenhouse gas emissions; they also lead to terrestrial biodiversity degradation due to volatilization and re-deposition of nitrogen, as well as to water quality losses by leaching of nitrate. This explains why our scenarios WATER and LAND, which assume policies to improve water quality and the state of terrestrial biodiversity also result in a strong reduction in nitrogen fertilizer. Finally, the food scenario also substantially lowers fertilizer application, as lower food demand, and in particular lower demand for animal source products results in less crop production and therefore also reduces fertilization requirements.

Greenhouse gas emissions are only significantly affected by the ENERGYCLIM and the FOOD scenario. It is interesting here that the FOOD scenario with more sustainable diets leads to a stronger reduction in GHG emissions than the mitigation scenario. This is because the diets assumed here do not only reflect the need for more environmentally sustainable diets, but also for more healthy diets. Moreover, the scenario is rather radical, and may be a stronger intervention into people's lifestyles than carbon pricing alone.

Forests are better protected in almost all NEXUS scenarios. Only in the case of water protection there seems to be a small trade-off, owing to the fact that rainfed production systems have lower yields, resulting in more area-expansion. It is interesting here that the LAND scenario does not result in a substantial increase in forest protection. This is due to the fact that in this scenario only the most biodiverse ecosystems were protected, resulting rather in a shift of deforestation to other areas than an actual reduction in deforestation.

