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

D1.2: USE CASES FOR SIM4NEXUS

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1ST	MPP	31/12/2018	1ST VERSION
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As a general comment, we would like to note that this is not the final version of Task 1.2, since the final version will be submitted at month 46, according to the GA.

EC Comments	Reply by UTH
Glossary is particularly welcome. Two missing definitions: Use Case and policy indicators. Inconsistencies in terminology with other deliverables must be corrected (e.g. D1.7, nexus domains in T1, D1.7, nexus components)	We added the following text: **Use case**: 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. (Use Case definition) **Policy indicator**: An indicator used to express, in quantitative terms, the success or failure of an implemented policy. It serves to evaluate the performance of a policy tested in the SG. (Policy indicator definition) Inconsistencies in terminology with other deliverables have been addressed.
Some clarification is needed on the inclusion of tourism as a nexus sector. Tourism does not play an equivalent role as the other nexus sector; it is rather a sector or application, as could be any other sector of activity (fisheries, industry, etc.)	We added the following text: Under the nexus framework, Use Cases were built for each nexus sector. Such sectors are: water, land, energy, agriculture & food and climate. Use Cases were also built for the sector of tourism as it puts extra pressures on the nexus sectors, especially in case of traditional tourist destinations such as Greece, Andalusia and Sardinia. Such pressures are multiple during the peak tourist season putting additional stresses to natural resources mainly water, food and energy.
The use of Use Cases in the project is not fully clear. For example, how they are used in the framework? (See D1.7)	We added the following text: In T1.7 specific performance indicators will be proposed to assess how efficiently environmental and human resources are used in the context of the S4N SG. Among the elements of each Use Case developed for the S4N SG are: a) the goal to be achieved, 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 through the use of respective indicators. Then, the definition of the different Use Cases for each

	Case Study details the different scenarios, in their corresponding context and with the different actions/interventions to be taken, the user will face will trying to achieve the different objectives, and while learning by doing.
The table on interlinkages is incomplete and somehow misleading. For example, why is the link Water-Energy not included? (water affects energy supply – e.g. hydro, thermal plants). This is different from the link Energy-Water. More complete interlinkages are available in other deliverables (e.g. section 4.2 of D1.7, mapping). More globally, why aren't all the interlinkages identified in D1.1 (appendix) included in the Use Cases?	A detailed description of all interlinkages is presented in D1.1. In this table only indicative interlinkages are presented that are associated with the specific Use Cases.
Can a user also explore actions which are not under his control?	No, only activated for the user options can be selected. The relevant text clarifying this issue is: Depending on each Case Study, users will count with the complete set of available actions or just a subset of them depending on the role in the game. Moreover, only coherent actions will be shown, avoiding users being able to select non-coherent actions (i.e. conflicts of interest, etc.).
Are actions thought as being implemented by the user? If yes, some actions are not fully relevant, such as water pricing for industrial use in Use Case W.2 where the user is industry.	We agree, but this has to be managed at Case Study level, and avoid non-coherent options to be selected. In other words, it is a matter of defining it correctly. Only coherent actions will be shown to the user. This is part of the Case Study definition.
More information would be needed on what is coming from stakeholder engagement or other sources in the definition of the generic Use Cases	We added the following text: More analytically, stakeholders supported the development of Use Cases by offering their valuable knowledge, experience and expertise. For example: Policy makers coming mainly from the public sector, pointed out the most important policy goals and priorities; private sector representatives highlighted several difficulties they face when implementing policies; NGOs stressed the necessity for the development of more sustainable policies, and; representatives from the academia shed light on the science behind a policy. Stakeholders contributed also to the identification of conflicts and alliances developed when a policy is implemented while they also showcased the necessary types of arrangements to be made in

	order to address inconsistencies at practical level. They were positive to explore in the future, the policies that may affect their future plans and actions as well as their influence during the decision making process. The interaction with stakeholders, via bilateral semi-structured interviews and workshops, resulted in the creation of a knowledge stock incorporated while Use Cases were built. This is of utmost importance because, as already mentioned, stakeholders are the possible future players of the SG and thus the SG should correspond to their interests and future needs.
Are actions thought as being implemented by the user?	Yes, they will be implemented by the user. If a user has an action available, then that means he/she is able to enable it and make it real in the game.
How were actions and indicators defined for each user? They are probably not exhaustive.	We have added the following text:
How were the users selected for each goal?	Moreover, the selection of the goals set in each Use Case was based on existing and future policy priorities and on stakeholders' interests. Therefore, the goals were selected for the users according to their professional and scientific orientation, their expertise and their areas of interest. The definition of actions is mostly related to the goal as they represent possible steps to be done towards its accomplishment. Relevant indicators were determined based on the actions taken, as a metric used to measure actions' performance. Also, the values of all indicators inform the user about the overall achievement of the goal. Once this logic is set, only relevant actions are shown to users which role is aligned.
Why are goals associated to only one type of user?	Goals are not associated to only one type of user. For example in Use Cases W.1 and W.2 the goal: "Water savings" is associated to two types of users, Public sector (Ministry of Agriculture) and Private sector (Industry). Also, in Use Cases E.1, E.2, E.3, E.4 the goal: "Expansion of RET in the electricity sector" is associated to Private sector, Public sector, Academic/Research Institutes and NGOs. The same happens with other Use Cases. Relevant text: Each UC describes the actions/steps that a specific type of actor (SG player) may take/follow

	to achieve the goal associated with the specific UC. For each type of actor, the necessary actions to achieve the same goal may not be the same. For that reason, for the same goal and different type of actor, a new UC is developed when necessary.
Reviewer's comment: Some actions and indicators are not "self-talking" or need clarification. For example, in Use Case W.1, does "total cost of agricultural water" refer to the investment by the Ministry of Agriculture, or to the total cost paid by farmers for water consumption?	We have added the following text: It refers to the investment by the Ministry of Agriculture
The "energy" nexus sector is focused only on electricity supply (see examples of Use Cases). Why no coverage of energy demand, and of other energy sources?	Electricity supply was considered in these use case examples as the idea was to only provide examples. Additionally, we intended to express the difference of a use case with the same goal but from the perspective of different stakeholders. This is why the use cases' E1, E2, E3, and E.4 share the same goal but are defined considering different users. The use case numbering has been updated to E.1.1 to E1.4. – and proceed similarly to other energy use cases sharing the same goal. An explanation of the reasoning behind the use cases choices addressing the EC feedback has been added. Regarding to energy demand, this is considered as an action in E1.3. Note that changing demands is probably a possibility suitable for a use case goal. It does make sense to see how the system configuration adjust over time to changing demands. We added the following text: In the next tables the Use Cases designed for energy are presented. Note that the Use Cases presented for the energy sector, more specifically to the electricity sector, were chosen considering common goals across case studies in order for Case Study teams to be able to relate to the goal presented. Use cases E1.1 to E1.4 represent examples of a same Use Case goal in the perspective of different users (i.e. private sector, public sector, academia and research,

	NGOs). Use cases E.2 and E.3 refer to different goals for a same user (in this case, the private sector).
Some actions and indicators are not "self-talking" or need clarification. In Use Case E.2, the mention of "electricity prices" as an action is surprising since electricity prices are the results of markets; do researchers mean feed-in tarrifs? Why not including here some of the actions included under Use Case E.3 such as CO_2 targets, fuel prices?	Use Case E.2 (now E1.2) has been changed and updated according to the comments. As for the "electricity prices", yes we mean feed-in-tariffs.
In Use Case C.3, "Define the foreseen reduction in hydropower production due to climate change" is not really an action to solve the issue (it is an intermediate measure needed to define other actions).	In Use Case C.3 (now C.2) this action was thought as an option for the user to select how much of HHP output would be reduced in reference to the baseline generation. For example, the user could manipulate the game and perform runs considering different reductions of HPP generation (e.g. -10%, -20%, -40%) and assess how the nexus systems evolve considering these restrictions of RE generation and the policies in place.
How will some of the proposed actions be modelled? For example actions proposed in Use Cases C.4, and in Use Cases related to land use and agriculture/food, are generic. The analytical description provided in Appendix I does not answer this question since it only mentions, for example for land use, "Choose 1 land management policy" without specifying which one.	We do not have information on how these actions are modelled, which is not the objective of this tasks. The objective of the Use Case is to provide examples that can guide the case studies in the development of their own use cases – which in many cases can be quite specific to the case and, consequently, to the set of modelling tools used.
There are some inconsistencies in the proposed steps of the SG (Appendix I). Use Case E.6.: Increase of electricity may reduce emissions in the importing country but increase them in the exporting country; how is it considered?	Use Case E.6 is now Use Case E.3. This depends on the energy mix of the countries exporting the electricity to the case study country/region. Another sub-set was added to account for the potential implication of the change in electricity trade dynamics – in case this is relevant for the case study to add. As models focus on countries and regions, and not so much on cross-country implications, it may not be straightforward to retrieve cross-border results related to the changes in other countries electricity mixes (as these are not being modelled in parallel). I only see the European case being able to inform on such implications.
There are some inconsistencies in the proposed steps of the SG (Appendix I). Use Case C.2: What	Use Case C.2 is now Use Case C1.2.

happens if different models provide different values for the same outputs? The price of carbon permits in the carbon market depends on supply and demand, you cannot define in advance the price of those permits.	The question is very pertinent but not to be answered by this task. We are aware that differences will exist between similar outputs retrieved from different modelling tools which inform on the same nexus domain. We will clarify that the partners are aware of potential differences and these should be handled and clarified by the case studies.
Missing USE CASES development for food and agriculture	The missing Use Cases for food and agriculture in Appendix I have now been completed.
Table of Appendix II seems unfinished (incomplete rows?). What is the difference between specific indicator and total indicator?	It seemed that there were incomplete rows because of the table's format. Now the format has changed and it is clear that the Table is finished. Moreover, the content of this table has been split in two distinct tables in order to avoid misunderstandings. The column "specific indicator" (first table of Appendix II) refers to the indicators per Use Case referring to a different actor. In the column "Total Indicator" (second table of Appendix II) all indicators from all Use Cases are presented.
Why not having a full list of indicators available for all users, with a preselected list, without excluding the other indicators?	Indicators have been classified per Use Case as they measure the performance of actions and goals of each Use Case. Thus, there is not matter of exclusion. Moreover, a full list of indicators is now presented in the second table of Appendix II per nexus sector.

1 Table of Contents

Figures

Tables

Executive summary

The primary objective of this deliverable is the development of generic Use Cases for the SIM4NEXUS Serious Game. Such Use Cases is expected to be adapted to the SIM4NEXUS Case Studies and their specific learning goals. The goal of Use Cases is to capture how the user will interact with the Serious Game to achieve their specific goal. Under this framework, the functionality of the Serious Game is described. An important part of this process is to identify all relevant actors that will be involved in the Serious Game as well as the goal that each group of actors wishes to achieve. Use Cases will define any preconditions known to be true when the Use Case begins; basic flows, or steps the actors take to accomplish the goal of the Use Case; alternative flows, or less common user interactions with the Serious Game that can come up; exceptional flows, or anything that could happen to prevent the user from achieving their goal; and post conditions – what must be true when the Use Case is complete. The deliverable focuses also on the role that a Use Case has in the context of a Serious Game; the definition of group of actors that may be the final players of the Serious Game / users of Use Cases; and the presentation of generic Use Cases having been built so far for each nexus sector.

Changes with respect to the DoA

Not applicable.

Dissemination and uptake

This report will be released on the project website. The deliverable has been written to support the development of the SIM4NEXUS project and is open to all stakeholders, including the Case Study leaders and researchers contributing to the Case Studies.

Short Summary of results (<250 words)

This report presents generic Use Cases having been built so far per each nexus sector. The nexus sectors refer to water, land, energy, food & agriculture, climate and tourism. Use Cases reflect the way that users will interact with the Serious Game in order to achieve their goals. In this context, four basic categories of actors have been identified: a) Public sector, b) Private sector, c) NGOs, d) Academic / Research Institutes. Each Use Case refers to a specific goal, a possible actor, a number of actions through which the goal will be achieved and a group of indicators that measure actions' performance and contribute to the goal's accomplishment. This report will support Case Studies in structuring more specific Use Cases, adapted to their specific learning goals. It provides valuable information on: how to build a Use Case for each nexus sector, the role of a Use Case in the Serious Game, the functionality of a Use Case and the possible users (groups of actors) of the Serious Game.

Evidence of accomplishment

Submission of report.

Glossary

Indicator: Metric used to express, in quantitative terms, the status of important elements within each nexus domain. They serve to evaluate the performance of an action, measure or change of status (climate), infer on its potential impact and/or implication, either directly or indirectly (proxy indicator). Further, indicators are often directly related to goals. Examples: Energy: Carbon intensity of electricity generation - CO_2/KWh; Water: annual water consumption per capita (m^3 PC).

Success indicator: A success indicator provides a quantitative reference/benchmark of the desired performance of a sector or system. It is derived based on the policy targets defined for that sector or system. Example: European Union Intended Nationally Determined Contribution (INDC) target - minimum of 40% domestic reduction in GHG emissions by 2030, in comparison to 1990 levels.

Policy indicator: An indicator used to express, in quantitative terms, the success or failure of an implemented policy. It serves to evaluate the performance of a policy tested in the SG.

Use Case: 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.

Key Performance Indicators (KPIs): enable to assess the extent objectives and expected impacts of a project are reached. Example: Number of deliverables published according to work plan of SIM4NEXUS.

Nexus approach: A systematic process of inquiry that explicitly accounts for water, land, energy, food and climate interactions in both quantitative and qualitative terms with the aim of better understanding their relationships and providing more integrated knowledge for planning and decision making in these domains.

Nexus interlinkage: A factor, connection, relation or association that connects or ties one thing to another (the condition of being linked) - in a nexus perspective it corresponds to interconnected elements within the same or between different nexus domains. A "linkage" is frequently used to convey a physical link or assemblies between parts of a mechanical device. A nexus challenge is derived from nexus interlinkages but the latter does not necessarily imply the former.

Nexus performance indicator: Indicators linking at least two nexus dimensions and quantifying their co-dependence, thus identifying possible vulnerabilities of one nexus dimension compared to another one. More advanced nexus indicators will link three or four nexus dimensions, e.g. the amount of *water* and *energy* required for the production of a unit of *food* and the amount of CO_2 produced (*climate*). Examples: *Energy* required for the production of *water* through desalination. A high value for this indicator will mean that the production of desalinated water is highly dependent on the availability of energy.

Policy goal: Policy goals are the basic aims and expectations that governments have when deciding to pursue some course of actions. They can range from abstract general goals (e.g. attaining sustainable development) to a set of less abstract objectives (e.g. increase energy efficiency) which may then be concretized in a set of specific targets and measures (e.g. achieve 10% renewable energy share).

Policy target: Policy goal expressed in a quantifiable manner. See policy goal. It informs on the success of achieving a policy. Example: Achieve 10% renewable energy share in a given year.

Systems Dynamic Model (SDM): Quantitative representation of the interactions and feedback loops within and between processes in a complex system (in the case of SIM4NEXUS, the main system structure is identified in the conceptual models). Relationships can often be non-linear and may include delay mechanisms. In SIM4NEXUS, the structure of the complex system developed for the SDM will be Case Study-specific (i.e. is developed in the form of the conceptual model with close cooperation with Case Study lead partners and stakeholders) and integrates elements from the five nexus domains in which the project focuses on. SDM is a modeling approach/philosophy, for which there are many software tools and graphic environments to develop quantitative models. SIM4NEXUS uses STELLA as the modeling software to develop the SDMs for each Case Study.

Knowledge Elicitation Engine (KEE): A Knowledge Elicitation Engine is the inference engine of an expert system (the Serious Game in SIM4NEXUS). Knowledge elicitation comprises a set of techniques and methods that attempt to elicit an expert's knowledge through some form of direct interaction with that expert.

Serious Game (SG): see Knowledge Elicitation Engine.

Complexity science conceptual model: Conceptual (sometimes also known as a 'mind map') representation of the key interactions between and within nexus systems in the form of a qualitative diagram. The conceptual design of how nexus domains interact in a Case Study will serve as the basis for the development of the quantitative System Dynamics Model (SDM). The conceptual model is an abstraction of reality, usually with both a physical and social meaning, and aims at providing a representation of the main complex relations between the sub-systems under investigation.

