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Serious games in support of transformative multi-stakeholder sanitation planning for increased resource recovery

Specifications for game development

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Sanitation game. Photo: Jaan-Henrik Kain
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ABSTRACT

Globally, 2.3 billion people lack sanitation. Innovative solutions are needed that allow for rapid service expansion to underserved populations. Serious games can bring new perspectives into rigid planning and decision-making by increasing the understanding of complex issues, supporting learning of alternative perspectives and enhancing stakeholders cooperation. Existing games are inadequate for addressing the sanitation challenge and current frameworks for game development are neither comprehensive, nor tailored to sanitation planning. The objectives of this report are a) to develop a generic framework for development of serious games supporting transformative planning and governance; and b) to develop a set of specifications for a serious game for transformative sanitation planning specifically, c) to present a sanitation planning game prototype, and d) to report on an assessment of this game prototype. The report is based on literature studies and prototyping with user tests. A comprehensive framework for game development is presented and specifications for a serious game in sanitation planning are described. Initial game prototyping found that not all specifications could be fulfilled. Yet, focusing the framework on the serious purpose of the game, its worldview, its content, and its context of use brought a different but useful logic into the game design process.

Key words: sustainable sanitation; transformative planning; social learning; serious games; game specifications

Contents

Preface

This report was produced in two parallel research projects:

Gamification of sanitation planning: Exploring technical and societal readiness of alternative nutrient-recovery systems

Adaptation and innovation in sanitation planning: Exploring technical and societal readiness of alternative nutrient-recovery systems

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1 Introduction

1.1 The global sanitation challenge

The global sanitation crisis is a major challenge facing our generation. The World Health Organization estimates that 2.3 billion people lack access to basic sanitation, posing severe risks to public health and to the environment (WHO, 2018). Sanitation systems also impact on planetary boundaries for nutrient flows and climate change (Rockström et al., 2009). There is a need for innovative solutions that protect public health and lead to the recovery of resources (nutrients, water, energy), in ways that allow for rapid service expansion to underserved populations (Larsen et al., 2013).

Implementing such innovations requires significant changes in the design, organization and management of sanitation (Lennartsson et al., 2019). Resource recovery may require changing service norms, as well as new organizational roles and responsibilities (McConville et al., 2017b). However, there is a high degree of path dependency and inertia in infrastructure systems (Geels, 2002), particularly in wastewater systems in industrialized countries with major sunk investments in existing infrastructure (Geels, 2006). Additionally, existing institutional structures are barriers for up-scaling of new sanitation systems by favoring traditional centralized sewerage systems (Fuenfschilling & Truffer, 2014). Processes of collaborative or social learning, where multiple stakeholder establish common visions and experiment with new ideas can address these obstacles (Kemp et al., 2002). Yet, establishing common visions and translating these into decision-making is not straightforward (Lennartsson et al., 2019). Introducing technical innovations thus needs to be paralleled with innovation in planning and decision-making.

1.2 The potential of serious games for the sanitation challenge

One way of addressing path dependency and inertia is to introduce serious games to soften up and bring in new perspectives into rigid planning and decision-making processes. Serious games are useful for increasing the understanding of complex issues, for learning of alternative perspectives and for enhancing cooperation between stakeholders (den Haan & van der Voort, 2018). They have "an explicit, cautious, educational function" (Abt, 1987, p. 5), with a "procedural rhetoric" (Bogost, 2007, p. ix) that engages and motivates people in dialogues processes (Poplin, 2014) and in learning (Katsaliaki & Mustafee, 2015).