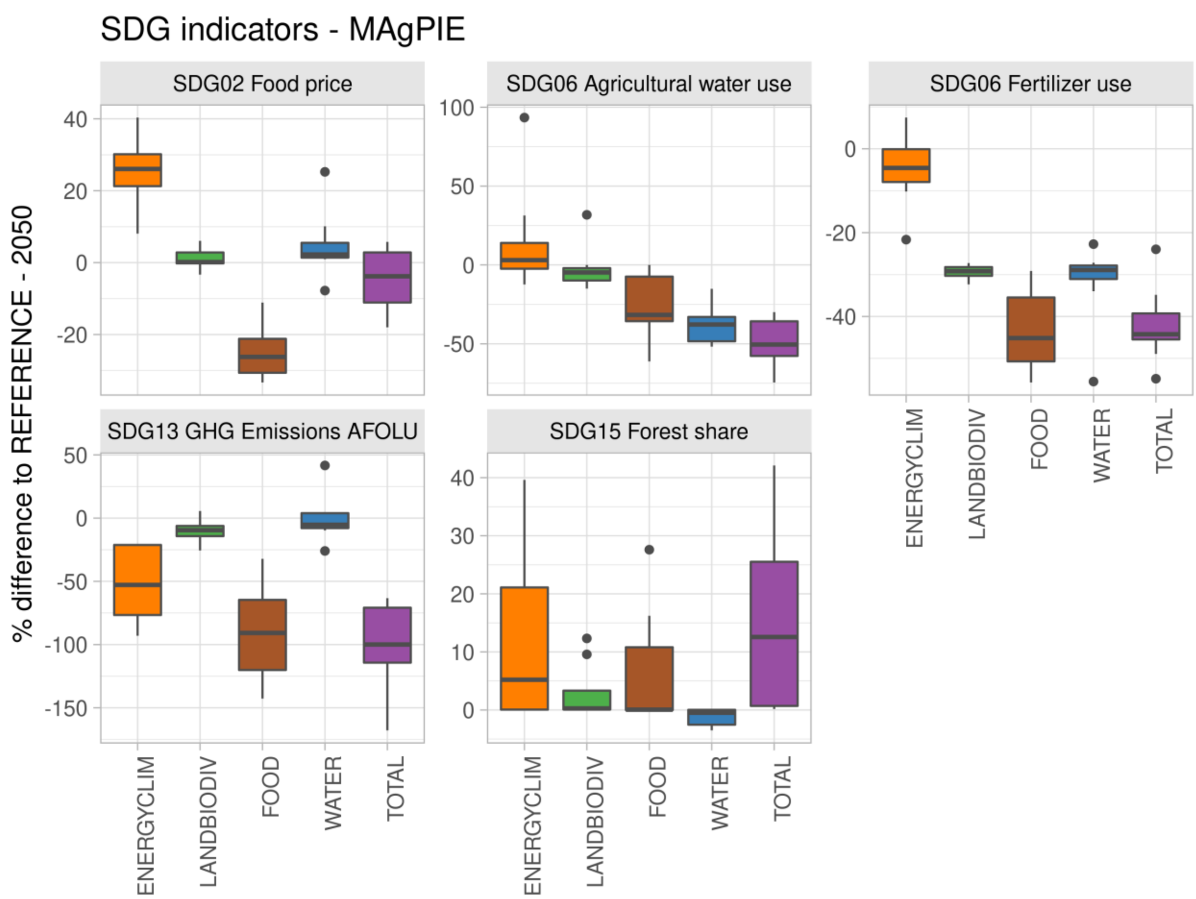


Figure 182 Boxplot of regional differences in percentage between reference and five target scenarios in 2050 for five SDG indicators based on MAgPIE model results

The IMAGE-MAGNET-GLOBIO results show a number of synergies and trade-offs. In the ENERGYCLIM scenario climate policy such as an increase in CO_2 pricing leads to major changes in the SDG indicators with a strong increase in the renewable energy share (+60% to +290%, SDG7) and a strong reduction in greenhouse gas emissions (-70% to -80%, SDG13). However, these policies also lead to an increase in food prices in all regions of the world (+3% to +30%) as extra land is protected to reduce emissions from land-use change, indicating a trade-off between climate policy and food security (SDG2). On the other hand, in most regions of the world there is an increase in forest share (0% to +70%) indicating a synergy with biodiversity ambitions (SDG15), as well as a substantial reduction in water withdrawal in almost all regions (+2 to -20%) showing a synergy with water targets (SDG6).

The biodiversity policies on extra land protection in the LANDBIODIV scenario lead to an increase in forest share in most regions (-20% to +20%, SDG15). As not only forests are protected the effect is smaller than in the ENERGYCLIM scenario. There is a small increase in food prices showing a trade-off (+3% to +8%, SDG2) and a small reduction in greenhouse gas emissions (0% to -12%, SDG13) showing a synergy. Also the pollution of rivers with nitrogen is slightly reduced due to less agricultural activities which also affects water withdrawal for irrigation.

The food policies in the FOOD scenario most importantly limits meat consumption causing strong effects on food prices (-40% to -60%) indicating improved overall food security (SDG2): this is related to reduced land use for livestock production and reduced consumption of feed crops by animals making more crops available for human consumption. The reduction in overall agricultural production leads to reduced land use resulting in an increase in forest share (+ 2% to +30%, SDG15), reduced greenhouse gas emissions (-2% to -14%, SDG13) and reduced nitrogen concentration (-1% to -16%, SDG6) which are also important synergies. As there are no major trade-offs in this analysis it shows that food policies reducing meat consumption is a coherent policy.

The WATER scenario shows a strong reduction in nitrogen concentration in most regions related to improved fertilizer use efficiency (+12% to -35%, SDG6). Also water withdrawal is substantially reduced due to improved efficiency in irrigation systems and water use in energy, industry and households (-10% to -21%). Unfortunately the feedbacks to the food system are in these runs not taken into account, so some trade-offs due to reduced water availability for irrigation on food security are missing in this analysis.

The TOTAL scenario aimed to combine all policies present in the different target scenarios. For most SDG indicators this lead to a further improvement of the Nexus sectors highlighting the synergies mentioned before: greenhouse gas emissions are even further reduced in the TOTAL scenario (-71% to -85%) than in the ENERGYCLIM scenario (-66% to -88%) as additional other natural land is protected and as agricultural production is reduced due to reduced meat consumption. Also water withdrawal is further reduced as water use is reduced in fossil-fuel based energy production due to climate policy, in irrigation due to lower meat consumption as well as due to further efficiency improvements (-10% to -30%). The food prices however are slightly less low in the TOTAL scenario (-34% to -58%) compared to the FOOD scenario (-43 to -59%) as the reduced pressure in the food system due to lower meat consumption is counteracted by a slight increase in pressure due to stricter land protection from both biodiversity and climate mitigation policies.

