BONUS RETURN

Reducing Emissions by Turning Nutrients and Carbon into Benefits

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X	PU	Public.
	PP	Restricted to other project partners.
	RE	Restricted to a group specified by the consortium.
	CO	Confidential, only for members of the consortium.

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Executive Summary

This deliverable is part of Work Package 6 and Task 6.2. – Serious Game System Development. The overall aim of the Serious Game System (SGS) is to provide a creative, safe and inclusive learning space that invites deliberation over the feasibility of different constellations of eco-technologies by drawing on the empirical insights generated by the BONUS RETURN project. Furthermore, it supports a participatory monitoring and assessment of the vulnerability of different constellations of eco-technologies within local Baltic Sea Region (BSR) contexts. The SGS is intended to serve as a platform to enhance agility and adaptive capacity when selecting eco-technologies in the face of disaster risks from unexpected nutrient and pollution emissions.

This report outlines the development efforts towards a digital SGS called MONITOR ECOTECH and presents the game features, components, and architecture, including the game engine, graphics and visualisations, user testing, game structure, as well as game mechanics and functions. The digital prototype featured in this report is a functional "alpha" version that utilises data generated from the playing of the board game version (see D6.7) to create a digitised interface. This interface allows for the monitoring and assessment of the performance of different constellations of ecotechnologies when they are exposed to social and biophysical shocks that amplify nutrient emissions in the BSR. This version is accessible at https://zygodact.itch.io/monitor-eco-tech.

The Digital SGS is currently in Alpha version and will be played at the final BONUS RETURN learning event and be made public shortly thereafter. The game is played with rules similar to the board game version together with facilitators.

Data from catchments coming from other WPs are incorporated into the operating system of the game. Stakeholder contributions, make up many of the eco-technologies, developments and natural hazards used in the game.

1. Introduction

The degradation of the Baltic Sea is an ongoing problem, despite investments in measures to reduce external inputs of pollutants and nutrients from both diffuse and point sources. Available technological and management measures to curb eutrophication and pollution flows to the sea have not been adapted adequately to the contexts in which they are being applied. Furthermore, measures are often designed based on single objectives, thereby limiting opportunities for multiple benefits.

In addition, there is a general sense that measures to address the deterioration of the Baltic ecosystem are primarily technologically-driven and lacking broader stakeholder acceptance – the "experts" who define these measures have little engagement with industry, investors, civil society and authorities. This problem is magnified by governance and management, taking place in sectoral silos with poor coordination across sectors.

As a result, research shows that limitations in regional institutional diversity is presently a barrier to transboundary cooperation in the Baltic Sea Region (BSR) and that actions to achieve national environmental targets can compromise environmental goals in the BSR (Powell et al. 2013). The regional dimension of environmental degradation in the BSR has historically received weaker recognition in policy development and implementation locally. However, developments in recent years suggest a new trend with growing investments in environmental protection supporting social, economic, and territorial cohesion.

The BSR is an environmentally, politically and economically significant region and like other regions globally, its rapid growth needs to be reconciled with the challenges of sustainable development in a global setting that demands unprecedented reductions in GHG emissions. This poses a truly wicked problem exacerbated by the fact that many of the challenges in the BSR will also magnify in a changing climate. In order to navigate the uncertainties and controversies associated with a transformation towards a good marine environment, BONUS RETURN will enact an innovative trans disciplinary approach for identifying and piloting systemic eco-technologies.

The focus is on eco-technologies that generate co-benefits within other interlinked sectors, and which can be adapted according to geophysical and institutional contexts. More specifically, emphasis is placed on eco-technologies that reconcile the reduction of present and future eutrophication in marine environments with the regional challenges of policy coherence, food security, energy security, and the provision of ecosystem services.

1.1. Project Objectives

The **overall** aim of BONUS RETURN is to improve the adaptation and adoption of eco-technologies in the Baltic Sea Region for maximum efficiency and increased co-benefits.

The **specific objectives** of the project can be divided into six categories presented below. These categories are interlinked but for the purpose of providing a step-wise description, the following overview of each category proves useful. BONUS RETURN is:

1) Supporting innovation and market uptake of eco-technologies by:

- Contributing to the application and adaptation of eco-technologies in the BSR through an evidence-based review (systematic map) of the developments within this field.
- Contributing to the development of emerging eco-technologies that have the capacity to turn nutrients and carbon into benefits (e.g. bio-energy, fertilizers), by providing an encompassing framework and platform for rigorous testing and analysis.
- Developing decision support systems for sustainable eco-technologies in the BSR.
- Contributing to better assessment of eco-technology efficiency via integrated and participatory modelling in three catchment areas in Finland, Sweden and Poland.
- Contributing to methodological innovation on application and adaptation of eco-technologies.