Mayer (2009) provides an extensive account of the history of gaming in policy and planning from the 1940s. In the 1980s, game development took three different routes (Mayer, 2009). The first went for improving quantitative simulation, e.g. through system dynamics, agent-based models, cellular automata, decision support systems, and geographical information systems (GIS). The second dismissed quantitative models altogether and instead embraced complexity through different types of conceptual mapping of "the world of ideas" (Meadows & Robinson, 2002, p. 276). The third route was "to open up the black box of quantitative models and to make them much more responsive and suitable for complex policy making" (Mayer, 2009, p. 836). Increased transparency, ease of use and interactivity were seen as crucial and "gaming was seen as the most appropriate candidate for designing computer-mediated interaction among

policy stakeholders" by providing "insights into how to arrange an experimental context with players, roles, rules, and a scenario" (Mayer, 2009, p. 836). Raghothama and Meijer (2018) argue that games can move beyond traditional aims of learning and experimentation and help us engage with complex urban systems infused by wicked problems. Geurts et al. (2007) identify the potential of policy games within five areas, "The Five Cs': Complexity, Communication, Creativity, Consensus and Commitment to Action" (p. 541). In particular, serious games facilitate and support collaborative or social learning (den Haan & van der Voort, 2018; Wendel & Konert, 2016), e.g. by improving the understanding of different stakeholder perspectives (Barreteau, 2003) and building trust and joint reflection (Gordon & Baldwin-Philippi, 2014). They are social laboratories that mimic real life situations, but with few effects on real settings (Barreteau, 2003).

Most games for environmental planning tend to fall into the third route of game development. For example, the BETAVILLE game is designed to foster participation in developing new ideas for urban environments (Koplin & Skelton, 2012), SIEVE provides landscape simulations for collaborative planning (Stock et al., 2008), and ALEGAMS supports social learning in the context of sustainable shrimp farming (Rodela et al., 2019). The number of games in the field of water management is growing (Medema et al., 2019), e.g. involving cooperation between stakeholders to deal with conflicting priorities (Morley et al., 2017), social learning (Zhou & Mayer, 2018), optimizing waster systems (Arbesser-Rastburg & Fuchs-Hanusch, 2020), water governance (Aubert et al., 2019), water safety (Ferrero et al., 2018), or flood prevention (Khoury et al., 2018). Breuer et al. (2017) argue that game-based learning locates learners into the complexity of real-world situations and lets them experiment in a way that books and videos cannot match. (For a review of numerous both digital and analog games for water management and planning, see e.g. Aubert et al., 2018).

Serious games in the sanitation and wastewater sector are more limited. Yet, interest is increasing and an increasing number of serious sanitation games are being made. For example, NITROGENIUS models nitrogen flows, but excludes human-generated nutrients (Erisman et al., 2002). SEGWADE lets multiple stakeholders compete to improve water distribution (Morley et al., 2017). RELIEF CAMP MANAGER trains the player to plan provision of water and sanitation in disaster zones (Aslam et al., 2017). In India, a serious board game has been piloted to engage social enterprises in the provision of sanitation (Damani et al., 2015).

Although game designers report that players understand the systems presented in the games (e.g. NITROGENIUS, SEGWADE and RELIEF CAMP MANAGER), there are few evaluations of learning and transitional effects from game application. For example, the developers of a game designed for social entrepreneurship in sanitation found that players not only learned about social enterprising, but also formed intentions, e.g. to do social work (Damani et al., 2015). KATAWARE, a scenario-based simulation tool for modelling catchment level water management (Farolfi & Hassan, 2003) succeeds in collaborative learning of complex socio-ecological systems related to river water use through iterative participatory modelling (Farolfi et al., 2010). Still, most planning games need improvement regarding their capacity to support participation, interaction, learning and knowledge transfer (Reinart & Poplin, 2014). There is also evidence that the process of game development in itself is an important moment of social learning (Rodela et al., 2019).

1.3 A systematic approach to sanitation game development

It is clear that serious games for transformational sanitation planning are in need of further development. Although there are helpful frameworks for game development (e.g. Lindley, 2003; Oceja & Fernández, 2017; Prieto De Lope & Medina-Medina, 2017; Uskov & Sekar, 2014), these are neither sufficiently comprehensive and systematic, nor tailored to the needs of sanitation planning. If serious games are to play a role in shifting sanitation management practices to more sustainable options and opening pathways for societal transformation, frameworks for sanitation game development needs to be further explored.