In line with IMAGE results, the OSeMOSYS modelling outcomes for the ENERGYCLIM scenario intend to show the impact of climate policies aiming at lowering GHG emissions worldwide, to limit the increase in global mean temperatures below 2 degree Celsius. The results highlight two main possible implications on the system: on one side the share of renewable energy sources in the Total Primary Energy Supply (TPES) is projected to increase by 50%, on the other side the total amount of GHG emissions accounted over the entire system is expected to decrease by 60% in comparison to the reference scenario. In addition, it envisions an increase in forest land by approximately 10%, possibly linked to minor changes in diet that contributes in lowering the food demand by 2% and therefore allows to reduce the use of land for agricultural purposes. Forest land is characterized by negative emissions in the OSeMOSYS model, to represent the capability of trees and vegetation to absorb and store CO_2 emissions. These outcomes highlight the need for significant changes in the development of the nexus sectors represented in the model up to 2050, in order to be able to meet the GHG emission reduction target.

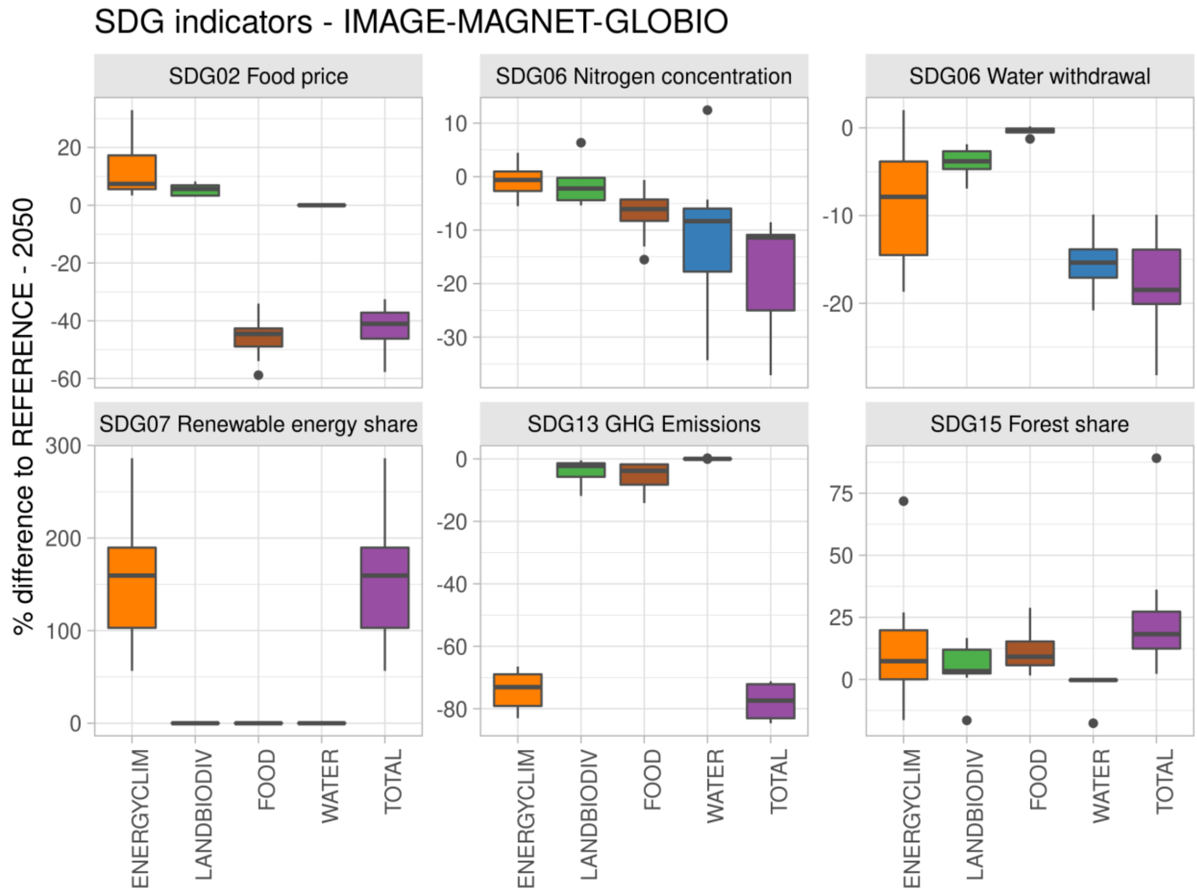


Figure 183 Boxplot of regional differences in percentage between the reference and five target scenarios in 2050 for six SDG indicators based on IMAGE-MAGNET-GLOBIO model results

The FOOD scenario in OSeMOSYS is assuming the implementation of policies aiming at achieving worldwide a healthy reference diet by 2050, as defined by the EAT-Lancet commission (Willett et al., 2019), and to improve the efficiency of the food production system by 50%. Looking at the modelling results, this seems to allow a decrease in food production of approximately 18% by 2050, due to the overall lower food intake (in kcal per capita) estimated by the EAT-Lancet commission. In addition, it seems to reduce the amount of water withdrawal by 40%, thanks to the reduced need for irrigated cropland supplying the food demand and the increased efficiency of the food production chain. Finally, the measures implemented in the food scenario seem to highlight the link between land use and forest land. A reduced need for cropland seems to cause a large increase of forest share over the total land cover by 100%, thus also providing more forest biomass to be used for energy purposes (hence the small increase by 15% of the renewable energy share).