2) Reducing knowledge gaps on policy performance, enabling/constraining factors, and costs and benefits of eco-technologies by:

- Assessing the broader socio-cultural drivers linked to eco-technologies from a historical perspective.
- Identifying the main gaps in the policy environment constraining the implementation of emerging eco-technologies in the catchments around the Baltic Sea.
- Informing policy through science on what works where and under which conditions through an evidence-based review (systematic map and systematic reviews) of eco-technologies and the regional economic and institutional structures in which these technologies evolve.

3) Providing a framework for improved systematic stakeholder involvement by:

- Developing methods for improved stakeholder engagement in water management through participatory approaches in the case study areas in Sweden, Finland and Poland.
- Enacting a co-enquiry process with stakeholders into opportunities for innovations in eco-technologies capable of transforming nutrients and pollutants into benefits for multiple sectors at different scales.
- Bringing stakeholder values into eco-technology choices to demonstrate needs for adaptation to local contexts and ways for eco-technologies to efficiently contribute to local and regional developments.
- Disseminating results and facilitating the exchange of learning experiences, first within the three catchment areas, and secondly across a larger network of municipalities in the BSR.
- Establishing new cooperative networks at case study sites and empowering existing regional networks by providing information, co-organizing events and engaging in dialogues.

4) Supporting commercialization of eco-technologies by:

- Identifying market and institutional opportunities for eco-technologies that (may) contribute to resource recovery and reuse of nutrients, micro-pollutants and microplastics (e.g. renewable energy).
- Identifying potential constraints and opportunities for integration and implementation of eco-technologies using economical models.
- Facilitating the transfer of eco-technologies contributing to win-win solutions to multiple and interlinked challenges in the BSR.
- Linking producers of eco-technologies (small and medium enterprises – SMEs), to users (municipalities) by providing interactive platforms of knowledge exchange where both producers and users have access to BONUS RETURN's envisaged outputs, existing networks, and established methodologies and services.

5) Establishing a user-driven knowledge platform and improved technology-user interface by:

- Developing an open-access database that maps out existing research and implementation of eco-technologies in the BSR. This database will be intuitive, mapped out in an interactive geographical information system (GIS) platform, and easily managed so that practitioners, scientists and policy-makers can incorporate it in their practices.
- Developing methodologies that enact the scaling of a systemic mix of eco-technological interventions within the highly diverse contexts that make up the BSR and allows for a deeply interactive medium of knowledge.

1.2. Project Structure

BONUS RETURN is structured around six Work Packages that will be implemented in three river basins: The Vantaanjoki river basin in Finland, the Słupia river basin in Poland, and Fyrisån river basin in Sweden.

- Work Package 1: Coordination, management, communication and dissemination.
- Work Package 2: Integrated Evidence-based review of eco-technologies.
- Work Package 3: Sustainability Analyses.
- Work Package 4: Environmental Modelling.
- Work Package 5: Implementation Support for Eco-technologies.
- Work Package 6: Innovative Methods in Stakeholder Engagement.

1.3. Deliverable context and objective

Deliverable 6.8 is part of WP6. The objective of WP6 is to serve as a platform to enable a co-enquiry process between stakeholders and the project. At the regional level the 40 municipalities connected to the Race for the Baltic will act as a sounding board to provide input to the Evidence-based Review in WP2. Stakeholder platforms have been established at the case study sites to support the identification of eco-technologies for analysis in WP3, WP4 and WP5. These platforms have served as opportunities to further test, develop, adapt and use the eco-technologies based on the assumption that their effectiveness and relevance depends on context, as defined by institutional, economic, social and bio-physical barriers and opportunities. Thus, WP6 has contributed to understanding historical drivers, policy instruments, governance structures and local needs in order to ensure that selected eco-technologies are possible to implement in the three case study sites.

The task connected to this deliverable is T 6.2 – Serious Game System Development. The aim of the Serious Game System (SGS) is to draw on empirical insights generated by the BONUS RETURN project, in a creative, safe and inclusive learning space that invites deliberation over the feasibility of different choices and constellations of eco-technologies. Furthermore, it supports participatory monitoring and assessment of the vulnerability of different constellations of eco-technologies to social and biophysical shocks in the Baltic Sea Region (BSR). It is intended that the SGS will serve as a platform to enhance agility and adaptive capacity when selecting eco-technologies, by being cognizant of the disaster risks that lead to unexpected nutrient and pollution emissions.

This deliverable describes the development of the SGS in the format of a digital game, hereafter referred to as MONITOR ECOTECH.

1.4. Outline of the report

The report begins by introducing the concept and purpose of MONITOR ECOTECH. Thereafter the methodologies for the digital game development are outlined, including the game engine, game graphics, user testing and game structure, and finally, the digital game mechanics and functions.