The aim of the present report is to present a systematic framework in support of developing games for urban planning, and in particular sanitation planning. The objectives are:

1. To develop a generic framework for development of serious games that support different types of planning and governance processes in urban transformation
2. To, based on this framework, develop a set of specifications for a serious game for transformative sanitation planning specifically, within the context of increased resource recovery
3. To present a sanitation planning game prototype based on these specifications
4. To report on an assessment of the game prototype against the specifications

2 Methods

This text reports on a process of developing a systematic framework for design of serious games for planning and governance (Part A), adapting it specifically to the context of sustainable sanitation (Part B), using it in the development of a game prototype (Part C), and a first assessment of this prototype (Part D). Development of the framework is based on studies of academic and grey literature (i.e. technical reports, policy papers, web pages, etc.) to address the two first objectives. Although the development of Part A and B below is described as a linear process, this process included a certain amount of iterations, where the sanitation perspective also contributed to improving the quality of Part A results.

For *Part A* (responding to Objective 1 above), searches were carried out in Scopus to identify previously developed criteria and taxonomies helpful for development of serious planning games. Taxonomies and frameworks for assessing and developing serious games in general, and urban planning games in particular, were analysed in the form of a scoping review (Arksey & O'Malley, 2005). Among the rather few relevant findings, the taxonomy by Prieto De Lope and Medina-Medina (2017) stood out as particularly useful, and was used as a backbone for the continued work. Still, it was found that a serious game for transformative urban/infrastructure planning and governance requires additional sub-categories not listed by Prieto De Lope and Medina-Medina. More detailed searches in Scopus were conducted to fill these gaps, based on search terms linking serious games to the sanitation challenge, frequently complemented by literature snowballing to pursue relevant references in the texts. The result was the identification of a number of relevant requirements for serious games for urban planning and governance, compiled into an overall generic framework.

In *Part B* (addressing Objective 2) game requirements from the previous section were linked to the specific issue of transformative sanitation planning, here drawing on academic and grey literature on sanitation planning, transition theory, social learning, stakeholder involvement, etc. This facilitated a translation of the more generic game requirements into a set of detailed specifications for a serious game in sanitation planning supporting increased resource recovery.

In *Part C*, an action-design prototyping research process was used to design a sanitation planning game based on the specifications (Objective 3). This process involved stakeholders from relevant organizations (see below) in an iterative cycle of game design, game testing and game evaluation (Haj-Bolouri et al., 2017). Organizational blockages often impede the implementation of new dialogue planning tools (Billger et al., 2017) and co-design involving both policy and research stakeholders serves to address such obstacles (Roux et al., 2017). Game development started by carrying out scoping studies in Sweden and Uganda in 2017-2018, including interviews with municipal planning and sanitation officers in Sweden and stakeholders on both national and municipal levels within the water, environment and agriculture sectors, as well as with NGOs working with sanitation. Topics covered included challenges in sanitation planning; the current state, potential and perceptions of nutrient recovery within the respective sanitation systems; and the potential of serious gaming in this context. The interest among stakeholders to take part was significantly higher in Uganda, compared to Swedish stakeholders that, due to time constraints, preferred to be involved when a game prototype was ready.

The game development process evolved through four main steps (see Billger et al., 2020 for more details):

1) Initial gaming exercises with sanitation stakeholders (February 2018): This step primarily involved more than 30 Ugandan sanitation stakeholders and 120 Ugandan environmental engineering students, exploring if and how serious sanitation gaming could be applied in Kampala. These activities provided valuable input on which directions to take in the game development. Due to the reluctance from Swedish stakeholders to take part, no co-design activities were carried out in Sweden and previous research and insights into Swedish sanitation planning (Lennartsson et al., 2019; McConville et al., 2017a; McConville et al., 2017b) and serious games in this context (McConville, 2013, 2016; McConville et al., 2017) had to serve as a first basis for game design.