In the OSeMOSYS model, the WATER scenario is modelled assuming an increase in irrigation efficiency by 1% in each year of the modelling period for the irrigated cropland. This seems to not have major impacts on the system, causing just a minor reduction in water withdrawal with no additional effects on the overall systems.

The TOTAL scenario combines all the assumptions mentioned above, thus assuming all the related policies are implemented. This seems to highlight the synergies and interlinkages between different sectors, with significant positive effects on all the SDG indicators in Figure 184). Thanks to the change in food diet coming from the FOOD scenario, less food (-18%) and related cropland are required to satisfy the demand, allowing the model to opt for increasing the share of forest land (+100%) in the system. This contributes to capture CO2 emissions, thus supporting the reduction in overall GHG emissions. At the same time, less need for cropland also means less need for water for irrigation, which summed up with the increase in irrigation efficiency coming from the WATER scenario turns into a reduction by 42% in water withdrawal. Finally, it is worth mentioning how the significant increase in forest share implies that forest land can increasingly contribute to the absorption of CO2, thus lowering GHG emissions. This consequently provides the energy sector with more flexibility in the selection of resources and technologies it can use to supply the energy demand. Therefore, the renewable energy share increases only by 38% in 2050 in comparison to the reference scenario, while being approximately 10% lower than in the ENERGYCLIM scenario and achieving the same reduction in GHG emissions.