2. Serious Game System - MONITOR ECOTECH

2.1. Motivation for a new approach to monitoring and assessment

The knowledge traditions underpinning environmental monitoring and assessment (EMA) are closely aligned with the dominant science tradition, embodied within a techno-centric worldview where social and ecological systems are treated as a dualism (Ison et al., 2011). Within this discourse, EMA has attempted to partition scientific knowledge e.g., the water, forestry, urban or agriculture sectors to inform the implementation of technologies and policies to address environmental problems.

EMA depends primarily upon the collection, storage and use of quantifiable data and objective information by scientific experts. This “rationalist” view of EMA has failed to attend to contestation and local and cultural knowledge that are often qualitative in nature and thus difficult to quantify in indicator systems (Díaz et al., 2018). By claiming that scientific knowledge is objective, is failing to recognize the role of agency and power that underpin the choice of what type of information/data is to be collected and how it is to be used and communicated in decision-making processes and the motivation, goals, and navigational tools underpinning these decisions. Furthermore, conventional EMA falls short in the face of “wicked” situations where “facts are uncertain, values are in dispute, the stakes are high and decisions are urgent” (Funtowicz and Ravetz, 1993). “Wickedness” calls for a more dynamic approach to EMA that extends beyond the normal boundaries of scientific disciplines to involve a wider constellation of stakeholders who bring on board a rich diversity of perspectives and interests. In order to support legitimate perspectives and actions, we argue that EMA should also embrace intersubjective rigor rather than just the orderly structures of “evidence-based” science.

More importantly, and with direct reference to this deliverable, traditional EMA is not suited to supporting decision making in complex and chaotic situations when the need to act is urgent (see fig. 1). Climate models project an increasing frequency and intensity of chaotic situations in the BSR; periods of more intense precipitation (as well as more intense droughts). While nutrient emissions to the Baltic Sea have decreased, the future of nutrient management under climate uncertainty, could jeopardize progress towards a clean Baltic Sea. During extreme flows, existing technologies are unable to track emission discharges. In absence of scientific evidence, we need to rely on proxy data, embodied in a diverse constellation of stakeholders who have high stakes and experience in deploying eco-technologies as a response to flood episodes. In recognition of complex and chaotic situations, transdisciplinary science (knowledge co-production between stakeholder and researchers), facilitated by participatory methods, such as the SGS, has emerged as a viable approach (Medema et al., 2019). There is increased recognition that serious games can serve as a platform to support participatory monitoring and assessment of the performance of constellations of eco-technologies under different conditions (Solinska-Nowak et al., 2018), and in so doing enhance the adaptive capacity of stakeholders when selecting eco-technologies in the face of disaster risks from unexpected nutrient and pollution emissions.

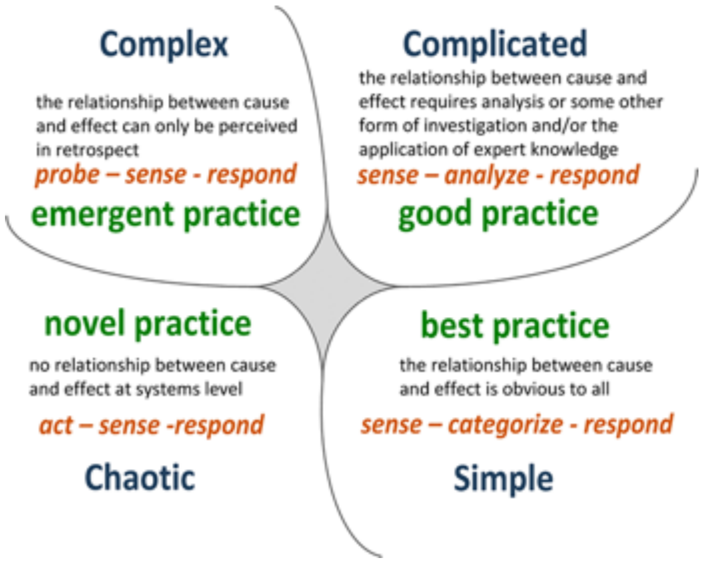

Figure 1. The spectrum of situations that require a range in approaches for evidence based decision support from "simpler" contexts where conventional monitoring and assessment is appropriate to complex and chaotic contexts that are "wicked" that demand an intersubjective approach to support decision making (Kurtz & Snowden, 2003)

Serious Game System: MONITOR ECOTECH in the context of BONUS RETURN

MONITOR ECOTECH is an interactive digital SGS underpinned by socio-ecological data and simulated dynamics. This supports an experiential and exploratory learning environment to enhance the adaptive capacity of stakeholders to respond to disaster risks from unexpected nutrient and pollution emissions that threaten the safety and security of the Baltic Sea.