2) Game development with contracted game designers in Sweden (August 2018 to March 2019): The research team and the game designer team carried out a series of game development workshops to playtest different versions of the sanitation board game developed by the game designers based on the game specifications and the experiences from Step 1. The purpose was to try out different game mechanics until a first playable prototype was produced. Ugandan stakeholders were included through SKYPE discussions.

3) First playtests with stakeholders and first revision of game (April to May 2019): The first round of playtests were carried out in two stakeholder workshops in Kampala, one with four sanitation students and the other with 20 participants from local sanitation organizations. One of the researchers guided the gameplay and the sessions were observed and recorded by another researcher. After playing, participants provided written feedback and also reflected together as a group. The feedback from playtests were brought back to the game design team in Sweden and the game was revised in response.

4) Second playtest with stakeholders and second revision of game (May to November 2019): The revised game version was tested with a sanitation officer from a Swedish municipality and two interaction design students. Again, the playtest was observed and documented, and the players were encouraged to reflect upon the gameplay. Final adjustments were made before finalizing a more elaborated prototype. Additionally, a Microsoft Excel application was developed as a complement to the main game, including simulations and visualizations of the sanitation systems created through gameplay.

5) Third playtests and finalisation of the game design (December 2019 to February 2020): The game and the digital add-on were tested jointly with one group of five technical graduate students and another of four researchers and students in architecture. Final adjustments to game mechanics (mainly game rules and role play) were made.

Finally in *Part D* (responding to Objective 4), the game prototype was tested with a group of students and the results from the gameplay and the prototype itself were then compared with the original game specifications as outlined in *Part B*. Each specification was judged as fulfilled, partially fulfilled or not fulfilled. A group of 14 Masters level engineering students played the game as part of their course work in the course Resource-oriented Water and Sanitation Systems at Luleå University of Technology, Sweden. The students were asked to fill in pre-game and post-game questionnaires to trace whether gameplay had affected their perception of resource-recovering sanitation, and to write a short reflection based on a number of guiding questions that, apart from probing deeper into their perception of sanitation, also were directed at reflecting on

the game-playing experience (see Appendix A). The student were five women and nine men. All the students reported less than five years of experience working with sanitation and the majority had no experience at all. With the exception of one being over 30-year old, the students were between 20-29 years of age.

3 Results Part A: A framework for development of serious planning games

Drawing on a detailed literature review, Prieto De Lope and Medina-Medina (2017) propose a comprehensive taxonomy, both for assessing existing games and for shaping design criteria for purpose-built games. It consists of six main categories with a number of sub-categories. To better fit serious gaming in urban planning and governance, this taxonomy was restructured and additional sub-categories were appended by drawing on other authors (see Table 1). Below, each main category is examined in detail, including referenced descriptions of the sub-categories.

Table 1 *A framework of game requirements for serious games in urban planning and governance. The taxonomy proposed by Prieto De Lope and Medina-Medina (Prieto De Lope & Medina-Medina, 2017) is supplemented by drawing on other authors, in their turn drawing on multiple sources. New sub-categories are marked with an asterisk*.*

Category	**Sub-category**	**Key references**
Game design	Application area	(Aubert et al., 2019; Prieto De Lope & Medina-Medina, 2017; Uskov & Sekar, 2014)
	Worldview*	(Dooghan, 2019; Fisher, 2017)
	Content*	(Dooghan, 2019; Duke & Geurts, 2004; Fisher, 2017; Raphael et al. 2010)
	Context of use	(Oceja & Fernández, 2017; Prieto De Lope & Medina-Medina, 2017; Reinart & Poplin, 2014)
	Genre	(Barreteau, 2003; Deterding et al., 2011; Oceja & Fernández, 2017; Prieto De Lope & Medina-Medina, 2017)
	Realism*	(Reinart & Poplin, 2014)
	Narrative	(Mannsverk, 2013; Medema et al., 2016; Prieto De Lope & Medina-Medina, 2017; Wood et al., 2014)
	Data/knowledge management and transfer*	(Billger et al., 2017; Pasini et al., 2017; Uskov & Sekar, 2014)
	Data/knowledge representation/ visualization*	(Billger et al., 2017; Pasini et al., 2017; Wood et al., 2014)
	Interactivity	(Prieto De Lope & Medina-Medina, 2017)