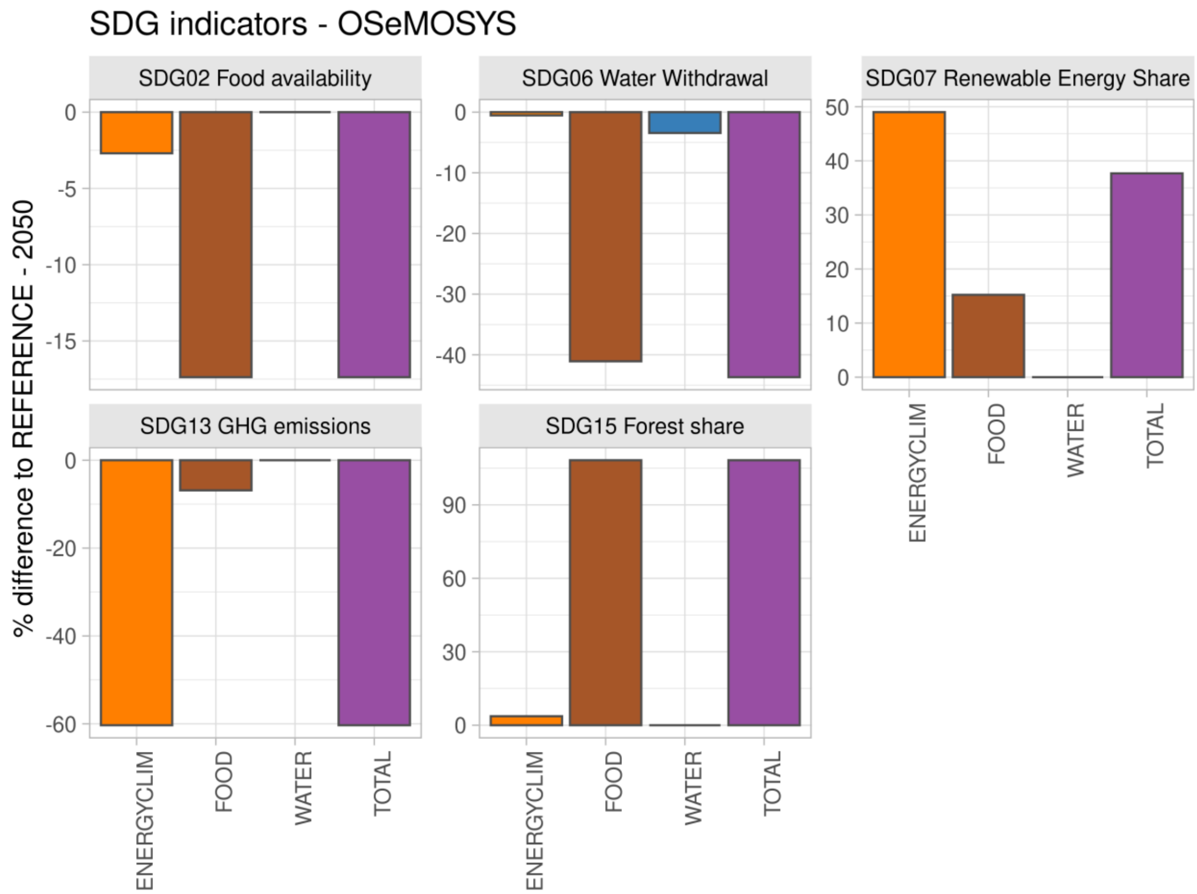


Figure 184 Bar chart of percentage difference between reference and four target scenarios in 2050 for five SDG indicators based on OSeMOSYS model results

13.6 Short-term and long-term policy recommendations

This section focusses on the challenges and sectors for which recommendations can be made. The most relevant stakeholders for the global case study are policy makers at the European level, other large regions or countries, and at international organizations. The policy recommendations for the Global (and European) level had also been summarized in a policy brief (Ref, January 2020). Building on this policy brief, policy recommendations from the global scale analysis are described here.

13.6.1 Policy recommendations

13.6.1.1 Summary of policy recommendations

- On all levels of policy making, using a nexus approach will maximize policy coherence, exploit synergies and address unwanted trade-offs between policy domains.
- A clean energy transition likely involves increased use of bioenergy as one of the renewable sources. Large scale provision of bioenergy from crops, plantations and forests may have severe trade-offs to water, land/biodiversity, global food security, climate adaptation and even mitigation (in case high-carbon soils would be converted to grow energy crops). Policies stimulating directly or indirectly the use of bioenergy should only be put in place if both food security, biodiversity protection and climate-neutrality are guaranteed.
- Replacing animal by plant-based proteins in our diet and increasing resource efficiency in the agro-food chain are synergistic with goals for energy, climate, natural resources and health. However, livestock farmers may need to change their business. On the other hand, this may provide large opportunities in the horticultural industry which would have to be scaled up massively.
- Biodiversity protection and restoration can have synergies with climate change mitigation as a so-called “natural climate solution”, but may also put risks to food security, similar to bio-energy deployment.
- There are high synergies between climate change mitigation, water quality and biodiversity protection when it comes to improved nitrogen use efficiency. A joint strategy is therefore recommended.

13.6.1.2 Detailed policy recommendations

Trade-offs from bioenergy

In the strategies to meet the Paris Agreement to keep climate change well below 2 degree, bioenergy will play a crucial role. According to global case modelling bio-energy will contribute 6-31% to the energy mix in 2050. Likewise, large-scale afforestation will also contribute to ambitions mitigation strategies. Both bio-energy plantation and afforestation may interfere with food security on the global scale. If implemented without counter-balancing measures, by 2050, globally up to 230 million more people compared to the reference scenario could be at risk of hunger under ambitious afforestation and bioenergy targets (Doelman et al., 2019). At the same time, the climate-neutrality of biomass sources cannot be guaranteed, due to continued deforestation in tropical regions and risks of indirect land-use change, especially with fragmented international climate policy.
Consequently, policies stimulating directly or indirectly afforestation and the use of bioenergy should only be put in place if both food security, biodiversity protection and climate-neutrality are guaranteed. With international policy instruments currently lacking, domestic supply combined with measures that lower land-use demand for other purposes is to be prioritized.