Acronyms

TERM	EXPLANATION/MEANING
CCS	Carbon Capture and Storage
CS	Case Study
FiTs	Feed-in Tariffs
NGO	Non-Governmental Organization
PEFC	Pan European Forest Certification
RET	Renewable Energy Target
S4N	SIM4NEXUS
SG	Serious Game
UI	User Interface
WP	Work Package

1 Introduction

The objective of this Deliverable is to report on the structure of generic Use Cases to be applied in the SIM4NEXUS SG. Use Cases refer to the way the player interacts with the SG in order to achieve their goal. Thus, the main steps for building a Use Case include: the definition of a goal to be achieved, the identification of the user (actor), the description of successive actions contributing to the accomplishment of the goal and the definition of indicators measuring actions' performance.

Under the nexus framework, Use Cases were built for each nexus sector. Such sectors are: water, land, energy, agriculture & food and climate. Use Cases were also built for the sector of tourism as it puts extra pressures on the nexus sectors, especially in case of traditional tourist destinations such as Greece, Andalusia and Sardinia. Such pressures are multiple during the peak tourist season putting additional stresses to natural resources mainly water, food and energy. Interlinkages among the nexus sectors were taken into consideration. A critical step was also the determination of actors/group of actors that may be the possible players of the SG. Four main categories of players were identified: a) Public sector, b) Private sector, c) NGOs and d) Academic/Research Institutes.

More analytically, the rationale upon which the Use Cases were structured incorporates the following steps:

- Selection of a nexus sector
- Definition of a relevant goal
- Definition of a player (actor)
- Description of actions implemented towards achieving the goal
- Determination of indicators measuring actions' performance

Thirty-three (33) Use Cases have been totally built. Three (3) of them refer to the sector of water, six (6) to the sector of energy, six (4) to the sector of climate, eight (8) to the sector of land and forest, nine (11) to the sector of agriculture & food and one (1) to the sector of tourism. They are generic Use Cases that will be further elaborated by each Case Study in order to be adapted to the CSs' specific learning goals.

In the reminder of this deliverable the interaction of WP1-Task 1.2 (Development of Use Cases) with other WPs is described (Section 2). Section 3 refers to the structure of Use Cases under a nexus perspective while section 4 focuses on the description of the functionality of Use Cases within a Serious Game environment. In section 5 the categorization of actors / possible players of the SG is carried out and in section 6 the general structure of the Use Cases having been built so far is presented. Finally, some conclusions are drawn (lessons learnt). The deliverable includes also two Appendices. In Appendix I, the analytical description of each Use Case is delineated. In Appendix II a list of indicators and variables involved in each Use Case is presented.

2 Interaction with other Work Packages

The development of Use Cases is assumed in close collaboration with the consortium stakeholders which is defined for each Case Study (CS) in WP5. Use Cases will also be instrumental in defining the learning goals and the logic of the Serious Game (SG) which is done in close interaction with WP4 (Figure 1).

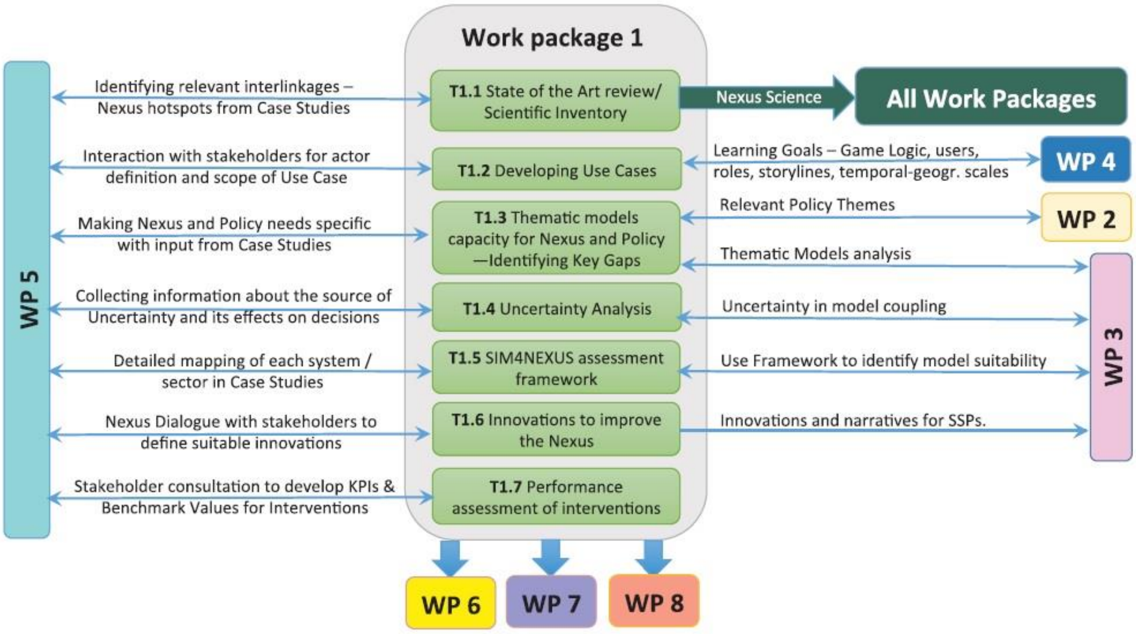

Figure 1: Task by task diagram of Work Package 1 and interactions with other Work Packages in the project as established in the SIM4NEXUS Grant Agreement

2.1 Interactions within WP1

In T1.1 "State of the art review – Creating a Scientific Inventory on the Nexus" a Scientific Inventory of the Nexus that will be used throughout the project was carried out. A thorough literature review related to the interlinkages of Water-Energy-Food-Land-Climate and Climate Change was composed. Low-carbon options were also reviewed. The literature review was based on a holistic approach and focused on the resource base taking into consideration both biophysical and socio-economic resources. T1.1 informed T1.2 through the clarification of interlinkages among the Nexus components in order such interlinkages to be embodied in the Use Cases designed. T1.2 is connected to T1.3 "Review on the Thematic Models in their capacity to address the Nexus and to cover relevant policy domains – Identifying Key Gaps" as the accomplishment of goals set by Use Cases are measured through a pool of indicators calculated by using the data provided by Thematic Models. T1.4 "Multifaceted uncertainty analysis" will provide feedback on uncertainty derived from complex interactions and human actions (human behaviour), parameters upon which the design of Use Cases is based on. T1.5 "SIM4NEXUS Framework for the Assessment of the Nexus in Case Studies" is expected to support the assessment of Use Cases' implementation into the several Case Studies of the project. T1.6 "Innovations to improve the Nexus for Case Studies" sets the basis upon which Use Cases will be implemented as it assists scenario definition through a participatory Nexus dialogue. Finally, T1.7 "Assessment of the performance of innovations/interventions via Nexus Performance Indicators" will support the assessment of interventions, in terms of their performance. In T1.7 specific performance indicators will be proposed to assess how efficiently environmental and human resources are used in the context of the S4N SG. Among the elements of each Use Case developed for the S4N SG are: a) the goal to be achieved, 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 through the use of respective indicators. Then, the definition of the different Use Cases for each Case Study details the different scenarios, in their corresponding context and with the different actions/interventions to be taken, the user will face while trying to achieve the different objectives, and while learning by doing.

2.2 Interactions with WP4

T1.2 is related to WP4 in the level of defining and integrating learning goals in the Game logic, the clarification of users' roles and the definition of storylines that will take place in several temporal-geographical scales. WP4 "Serious Game development and testing" concerns the definition of learning goals, the logic of the Game, the creation of the Game's Semantic Repository, the development of the knowledge elicitation engine, the development of the SG GUI, the integration of the relative components, the test of the system with hypothetical scenarios and actors as well as the data management process. In the framework of a Use Case a learning goal is of crucial importance as it refers to *what the user will finally learn by implementing a Use Case in the Serious Game*. Also, it is easily understandable that Use Cases constitute an essential part of the SG design process as they set the basis for the interaction of users with the Game through the definition of goals, the undertaking of relative actions and the development of indicators measuring the accomplishment of goals.

2.3 Interactions with WP5

The key element that connects T1.2 with WP5 is the interaction with stakeholders and the adaptation of Use Cases to their needs and their goals. Actors who are going to implement each Use Case in the SG are defined and the scope of each Use Case according to actors' orientation is clarified. Such information is strongly related to the design of Case Studies and the identification of actors involved in each of them. WP5 "Implementing Nexus-compliant practices" briefly includes the development of a common application and evaluation framework for SIM4NEXUS tools, the management of the nexus challenges in the Case Studies and the definition of policy recommendations. Under this framework, Use Cases will be implemented by the Case Studies designed in WP5. Use Cases are taking into consideration both nexus challenges and policy paths that will address the management of nexus components through actions taken by users in order to achieve several policy goals.

3 Use Cases and the Nexus

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, the process of structuring Use Cases pays attention not only on the management and future perspectives of the principle component that a specific Use Case deals with, but also on possible impacts on other nexus components.

In Table 1, indicative interlinkages (Laspidou et al., 2017) involved in each Use Case are presented. A detailed description of all interlinkages is presented in D1.1.

Table 1: Interlinkages existing in each Use Case

Use Case (per nexus component)	Examples of interlinkages	Description
Water	– Water-Land	Water availability affects land use. For example, the agricultural sector cannot be developed under water deficit conditions.
	– Water-Food	Water availability affects food production. Crops and animal products cannot be produced under water deficit conditions.
Energy	– Energy-Climate	Emissions derived from the energy sector affect climate.
	– Energy-Food	Energy infrastructures or cultivation of energy crops use land with agriculture potential. This may affect the production of agri-food or livestock products that cover food needs (reduction of agricultural land).
	– Energy-Water	Water is consumed for thermal power cooling.
	– Energy-Land	Land is needed for the establishment of energy infrastructures.
Climate	– Climate-Energy	Climate change may imply the increase of energy stocks for cooling or heating purposes.
	– Climate-Land	Climate change affects land uses.
	– Climate-Food	Climate change has impacts on the available agricultural land and thus on the production of

		agri-food and livestock products.
	– Climate-Water	Climate change has impacts on water availability as it enhances the occurrence of extreme weather conditions and droughts
Land	– Land-Food	Availability of land for food production has impacts on covering food needs (e.g. availability of agricultural land).
	– Land-Climate	Forest land contributes to C sequestration.
	– Land-Energy	Availability of land for the development of energy infrastructures affects energy production for covering existing/future needs
Food	– Food-Land	Covering food needs impose land availability for the production of agri-food and livestock products.
	– Food-Water	Food production presupposes the availability of water for irrigation.
	– Food-Energy	Food production implies energy consumption by the agricultural and industrial sectors.

4 Use Cases and the SIM4NEXUS Serious Game

The Use Cases definition is basic input for a correct SG design and implementation, as Use Cases define in detail the interaction between the users and the Game and vice versa. Each Use Case needs to specify a goal, which has to be reached by the user through the game steps by applying actions, which are also part of the Use Case definition. Depending on each Case Study, users will count with the complete set of available actions or just a subset of them depending on the role in the game. Moreover, only coherent actions will be shown, avoiding users being able to select non-coherent actions (i.e. conflicts of interest, etc.). The actions are translated into the Game context as Interventions selection (or unselection) by the user. Finally, it is also needed a numerical way, based on the SDM available data, to check the achievement of the Use Case goals. This is done by defining indicators and thresholds.

4.1 Functionality of the SIM4NEXUS Serious Game

At the top of the solution schema there is the Serious Game Graphic User Interface, which allows the users to interact with the system. Users can take different decisions and actions, and understand the consequences of the actions performed through the game status changes after each step. In the next layer, there is the Knowledge Elicitation Engine (KEE), the core of the system, which includes the Web Service API (WS), the Login system, the Coordination Module (CM), the Semantic Repository (SR), the Decision Support System (DSS), the Inference Engines (IE), the Agent Based Modelling (ABM) and the Analytical Engine (AE).

The Web Service API provides the communication between the SG UI and the KEE, dealing with all the requests and responses, and interacting with the Semantic repository storing them. In the following layer, the Coordination Module manages all the logic in the system and monitors all the infrastructure status. The Semantic Repository works as a knowledge base, where the generated data is stored following the defined ontology, allowing the Analytical Engine to be able to learn from these data through machine learning algorithms. The Decision Support System provides recommendations and feedback to users in each step of the SG. Finally, the Agent Based Modelling implements intelligent software agents, based on the acquired knowledge.

The bottom layer of the schema is the Nexus Integration, which provides the system with the basic Nexus knowledge to operate with, based on the Thematic Models, through the SDM Engine.

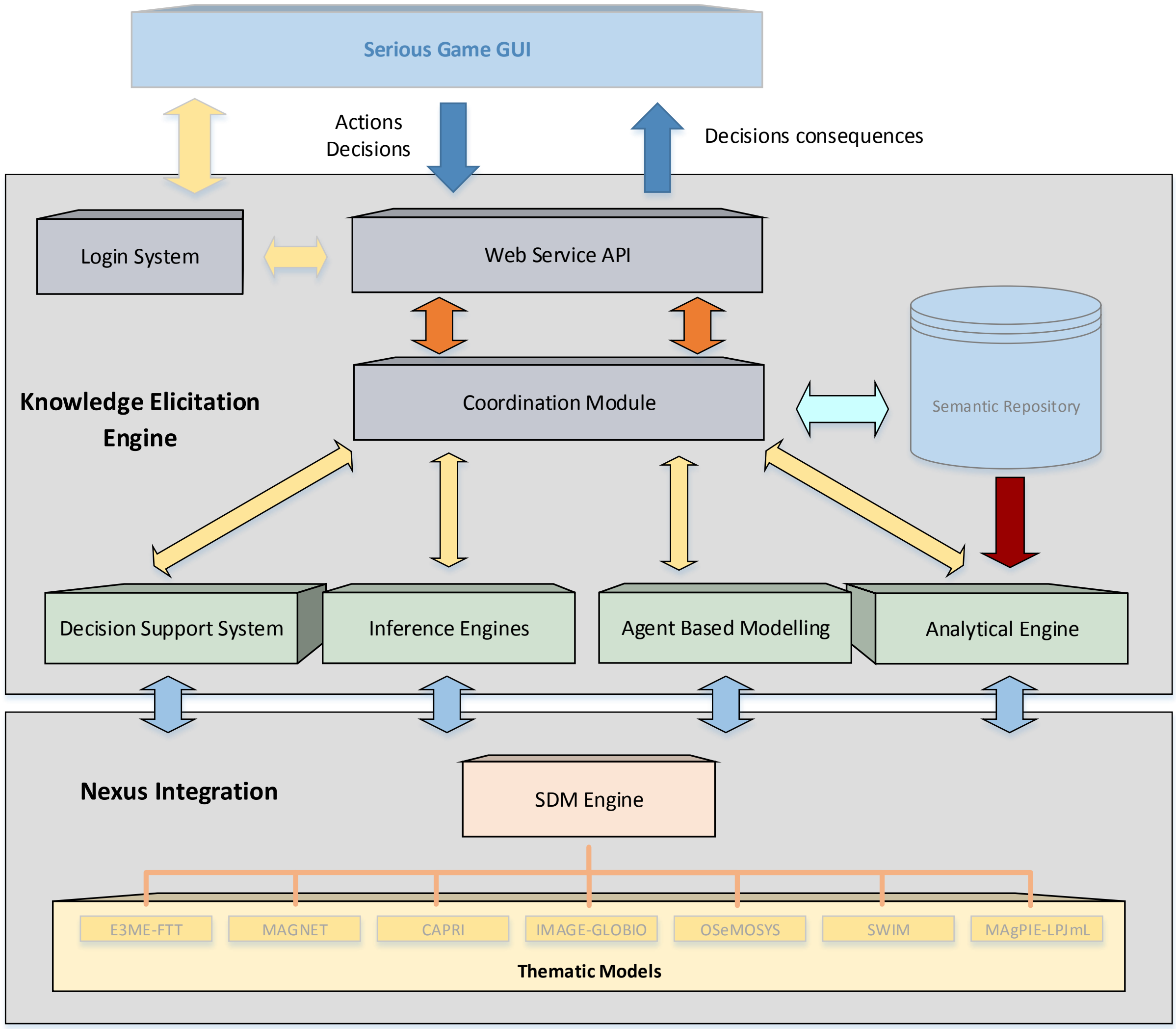

Figure 2: Functionality of the S4N SG

In each Game step, the KEE takes as an input the User actions/decisions and the Game status, and process this information through the SDMs and Game logic to obtain the next Game status. The actions/decisions corresponds to: i) the Interventions selected and ii) the Interventions cancelled by the users in each step. The Game status corresponds to the current: i) Game turn, ii) applied or cancelled Interventions and iii) SDM stocks.