The digital SGS is based on the preceding board game system (see D.6.7 – Serious Game System – SELECT ECOTECH) further strengthened and facilitated by the computational power of a digital game engine. It helps to keep track of the many transactions occurring in the system and the dynamic outcomes and impacts. Each turn requires the player to make eco-technology choices that significantly impact the flows of nutrients into the Baltic Sea and the status of different stakeholder interests. The digital version keeps track of data and values of the various flows in the system and how these flows are impacted by developments and eco-technologies as chosen by the players. The emissions of nutrients are also calculated and tracked throughout the game. The game hosts a series of scenarios and outcomes which further illustrate how player's choices and system shocks impact the system.

Key attributes of **MONITOR ECOTECH**:

While the digital version incorporates the experiences and feedback emerging from previous playtesting sessions in the board game version, it is better suited to support participatory monitoring and assessment of the performance of eco-technologies on account of the following attributes:

- Data tracking and representation: The capacity for tracking nutrient emissions and resources is greater, with finer granularity represented with statistical information from visualisations such as bar charts and flow data which provide information for participants to better monitor the outcomes of their actions in the system.

- The number variables: The number of constellations of eco-technologies and the variables that can be taken into consideration are greater. This gives rise to the ability to test and monitor more constellations for assessment.

- The operational mechanics of the game system are optimized by the computational power making it easier and faster to play. Thus, allowing players to more easily test and assess more choices and constellations of eco-technologies over time.

- The number of “turns” in the game can be greater. This affords players the ability not only to choose eco-technologies but to also monitor them over a longer period of game-time and to build a greater variety of constellations. Because the game engine does the necessary calculations in the digital SGS, it is easier to play longer game sessions and also several game sessions. The longer game sessions allow for players to choose and monitor individual ecotechnologies and constellations for best performance in situations characterised by disaster risks or system shocks.

- Being able to play several games in rapid succession affords players the ability to try out different practices and strategies related to selecting and implementing constellations of eco-technologies as well as assess outcomes in relation to system shocks.

- The digital game provides data on the level of emissions being emitted and also the number of emissions being reduced during each turn. It is also possible to track and monitor emissions as they enter the Baltic Sea and to track causal relationships between player actions and emissions into the Baltic Sea.

2.2. Methodologies for MONITOR ECOTECH

2.2.1. Game Engine

The game engine used in the digital production is Unity 3D, version 19.2. This choice is motivated by the capacity of this game engine to support both digital 2D- and 3D-environments as required by this project. In comparison to other alternatives such as the Unreal game engine, Unity is less optimized for photorealistic graphics, however it is better adapted for optimized prototyping and iterative agile development. For this digital SGS it was an optimal choice.

2.2.2. Game Graphics

The Digital SGS uses both 2D- and 3D-graphics in a virtual 3D world. The 2D-graphics are produced with Adobe Photoshop & Illustrator, Substance designer, and various Unity plug-ins, tools and assets. The 3D-graphics are produced with Maya, Blender, Z-brush, Photoshop, Illustrator, and Substance designer, and various Unity plug-ins, tools and assets.

The visual appearance of the digital SGS, MONITOR ECOTECH, is consistent with the board game SELECT ECOTECH (see D 6.7). The playing field is an abstract hexagonal representation of a land use area. Similar to the board game system (REF to D 6.7), each catchment has three land use areas for each player or team of players. The overall composition is two sets of three hexagons for different land use systems (agriculture, forestry, urban) which are interconnected with each other and also surround a center hexagon that represents the Baltic Sea. This game architecture provides a systematic arrangement of baseline emissions, water flows, development interventions and eco-technologies. As in the board game, the digital game consists of a similarly formal and representational system. The difference is the support of interaction through digital representation of the analog components in the board game and the ability of players to view realtime data emerging form the various scenarios and outcomes and subsequent state changes occurring in the system. These state changes are system outcomes resulting from player choices and constellations of eco-technologies and developments as impacted by system shocks or disasters. A representational game world using simplified “low-poly” 3D-models (minimalistic models with a low number of polygons), was chosen to facilitate representational clarity and simplicity while avoiding detailed granularity that might distract players from the systemic nature of the game. This approach was used to maintain a balance between clear representation of systemic choices, while providing an interesting representation of the world. As the explorational focus is on the systemic properties of game world and not the world itself, players are able to monitor in real time, what choices they have made in their selection of single eco-technologies, what constellations they have created, the impact their actions have in tackling disaster risks within the BSR. This resulted in the development of the digital game using an objective camera angle displaying the entire playing board and the representation of the flows in the system.