Climate mitigation in agriculture may raise prices and decrease livestock

Imposing GHG prices on agriculture to reduce emissions will increase the price of farm products, especially meat and dairy products, and thus decrease demand and production, particularly in the livestock sector, according to model calculations. Crop production is projected to be significantly less impacted as crop activities can expand into areas previously used for livestock. While in some region this price effect on livestock may be regarded beneficial and actually in line with the transition to reduced consumption of livestock products, regions with lower consumptions of meat and dairy will also show trade-offs with food security. While acknowledging the importance of GHG mitigation in the agriculture and livestock sector, the appropriate measure is not through full emission taxing, but through technology transfer, regulation and possibly subsidies to achieve low-emission production systems

Food system: environmental benefits of a healthy diet

The transition to a diet with more vegetable and less animal products can have substantial environmental and health benefits. Results from the global case scenarios projects that such a dietary transition towards more plant-based commodities would result in agricultural land use to be reduced by 9-53% in 2050 compared to the baseline (based on MAgPIE, IMAGE-MAGNET-GLOBIO and CAPRI results). This in turn results in a decrease in greenhouse gas emissions from agriculture of 27-92% in 2050 compared to the reference scenario. In contrast with imposing extra greenhouse gas mitigation measures on the agricultural sector, a change in consumer behavior leads to decreasing prices for livestock products (resulting from a reduction in consumer demand), which may benefit access to livestock commodities for the global poor. However, in both scenarios (GHG pricing or dietary transition) livestock farmers will see a reduced demand for their products. On the other hand, healthy diets would also require a scaling up of the horticultural sector which also provides large value-added.
The effects of such a food transition would be maximal if implemented in all 'developed' world regions. If Europe would be the only region that changes to more plant-based diets, the effect on emissions from European agriculture might be relatively small, when European livestock farmers would direct part of their production to export markets. Therefore, a reduction in both livestock demand and production, together with alternative income models for livestock farmers should be pursued. A smaller livestock sector will not only show the above-mentioned benefits but make room for lower intensity arable farming and all its benefits for landscape restoration, reduced pesticide use, improved nutrient balances and water quality.

Biodiversity strategies beyond classic conservation

The scenario for biodiversity protection in the global case applies a classical conservation strategy, protecting terrestrial ecosystems via an expansion of reserves. This results in larger forest fractions. As observed earlier, expansion of protected area for biodiversity conservation either has limited effects (due to land-use changes just being relocated to non-protected areas), or has strong trade-offs with food security. Therefore, additional demand and supply side measures need to go along with biodiversity conservation to ensure its sustainable effect.

Nitrogen management links climate change mitigation, livestock sector, water quality and biodiversity

Improving the nitrogen use efficiency in agriculture (in global case scenarios modelled as part of the *water* scenario, shows benefits for fertilizer use, and slightly decreasing for GHG emissions, water quality (i.e. nutrient concentration), and ultimately biodiversity (not covered explicitly in global case scenarios presented here). Furthermore, reduction of the livestock sector through dietary transitions shows an even larger effect on nutrient balances, and water quality. Therefore, the management for nitrogen in both livestock and arable agriculture (and in parallel other nutrients like phosphorous) is central to addressed in climate mitigation, water quality and biodiversity.

13.7 Conclusion

In the global case we investigated the water-land-energy-food-climate nexus at the global scale. A large number of nexus challenges were addressed with multiple thematic models. Examples of interesting nexus challenges are the trade-offs between climate mitigation such as greenhouse gas pricing in agriculture and bio-energy production with food security, the synergies between diet policies, water quality, greenhouse gas emissions and biodiversity, and the synergies between nitrogen management, the livestock sector, water quality and biodiversity.

The global case involved multiple thematic models, each with different strengths and weaknesses. Interactions between the partners in the global case enhanced cooperation between nexus modellers and resulted in interesting exchanges of knowledge. Using multiple models also made sure that nexus connections that were covered by one model differently from another were covered as comprehensively as possible.

In the final section of this report we use the results from the global case modelling work to formulate policy recommendations. Recommendations are given in the fields of climate mitigation, dietary change, biodiversity protection strategies and nitrogen management. Approaching these topics with a nexus approach highlights synergies across nexus sectors between policy actions which underlines the quality of certain strategies. For other strategies it shows that approaching a problem from one sector only could result in missing out on crucial trade-offs. All in all it shows the relevance of the nexus approach and the necessity to continue research in this field.

13.8 References

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14 Overview and conclusions

The "philosophy" behind the case studies, as described in Deliverable 5.1, was to consider evenly the expectations from researchers of the other workpackages and the needs and inquiries by the case studies' stakeholders. The top-down provision of tools and methodologies had to match the bottom-up expression of questions in order to co-design the most appropriate and practical solutions. The work was planned as an iterative process, alternating between inputs and feedbacks on both sides.