4.2 Interaction between the User and the Serious Game

The Serious Game User Interface allows the users to interact with the system, creating a realistic environment, where they can take different decisions and actions, giving them the corresponding consequences and, finally, allowing the fact "to learn by doing".

Through the UI, the User is able to know, at any time, the Game status (via tables or graphics), the Game Goals and the corresponding level of achievement, a detailed description of the active and available Interventions, etc. The UI provides the User with the ability to select new Interventions to be applied in the coming turns or to cancel any active one.

5 Actors Engaging with the Serious Game

This section refers to the actors engaging with the Serious Game, namely the possible players/users of the Game. Actors will interact with the Game by applying relative Use Cases (Constantine and Lockwood, 2000). In this context, they will have the chance to implement a series of actions, review their impacts and perceive the level of accomplishment of a respective goal.

Each Case Study has involved in the project several stakeholders' representatives of public services, private sector, insurance sector, etc. During the design of Use Cases, such stakeholders have been classified into four broad categories (public sector, private sector, NGOs, academic/research institutes), called "actors" in order general Use Cases to be structured. It should be mentioned that the role of each actor is a key driver for designing Use Cases as actors' goals, future perspectives, interests and preferences should be taken into consideration. Use Cases reflecting their needs will capture their interest and stimulate their willingness to test the SG.

More analytically, stakeholders supported the development of Use Cases by offering their valuable knowledge, experience and expertise. For example: Policy makers coming mainly from the public sector, pointed out the most important policy goals and priorities; private sector representatives highlighted several difficulties they face when implementing policies; NGOs stressed the necessity for the development of more sustainable policies, and; representatives from the academia shed light on the science behind a policy. Stakeholders contributed also to the identification of conflicts and alliances developed when a policy is implemented while they also showcased the necessary types of arrangements to be made in order to address inconsistencies at practical level. They were positive to explore in the future, the policies that may affect their future plans and actions as well as their influence during the decision making process. The interaction with stakeholders, via bilateral semi-structured interviews and workshops, resulted in the creation of a knowledge stock incorporated while Use Cases were built. This is of utmost importance because, as already mentioned, stakeholders are the possible future players of the SG and thus the SG should correspond to their interests and future needs.

A series of Use Cases has been built for each nexus component. Each of them sets a goal and is addressed to a respective actor. According to the role of the actor, they can implement a number of actions in order to achieve a goal. Relevant indicators show the level of achievement. Consequently, it is easily understandable that Use Cases differentiate with each other according to the role of each actor. In the sequence, a classification of relevant actors, expected to be involved in the SG is presented. Moreover, the overall framework concerning their interaction with the Game in order to achieve a goal is described. The latter constitutes an essential element of the logic upon which the Use Cases were built and adapted to the profile of each actor.

5.1 Classification (categorization) of Relevant Actors/Users

The SG, as an integrated resource-use and policy assessment tool, is designed for and expected to be used by NGOs, private companies, policy makers, practitioners and insurance companies. It will be implemented in 12 Case Studies of different spatial/geographical scale. Thus, it should be adapted to the specific characteristics of each CS by incorporating variables, parameters, indicators and policies reflecting its state of the art and its future perspectives. In addition, Case Studies are encouraged to approach and engage stakeholders in the project as possible future users of the SG. Stakeholders support the design of the SG by offering valuable feedback, knowledge and expertise while they are also invited to express their expectations with regards to the Game (Papadopoulou et al., 2017). Such expectations are of utmost importance as they allow for incorporating their needs and requirements in a Game that is designed "for them". Consequently, it is quite impossible to design the game without their contribution.

Building Use Cases asks for specifying textual requirements that capture how the user will interact with the SG to achieve his/her specific goal. Such goals are defined in close collaboration with stakeholders having already been involved in the project in each CS. However, because of the diversity of each CS and the respective stakeholders, a need for generalization in order to build generic Use Cases that may be adapted to each CS has come up. Therefore, the design of Use Cases was started with the classification of actors /potential players into broad categories including all possible groups of final users. Four broad categories were defined, namely:

- *Public sector*: includes mainly decision / policy makers (Ministries, Directorates, Administrative Authorities, etc.), public services, public partnerships and chambers.
- *Private sector*: concerns businesses, insurance companies, the bank sector, entrepreneurs and investors.
- *NGOs*: refer mainly to environmental NGOs, interested in the protection of natural environment and the sustainable and efficient use of resources.
- *Academic / Research institutes*: include universities and research organizations. Students are also included.

The aforementioned groups of actors represent the possible players of the Game and Use Cases take into account their specific needs, goals and interests. The design of Use Cases was based on such specific user requirements and each of them adopts a respective orientation. According to the user, each Use Case includes the implementation of differentiated actions contributing to the accomplishment of a specific goal. A group of indicators informs the player about the level that he/she has achieved the goal.

Conclusively, the classification of actors serves the design of user-oriented Use Cases; the exploration of the specific context that each goal obtains with respect to the actor; the different needs that each goal satisfies; the differentiation of actions taken to achieve a goal and; the investigation of indicators measuring the achievement of goals.

5.2 Achievement of Goals by the Actors

Each Use Case focuses on the accomplishment of a goal corresponding to the needs of the player. The achievement of a goal comes through the undertaking of a series of actions, depending on the actor who plays the game. An initial state is firstly presented and then, several actions start to take place. After the completion of a Use Case the player is given a final result about the level of success.

More analytically, the user interacts with the SG by implementing / testing a Use Case. The progress of the Use Case comes through a number of conditions and flows developing during the several sessions of the Game. Thus, a Use Case should define any *preconditions* known to be true when the Use Case begins; *basic flows* or steps the actors take to accomplish the goal of the Use Case; *alternative flows* or less common user interactions with the SG that come up; *exceptional flows* or anything that could happen to prevent user from achieving their goal; and *post conditions* showing what must be true when the Use Case is complete.

By following a main path of actions along with several alternative paths, the player learns about the impacts that the choice of the specific path of actions entails. Thus, the implementation of a Use Case is a learning process offering a dynamic flow of information to the user. Indicators measure the achievement of the goal and mobilize the willingness of actors to test an alternative path in order to gain better results.

6 General Structure of a Use Case

As already mentioned Use Cases support the interaction between the user (player) and the system (SG). Under this framework, the role of the player, his/her goals, the actions he/she implements and the level of accomplishment of a goal lie at the "heart" of a Use Case. A Use Case defines how the SG will correspond to several requirements through a flow of information between the user and the system that takes place by following a path of actions. In the end, the user learns about the impacts of the selected path on the sustainable and effective use of resources.

Based on this rationale, we have built some common (general) Use Cases that set different goals having been classified with respect to the nexus components. Each Use Case presents an initial state to the user who selects a goal and starts the effort for achieving it. Several options are offered to the users (different actors) and he/she is invited to choose a path of actions towards the accomplishment of the selected goal. Metrics (indicators) measure the achievement of the goal.

In this section, the Use Cases having been designed so far are presented per nexus component. The analytical description of each Use Case along with the steps followed in the SG for its implementation is in Appendix I. The general structure of a Use Case is delineated in Figure 2.

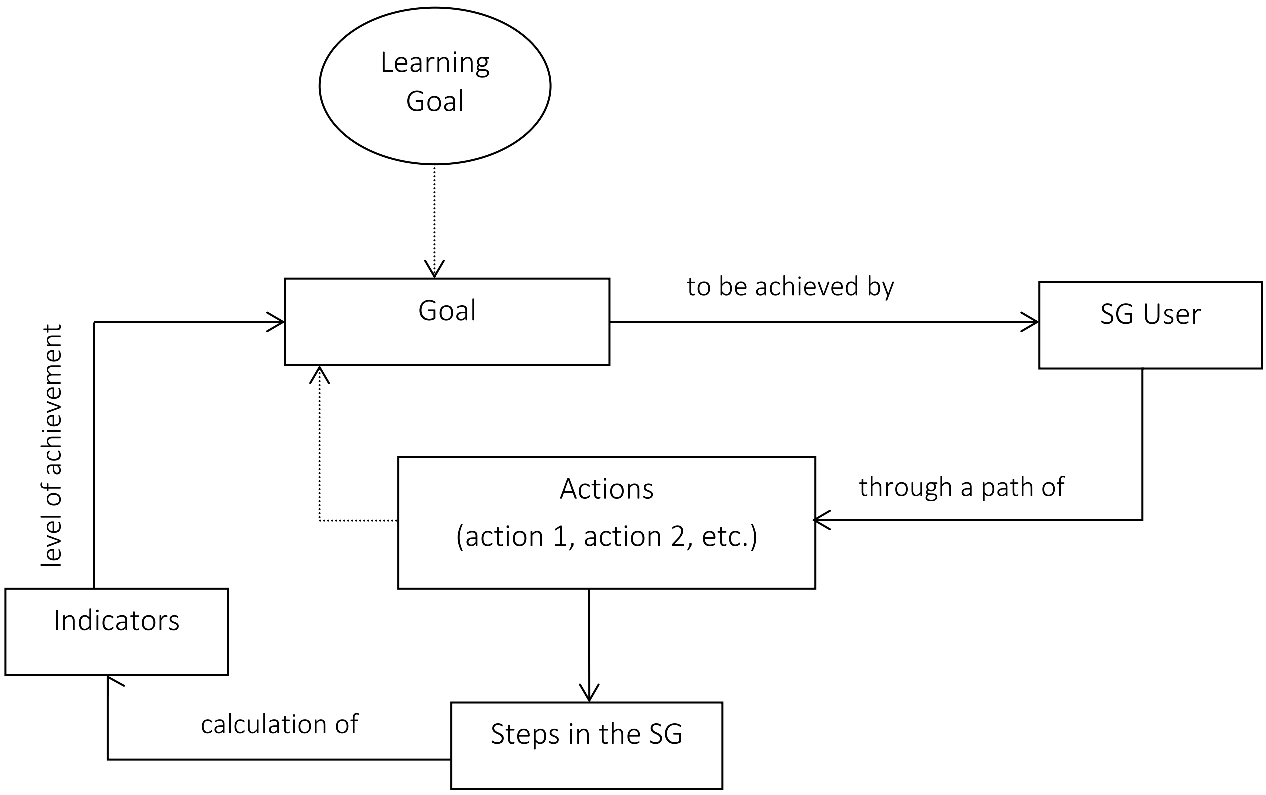

Figure 3: General structure of a Use Case

It should be mentioned that actions are taken under the framework of a nexus-related policy being applied in the context of a specific Use Case in a Case Study. Moreover, the selection of the goals set in each Use Case was based on existing and future policy priorities and on stakeholders' interests. Therefore, the goals were selected for the users according to their professional and scientific orientation, their expertise and their areas of interest. The definition of actions is mostly related to the goal as they represent possible steps to be done towards its accomplishment. Relevant indicators were determined based on the actions taken, as a metric used to measure actions' performance. Also, the values of all indicators inform the user about the overall achievement of the goal. Once this logic is set, only relevant actions are shown to users which role is aligned.

6.1 Brief Presentation of the Use Cases

Each UC describes the actions/steps that a specific type of actor (SG player) may take/follow to achieve the goal associated with the specific UC. For each type of actor, the necessary actions to achieve the same goal may not be the same. For that reason, for the same goal and different type of actor, a new UC is developed when necessary.

6.1.1 Water

In the next tables the Use Cases designed for water are presented.

USE CASE W.1	Water
Goal	Water savings
User	Public Sector: Ministry of Agriculture
Actions	• Invest-funding new irrigation systems • Water pricing policy
Indicator	• Total cost for agricultural water (It refers to the investment by the Ministry of Agriculture) • Volume of fresh water from surface / groundwater sources

USE CASE W.2	Water
Goal	Water savings
User	Private Sector: Industry
Actions	• Water reuse – Invest / Funding technologies for cleaning water (industrial waste) (It refers to investment by the industry only – the user) • Reduce water losses • Water pricing for industrial use

Indicator	• Total cost for water reuse technology • Volume of water needed for covering industrial uses • Measuring water losses • Total cost for industrial water (operation)

USE CASE W.3	Water
Goal	Sustainable use of groundwater
User	Private Sector: Farmers
Actions	• Optimize water pumping scheduling • Groundwater pricing for agricultural use • Transfer irrigation water from elsewhere
Indicator	• Total cost for groundwater use • Volume of groundwater needed for covering agricultural uses • Measuring groundwater misuse

6.1.2 Energy

In the next tables the Use Cases designed for energy are presented. Note that the Use Cases presented for the energy sector, more specifically to the electricity sector, were chosen considering common goals across Case Studies in order for Case Study teams to be able to relate to the goal presented. Use cases E1.1 to E1.4 represent examples of a same Use Case goal in the perspective of different users (i.e. private sector, public sector, academia and research, NGOs). Use cases E.2 and E.3 refer to different goals for a same user (in this case, the private sector).

USE CASE E.1.1	Energy
Goal	Expansion of RET in the electricity sector
User	Private Sector: Electricity generation utilities, transmission and distribution system operators
Actions	• Private: investments in RET (solar, wind, geothermal, biomass, other)
Indicator	• Cost of electricity generation (includes transmission and distribution costs) • Share of RET generation (electricity generation from RET/total electricity generation)

	• Installed capacity by RET type (e.g. solar, on-shore wind, geothermal, etc.) • Total investments in the electricity sector (annual; 10-year time step, or applicable; total investment per period of analysis) • CO2,eq emissions/total electricity generation OR Annual emissions of CO2,eq by the electricity sector • Use of land with agriculture potential • Annual water consumption1 for thermal power cooling • Cost of buying / renting land for RE infrastructure • Total land area used for RET infrastructure (wind power, solar PV (if not rooftop) and CSP)

USE CASE E.1.2	Energy
Goal	Expansion of RET in the electricity sector
User	Public Sector: e.g. Ministry of Energy, Ministry of Environment
Actions	• Targets for RES in the electricity sector • Electricity prices (Feed-in-tariffs)
Indicator	• Costs of electricity generation (includes transmission and distribution costs) • Total investments in the electricity sector • Share of RET generation (electricity generation from RET/total electricity generation) • Total annual CO_2 eq emissions from electricity generation • Change in food prices (relative, %) • Total annual water consumption[2] for cooling systems in power plants • Total land used for RET infrastructure (annual)

USE CASE E.1.3	Energy
Goal	Expansion of RET in the electricity sector
User	Academic / Research Institutes
Actions	• Targets for RES in the electricity sector

[1] Water consumption is defined, in this context, as the amount of water not returned to the original source from where it was extracted, and consumed in the thermal power plant cooling system.

[2] Ibid.

	• CO_2 eq emission reduction targets • Fuel prices (oil, gas, coal) • Changing electricity demand varying population, GDP or directly manipulate electricity growth rate
Indicator	• Cost of electricity generation (includes transmission and distribution costs) • Electricity price • Total investments in the electricity sector • Share of RET generation (electricity generation from RET / total electricity generation) • Total annual CO_2 eq emissions from electricity generation (10 year time step, or applicable) • Final annual electricity consumption per capita (kWh/capita/year) • Total annual water consumption for cooling systems in power plants • Total land area used for RET infrastructure (annual)

USE CASE E.1.4	Energy
Goal	Expansion of RET in the electricity sector
User	NGOs
Actions	• CO_2 eq emission reduction targets
Indicator	• Cost of electricity generation (includes transmission and distribution costs) • Total investments in the electricity sector • Electricity price • Share of RET generation (electricity generation from RET / total electricity generation) • Total annual CO_2 eq emissions from electricity generation (10 year time step, or applicable) • Total land area for RET infrastructure (annual) • Total annual water consumption for cooling systems in power plants

USE CASE E.2	Energy
Goal	Energy efficiency in the electricity sector
User	Private Sector: Electricity generation utilities, transmission and distribution system operators

Actions	• Refurbishments / upgrade of existing electricity generation technologies • Investments in more efficient electricity generation infrastructure
Indicator	• Cost of electricity generation (including transmission and distribution fees) • Total investment in energy efficiency in electricity generation and in transmission and distribution • Electricity generation energy intensity (energy used (e.g. MJ) to produce one kWh of electricity) • % technical losses in electricity transmission and distribution (100*losses / total generation) • carbon intensity of electricity consumption (tonCO_2eq/total final energy consumption) • Annual water consumption in the electricity sector (cooling systems)

USE CASE E.3	Energy
Goal	Increased interconnection of electric power systems
User	Private Sector (e.g. Transmission and distribution system operators)
Actions	• Set target for transmission interconnector installed capacity
Indicator	• Cost of electricity generation (including transmission and distribution fees) • Installed capacity of cross-border interconnectors • % net import of electricity [(imports – exports)/total electricity consumed (i.e. electricity produced plus electricity imports)] • Electricity exports as a % of the total electricity generation • Capital Investment (annual; 10-year time step, or applicable; total investment per period of analysis) • Total land area for RET infrastructure (annual) • annual CO_2,eq emissions from electricity generation (OSeMOSYS, E3ME, SDM)

6.1.3 Climate

In the next tables the Use Cases designed for climate are presented. Similarly to the approach in the Energy nexus domain, Use Cases C1.1 and C1.2 illustrate examples of Use cases with the same goal (GHG emission reduction in the electricity sector) but addressed to different users (private sector and public sector); while C.2 and C.3 correspond to different goals but are designed for the same user (public sector), both can also be compared to C.1.2.