2.2.3. User Testing

Initial user testing for game design through the board game has been conducted iteratively throughout the stakeholder workshops (see D 6.7 for more details) in the three catchment areas. The testing of the digital version was undertaken by staff and students at Uppsala University iteratively throughout the entire development process. This was done after each of seven Agile development cycles. Agile software development prioritizes iterative cycles of functioning code (Beck et al., 2001). Each development cycle was play tested for potential bugs in the system, for player usability testing and for targeted system functionality. Each cycle represented a limited addition of functionality and features that could be added and tested discreetly and as implemented together with the other components of the game system. By using Agile development practices, the digital game was able to be structured and programmed in iterative steps in parallel to the tabletop board game.

2.2.4. Game Structure

The digital game is a turn-based strategy game for two players or teams. The playing field is a single-screen digital representation of the SGS board game used in preceding stakeholder workshops. Flows in the system and resulting data are used to exemplify and illustrate various positive or negative outcomes resulting from players' choices and actions. Statistics are provided to players throughout the game. These statistics provide data about resources and emissions operating in the game. Both flows and statistics can be clicked on for viewing during the play session. As there is a vast amount of data being monitored and calculated in relation to the player choices, the data about the many components is made available to the players when they click on a particular item in the game such as a development, eco-technology, a constellation, a water flow or the Baltic Sea. By having real-time data accessible in context and on demand, players are better able to assess and inform their choices and monitor the outcomes.

2.2.5. The Data underpinning the SGS

Data included in the digital SGS is derived from two main sources: i) data from RETURN's Environmental Modelling work package (WP4) (see https://ckan.ymparisto.fi/dataset/free-access-to-functioning-swat-application-of-the-three-river-basins) and; ii) stakeholder and expert consultation undertaken by way of a series of meetings and workshops.

WP4 provided the data on the baseline emissions from different forms of land use (agriculture, forestry and urban) in three catchments. Also, WP4 provided data depicting the reduction of nutrient emissions for those eco-technologies that were possible to model within the Soil and Water Assessment Tool (SWAT). The emission data was subsequently scaled to a range of values 1-100 so it could be operational in the game setting (see Table 1 and the eco-technologies denoted with an * in Table 2). Here it is the relational data, i.e. data depicting the relations rather than the absolute data that are important. In so doing, it was possible to retain an appropriate level of data fidelity while being attentive to the modus operandi and the playability of the game system. Following Masuch & Röber (2004), we argue that the quality of player engagement in the SGS depends more on the believability rather than true-to-life depiction of the real world situation. This design strategy enabled us to focus on important points that supported the creation of a meaningful narrative and game play for learning and deliberation. Some studies (e.g. Rooney, 2012) also posit that higher levels of data fidelity does not necessarily enhance the learning process, but in fact can impede learning due to unnecessary complexity, causing cognitive overload and making the game less fun to play.

Table 1. Relative contribution of total emissions between the three sectors from the three case studies

	Agriculture	Forestry	Urban area
Fyrisån	38%	52%	10%
Vantaanjoki	80%	4%	16%
Slupia	53%	40%	7%

In addition to the data provided by Environmental Modelling WP, data was generated by way of a stakeholder engagement process (see Deliverable 6.7 for more details). This included: (1) the data depicting the nutrient emission reduction potential of those eco-technologies that could not be modelled within SWAT; (2) the nutrient emissions generated or captured by the development interventions and; (3) the costs of eco-technologies and development interventions. The cost-effectiveness data were scaled between 1-5 with 1 being the most cost-effective and 5 being the least cost-effective. Cost-effectiveness provides a ranking of the relative performance of different technologies and is expressed in the cost (i.e. the cost to purchase an eco-technology or a development) per effectiveness unit (i.e. the amount of emissions reduced in case of eco-technologies or the amount of resources generated in case of developments). The relative costs for eco-technologies and development interventions used in the digital SGS can be found in **Tables 2 & 3** respectively. As with the emission data, the cost data depicts representational values, which means the data shows the relations between the different values rather than the absolute values.

Table 2. Relative costs of the eco-technologies used in the digital SGS

No.	Eco-technology	Cost-effectiveness	Costs	Emission reduction
1.	*Wetlands	1	40	40
2.	*Buffer strips	2	25	13
3.	*Catch crops	3	15	5
4.	Crop rotation	3	15	5
5.	*Retention ponds	2	25	13
6.	Biochar application Agriculture	3	15	5
7.	Biochar application Forest	5	10	2
8.	Compost application Agriculture	3	15	5
9.	Compost application Forest	5	10	2
10.	Sludge application Agriculture	1	40	40
11.	Sludge application Forest	3	15	5
12.	Improving drainage management on farms	3	15	5
13.	Restoration of riparian areas	3	15	5
14.	Floodplains	3	15	5
15.	Liming / gypsum	4	13	3
16.	Optimizing fertilization rates based soil parameters using geo-location systems	1	40	40
17.	Optimization of livestock density for nutrient management	2	25	13
18.	Microstrainer technologies at fish farms	3	15	5
19.	Connecting 100% of population to wastewater treatment	4	13	3
20.	Improved stormwater management	3	15	5
21.	Improving on-site treatments	5	10	2
22.	Source separation of waste for scattered settlements	3	15	5
23.	Urine-diversion toilets	4	13	3

