# From System Concept to serious game: The SIM4NEXUS Approach to Policy-Relevant Nexus Research

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**Abstract**
There is growing interest in using serious games for a wide range of applications and in the water-energy-food/land-climate nexus, where interactions in one sector lead to impacts in other sectors. Much practice revolves around sectoral silos, with little consideration of wider impacts. Serious games could help erode these silos, fostering efforts towards holistic policy making, where impacts can be explored and assessed without real consequences. SIM4NEXUS (www.sim4nexus.eu) develops policy-relevant serious games for 12 case studies, and is achieved by close case study stakeholder involvement, from qualitative system design, policy analysis, quantitative model development and serious game testing and playing. SIM4NEXUS covers five nexus sectors and develops scientifically-robust system dynamics models assessing nexus relationships. Models explore the impacts of changes in one sector on all other sectors. The SIM4NEXUS serious games 'play' the underlying models in a way accessible to those not familiar with modeling. Through intelligent game design, nexus-wide policy and climate impacts can be effectively communicated to stakeholders and policy makers while being fun to play, offering opportunity for nexus exploration in an educational setting. This work details the process in SIM4NEXUS, emphasising the constant stakeholder collaboration to ensure that the research and outputs remain relevant and accessible.
**Keywords:** policy; nexus; serious game; system dynamics; water-energy-food-land-climate.

## 1. Introduction

Water, energy, food, land and climate exist in a 'hyperconnected' system (WEF, 2016). Global research, politicians and multinational corporations are showing increased interest in the nexus and its potential implications for business (World Bank, 2016; IMechE, 2013; EEA, 2015). Efforts are required to consider many nexus sectors together at a range of scales to develop better understanding of nexus behaviour, and the potential impact of climate, socio-economic and policy changes. A serious gaming approach combines a learning objective with a fun activity in an attempt to increase the potential for learning uptake (Mayer, 2009; Savić et al. 2016). A well-designed serious game environment provides a feedback mechanism that allows the player to reflect on their actions and adopt different approaches or strategies. No comprehensive serious game has been developed to deal with the water-energy-food-land-climate nexus, which represents a clear gap in the literature. There is a need to: (1) improve scientific understanding of the water-food-land-energy-climate nexus; and (2) to develop serious games addressing the water-energy-food-land-climate nexus. Such serious games should be grounded in robust science and analysis. They should also be appropriately 'packaged' and targeted to certain users, namely those in decision-making or decision-influencing positions. The main purpose of these serious games should be to enable stakeholders to understand and learn about the medium and long-term implications of nexus-related policies applied to each case study. The work presented refers to an ongoing (2016–2020) EU Horizon2020 project SIM4NEXUS (www.sim4nexus.eu). While previous efforts have considered nexus elements either in complete isolation or only in 'partial integration', SIM4NEXUS aims to address all the nexus elements together.

## 2. Serious Game Development Process

SIM4NEXUS develops serious games for 12 case studies. The general process of model development and serious game design follows five main steps: Case study system conceptualisation; Thematic data collection; System dynamics modelling; the Knowledge Elicitation Engine; Serious game front-end development.

### *2.1 Case Study System Conceptualisation*

Together with case study leaders and stakeholders, the main case study nexus issue(s) is identified. From the central theme, interactions with all nexus sectors are

identified, including feedback. A dedicated Work Package on policy analysis provides the most pertinent nexus-relevant policies for each case study. The end product of this process is a conceptual diagram defining the central nexus issue and elaborating key interactions with other sectors. Key policies to potentially be played in the final game are identified. Data requirements for quantitative modelling are identified at this stage, and data are gathered.

*2.2 System Dynamics Modelling (Step 3)*

Based on the conceptual models, quantitative models are developed in STELLA (www.iseesystems.com; Figure 1), a system dynamics modelling (SDM; Ford, 2010) software that allows for the exploration of complex systems. Each SDM covers all five nexus sectors, and the interactions between them. Data for the models come from local sources and a suite of 'thematic models', including E3ME Cambridge Econometrics, 2014), CAPRI (Britz and Witzke, 2014), MAGNET (www.magnet-model.org) and GLOBIO (www.globio.info). Once model structure is deemed representative in consultation with local stakeholders, appropriate data are input and the model outputs are discussed with local case study experts to verify if the models are yielding sensible results. The next step is to convert the models into a Python script that can be integrated with the Knowledge Elicitation Engine (KEE; Step 4) and the serious game (SG; Step 5).

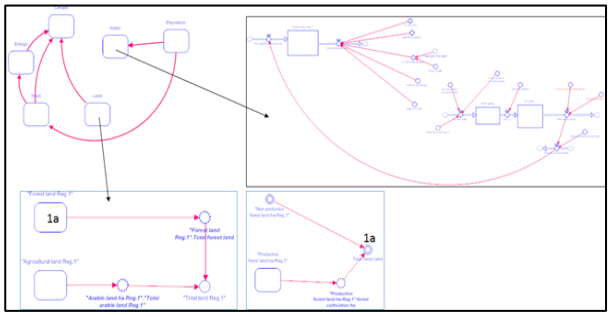


**Figure 1.** Part of the developed SDM for the Sweden case.

*2.3 Knowledge Elicitation Engine (KEE; Step 4)*

The KEE focuses on integrating knowledge and strategies at different spatial and temporal scales. The KEE enables the analysis of interactions within existing regulatory frameworks and barriers to implementation (Steps 1 and 2). The KEE provides the SG with the system-wide impact of each action implemented. Moreover, the KEE permits a top-down learning approach based on serious game front-end user decisions (Step 5) and a bottom-up approach based on classical machine learning methodologies. The KEE comprises three main items: (i) the game decision support system; (ii) the inference engine; and (iii) an agent-based module. Thus, the KEE integrates knowledge coming from Steps 1 and 2, nexus complexity science from Step 3 and the serious game front-end (Step 5). The SIM4NEXUS ontology has been done by following the NeON methodology. In case of the SIM4NEXUS Ontology, main analysed vocabularies refer to common variables and sensing ontologies like SAREF, WatERP (Anzaldi, 2015), IoTSchema and SOSA ontologies.

*2.4 Serious Game Front-End (Step 5)*

The goal of the SIM4NEXUS games is to bridge the gap between science and policy stakeholders by translating complex modelling results into an interactive virtual world through a "learning by playing" approach. As a player, you represent decision makers. Your aim is to achieve the targets set out by relevant bodies by changing or adapting new policies. To succeed, you must learn how to achieve these targets by mixing and matching various cross-sectoral policies without compromising the existing 'goal attainment' of other sectors. The main content in the serious game is provided both through the interfaces and the logics that the game contains, as well as through the KEE (Step 4). Steps 4 and 5 are critically linked. Game content is divided into three main parts: 1. Core experience; 2. Base mechanics; 3. Penalties and Reward system. In SIM4NEXUS, silo-thinking in decision making and policy implementation within the game is discouraged. The game can be played in different modes. It can be used by a single player. It can be used for playing the game in sessions led by a trainer or group facilitator. Lastly, it can be played with artificial agents.

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