USE CASE C.1.1.	Climate
Goal	GHG emission reduction in the electricity sector
User	Private Sector (e.g. Electricity utilities, auto-producers (industries, commercial sector)
Actions	• Policy & Private: investment on more efficient thermal generation technologies • Policy & Private: investing in Carbon Capture and Storage (CCS) in electricity generation • Policy & Private: investments in Renewable Energy Technologies
Indicator	• kg CO_2,eq emissions in the electricity generation sector/ total electricity generation • Total annual CO_2 eq emissions from electricity generation • Cost of electricity generation including transmission and distribution fees (euro/kWh) • Capital investments

USE CASE C.1.2	Climate
Goal	GHG emission reduction in the electricity sector
User	Public Sector (e.g. Ministry of Energy, Ministry of Environment)
Actions	• Investment in more efficient thermal generation technologies, CCS in electricity generation, Renewable Energy Technologies • Set CO_2 eq emission reduction targets
Indicator	• kg CO_2,eq emissions in the electricity generation sector/ electricity generated • Total annual CO_2 eq emissions from electricity generation • Cost of electricity generation including transmission and distribution fees (EUR/kWh) • Capital investments • Electricity tariffs

USE CASE C.2	Climate

Goal	Improve climate resilience in the electricity sector
User	Public Sector (e.g. Ministry of Energy Planning)
Actions	• Define the foreseen reduction in hydropower production due to climate change • Diversification of the electricity generation mix • Power purchase agreements (electricity import agreements) must be established with neighbouring 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 • Improve power plant efficiency
Indicator	• Cost of electricity generation (including transmission and distribution fees) • Water used (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 • Cost of adaptation to climate change (Regret cost calculation based on choice of climate)

USE CASE C.3	Climate
Goal	Climate proofing the agricultural sector
User	• Public Sector: Ministry of Agriculture, Ministry of Environment
Actions	• Setting up an adaptation plan to ensure food security • Establishing sustainable water management policies • Establishing a seed bank in case of severe drought to help farmers in rural areas • Increasing awareness about Climate change through capacity building programs • Policy directives for flood prevention • Establishing sufficient Finance mechanisms to combat unexpected changes in climate
Indicator	• Number of water storage facilities for seasonal/ monthly storage • No. of courses and initiatives organized to educate farmers • No. of flood meadows established on rivers with frequent flooding • No. of insurance schemes enrolled by farmers

	• Seed bank initiatives • Cost of inaction

6.1.4 Land and Forest

In the next tables the Use Cases designed for land and forest are presented. The tables depict two different goals (sustainable management of land and sustainable management of forests) from the point of view of 4 different players. Therefore, L1 to L4 share the same goal but the actions and relevant indicators are represented from 4 different points of view. L4 and L8 have different goals but target the same user: students.

The modelling of the actions depends very much on the models available for each Case Study, the way each Case Study has chosen to represent land and forest in the SDM, as well as the policies that will be chosen. The tables below aim at providing examples that can guide the case studies in the development of their own use cases. The actions will have to match the set of parameters that each Case Study can trigger.

USE CASE L.1	Land and Forest
Goal	Sustainable management of land
User	Public Sector: Land management authority
Actions	• Set the share between the different land uses • Allow or forbid practices in forestry / in agriculture • Allow of forbid settlements (new constructions) • Change subsidies and taxes for each land-use type • Set land prices
Indicator	• Income from land taxes vs. Costs of policy = Benefit • Share of natural land • Virtual land (land used in other territories to produce imported food or energy) • C sequestration • Risk of erosion / Degradation

USE CASE L.2	Land and Forest
Goal	Sustainable management of land
User	Private Sector: Agriculture / Industry / Housing representatives
Actions	• Negotiate the share between the different land uses • Choose practices in forestry / in agriculture • Choose to develop settlements (new constructions)

	• Choose a set of land taxes
Indicator	• Income from land taxes vs. Costs of policy = Benefit • Share of natural land • Virtual land (land used in other territories to produce imported food or energy) • C sequestration • Risk of erosion / Degradation

USE CASE L.3	Land and Forest
Goal	Sustainable management of land
User	NGOs: Landscape / Biodiversity / Soil protection
Actions	• Negotiate the share between the different land uses • Choose practices in forestry / in agriculture • Choose to develop settlements (new constructions) • Promote set of land taxes
Indicator	• Income from land taxes vs. Costs of policy = Benefit • Share of natural land • Virtual land (land used in other territories to produce imported food or energy) • C sequestration • Risk of erosion / Degradation

USE CASE L.4	Land and Forest
Goal	Sustainable management of land
User	Students / Researchers
Actions	• Set the share between the different land uses • Allow or forbid practices in forestry / in agriculture • Allow of forbid settlements (new constructions) • Change subsidies and taxes for each land-use type • Set land prices
Indicator	• Income from land taxes vs. Costs of policy = Benefit • Share of natural land • Virtual land (land used in other territories to produce imported food or energy) • C sequestration • Risk of erosion / Degradation

USE CASE L.5	Land and Forest
Goal	Sustainable management of forests
User	Public Sector: Forest management authority
Actions	• Decide on the share dedicated to biomass • Choose forestry practices • Promote labels such as PAN EUROPEAN FOREST CERTIFICATION (PEFC) label
Indicator	• Total forest cover • Share of forests with PEFC label • Share of forests for biomass production (building / energy) • Share of biomass in the energy mix • Employment in forestry sector • Benefits of forestry sector (incomes – costs) • C sequestration • Harvesting • Forest fires

USE CASE L.6	Land and Forest
Goal	Sustainable management of forests
User	Private Sector: Forest managers / Owners
Actions	• Decide on the share dedicated to biomass • Choose forestry practices • Take-up labels such as PEFC label
Indicator	• Total forest cover • Share of forests with PEFC label • Share of forests for biomass production (building / energy) • Share of biomass in the energy mix • Employment in forestry sector • Benefits of forestry sector (incomes – costs) • C sequestration • Harvesting • Forest fires

USE CASE L.7	Land and Forest
Goal	Sustainable management of forests

User	NGOs: Biodiversity / Soils / Climate protection
Actions	• Negotiate the share dedicated to biomass • Promote forestry practices • Promote labels such as PEFC label
Indicator	• Total forest cover • Share of forests with PEFC label • Share of forests for biomass production (building / energy) • Share of biomass in the energy mix • Employment in forestry sector • Benefits of forestry sector (incomes – costs) • C sequestration • Harvesting • Forest fires

USE CASE L.8	Land and Forest
Goal	Sustainable management of forests
User	Students / Researchers
Actions	• Decide on the share dedicated to biomass • Allow forestry practices • Promote labels such as PEFC label
Indicator	• Total forest cover • Share of forests with PEFC label • Share of forests for biomass production (building / energy) • Share of biomass in the energy mix • Employment in forestry sector • Benefits of forestry sector (incomes – costs) • C sequestration • Harvesting • Forest fires

6.1.5 Agriculture and Food

In the next tables the Use Cases designed for agriculture and food are presented.

USE CASE A&F.1	Agriculture and Food
Goal	Resource efficiency
User	Public Sector

Actions	• Production activities targeted at the efficient use of nutrients, energy, water, climate and land • Agricultural production • Use of nutrients • Energy use in agriculture • Water use in agriculture • Greenhouse gas emissions in agriculture • Agricultural land use
Indicator	• Resource use (nutrients, energy, water, greenhouse gas emissions and land) per unit of output

USE CASE A&F.2	Agriculture and Food
Goal	Profit maximization
User	Public Sector
Actions	• Promote good farming practices • Production is targeted at optimizing farm income
Indicator	• Aggregate value of production at farm level to sectoral total • Gross value added from agriculture (M€ by sector, region, country)

USE CASE A&F.3	Agriculture and Food
Goal	Environmental frontier
User	Public Sector
Actions	• Promote good farming practice • Production is targeted at minimizing environmental impacts
Indicator	• Adoption of new environmental technology

USE CASE A&F.4	Agriculture and Food
Goal	Resource efficiency
User	Representative from farmers' organization (or individual farmer)
Actions	• Production activities targeted at the efficient use of nutrients, energy, water and land

	• Net output (output of production minus variable costs of production, excluding labour and land) at regional level (CAPRI) • Maximize net output from farming
Indicator	• Resource use (nutrients, energy, water and land) per unit of output (e.g. kg of N per € value of production)

USE CASE A&F.5	Agriculture and Food
Goal	Profit maximization
User	Representative from farmers' organization (or individual farmer)
Actions	• Production is targeted at optimizing farm income
Indicator	• Farm income (€ per farm) • Sector income (M€ by sector)

USE CASE A&F.6	Agriculture and Food
Goal	Environmental frontier
User	Representative from farmers' organization (or individual farmer)
Actions	• Production is targeted at minimizing environmental impacts
Indicator	• Adoption of new environmental technology • Adoption of precision farming

USE CASE A&F.7	Agriculture and Food
Goal	Food security
User	Public Sector
Actions	• Physical availability, economic access to sufficient food and stability over time (FAO definition) • Food supplies (production and imports) are adequate to match with regional or national food demand
Indicator	• Mton of food produced or imported (crops and animal products) – Also considering stocks

USE CASE A&F.8	Agriculture and Food

Goal	Nutrition security
User	Public Sector
Actions	• Access by all people at all times to the adequate utilization and absorption of nutrients in food, in order to be able to live a healthy and active life (FAO definition) • Access to food but also to health care and hygienic conditions (source: http://edepot.wur.nl/305182)
Indicator	• Number of people who are lifted out of undernourishment between now and 2030. Effects regarding food intake, access to food and nutritional resilience will result in a decline in undernourishment. Link to Sustainable Development Goal • End hunger and children's undernourishment

USE CASE A&F.9	Agriculture and Food
Goal	Food waste
User	Public Sector
Actions	• Food waste is food that is discarded or lost uneaten (Wikipedia). It may occur at any stage of food production, processing, retail or household
Indicator	• SDG target 12.3: "By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses"

USE CASE A&F.10	Agriculture and Food
Goal	Healthy diets
User	Public Sector
Actions	• Move towards diets with a bigger share of plant-based food and fewer animal source foods • A change in dietary preferences for livestock products based on the USDA recommendations for healthy diets (https://www.cnpp.usda.gov/USDAFoodPatterns) where animal calorie intake is decreased to 430 kcal/capita/day by 2030 in countries exceeding this threshold (see Willet et al., 2019).

Indicator	• Recommended intake levels of certain food items e.g. red meat etc. in a diet) were based on the GENUS database • SDG target 12.3: "By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses"

USE CASE A&F.11	Agriculture and Food
Goal	Sustainable food systems
User	Public Sector
Actions	• Move from high quantities of production to producing healthy food. • Sustainably intensify production, increasing high-quality food.
Indicator	• Improved production practice • Sustainable food production

6.1.6 Tourism

In the next tables the Use Cases designed for tourism are presented.

USE CASE T.1	Tourism
Goal	Sustainable performance of tourist infrastructures
User	Private Sector: Tourist entrepreneurs (accommodation sector)
Actions	• Energy saving in tourist infrastructures (e.g. hotels) • Invest in water saving practices • Provide financial support tools
Indicator	• Total energy demand by the tourist sector • Total energy consumption by the tourist sector • GHG emissions by the tourist sector • Volume of water needed to cover tourist demand • Total land used for new tourist activities

7 Lessons learned and future work

Now that generic Use Cases have been developed, each Case Study is required to develop the specific Use Cases suitable for its own expectations. In each Case Study, stakeholders that would potentially become players of the game shall be split into the 4 categories. The Use Case can first be adapted to match better the needs of the actors, taking into account their interests, their level of understanding of the Nexus issues, their experiences with gaming, etc. The Use Cases shall also be adapted to match the policy scenarios that each Case Study has identified: policy goals, policy measures and policy instruments. These policies control the actions that the player can choose or trigger.

Finally, the indicators can be defined according to the results (or model outputs) that have been agreed upon with the stakeholders. Relevant indicators can be picked up from the above examples or from other Case Studies, but it is important that they are understandable for the players and tailored to the policy scenarios.

It would be interesting to monitor closely the indicators chosen by Case Studies. External expertise from SIM4NEXUS partners would be interesting (from WP1 / WP4 / WP5) to make sure the indicators are relevant. Sharing a pool of indicators would also be helpful to the least advanced Case Studies. Finally, this list could be capitalised to design future Nexus Serious Games on different European territories (WP6 replicability issues).

In brief, the main issues related to the definition and use of indicators may be:

- Pool of indicators collected from each Case Study: 1) defined by experts; and 2) defined by stakeholders.
- Attribute indicators to the critical interactions as identified and represented in the conceptual map; and later transposed to the SDM
- Comparison of nexus challenges against the list of indicators – selection of indicators that are implicated with each specific challenge
- For the set of policies to be implemented in each scenario, identification of indicators that can inform on the impacts / implications of the implementations of a specific policy. Would the different policies be reflected primarily on a specific indicator or do their actions propagate with higher magnitude to certain indicators?

Here it will be important to match the policy indicators and the SDM indicators to the cases. Will these be the same, different, or a combination of both?

- The definition of Use Cases is built from a combination of activities in the project. They provide an opportunity to the Case Study teams to go a step further in the conceptualization of their respective Serious Game;
- The definition of Use Cases by the Case Study teams enables their active, and essential, participation in the development of the SG;
- Case-specific Use Cases ensure that the SG is consistent with the objectives of the analyses, aligned with stakeholder input, and that the players have an integrated perspective of systems dynamics, i.e., implications of sectoral actions across the Nexus;

- Case Study teams play a crucial role in establishing the link between the science (scientific analysis) and the policy domains, by tailoring how the quantification incorporates and translates into messages that are easy to understand by different target-audiences.

7.1 Key steps in defining Use Cases for the Case Studies

The development of Use Cases in each Case Study results from a combination of activities. Important elements to the Use Cases were collected in different steps of the development of the Case Studies. One of these first steps resulted from the identification of nexus interlinkages which then led to the selection of critical interlinkages and identification of nexus challenges. In some cases, sectoral challenges were the guiding step. However, all of the cases consolidated this learning into conceptual maps that lay the basis of the SDMs, and use a set of thematic models to represent the nexus systems.

For the development of the Use Cases, Case Study teams would need to compare and analyse information retrieved and produced in different stages of the Case Study development. We suggest the following steps:

- **Start by stating/defining the most important questions investigated in your Case Study**. These will be related to the nexus challenges and pathways already identified, and from the policy analysis.
- Prepare a list of indicators collected (or to be prepared) from each Case Study based on 1) defined by experts and modelling teams 2) in the SDM; and 3)defined and/or validated by the stakeholders. These list may already exist, however it could be important to revise at this stage.
- Attribute indicators to the critical interactions as identified and represented in the conceptual map; and later transposed to the SDM.
- **Compare the questions defined in Step 1 against the list of indicators**. Select indicators that are implicated with each specific challenge and that you expect to be the most affected within the questions context. These may be related to one particular system of the nexus, however, it will be important to identify other nexus systems indicators that may be indirectly affected.
- **Use the questions to define goals for the different nexus domains**. Then match actions that could be executed to achieve that goal, and identify which indicators could inform on the performance of those actions.
- **If necessary, revise the list of indicators prepared in Step 2**, to ensure the players of the game will be adequately inform of the implications of their choices that result from the selection actions available.
- For the set of policies to be implemented in each scenario, identify indicators that can inform on the impacts / implications of the implementations of a specific policy. Would the different policies be reflected primarily on a specific indicator or do their actions propagate with higher magnitude to certain indicators?