24.	Wastewater improvements that deal with overflow	3	15	5
25.	Biochar treated with source-separated blackwater as soil improver	3	15	5
26.	Incineration and phosphorus recovery from ash	4	13	3
27.	Biochar filter	3	15	5
28.	Enhanced wastewater treatment level through ultrafiltration and UV-disinfection	2	25	13
29.	Irrigation with seawater	3	15	5
30.	Mussel farming	3	40	13
31.	Seaweed farming	1	40	40
32.	Precision technologies in agriculture	2	40	20

Table 3. Relative costs of the development interventions used in the digital SGS

No.	Development	Cost-effectiveness	Set up costs	Annual Returns	Emissions
1.	District heating Rural	3	40	13	0
2.	Green house	3	40	13	0
3.	Tourism	2	40	20	5
4.	Building houses for rent on farms	3	40	13	5
5.	Slaughterhouse	3	40	13	13
6.	Biogas plant	4	40	10	-13
7.	Increase in fertilisation	1	13	13	40
8.	Intensify biomass removal from forests	4	20	5	2
9.	Seaweed farm	5	40	8	-40
10.	Mussel farm	2	40	20	-13
11.	Irrigation with sea water	2	15	7	-5
12.	Fish farm (freshwater)	1	20	20	40
13.	Investment in machinery in agriculture	2	40	20	20

(Note: Emissions in negative values mean that the developments help reduce emissions instead of generating emissions)

2.3. Description of the digital game mechanics and functions

The digital game mechanics and functions of the digital SGS are demonstrated in the following link https://zygodact.itch.io/monitor-eco-tech

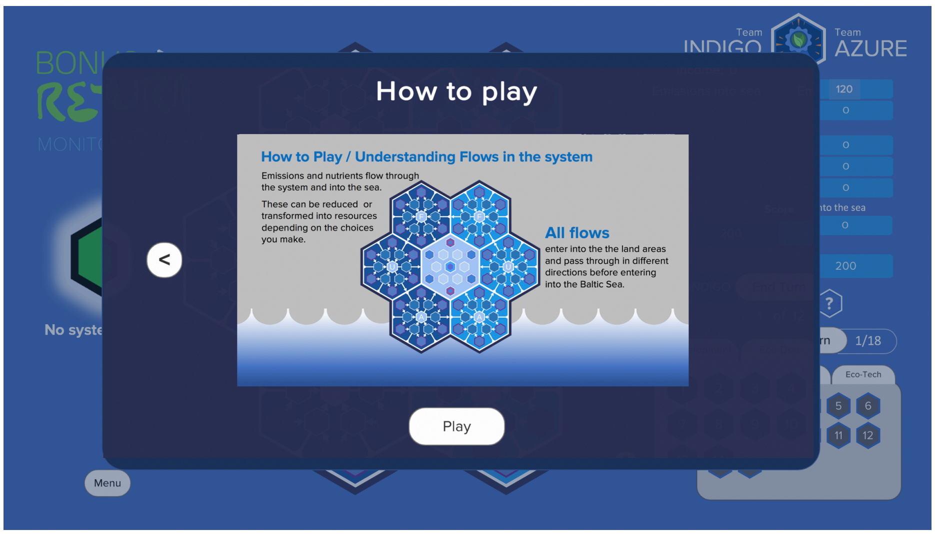

Figure 2. View of the pre-game tutorial. The game is explained by this and an interactive information function inside the game.