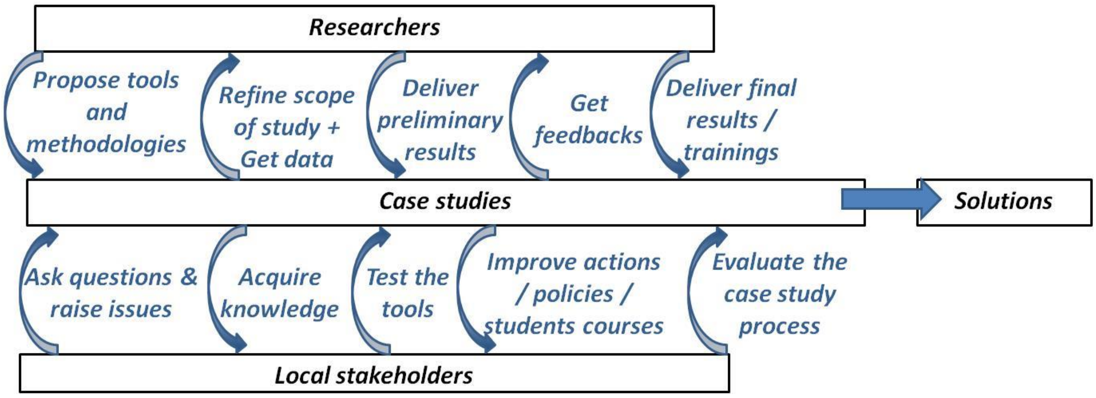

Figure 185 Case studies "philosophy" described in D5.1

The case studies' reports are proof that **this iterative process was implemented successfully**.
Through the case studies, qualitative and quantitative inputs were combined, policies and research results were merged. The dynamics of the research work and the stakeholders process on the case study's progress are complementary, as schematised in the figure below.

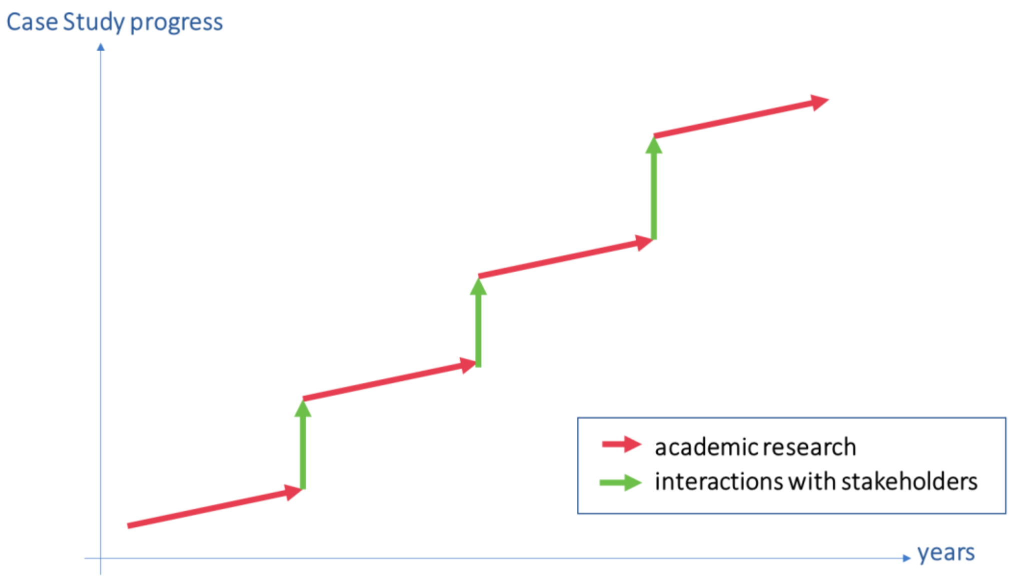

Figure 186 Simplified representation of the combination between the academic research performed by the case studies teams and the stakeholders' engagement activities in SIM4NEXUS

The research work represented the large majority of the time spent by the case studies teams (meaning the lead partners as well as the associated partners from other workpackages providing methodological guidance, performing modelling or building the Serious Game). Indeed the research work includes numerous interactions within the SIM4NEXUS consortium, reviewing the literature, collecting and processing data, analysing results and contributing to the project's deliverables.