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Appendix I: Analytical description of Use Cases

A1 Water

USE CASE W.1	Water
Related Learning Goals	
Goal	Water savings
User	Public Sector: Ministry of Agriculture
Actions	• Invest-funding new irrigation systems • Water pricing policy
Indicator	• Total cost for agricultural water (It refers to the investment by the Ministry of Agriculture) • Volume of fresh water from surface / groundwater sources

Step in the SG

1. Identify agricultural land use (SDM), agricultural water demand (Thematic models – CAPRI, or other calculations), surface water and groundwater availability (SDM), cost of irrigation water (SDM, or Thematic model—CAPRI)
2. Calculate hydrological water balance, given climate data (PIK) and water demands
3. Calculate rate of change of hydrological water balance (monthly or yearly step)
    - If rate of change lower than threshold value: no need for immediate action
    - If rate of change higher than threshold value: reduce agricultural water use by e.g. 5% by investing in a new irrigation system, maintaining losses, etc.

An additional cost is added related to the taken action

Subject to: rate of change of hydrological balance

↓

If the cost of irrigation water + additional cost (new irrigation system) is not acceptable, then an increase of cost of irrigation water may be imposed by e.g. 15% in order to reduce water consumption (water use reduction) and collect money for a period in order to cover the additional cost of the new irrigation system.

USE CASE W.2	Water
Goal	Water savings
User	Private Sector: Industry
Actions	• Water reuse – Invest / Funding technologies for cleaning water (industrial waste) (It refers to investment by the industry only – the user) • Reduce water losses • Water pricing for industrial use
Indicator	• Total cost for water reuse technology • Volume of water needed for covering industrial uses • Measuring water losses • Total cost for industrial water (operation)

Step in the SG

1. Identify industrial water demand (SDM), surface water and groundwater availability (SDM), cost of industrial water (policy)
2. Calculate hydrological water balance, given climate data (PIK) and water demands
3. Calculate rate of change of hydrological water balance (monthly or yearly step)
   - If rate of change lower than threshold value: no need for immediate action
   - If rate of change higher than threshold value: water reuse by investing in new technologies **OR** reduce water losses by x% by investing in new technologies

An additional cost is added related to the taken action

Subject to: rate of change of hydrological balance

↓

If the cost of new technologies (water treatment, monitoring water losses) is not acceptable then an increase of industrial water unit cost (water pricing system) may be imposed by y% in order to transfer water from elsewhere and collect money for a period of t years in order to invest on water saving technologies in the future.

USE CASE W.3	Water
Goal	Sustainable use of groundwater

User	Private Sector: Farmers
Actions	• Optimize water pumping scheduling • Groundwater pricing for agricultural use • Transfer irrigation water from elsewhere
Indicator	• Total cost for groundwater use • Volume of groundwater needed for covering agricultural uses • Measuring groundwater misuse

Step in the SG

1. Identify irrigation water demand (CAPRI or calculations), portion of water demand covered by groundwater (SDM), cost of agricultural water (SDM or CAPRI)
2. Calculate hydrological water balance for groundwater, given climate data (PIK) and water demands
3. Calculate rate of change of hydrological water balance for groundwater (monthly or yearly step)
   - If rate of change lower than threshold value: no need for immediate action
   - If rate of change higher than threshold value: impose an extra cost to transfer irrigation water from elsewhere **OR** optimize water pumping scheduling by monitoring water table drawdown so an additional cost is added **OR** impose an extra cost for new irrigation systems in order to reduce water demand

An additional cost is added related to the taken action

Subject to: rate of change of hydrological balance for groundwater

↓

If the cost to adopt innovative practices concerning sustainable management of groundwater is not acceptable, then an increase of cost (water pricing system) for agricultural groundwater unit may be imposed by y% in order to reduce groundwater consumption (groundwater use reduction) and collect money for a period in order to cover the additional cost of a new measure / agricultural practice.

A2 Energy

USE CASE E.1.1	Energy
Goal	Expansion of RET in the electricity sector
User	Private Sector: Electricity generation utilities, transmission and distribution system operators
Actions	• Private: investments in RET (solar, wind, geothermal, biomass, other)
Indicator	• Cost of electricity generation (includes transmission and distribution costs) • Share of RET generation (electricity generation from RET/total electricity generation) • Installed capacity by RET type (e.g. solar, on-shore wind, geothermal, etc.) • Total investments in the electricity sector (annual; 10-yeat time step, or applicable; total investment per period of analysis) • CO_2,eq emissions/total electricity generation OR Annual emissions of CO_2,eq by the electricity sector • Total land area used for RET infrastructure (wind power, solar PV (if not rooftop) and CSP)

Step in the SG

1. Identify share of RET in the electricity generation mix (SDM or Thematic model - OSeMOSYS, E3ME), the total land area used for RET infrastructure (SDM), annual $CO_{2,eq}$ emissions from electricity generation (OSeMOSYS, E3ME), and cost of electricity generation (OSeMOSYS, E3ME).
2. Define a threshold for the total investment in RETs for the period of the game.
3. Define the share of electricity generation from RETs relative to the total electricity generation in 2050 as x% (e.g. 5% of electricity generation produced from a combination of RETs, e.g. solar, on-shore wind, geothermal, biomass, waste-to-energy);
4. When total investment :

   a) reaches the threshold defined in 2) and the target set in 3), values of the indicators in 1) are displayed.

   b) If the 2050 RET share (set in step 3) is not reached, values of indicators in 1) are displayed as well as by how much the electricity demand would have to decrease so that the RET share achieved matches the goal set in 3.

c) is lower than the threshold and the RET goal is met, indicators in 1) are shown and no further action is needed.

USE CASE E.1.2	Energy
Goal	Expansion of RET in the electricity sector
User	Public Sector: e.g. Ministry of Energy, Ministry of Environment
Actions	• Targets for RES in the electricity sector • Electricity prices
Indicator	• Cost of electricity generation (includes transmission and distribution costs) • Total investments in the electricity sector • Share of RET generation (electricity generation from RET / total electricity generation) • Total annual CO_2,eq emissions from electricity generation • Change in food prices (relative, %) • Total annual water consumption[3] for cooling systems in power plants • Total land used for RET infrastructure (annual)

Step in the SG

1) Identify current cost of electricity generation (E3ME, OSeMOSYS, SDM), the share of RET in the electricity generation mix (OSeMOSYS, E3ME, SDM); total land area used for RET infrastructure (SDM); annual CO_2,eq emissions from electricity generation (OSeMOSYS, E3ME); annual volume of water consumption for cooling systems (OSeMOSYS, E3ME, SDM); and, prices of selected crops (CAPRI, MAGNET).
2) Define the share of electricity generation from RETs relative to the total electricity generation in 2050 as x% (e.g. 5% of electricity generation produced from a combination of RETs, e.g. solar, on-shore wind, geothermal, biomass, waste-to-energy);
3) Set a threshold for the electricity price in 2050 (or per decade?) as y euro/kWh.
4) The cost of electricity generation depends on the electricity generation mix of the country. If the cost of electricity generation for a specific year, period or end-year:

   a) is lower than the threshold in set in 3), the of the indicators in 1) are displayed, plus the absolute and relative differences between the cost of generating electricity

[3] Water consumption is defined, in this context, as the amount of water not returned to the original source from where it was extracted, and consumed in the thermal power plant cooling system.

and the electricity tariff. This gives an indication of how much taxes or other fees can be applied to the electricity tariff.

b) is equal or higher to the electricity price, values of the indicators in 1) are displayed as are the absolute and relative differences between the cost of generating electricity and the electricity tariff. This gives an indication that electricity prices, for the x% of RET defined, would have to be subsidized by the government.

USE CASE E.1.3	Energy
Goal	Expansion of RET in the electricity sector
User	Academic / Research Institutes
Actions	• Targets for RES in the electricity sector • CO_2, eq emission reduction targets • Fuel prices (oil, gas, coal) • Changing electricity demand varying population, GDP or directly manipulate electricity growth rate
Indicator	• Cost of electricity generation (includes transmission and distribution costs) • Electricity price • Total investments in the electricity sector • Share of RET generation (electricity generation from RET / total electricity generation) • Total annual CO_2,eq emissions from electricity generation (10 year time step, or applicable) • Final annual electricity consumption per capita (kWh/capita/year) • Total annual water consumption[4] for cooling systems in power plants • Total land area used for RET infrastructure (annual)

Step in the SG

[4] Water consumption is defined, in this context, as the amount of water not returned to the original source from where it was extracted, and consumed in the thermal power plant cooling system.

- Identify current cost of electricity generation (E3ME, OSeMOSYS, SDM), the share of RET in the electricity generation mix (OSeMOSYS, E3ME, SDM); total land area used for RET infrastructure (SDM); annual CO_2,eq emissions from electricity generation (OSeMOSYS, E3ME); annual volume of water consumption for cooling systems (OSeMOSYS, E3ME, SDM); and, prices of selected crops (CAPRI, MAGNET).

1) Define the share of electricity generation from RETs relative to the total electricity generation in 2050 as x% (e.g. 5% of electricity generation produced from a combination of RETs, e.g. solar, on-shore wind, geothermal, biomass, waste-to-energy);
2) Define the increase in final annual electricity consumption per capita (z%);
3) Set a threshold for the electricity price in 2050 (or per decade?) as y euro/kWh.
4) The cost of electricity generation depends on the electricity generation mix of the country, which is bound to the final electricity demand. If the cost of electricity generation for a specific year or end-year :

   a) is lower than the threshold in set in 4), the indicators in 1) are displayed, plus the absolute and relative differences between the cost of generating electricity and the electricity tariff. This gives an indication of how much taxes or other fees can be applied to the electricity tariff.

   b) is equal or higher than the electricity price, values of the indicators in 1) are displayed as are the absolute and relative differences between the cost of generating electricity and the electricity tariff. This gives an indication by how much electricity prices, for the x% of RET and demand increase defined, would have to be subsidized by the government; or by how much prices of electricity would have to increase based on the electricity tariff cost structure

USE CASE E.1.4	Energy
Goal	Expansion of RET in the electricity sector
User	NGOs
Actions	• CO_2,eq emission reduction targets
Indicator	• Cost of electricity generation (includes transmission and distribution costs) • Total investments in the electricity sector • Electricity price • Share of RET generation (electricity generation from RET / total electricity generation) • Total annual CO_2,eq emissions from electricity generation (10 year time step, or applicable) • Total land area for RET infrastructure (annual)

	• Total annual water consumption[5] for cooling systems in power plants

Step in the SG

- Identify current cost of electricity generation (E3ME, OSeMOSYS, SDM), the share of RET in the electricity generation mix (OSeMOSYS, E3ME, SDM); total land area used for RET infrastructure (SDM); annual CO_2,eq emissions from electricity generation (OSeMOSYS, E3ME, SDM); annual volume of water consumption for cooling systems (OSeMOSYS, E3ME, SDM).

1) Define the target for CO2,eq emissions in 2050 (or per decade?) as x million ton CO2,eq.
2) The annual CO2 emissions depends on the generation mix. Higher share of RET in the mix corresponds to lower CO2,eq emissions. If the CO2,eq emissions target defined in 2) for the end-year (or another specific year or period) is:
   - Lower or equal than the threshold defined in 2), no further action is needed. The indicators in 1) are displayed and the absolute difference between total annual emissions and the target in 2).
   - Higher than than the threshold, equivalent emissions allowance or international emissions credits are bought matching the emissions' surplus. The extra spending is incorporated in the electricity tariff. The indicators in 1) are displayed and also the absolute difference between total annual emissions and the emissions target, total cost of CO2 emissions, and y% increase in the electricity price due to the surplus of CO2,eq emissions.

USE CASE E.2	Energy
Goal	Energy efficiency in the electricity sector

[5] Water consumption is defined, in this context, as the amount of water not returned to the original source from where it was extracted, and consumed in the thermal power plant cooling system.

User	Private Sector: Electricity generation utilities, transmission and distribution system operators
Actions	• Refurbishments / upgrade of existing electricity generation technologies • Investments in more efficient electricity generation infrastructure
Indicator	• Cost of electricity generation (including transmission and distribution fees) • Total investment in energy efficiency in electricity generation and in transmission and distribution • Electricity generation energy intensity (energy used (e.g. MJ) to produce one kWh of electricity) • % technical losses in electricity transmission and distribution (100*losses / total generation) • carbon intensity of electricity consumption (tonCO_2eq/total final energy consumption) • Annual water consumption[6] in the electricity sector (cooling systems)

Step in the SG

- Identify current cost of electricity generation (E3ME, OSeMOSYS, SDM), energy intensity of electricity generation (E3ME, OSeMOSYS, SDM), % losses in electricity transmission and distribution (E3ME, OSeMOSYS, SDM), annual CO_2,eq emissions from electricity generation (OSeMOSYS, E3ME, SDM), annual volume of water consumption for cooling systems in thermal power plants (OSeMOSYS, E3ME, SDM).
- Set a reduction for electricity transmission and distribution losses relative to 2010 for decades 2030, 2040 and 2050 (e.g. x% of reduction of T&D losses by 2030 and y% by 2050; if no reductions are planned, 0% should be indicated).
- Select systems where improvements should be implemented (transmission, distribution or both).
- Define the target for improvement of electricity generation energy intensity by selected years (e.g. z% increase in energy intensity by 2030 and w% by 2050, if no improvements are considered, 0% should be indicated).
- Select measures for improvement of efficiency, e.g. minimum efficiency of natural gas power plants should be 50%, implement control and monitoring systems,

[6] Water consumption is defined, in this context, as the amount of water not returned to the original source from where it was extracted, and consumed in the thermal power plant cooling system.

upgrading elements in the power plants, define minimum efficiency of power plants to be installed, etc.

Run the model / game.

- Display indicators listed in 1). Improvement of energy efficiency reduces carbon intensity of energy consumption, water consumption for cooling systems (if thermal generation is affected) and increases the energy intensity of electricity generation. Depending on the energy-efficiency related investments, electricity generation costs plus transmission and distribution fees may increase.

USE CASE E.3.	Energy
Goal	Increased interconnection of electric power systems
User	Private Sector (e.g. Transmission and distribution system operators)
Actions	• Set target for transmission interconnector installed capacity
Indicator	• Cost of electricity generation (including transmission and distribution fees) • Installed capacity of cross-border interconnectors • % net import of electricity [(imports – exports)/total electricity consumed (i.e. electricity produced plus electricity imports)] • Electricity exports as a % of the total electricity generation • Capital Investment (annual; 10-year time step, or applicable; total investment per period of analysis) • Total land area for RET infrastructure (annual) • annual CO_2,eq emissions from electricity generation (OSeMOSYS, E3ME, SDM)

Step in the SG

- Identify current cost of electricity generation (E3ME, OSeMOSYS, SDM), installed capacity of cross-border interconnectors (E3ME, OSeMOSYS, SDM, other data), share of net electricity imports (E3ME, OSeMOSYS, SDM), share of electricity exports (E3ME, OSeMOSYS, SDM), annual CO_2,eq emissions from electricity generation (OSeMOSYS, E3ME, SDM), total investments in cross-border transmission infrastructure (E3ME, OSeMOSYS, SDM), total investments in RET (E3ME, OSeMOSYS, SDM), annual volume of water consumption for cooling systems in thermal power plants (OSeMOSYS, E3ME, SDM), total land area used for RET infrastructure (E3ME, OSeMOSYS, SDM).
- Set a target for the share of transmission capacity of interconnectors (x%) relative to the total installed capacity for 10-year periods, from 2030 onward. According to

an EU recommendation, total nominal interconnectors installed capacity should not be lower than 30% of RE generation capacity installed in the country. Run the model/game. Display indicators from step 1).