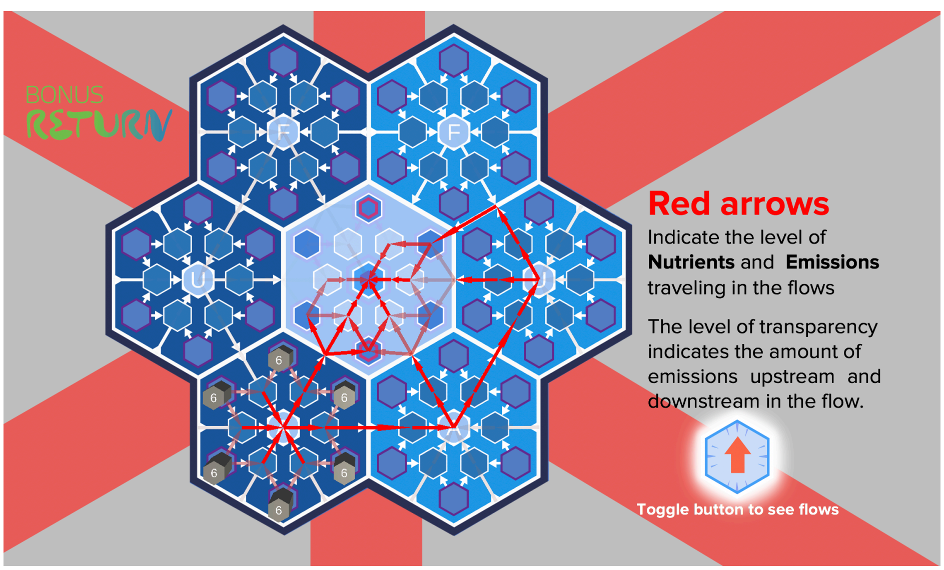

Figure 3. View of the red flows of emissions in the system. These increase in opacity as the level of emissions increase.

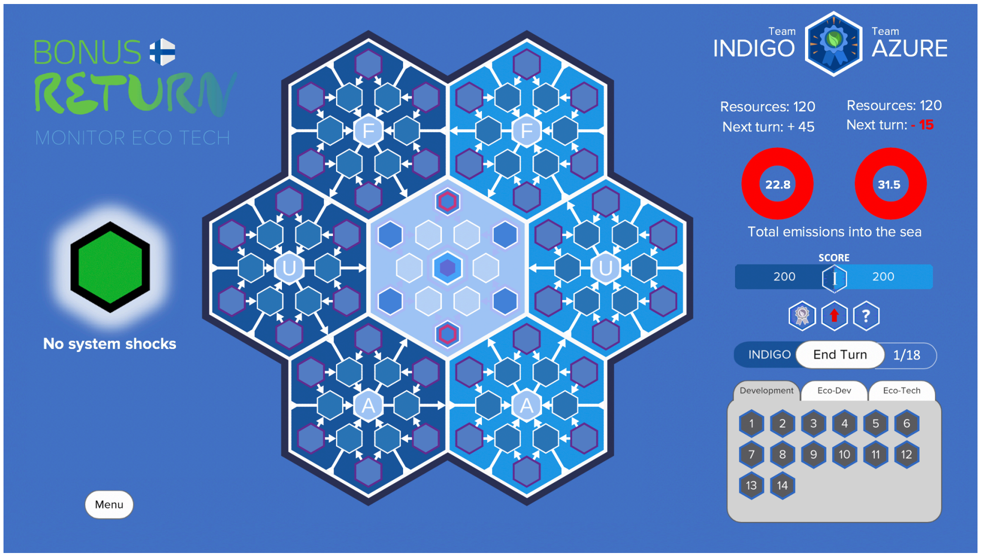

Figure 4. Default display showing the resources and the total emissions being released into the Baltic sea.

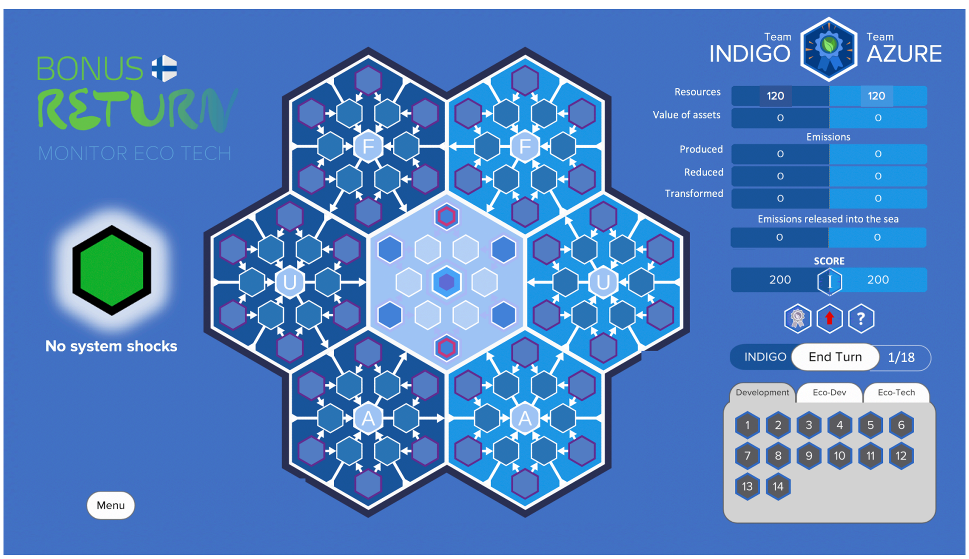

Figure 5. Display with data bars indicating levels of emissions and resources to help players navigate choices impacting emission levels and resources.