The interactions with the stakeholders are occasional : few hours interview, 1 day workshop, few weeks survey, … but they represent majors steps in the case study's life. Indeed, these activities are designed to take important decisions (i.e. policy scenarios to be studied), to validate research results (i.e. conceptual models, or thematic models outputs) and to agree on next steps to be performed by the case studies teams.

The **intricate science-policy interface** that SIM4Nexus managed to build through the 12 case studies is also the result of the choice of the case studies' lead partners. UTH and KTH are leading WP1 and are also lead partners for Greece and Azerbaijan case studies. PBL is leading WP2, as well as the Global case study, and is strongly involved in the European and Dutch case studies. UNEXE is leading WP3 and strongly involved in the South-West UK case study, while UPM, the co-lead of WP3, is lead partner for the regional case study in Andalusia. WUR and ACTeon are leading WP5 and lead partners for the European and the Dutch case study, and for the France-Germany case study, respectively. The WP leaders were therefore very knowledgeable of the case studies' progresses, multiplicity of tasks and implementation challenges. They were therefore able to provide **relevant and timely guidance to the case studies**. This organisation also contributed to the **recognition of the value of the stakeholders' inputs** in our research approach.

A diversity of means was used to mobilise local experts and decision makers in our case studies : workshops, conferences, interviews, surveys, … A minimum of 2 workshops is organised by each case study, counting up to 4 (on the date of publication of this deliverable – 5 by the end of the project) in Latvia or the Netherlands. Participation to the case studies' workshops ranged from 15 to 30 people – representing a diversity of public or private organisations across the 5 Nexus domains. Interviews or surveys increased the number of contributors providing expert knowledge. Overall, **each SIM4Nexus case study managed to engage between 30 to 60 organisations in the process**.

The stakeholder engagement processes in the 12 case studies range **from expert consultation to joint strategic planning.** This diversity of situations is explained by :

a/ **existing working habits** between the case study lead partner and the stakeholders. Some case study leaders already have a very good knowledge of the governance, interests and powers in place on their territory. It can be inherited from previous research collaborations (i.e. Sardinia, Latvia) or through institutionalised relationships (i.e. South-West UK). The acquaintances speeded up the mobilisation of relevant stakeholders representatives in the case study activities. On the opposite side, the absence of local partner from Azerbaijan in the SIM4Nexus consortium was a serious threat for the success of the national case study. It could be overcome by sub-contracting a local consultant who had these precious relations with relevant Azeri stakeholders.

b/ **Nexus-issues expertise**. Lead partners who had a very good understanding of the Nexus issues on their territory (i.e. Andalucía, Greece) managed to define the case study's scope, in line with the local interests. This contributes to a higher involvement, as stakeholders can immediately see the benefits of getting involved in the case studies activities. On the opposite side, some Partners struggled to identify and narrow-down the Nexus challenges to be dealt with (i.e. France-Germany, Sweden). The engagement process was slower to start, but had no major consequence on the latter progress of the case study.

c/ **on-going policy processes**. Some case studies' Nexus challenges were tailored to the political agenda. This offered the opportunity for the lead partners to be active in the regional or national debates – flagging the lessons learnt from SIM4Nexus and drawing attention towards the case studies' activities. For instance, the Dutch case study focus over energy transition and low-carbon economy met the national debate on methanisation development. In Slovakia, the land-water-climate Nexus investigated in the case study echoed the development of the regional land management strategy, resulting in strong interactions with local stakeholders. On the opposite side, some political switches can threaten the stakeholders engagement process by modifying strongly the priorities (i.e. Brexit discussions in 2018-2019) or the key representatives (i.e. in Sardinia in 2019).

The main challenges faced by the case studies to engage and retain the stakeholders' interest were :

- **the length of the process**. The case studies implementation covers a 4 years timeframe, which means the participant have to wait several years to see the final results or products built from their contributions. There is also a risk that committed participants change job or become too busy to continue.
- **the limited availability of decision-makers**. SIM4NEXUS results are targeted at local decision-makers, though they are usually very busy people.
- **the legitimacy of involved experts**. Some participants feared they lacked the legitimacy to judge the coherence of public policies, to validate modelling results or to make recommendations outside of their field of expertise.
- **the unknown "Nexus" word.** The use of the Nexus word is not yet mainstream in the administrations or private organisations, especially at local level. Case studies' communication had to be adapted to the target stakeholders' language to make sure they feel concerned.