- If the total installed capacity of interconnectors is higher than the 30% installed RE capacity, no further action is required.
- If interconnectors total capacity is below the 30% bound, investments in RE are automatically made so to match this lower limit. Total investment costs increase due to the expansion of RET, export capacity probably also increases while CO2 emissions and net imports decrease.
- Note to the Case Study for consideration when developing a similar Use Case as E.3: Changing dynamics of electricity trade has implications to the electricity trade context of the Case Study's neighbouring countries. The expansion of the cross-border electricity transmission network could result in increased CO2 emissions if it favours the trade of electricity produced from fossil fuels. Oppositely, it can also favour the deployment of RET and increase the flexibility of the European electricity system to accommodate the intermittent electricity produced from RES.

A3 Climate

USE CASE C.1.1	Climate
Goal	GHG emission reduction in the electricity sector
User	Private Sector (e.g. Electricity utilities, auto-producers (industries, commercial sector)
Actions	• Policy & Private: investment on more efficient thermal generation technologies • Policy & Private: investing in CCS in electricity generation • Policy & Private: investments in Renewable Energy Technologies •
Indicator	• kg CO_2,eq emissions in the electricity generation sector/ total electricity generation • Total annual CO_2,eq emissions from electricity generation • Cost of electricity generation including transmission and distribution fees (euro/kWh) • Capital investments

Step in the SG

1. Identify current cost of electricity generation (E3ME, OSeMOSYS, SDM), carbon intensity of electricity generation (kgCO2,eq/kWh) (E3ME, OSeMOSYS, SDM), total CO2,eq emissions from electricity generation (E3ME, OSeMOSYS, SDM) and total investments in the electricity sector (E3ME, OSeMOSYS, SDM).
2. Define targets for several elements that allow for the reduction of CO2,eq emissions in the electricity sector:

   a) Selection/definition of the minimum efficiency of generation technology of thermal power plants. This affects electricity generation costs due to the investment required, but it also uses less fuel to produce one unit of electricity, and, consequently less emissions.

   b) Option to select the use or not of CCS technologies for new thermal facilities. (Select CCS in thermal electricity generation power plants: yes or no).

   c) Set a minimum of % of final electricity demand supplied by RET (e.g. solar, on-shore wind, geothermal, biomass, waste). Options to invest on a portfolio of RE technologies should be possible. The mix selected would result in different CO2,eq emissions.
3. Run model /game and display indicators of step 1.

USE CASE C.1.2	Climate
Goal	GHG emission reduction in the electricity sector
User	Public Sector (e.g. Ministry of Energy, Ministry of Environment)
Actions	• Investment in more efficient thermal generation technologies, CCS in electricity generation, Renewable Energy Technologies • Set CO_2,eq emission reduction targets
Indicator	• kg CO_2,eq emissions in the electricity generation sector/ electricity generated • Total annual CO_2,eq emissions from electricity generation • Cost of electricity generation including transmission and distribution fees (euro/kWh) • Capital investments • Electricity tariffs

Step in the SG

1. Identify current cost of electricity generation (E3ME, OSeMOSYS, SDM), carbon intensity of electricity generation (kgCO2,eq/KWh) (E3ME, OSeMOSYS, SDM), total CO2,eq emissions from electricity generation (E3ME, OSeMOSYS, SDM), and total investments in the electricity sector (E3ME, OSeMOSYS, SDM).
2. Define the total CO2,eq emissions produced in the electricity generation sector until 2050;
3. Set a maximum limit for the electricity price per decade, starting from 2030, as y euro/kWh.
4. Select the options to be considered for reduction of CO2,eq emissions in the electricity sector in each decade: investments in more efficient thermal generation plants, increase of RET in the electricity generation mix, deployment of CCS in thermal generation power plants.
5. Run the model/game. If the electricity price:
   - Stays below or equal to the limit, and the CO2,eq target is met, display indicators presented in 1);
   - If the CO2 target is not met because of the threshold imposed by the electricity price, the excess of emissions have to be compensated in the carbon market and the expenses incurred added distributed over the electricity price, and the increase in price displayed as a share.

USE CASE C.2	Climate
Goal	Improve climate resilience in the electricity sector
User	Public sector (e.g. Ministry of Energy Planning)
Actions	• Define the foreseen reduction in hydropower production due to climate change • Diversification of the electricity generation mix • Power purchase agreements (electricity import agreements) must be established with neighbouring 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 • Improve power plant efficiency
Indicator	• Cost of electricity generation (including transmission and distribution fees) • Water used (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 • Cost of adaptation to climate change (Regret cost calculation based on choice of climate)

Step in the SG

1. Identify current cost of electricity generation (E3ME, OSeMOSYS, SDM), annual hydropower production (E3ME, OSeMOSYS, E3ME), annual electricity imports (E3ME, OSeMOSYS, SDM), water use (withdrawn) for cooling systems in thermal power plants (E3ME, OSeMOSYS, SDM), and total investments in the electricity sector (E3ME, OSeMOSYS, SDM).
2. Set a forecast of reduction in hydropower generation, -x% of base year generation; and a decrease in surface water availability for cooling systems, -y% of water used for cooling in the base year, and a maximum increase to the electricity generation costs (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: a) Increase deployment of RET in electricity generation (e.g. solar, wind, biomass); b) Phase out of once-through or upgrade cooling systems to less water intensive options (e.g. closed-cycle, dry-air cooling); c) Set a minimum of electricity imports at a fixed price correspondent to, for example, to the decrease in annual hydropower generation;
4. Run model / game. Indicators presented in 1) are displayed.

5. If electricity prices are not feasible, re-start game acting over the elements manipulated in 2).

USE CASE C.3	Climate
Goal	Climate proofing the agricultural sector
User	• Public Sector: Ministry of Agriculture, Ministry of Environment • Private Sector • Researchers / Students • NGOs
Actions	• Setting up an adaptation plan to ensure food security • Establishing sustainable water management policies. • Establishing a seed bank in case of severe drought to help farmers in rural areas • Increasing awareness about Climate change through capacity building programs • Policy directives for flood prevention • Establishing sufficient Finance mechanisms to combat unexpected changes in climate
Indicator	• Water Use/ unit $ of revenue from agricultural sector (has to be discussed; this can be interpreted in many ways) • Increase in the number of water storage facilities for seasonal/ monthly storage • No. of courses and initiatives organized to educate farmers • No. of flood meadows established on rivers with frequent flooding • No. of insurance schemes enrolled by farmers • Seed bank initiatives • Cost of inaction

Step in the SG

User Case 2: climate notes

There is significant uncertainty on how the future climate will develop. There is no certain pathway moving forward. Hence, the user of the SG should be (suggestion) allowed to choose from a list of climates; and depending on the choice, there will be certain effects. The actions will be dependent on the climate chosen by the user.

- **Current case**: reference climate (no changes in climate, historical climate)
- The user will select a climate from the list. The list will be (this is a suggestion) populated with different climate scenarios from different model outputs of the Coupled Model Inter-comparison project phase 5(CMIP5).(baseline climatic input

for any model used in SIM4NEXUS) There are many criteria to select the models/scenarios from the list. Climate Moisture index (which is a measure of aridity in the region) could be used as an initial suggestion (can be calculated based on climate variables, Temperature, precipitation) This can either be calculated for the entire EU or any of the member states depending on whether the user can choose the region/member state. Eventually the user will be able to choose a either a wetter climate or a drier one. (MAGNET, CAPRI, IMAGE and MAgPIE: all these models should have climatic input data in some form)

- Depending on the chosen climate, the impact on the agriculture sector can be quantified (MAgPIE or IMAGE). For example, the impact of a particular climate scenario on crops can be obtained from the Global Agro Ecological Zoning Database (GAEZ). The possibility of flood occurrence is also another parameter that can be derived from outputs of flood control/relevant models (IMAGE-GLOBIO). Another parameter could be the difference in precipitation between the current scenario and a base case (same models as in point 2)
- The user should then be able to choose from a list of actions that are available for him to play with. This can be in two forms (either a yes/no option) or an action with varying levels of implementation.
- Depending on the choice of action by the choice, a corresponding section will be made from the list of indicators to measure or rank the effectiveness of the action.

Relation between actions and indicators

Action	User Category	Indicator
Setting up an adaptation plan to ensure food security Subsidized food schemes in situations of extreme drought Import of essential food/crops if necessary	Public (ministries) Private (companies funded by the government)	**Average dietary energy supply adequacy** - a measure of food security in the country. Can be a modelled output
Establishing sustainable water management policies Policy directives for flood prevention activates Developing barrages or flood meadows as precaution against high precipitation/extreme flooding climates Building water storage facilities	Public (ministries) Private companies and NGOs(companies funded by the government to establish infrastructure to prevent flooding incidents) Same as No.2	Number of Flood meadows created on river banks which get flooded Number of water storage facilities in regions which experience seasonal water shortages
Increasing awareness on Climate change Capacity building programs on how crops	Public (ministries) & Institutions(teaching/University)	Number of courses/workshops held to increase awareness

Establishing sufficient Finance mechanisms Loans for Agriculture Insurance schemes for loss of crops etc.	1&2: Private companies & micro Finance institutions	Number of loan/insurance schemes available to farmers

Common Indicator: Regret costs or costs of inaction can be calculated for each of these options to show that if a certain action is not implemented, the cost of inaction would be XX Million USD (MAgpie)

A5 Land and Forest

USE CASE L.1	Land and Forest
Goal	Sustainable management of land
User	Public Sector: Land management authority
Actions	• Set the share between the different land uses • Allow or forbid practices in forestry / in agriculture • Allow of forbid settlements (new constructions) • Change subsidies and taxes for each land-use type • Set land prices
Indicator	• Income from land taxes vs. Costs of policy = Benefit • Share of natural land • Virtual land (land used in other territories to produce imported food or energy) • C sequestration • Risk of erosion / Degradation

Step in the SG

1. Identify current (t0) share of land on the territory (SWIM, CAPRI, GLOBIO), land prices (local data), C sequestration (GLOBIO), virtual land (SDM), level of eroded/degraded land (SWIM, GLOBIO)
2. Choose 1 land management policy from the list of possible actions
3. Set land prices for each use (if relevant)
4. Run the models / Progress through time
5. Display (t1) indicators
    - If share of natural land increases: Other land uses are decreasing, virtual land may increase if the needs of the territory (energy, food, housing) remain the same, C

sequestration increases, risk of erosion decreases. Competition for available non-natural land, potentially a more intensive use of the non-natural land. Reduced risks (landslides, GHG emissions and climate change, heat-island effect, pollutions, etc.)

- If good practices on land increase: C sequestration increases, risk of erosion decreases **but** benefits from the land may decrease (higher costs of implementing good practices or reduced income due to lower yields / productivity). Action can be taken to alleviate the loss of benefits (subsidies for good practices, compensation of reduced income, etc.)
- If share of natural land decrease / C sequestration increase / degraded land increase: The goal is not reached, risks increase. Actions must be taken to increase the share of natural land and/or the good practices (land management policies including land use limitations, rules on good practices, land taxes, etc.)
- Start again from 1

USE CASE L.2	Land and Forest
Goal	Sustainable management of land
User	Private Sector: Agriculture / Industry / Housing representatives
Actions	• Negotiate the share between the different land uses • Choose practices in forestry / in agriculture • Choose to develop settlements (new constructions) • Choose a set of land taxes
Indicator	• Income from land taxes vs. Costs of policy = Benefit • Share of natural land • Virtual land (land used in other territories to produce imported food or energy) • C sequestration • Risk of erosion / Degradation

Step in the SG

1. Identify current (t0) share of land on the territory (SWIM, CAPRI, GLOBIO), land prices (local data), C sequestration (GLOBIO), virtual land (SDM), level of eroded/degraded land (SWIM, GLOBIO)
2. Implement 1 land management policy from the list of possible actions
3. Choose 1 set of land prices for each use (if relevant)
4. Run the models / Progress through time
5. Display (t1) indicators (same as above)
6. Start again from 1

USE CASE L.3	Land and Forest
Goal	Sustainable management of land
User	NGOs: Landscape / Biodiversity / Soil protection
Actions	• Negotiate the share between the different land uses • Choose practices in forestry / in agriculture • Choose to develop settlements (new constructions) • Promote set of land taxes
Indicator	• Income from land taxes vs. Costs of policy = Benefit • Share of natural land • Virtual land (land used in other territories to produce imported food or energy) • C sequestration • Risk of erosion / Degradation

Step in the SG

1. Identify current (t0) share of land on the territory (SWIM, CAPRI, GLOBIO), land prices (local data), C sequestration (GLOBIO), virtual land (SDM), level of eroded/degraded land (SWIM, GLOBIO)
2. Promote 1 land management policy from the list of possible actions
3. Promote 1 set of land prices for each use (if relevant)
4. Run the models / Progress through time
5. Display (t1) indicators (same as above)
6. Start again from 1

USE CASE L.4	Land and Forest
Goal	Sustainable management of land
User	Students / Researchers
Actions	• Set the share between the different land uses • Allow or forbid practices in forestry / in agriculture • Allow of forbid settlements (new constructions) • Change subsidies and taxes for each land-use type • Set land prices
Indicator	• Income from land taxes vs. Costs of policy = Benefit

	• Share of natural land • Virtual land (land used in other territories to produce imported food or energy) • C sequestration • Risk of erosion / Degradation

Step in the SG

1. Identify current (t0) share of land on the territory (SWIM, CAPRI, GLOBIO), land prices (local data), C sequestration (GLOBIO), virtual land (SDM), level of eroded/degraded land (SWIM, GLOBIO)
2. Choose 1 land management policy from the list of possible actions
3. Set land prices for each use (if relevant)
4. Run the models / Progress through time
5. Display (t1) indicators (same as above)
6. Start again from 1

USE CASE L.5	Land and Forest
Goal	Sustainable management of forests
User	Public Sector: Forest management authority
Actions	• Decide on the share dedicated to biomass • Choose forestry practices • Promote labels such as PEFC label
Indicator	• Total forest cover • Share of forests with PEFC label • Share of forests for biomass production (building / energy) • Share of biomass in the energy mix • Employment in forestry sector • Benefits of forestry sector (incomes – costs) • C sequestration • Harvesting • Forest fires

Step in the SG

1. Identify current (t0) forest cover (CAPRI, MAGPIE, GLOBIO, SWIM), employment in forestry sector (E3ME, MAGNET), share of forests under PEFC label (GLOBIO, SWIM, SDM), share for biomass production (E3ME, MAGPIE, MAGNET), share of biomass in the energy mix of the Case Study (OSeMOSYS, MAGNET), benefits of forestry sector (E3ME, MAGNET), C

sequestration (GLOBIO), harvesting of forestry products (MAGNET, MAGPIE, E3ME, CAPRI), risk of forest fires (SDM, local data)

2. Choose 1 forestry policy from the list of possible actions
3. Run the models / Progress through time
4. Display (t1) indicators
    - If forest cover increases: Employment and benefits increase, C sequestration and harvesting increase but also risk of forest fires. It is uncertain how the share of PEFC labeled forests, biomass production, benefits will change. Action need be taken to orientate practices and uses for forest areas.
    - If forest with PEFC label increases: C sequestration increases too. Benefits for the forestry sector may decrease (higher costs, lower harvest), imported wood may increase. Action to be taken to support forestry sector (lower taxes, subsidies, etc.).
    - If share of forest for biomass production increases, share of biomass in the energy mix rises, harvesting rises: Forest fires may decrease **but** intensive practices may increase. Action to be taken, to make sure intensive practices are limited. (regulations)
5. Start again from 1

USE CASE L.6	Land and Forest
Goal	Sustainable management of forests
User	Private Sector: Forest managers / Owners
Actions	• Decide on the share dedicated to biomass • Choose forestry practices • Take-up labels such as PEFC label
Indicator	• Total forest cover • Share of forests with PEFC label • Share of forests for biomass production (building / energy) • Share of biomass in the energy mix • Employment in forestry sector • Benefits of forestry sector (incomes – costs) • C sequestration • Harvesting • Forest fires

Step in the SG

1. Identify current (t0) forest cover (CAPRI, MAGPIE, GLOBIO, SWIM), employment in forestry sector (E3ME, MAGNET), share of forests under PEFC label (GLOBIO, SWIM, SDM), share

for biomass production (E3ME, MAGPIE, MAGNET), share of biomass in the energy mix of the Case Study (OSeMOSYS, MAGNET), benefits of forestry sector (E3ME, MAGNET), C sequestration (GLOBIO), harvesting of forestry products (MAGNET, MAGPIE, E3ME, CAPRI), risk of forest fires (SDM, local data)

2. Implement 1 forestry policy from the list of possible actions
3. Run the models / Progress through time
4. Display (t1) indicators (same as above)
5. Start again from 1