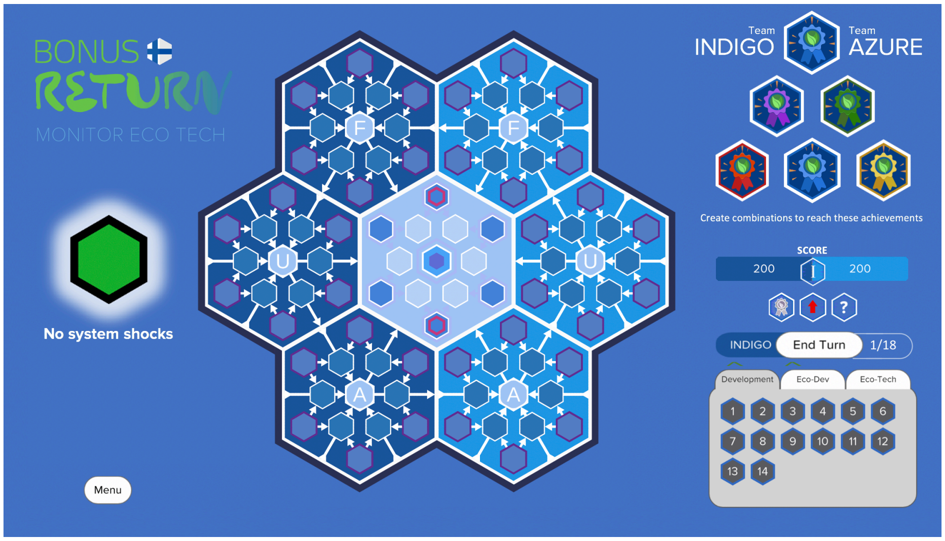

Figure 6. Display with achievements for the construction of synergetic constellations towards targeted goals such as Preparedness, Biodiversity, SDG 9, and SDG 13.

3. Concluding Remarks

This report features the development of MONITOR ECOTECH, an interactive digital SGS. The SGS is underpinned by socio-ecological data and simulated dynamics to enact an experiential and exploratory learning environment. The overarching aim is to support stakeholder deliberation, action (emergent or novel practices), monitoring and assessment in "wicked" situations; situations characterised by unexpected nutrient and pollution emissions. For the purposes of the digital game these situations are characterised as either (1) when relationships between cause and effect can only be assessed retrospectively or; (2) when there is no relationship between cause and effect (see figure 1).

Drawing on the experience and feedback emerging from previous playtesting sessions in the board game version, the digital game system utilizes the computational power to provide tracking capacity, finer granularity of data and the ability to test and evaluate a multiplicity of choices and constellations of eco-technologies. The increased optimisation of the system mechanics operating in the game allows for game sessions with an increased number of turns for the participants providing them with an increased opportunity to monitor constellations of eco-technologies over time. Participant progress and data emerging from constellations of eco-technologies in relation to water flows is calculated in real time and data can be accessed by players by clicking on items in the game system.

MONITOR ECOTECH and SELECT ECOTECH are both part of the same iterative development process. This process began as explained in D.6.7 – Serious Game System – SELECT ECOTECH, with stakeholder interviews, workshops, and iterative play-testing sessions. This led to the generation of data being implemented into the tabletop version of the SGS (SELECT ECOTECH). The MONITOR ECOTECH version is a more formalised derivative of the previous version in a digital interactive format, whereas the SELECT ECOTECH in comparison is inherently dialogue based. This version incorporates the outcomes of those dialogues and brings them into the system to be calculated by the game engine, further facilitating a monitoring capacity. The MONITOR ECOTECH system also collects player data from each game session while aggregating data from every play session. This offers further data each time the SGS is played allowing for further research opportunities. The noted challenge in designing an SGS as opposed to a Serious Game (SG) is the exploratory nature of the contents and structure of the formal systems supporting the game transactions.

In traditional game design, learning outcomes are often more predetermined and the data underpinning the game are often described and decided prior to development and construction. In the case of the SGS, the process both in the tabletop version (SELECT ECOTECH) and in the digital version (MONITOR ECOTECH) was designed to incorporate emergent data generated by ongoing interactions with stakeholders and work packages iteratively. In order to accommodate this process a robust conceptual framework was developed, manifest as the SGS's operating environment. The underlying continuity supported by the operating environment allowed stakeholders to focus on content which was specific to their area of expertise.

The sequential SGS development process has resulted in the more dialogue-based tabletop version, with a focus on selecting constellations of eco-technologies. This is in turn coupled with the more system-based digital SGS that supports the monitoring and assessment of these constellations under the complex and chaotic conditions that lead to unexpected nutrient emissions.

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