USE CASE L.7	Land and Forest
Goal	Sustainable management of forests
User	NGOs: Biodiversity / Soils / Climate protection
Actions	• Negotiate the share dedicated to biomass • Promote forestry practices • Promote labels such as PEFC label
Indicator	• Total forest cover • Share of forests with PEFC label • Share of forests for biomass production (building / energy) • Share of biomass in the energy mix • Employment in forestry sector • Benefits of forestry sector (incomes – costs) • C sequestration • Harvesting • Forest fires

Step in the SG

1. Identify current (t0) forest cover (CAPRI, MAGPIE, GLOBIO, SWIM), employment in forestry sector (E3ME, MAGNET), share of forests under PEFC label (GLOBIO, SWIM, SDM), share for biomass production (E3ME, MAGPIE, MAGNET), share of biomass in the energy mix of the Case Study (OSeMOSYS, MAGNET), benefits of forestry sector (E3ME, MAGNET), C sequestration (GLOBIO), harvesting of forestry products (MAGNET, MAGPIE, E3ME, CAPRI), risk of forest fires (SDM, local data)
2. Promote 1 forestry policy from the list of possible actions
3. Run the models / Progress through time
4. Display (t1) indicators (same as above)
5. Start again from 1

USE CASE L.8	Land and Forest
Goal	Sustainable management of forests
User	Students / Researchers
Actions	• Decide on the share dedicated to biomass • Allow forestry practices • Promote labels such as PEFC label
Indicator	• Total forest cover • Share of forests with PEFC label • Share of forests for biomass production (building / energy) • Share of biomass in the energy mix • Employment in forestry sector • Benefits of forestry sector (incomes – costs) • C sequestration • Harvesting • Forest fires

Step in the SG

1. Identify current (t0) forest cover (CAPRI, MAGPIE, GLOBIO, SWIM), employment in forestry sector (E3ME, MAGNET), share of forests under PEFC label (GLOBIO, SWIM, SDM), share for biomass production (E3ME, MAGPIE, MAGNET), share of biomass in the energy mix of the Case Study (OSeMOSYS, MAGNET), benefits of forestry sector (E3ME, MAGNET), C sequestration (GLOBIO), harvesting of forestry products (MAGNET, MAGPIE, E3ME, CAPRI), risk of forest fires (SDM, local data)
2. Choose 1 forestry policy from the list of possible actions
3. Run the models / Progress through time
4. Display (t1) indicators (same as above)
5. Start again from 1

A5 Food and Agriculture

USE CASE A&F.1	Agriculture and Food
Goal	Resource efficiency
User	Public Sector
Actions	• Production activities targeted at the efficient use of nutrients, energy, water, climate and land • Agricultural production • Use of nutrients • Energy use in agriculture • Water use in agriculture • Greenhouse gas emissions in agriculture • Agricultural land use
Indicator	• Resource use (nutrients, energy, water, greenhouse gas emissions and land) per unit of output

Step in the SG

- Identify agricultural land use (CAPRI)
- Quantify crop production and animal production per unit of utilized agricultural area (in physical units) (CAPRI)
- Quantify use of nutrients from chemical fertilizer (in kg Nitrogen and Phosphorous) per unit of agricultural land (CAPRI, local sources)
- Quantify use of energy for transport and heating (e.g. tractor, electricity) (kwh) per unit of agricultural area (local sources)
- Quantify water use in agriculture (abstraction of water for irrigation) per unit of agricultural area (local sources)
- Greenhouse gas emissions in agriculture (CO_2, CH_4 from animal production, N_2O from soils) (all in kg CO_2 equivalent) (CAPRI, MAGNET, local sources)

1. Select a policy from the list of possible actions
2. Run the models / Progress through time
3. Display (t1) indicators (same as above)
4. Start again from 1

USE CASE A&F.2	Agriculture and Food
Goal	Profit maximization
User	Public Sector
Actions	• Promote good farming practices • Production is targeted at optimizing farm income
Indicator	• Aggregate value of production at farm level to sectoral total • Gross value added from agriculture (M€ by sector, region, country)

Step in the SG

- Added value of farming by region (CAPRI)
- Optimize supply and demand across regions (CAPRI)
- Added value of farming by sector (CAPRI)
- Aggregated production by region and country (CAPRI)

1. Select a policy from the list of possible actions
2. Run the models / Progress through time
3. Display (t1) indicators (same as above)
4. Start again from 1

USE CASE A&F.3	Agriculture and Food
Goal	Environmental frontier
User	Public Sector
Actions	• Promote good farming practice • Production is targeted at minimizing environmental impacts
Indicator	• Adoption of new environmental technology

Step in the SG

- Identify agricultural land use (CAPRI)
- Quantify crop production and animal production per unit of utilized agricultural area (in physical units) (CAPRI)

- Quantify use of nutrients from chemical fertilizer (in kg Nitrogen and Phosphorous) per unit of agricultural land (CAPRI, local sources)
- Quantify use of energy for transport and heating (e.g. tractor, electricity) (kwh) per unit of agricultural area (local sources)
- Quantify water use in agriculture (abstraction of water for irrigation) per unit of agricultural area (local sources)
- Greenhouse gas emissions in agriculture (CO_2, CH_4 from animal production, N_2O from soils) (all in kg CO_2 equivalent) (CAPRI, MAGNET, local sources)
- Introduce training courses for good farming practices (Local data)
- Introduce new technologies minimizing environmental impacts (Local data)

1. Select a policy from the list of possible actions
2. Run the models / Progress through time
3. Display (t1) indicators (same as above)
4. Start again from 1

USE CASE A&F.4	Agriculture and Food
Goal	Resource efficiency
User	Representative from farmers' organization (or individual farmer)
Actions	• Production activities targeted at the efficient use of nutrients, energy, water and land • Net output (output of production minus variable costs of production, excluding labour and land) at regional level (CAPRI) • Maximize net output from farming
Indicator	• Resource use (nutrients, energy, water and land) per unit of output (e.g. kg of N per € value of production)

Step in the SG

- Identify agricultural land use (CAPRI)
- Quantify crop production and animal production per unit of utilized agricultural area (in physical units) (CAPRI)
- Quantify use of nutrients from chemical fertilizer (in kg Nitrogen and Phosphorous) per unit of agricultural land (CAPRI, local sources)
- Quantify use of energy for transport and heating (e.g. tractor, electricity) (kwh) per unit of agricultural area (local sources)
- Quantify water use in agriculture (abstraction of water for irrigation) per unit of agricultural area (local sources)
- Greenhouse gas emissions in agriculture (CO_2, CH_4 from animal production, N_2O from soils) (all in kg CO_2 equivalent) (CAPRI, MAGNET, local sources)

1. Select a policy from the list of possible actions
2. Run the models / Progress through time
3. Display (t1) indicators (same as above)
4. Start again from 1

USE CASE A&F.5	Agriculture and Food
Goal	Profit maximization
User	Representative from farmers' organization (or individual farmer)
Actions	• Production is targeted at optimizing farm income
Indicator	• Farm income (€ per farm) • Sector income (M€ by sector)

Step in the SG

- Added value of farming by region (CAPRI)
- Optimize supply and demand across regions (CAPRI)
- Added value of farming by sector (CAPRI)
- Aggregated production by region and country (CAPRI)

1. Select a policy from the list of possible actions
2. Run the models / Progress through time
3. Display (t1) indicators (same as above)
4. Start again from 1

USE CASE A&F.6	Agriculture and Food
Goal	Environmental frontier
User	Representative from farmers' organization (or individual farmer)
Actions	• Production is targeted at minimizing environmental impacts
Indicator	• Adoption of new environmental technology • Adoption of precision farming

Step in the SG

- Identify agricultural land use (CAPRI)
- Quantify crop production and animal production per unit of utilized agricultural area (in physical units) (CAPRI)
- Quantify use of nutrients from chemical fertilizer (in kg Nitrogen and Phosphorous) per unit of agricultural land (CAPRI, local sources)
- Quantify use of energy for transport and heating (e.g. tractor, electricity) (kwh) per unit of agricultural area (local sources)
- Quantify water use in agriculture (abstraction of water for irrigation) per unit of agricultural area (local sources)
- Greenhouse gas emissions in agriculture (CO_2, CH_4 from animal production, N_2O from soils) (all in kg CO_2 equivalent) (CAPRI, MAGNET, local sources)
- Introduce training courses for good farming practices (Local data)
- Introduce new technologies minimizing environmental impacts (Local data)
- Select a policy from the list of possible actions
- Run the models / Progress through time
- Display (t1) indicators (same as above)
- Start again from 1

USE CASE A&F.7	Agriculture and Food
Goal	Food security
User	Public Sector
Actions	• Physical availability, economic access to sufficient food and stability over time (FAO definition) • Food supplies (production and imports) are adequate to match with regional or national food demand
Indicator	• Mton of food produced or imported (crops and animal products) – Also considering stocks

Step in the SG

- Food production and import of food (all in Mton) by country (MAGNET)
- Food consumption (all in Mton) by country (MAGNET)
- Availability of food by country (Supply versus demand) (MAGNET)
- Availability and access to sufficient food (FAO definition)
- Select a policy from the list of possible actions
- Run the models / Progress through time
- Display (t1) indicators (same as above)
- Start again from 1

USE CASE A&F.8	Agriculture and Food
Goal	Nutrition security
User	Public Sector
Actions	• Access by all people at all times to the adequate utilization and absorption of nutrients in food, in order to be able to live a healthy and active life (FAO definition) • Access to food but also to health care and hygienic conditions (source: http://edepot.wur.nl/305182)
Indicator	• Number of people who are lifted out of undernourishment between now and 2030. Effects regarding food intake, access to food and nutritional resilience will result in a decline in undernourishment. Link to Sustainable Development Goal • End hunger and children's undernourishment

Step in the SG

- Food consumption (all in Mton) by country (MAGNET)
- Availability of food by country (Supply versus demand) (MAGNET)
- Availability and access to sufficient food (FAO definition)
- Select a policy from the list of possible actions
- Run the models / Progress through time
- Display (t1) indicators (same as above)
- Start again from 1

USE CASE A&F.9	Agriculture and Food
Goal	Food waste
User	Public Sector
Actions	• Food waste is food that is discarded or lost uneaten. It may occur at any stage of food production, processing, retail or household
Indicator	• SDG target 12.3: "By 2030, halve per capita global food waste at the retail and consumer levels and reduce food

		losses along production and supply chains, including post-harvest losses”

Step in the SG

- Food production and import of food (all in Mton) by country (MAGNET)
- Food consumption (all in Mton) by country (MAGNET)
- Availability of food by country (Supply versus demand) (MAGNET)
- Percentage of food available (Mton) that is wasted (MAGNET database)
- Select a policy from the list of possible actions
- Run the models / Progress through time
- Display (t1) indicators (same as above)
- Start again from 1

USE CASE A&F.10	Agriculture and Food
Goal	Healthy diets
User	Public Sector
Actions	• Move towards diets with a bigger share of plant-based food and fewer animal source foods • A change in dietary preferences for livestock products based on the USDA recommendations for healthy diets (https://www.cnpp.usda.gov/USDAFoodPatterns) where animal calorie intake is decreased to 430 kcal/capita/day by 2030 in countries exceeding this threshold (see Willet et al., 2019).
Indicator	• Recommended intake levels of certain food items e.g. red meat etc. in a diet) were based on the GENUS database (Zurek et al., 2017) • SDG target 12.3: “By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses”

Step in the SG

- Food consumption (per capita) per country (MAGNET database) (Macronutrient intake, in grams per day; caloric intake in Kcal per day) (source: Willet et al., 2019)
- Compare actual intake with recommended intake and quantify gap

- Identify trajectory to reach healthy diets (source: Willet et al., 2019)
- Select a policy from the list of possible actions
- Run the models / Progress through time
- Display (t1) indicators (same as above)
- Start again from 1

USE CASE A&F.11	Agriculture and Food
Goal	Sustainable food systems
User	Public Sector
Actions	• Move from high quantities of production to producing healthy food. • Sustainably intensify production, increasing high-quality food.
Indicator	• Improved production practice • Sustainable food production

Step in the SG

- Identify agricultural land use (CAPRI)
- Quantify crop production and animal production per unit of utilized agricultural area (in physical units) (CAPRI)
- Quantify use of nutrients from chemical fertilizer (in kg Nitrogen and Phosphorous) per unit of agricultural land (CAPRI, local sources)
- Quantify use of energy for transport and heating (e.g. tractor, electricity) (kwh) per unit of agricultural area (local sources)
- Quantify water use in agriculture (abstraction of water for irrigation) per unit of agricultural area (local sources)
- Greenhouse gas emissions in agriculture (CO_2, CH_4 from animal production, N_2O from soils) (all in kg CO_2 equivalent) (CAPRI, MAGNET, local sources)
- Quantify planetary boundaries for Greenhouse gas emissions, cropland, freshwater use, nutrient application and quantify the gap between actual use and planetary boundaries.
- Select a policy from the list of possible actions

1. Run the models / Progress through time
2. Display (t1) indicators (same as above)
3. Start again from 1

A6 Tourism

USE CASE T.1	Tourism
Goal	Sustainable performance of tourist infrastructures
User	Private Sector: Tourist entrepreneurs (accommodation sector)
Actions	• Energy saving in tourist infrastructures (e.g. hotels) • Invest in water saving practices • Provide financial support tools
Indicator	• Total energy demand by the tourist sector • Total energy consumption by the tourist sector • GHG emissions by the tourist sector • Volume of water needed to cover tourist demand • Total land used for new tourist activities

Step in the SG

1. Identify energy demand, energy consumption and GHG emissions (E3ME, OSeMOSYS), water demand (SDM), cost of water (SDM), area of "tourist land" (SDM)
2. Calculate energy balance and GHG emissions: energy availability, rate of change of energy demand due to tourism, corresponding GHG emissions
    - If rate of change of energy demand due to tourism lower than threshold value: no need for immediate action
    - If rate of change of energy demand due to tourism higher than threshold value: reduce energy consumption by x% **OR** adoption of RES for in-house energy production **OR** invest in energy saving technologies in tourist infrastructures
    - If rate of change of water demand due to tourism lower than threshold value: no need for immediate action
    - If rate of change of water demand due to tourism higher than threshold value: adopt water saving practices **OR** use of treated or/and desalinated water

An additional cost is added related to the taken action

Subject to: rate of change of hydrological and energy balance due to tourism

↓

If the cost for the adoption of innovative practices / technologies concerning sustainable management of water and energy in tourism is not acceptable, then:

- An increase of cost (water / energy pricing system) may be imposed by y% to force them towards that direction
- A financial support with very low interest should be given to invest in new practices and reduce their water consumption and GHG emissions

Appendix II: List of indicators and variables

SECTOR	GOAL	ACTOR	SPECIFIC INDICATOR (per Use Case and actor)
Water	Water savings	Public sector (e.g. Ministry)	1. Total cost for agricultural water
			2. Volume of freshwater from surface/groundwater sources
		Private sector (e.g. Industry)	1. Total cost for water reuse technology
			2. Volume of water needed for covering industrial uses
			3. Water losses
			4. Total cost for industrial water (operation)
	Sustainable use of groundwater	Private sector (e.g. farmers)	1. Total cost of groundwater use
			2. Volume of groundwater needed for covering agricultural uses
			3. Calculating groundwater misuse
Tourism	Sustainable performance of tourist infrastructures	Private sector (e.g. tourist entrepreneurs)	1. Total energy demand by the tourist sector
			2. Total energy consumption by the tourist sector
			3. GHG emissions by the tourist sector
			4. Volume of water needed to cover tourist demand
			5. Total land used for new tourist activities
Energy			1. Cost of electricity generation

SECTOR	GOAL	ACTOR	SPECIFIC INDICATOR (per Use Case and actor)
	Expansion of RET deployment in the electricity sector	Private sector (e.g. electricity generation utilities, transmission and distribution system operators)	2. Electricity generation from RET / Total electricity generation
			3. % RE in the grid network system
			4. Capital investment (annual; 10 year time step or applicable; total investment per period of analysis)
			5. $CO_{2,eq}$ emissions / Total electricity generation OR Annual emissions of $CO_{2,eq}$ by the electricity sector
			6. Use of land with agriculture potential
		Private sector (e.g. electricity generation utilities, transmission and distribution system operators)	7. Annual water consumption for thermal power cooling
			8. Cost of buying/renting land for RE infrastructure
			9. Total land area used for RET infrastructure [wind power, solar PV (if not rooftop) and CSP]
			10. Electricity trade (in absolute terms OR as a % of the total electricity generation)
			11. Electricity generation surplus in different countries
	Expansion of RET deployment in the electricity sector		12. Generation capacity of the interconnectors
		Public sector (e.g. Ministry)	1. Electricity tariffs
			2. Electricity generation from RET / Total electricity generation (10 year time step or applicable)
			3. Capital investments or total cost of incentives (impacts the tariffs?)
			4. % RE in the national electricity generation sector

SECTOR	GOAL	ACTOR	SPECIFIC INDICATOR (per Use Case and actor)
			5. Total annual $CO_{2,eq}$ emissions from electricity generation (10 year time step or applicable)
			6. Change in food prices (relative, %)
			7. Reduction of agricultural land (in absolute / relative terms)
			8. Annual water consumption for thermal power cooling
	Expansion of RET deployment in the electricity sector	Educators / Students	1. Cost of electricity generation
			2. Electricity tariffs
			3. Electricity generation from RET / Total electricity generation
			4. % RE in the national electricity generation sector
			5. Total annual CO2,eq emissions from electricity generation (10 year time step or applicable)
		NGOs	1. Cost of electricity generation
			2. Electricity tariffs
			3. Electricity generation from RET / Total electricity generation
			4. Total annual CO2,eq emissions from electricity generation (10 year time step or applicable)
			5. Land area requirement for RET infrastructure by type (area for large PV, wind farms, CSP)

SECTOR	GOAL	ACTOR	SPECIFIC INDICATOR (per Use Case and actor)
			6. Number of species in areas with newly RET infrastructure (e.g. bird species in wind farm locations)
	Energy efficiency in the electricity sector	Private sector (e.g. electricity generation utilities, transmission and distribution system operators)	1. Cost of electricity generation
			2. Total investment in energy efficiency in the electricity supply side (infrastructure)
			3. Energy intensity of the electricity sector
			4. Change in electricity demand in reference to base year
			5. Annual emissions of CO_2 eq.
			6. Annual water use by the electricity sector
Climate	GHG emission reduction in the electricity sector	Private sector (e.g. electricity utilities, auto producers)	1. kg of CO_2 eq in the electricity generation sector / electricity generated (kWh)
			2. Capacity generation mix in each time step (MW/technology or fuel type)
			3. Total annual CO_2 eq emissions from electricity generation (10 year time step or applicable)
			4. Cost of electricity generation
			5. Capital investments
		Public sector (e.g. Ministry)	1. kg of CO_2 eq in the electricity generation sector / electricity generated (kWh)
			2. Capacity generation mix in each time step (MW/technology or fuel type)

SECTOR	GOAL	ACTOR	SPECIFIC INDICATOR (per Use Case and actor)
			3. Total annual CO_2 eq emissions from electricity generation (10 year time step or applicable)
			4. Cost of electricity generation
			5. Capital investments
			6. Electricity tariffs
	GHG emission reduction in the electricity sector	Educators / Students	1. kg of CO_2 eq in the electricity generation sector / electricity generated (kWh)
			2. Capacity generation mix in each time step (MW/technology or fuel type)
			3. Total annual CO_2 eq emissions from electricity generation (10 year time step or applicable)
			4. % CO_2 eq emission reduction in the electricity sector (in comparison to the base year)
			5. CO_2 eq emission reduction in overall CO_2 eq emissions (all sectors)
			6. Cost of electricity generation
			7. Electricity tariffs
			8. kg of CO_2 eq emissions in electricity generation / capita
		NGOs	1. kg of CO_2 eq in the electricity generation sector / electricity generated (kWh)
			2. Capacity generation mix in each time step (MW/technology or fuel type)
			3. Total annual CO_2 eq emissions from electricity generation (10 year time step or applicable)
			4. CO_2 eq emission reduction in overall CO_2 eq emissions (all sectors)

SECTOR	GOAL	ACTOR	SPECIFIC INDICATOR (per Use Case and actor)
			5. Electricity tariffs
			6. kg of CO_2 eq emissions in electricity generation / capita
	Climate proofing the agricultural sector	Public sector (e.g. Ministry)	1. Water use / unit $ or revenue from agricultural sector
			2. Increase in the number of water storage facilities for seasonal / monthly storage
			3. No of Courses and initiatives organized to educate farmers
			4. No of flood meadows established on rivers with frequent flooding
			5. No of insurance schemes enrolled by farmers
			6. Seed bank initiatives
			7. Cost of inaction ($/scenario)
	Improving climate resilience in the electricity sector	Public sector (e.g. Ministry) and Private sector (e.g. power plant operators and energy companies)	1. Yearly cost of electricity generation
			2. Cost of adaptation to climate change (Regret cost calculation based on choice of climate)
Land / Forest	Sustainable management of land	Public sector (e.g. land management authority)	1. Income from land taxes vs costs of policy = Benefit
			2. Share of natural land
			3. Virtual land (land used in other territories to produce imported food or energy)
			4. C sequestration
		Private sector (e.g. agriculture, industry, housing representatives)	1. Income from land taxes vs costs of policy = Benefit
			2. Share of natural land
			3. Virtual land (land used in other territories to produce imported food or energy)
			4. C sequestration

SECTOR	GOAL	ACTOR	SPECIFIC INDICATOR (per Use Case and actor)
			5. Risk of erosion/degradation
		NGOs (e.g. landscape, biodiversity, soil protection)	1. Income from land taxes vs costs of policy = Benefit
			2. Share of natural land
			3. Virtual land (land used in other territories to produce imported food or energy)
			4. C sequestration
			5. Risk of erosion/degradation
		Students / Researchers	1. Income from land taxes vs costs of policy = Benefit
			2. Share of natural land
			3. Virtual land (land used in other territories to produce imported food or energy)
			4. C sequestration
			5. Risk of erosion/degradation
	Sustainable management of forests	Public sector (e.g. forest management authority)	1. Total forest cover
			2. Share of forests with PEFC label
			3. Share of forests for biomass production (building/energy)
			4. Share of biomass in the energy mix
			5. Employment in the forestry sector
			6. Benefits of forestry sector (incomes-costs)
			7. C sequestration
			8. Harvesting
			9. Forest fires
		Private sector (e.g. forest managers, owners)	1. Total forest cover
			2. Share of forests with PEFC label
			3. Share of forests for biomass production (building/energy)
			4. Share of biomass in the energy mix
			5. Employment in the forestry sector

SECTOR	GOAL	ACTOR	SPECIFIC INDICATOR (per Use Case and actor)
			6. Benefits of forestry sector (incomes-costs)
			7. C sequestration
			8. Harvesting
			9. Forest fires
		NGOs (e.g. biodiversity, soils, climate protection)	1. Total forest cover
			2. Share of forests with PEFC label
			3. Share of forests for biomass production (building/energy)
			4. Share of biomass in the energy mix
			5. Employment in the forestry sector
			6. Benefits of forestry sector (incomes-costs)
			7. C sequestration
			8. Harvesting
			9. Forest fires
		Scientists / Researchers	1. Total forest cover
			2. Share of forests with PEFC label
			3. Share of forests for biomass production (building/energy)
			4. Share of biomass in the energy mix
			5. Employment in the forestry sector
			6. Benefits of forestry sector (incomes-costs)
			7. C sequestration
			8. Harvesting
			9. Forest fires
Agri-culture	Resource-efficiency	Public sector	1. Resource use (nutrients, energy, water, greenhouse gas emissions and land) per unit of output
		Representatives from farmers' organization (or individual farmer)	1. Resource use (nutrients, energy, water, land) per unit of output (e.g. kg N per euro value of production)

SECTOR	GOAL	ACTOR	SPECIFIC INDICATOR (per Use Case and actor)
	Profit maximization	Public sector	1. Gross value added from agriculture (M€ by sector, region, country) 2. Aggregate value of production at farm level to sectoral total
		Representatives from farmers' organization (or individual farmer)	1. Farm income (€ per farm); 2. Sector income (M€ by sector)
	Environmental frontier	Public sector	1. Adoption of new environmental technology
		Representatives from farmers' organization (or individual farmer)	1. Adoption of new environmental technology 2. Adoption of precision farming
Food	Food security	Public sector	1. Mton of food produced or imported (crops and animal products) - Also considering stocks
	Nutrition security	Public sector	1. Number of people who are lifted out of under nourishment between now and 2030 2. Effects regarding food intake, access to food and nutritional resilience will result in a decline in undernourishment 3. Link to Sustainable Development Goal 2: end hunger and children's undernourishment
	Food waste	Public sector	1. SDG target 12.3: "By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses"
	Healthy diets	Public sector	1. Recommended intake levels of certain food items e.g. red meat etc. in a diet) were based on the GENUS database 2. SDG target 12.3: “By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses”
	Sustainable food systems	Public sector	1. Improved production practice 2. Sustainable food production

NEXUS SECTOR	TOTAL INDICATOR (per nexus sector)	VARIABLES[i] (per nexus sector)
Water	• Total cost for agricultural water • Volume of freshwater from surface/groundwater sources • Total cost for water reuse technology • Volume of water needed for covering industrial uses • Water losses • Total cost for industrial water (operation) • Total cost of groundwater use • Volume of groundwater needed for covering agricultural uses • Calculating groundwater misuse	• Water demand for irrigation • Water losses/leakages by irrigation system/technology • Cost of agricultural water • Cost for renovating irrigation systems • Current water consumption for irrigation • Cost for water reuse • Cost of water-cleaning technologies • Cost for water losses reduction • Cost of water for industrial use • Water demand by the industrial sector • Water consumption by the industrial sector • Water losses by the industrial sector • Groundwater demand by the agricultural sector • Groundwater consumption by the agricultural sector • Cost of groundwater for irrigation purposes • Cost for pumping • Energy for pumping • Cost of new (more effective) irrigation systems
Tourism	• Total energy demand by the tourist sector • Total energy consumption by the tourist sector • GHG emissions by the tourist sector • Volume of water needed to cover tourist demand • Total land used for new tourist activities	• Cost of water saving practices • Cost of energy saving technologies • Energy consumption from RES • Cost of RES technologies use in the tourist sector • Energy demand by the tourist sector • Energy consumption by the tourist sector • Emissions by the tourist sector • Water demand by the tourist sector • Water consumption by the tourist sector • Cost of water in the tourist sector • Area of tourist land

NEXUS SECTOR	TOTAL INDICATOR (per nexus sector)	VARIABLES[i] (per nexus sector)
		• Number of tourists

Energy	• Cost of electricity generation • Electricity generation from RET / Total electricity generation • % RE in the grid network system • Capital investment (annual; 10 year time step or applicable; total investment per period of analysis) • CO_{2eq} emissions / Total electricity generation OR Annual emissions of CO_{2eq} by the electricity sector • Use of land with agriculture potential • Annual water consumption for thermal power cooling • Cost of buying/renting land for RE infrastructure • Total land area used for RET infrastructure [wind power, solar PV (if not rooftop) and CSP] • Electricity trade (in absolute terms OR as a % of the total electricity generation) • Electricity generation surplus in different countries • Generation capacity of the interconnectors • Electricity tariffs • Capital investments or total cost of incentives • % RE in the national electricity generation sector • Total annual CO_{2eq} emissions from electricity generation (10 year time step or applicable) • Change in food prices (relative, %) • Reduction of agricultural land (in absolute / relative terms) • Land area requirement for RET infrastructure by type (area for large PV, wind farms, CSP) • Number of species in areas with newly RET infrastructure (e.g. bird species in wind farm locations) • Total investment in energy efficiency in the electricity supply side (infrastructure) • Energy intensity of the electricity sector • Change in electricity demand in reference to base year • Annual emissions of CO_{2eq} • Annual water use by the electricity sector	• RES use for electricity production • Cost of RES per technology OR cost of investments by RES technology • Electricity consumption • Electricity demand - Needs • Cost for electricity production from RES • Reduction of GHG emissions due to the use of RES • Available land for RES infrastructures • Auto-production • Funding opportunities in the energy sector to promote RES • Increase of electricity production from RES OR by RES technology • Decrease of coal for electricity production • Cost for upgrading existing electricity generation technologies • Cost for the purchase and installation of more efficient electricity generation infrastructure • Funding opportunities / Subsidies for the private sector • Cost for renovating / expanding the electricity grid • Electricity surplus

NEXUS SECTOR	TOTAL INDICATOR (per nexus sector)	VARIABLES[i] (per nexus sector)
Climate	• kg of CO_{2eq} in the electricity generation sector / electricity generated (kWh) • Capacity generation mix in each time step (MW/technology or fuel type) • Total annual CO_{2eq} emissions from electricity generation (10 year time step or applicable) • Cost of electricity generation • Capital investments • Electricity tariffs • % CO_2 eq emission reduction in the electricity sector (in comparison to the base year) • CO_2 eq emission reduction in overall CO_2 eq emissions (all sectors) • kg of CO_2 eq emissions in electricity generation / capita • Water use / unit $ or revenue from agricultural sector • Increase in the number of water storage facilities for seasonal / monthly storage • No. of Courses and initiatives organized to educate farmers • No. of flood meadows established on rivers with frequent flooding • No. of insurance schemes enrolled by farmers • Seed bank initiatives • Cost of inaction ($/scenario) • Yearly cost of electricity generation • Cost of adaptation to climate change (Regret cost calculation based on choice of climate)	• GHG emissions • Cost of efficient thermal generation technologies • Cost of RE technologies • Cost of CCS technologies • Water demand by the agricultural sector • Water consumption by the agricultural sector • Food production - Quantity of agricultural products • Changes in agricultural land due to climate change • Diversification of crops • Hectares of land that is more prone to floods • Adequate food production • Energy mix - Share of each energy resource used for electricity production • Distribution of power plants according to climate change conditions

NEXUS SECTOR	TOTAL INDICATOR (per nexus sector)	VARIABLES[i] (per nexus sector)
Land/Forest	• Income from land taxes vs. costs of policy = Benefit • Share of natural land • Virtual land (land used in other territories to produce imported food or energy) • C sequestration • Risk of erosion/degradation • Total forest cover • Share of forests with PEFC label • Share of forests for biomass production (building/energy) • Share of biomass in the energy mix • Employment in the forestry sector • Benefits of forestry sector (incomes-costs) • C sequestration • Harvesting • Forest fires	• Land uses (e.g. hectares per land use) • Cost of land (agricultural land, tourist land, etc.) • Taxes • Total area of forest land • Forest biomass • Employees in the forestry sector • Income from forest activities • Forest land prone to fires • Forest products
Food	• Number of people who are lifted out of under nourishment between now and 2030 • Effects regarding food intake, access to food and nutritional resilience will result in a decline in undernourishment • Link to Sustainable Development Goal 2: end hunger and children's undernourishment • SDG target 12.3: "By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses" • Mton of food produced or imported (crops and animal products) (also considering stocks) • Percentage of food available (Mton) that is wasted • Food consumption (per capita) per country (Macronutrient intake, in grams per day; caloric intake in Kcal per day) • Planetary boundaries for Greenhouse gas emissions, cropland, freshwater use, nutrient application and quantify the gap between actual use and planetary boundaries	• Food exports • Food imports • Food waste • Adequate food quantity for covering existing needs • Cost for food production (e.g. agri-food) • Available land for food production

NEXUS SECTOR	TOTAL INDICATOR (per nexus sector)	VARIABLES[i] (per nexus sector)
Agriculture	• Resource use (nutrients, energy, water, land) per unit of output (e.g. kg N per euro value of production) • Gross value added from agriculture (M€ by sector, region, country) • Farm income (euro per farm); sector income (M€ by sector) • adoption of precision farming • Adoption of new environmental technology; • Energy use per unit of agricultural output • Water use per unit of agricultural output • Greenhouse gas emissions per unit of agricultural output • land use per unit of agricultural output • Use of nutrients per unit of agricultural output • Adopt new technologies minimizing environmental impacts (Local data)	• Energy consumption by the agricultural sector • Water demand by the agricultural sector • Water consumption by the agricultural sector • Water losses by the agricultural sector • Cost of agricultural water • Cost for renovation of technologies/agricultural systems • Agricultural income • Hectares of agricultural land • Agricultural products • Energy demand by the agricultural sector

[i] Variables that each CS may have in the SDM in order relevant indicators to be calculated