Game use	Gameplay	(Korn & Voida, 2015; Lehner et al., 2014; Medema et al., 2016; Montola, 2009; Pasini et al., 2017; Prieto De Lope & Medina-Medina, 2017; Wendel & Konert, 2016; Wood et al., 2014)
	Learning/social learning and collaboration	(Al-Kodmany, 1999; Billger et al., 2017; Bishop & Stock, 2010; Medema et al., 2016; Prieto De Lope & Medina-Medina, 2017; Wood et al., 2014)
	Links to the wider planning and action context*	(Billger et al., 2017; Gordon et al., 2011; Oceja & Fernández, 2017; Wood et al., 2014)
	Adaptation of the game	(Butz et al., 2008; Kickmeier-Rust & Albert, 2012; Prieto De Lope & Medina-Medina, 2017; Wonica, 2017)
	Assessment	(Aubert et al., 2018; Prieto De Lope & Medina-Medina, 2017)
Game users	Target audience	(Aubert et al., 2018; Duke & Geurts, 2004; Gordon et al., 2011; Keijser et al., 2018; Prieto De Lope & Medina-Medina, 2017)
	Player interaction	(Prieto De Lope & Medina-Medina, 2017; Reinart & Poplin, 2014; Te Brömmelstroet & Schrijnen, 2010; Wendel & Konert, 2016)
	Dedication	(Prieto De Lope & Medina-Medina, 2017)
Game development	Authorship	(Prieto De Lope & Medina-Medina, 2017)
	Development methodology	(Khaled & Vasalou, 2014; Mayer, 2009°; Prieto De Lope & Medina-Medina, 2017; Sein et al., 2011; Solinska-Nowak et al., 2018)
Game platform	Hardware architecture and deployment	(Kaufman & Flanagan, 2016; Prieto De Lope & Medina-Medina, 2017; Solinska-Nowak et al., 2018; Wonica, 2017)
Business model	License	(Prieto De Lope & Medina-Medina, 2017)
	Sustainability*	(Billger et al., 2017)

° Referring to Meadows & Robinson (2002).

3.1 Game design

Application area: The domain (e.g. health, education, public policy) and serious purpose(s)/desired impact(s) of the game (e.g. collection, exploration, simulation, exchange and sharing of data/knowledge, education and training, motivation, persuasion, behavioural change, decision-making, policy-making) should be defined (Prieto De Lope & Medina-Medina, 2017; Uskov & Sekar, 2014). The purpose can also be defined according to the different phases of the governance process, i.e. defining goals, building commitment, identifying system gaps, strategy and action development, implementation, and monitoring and evaluation (Aubert et al., 2019).

Worldview: The perspective represented by the game, based on the pre-understandings, ideology, etc. of the game developers and/or their clients is recognized and clearly stated (Dooghan, 2019; Fisher, 2017).

Content: The issues to be managed by the game, both the substantive content (e.g. sanitation systems) and the implications of these issues (e.g. how sanitation impacts on health) are identified (Duke & Geurts, 2004; Raphael et al., 2010).

Context of use: Specifies the situation in which the game will be used. This consists of the available resources (money, time, technologies, space), level of interest and commitment among stakeholders, and cultural and political aspects of game use (Prieto De Lope & Medina-Medina, 2017), including if it will be played in formal and/or informal settings (Oceja & Fernández, 2017).

Genre: What type of game is desired, e.g. action, adventure, logic, simulation and/or strategy (Prieto De Lope & Medina-Medina, 2017). For planning/policy settings, role play supports knowledge development, learning, stakeholder negotiation and collective decision making (Barreteau, 2003). Genre also includes whether the objective is a complete game or gamification, i.e. the use of game elements in non-game settings (Deterding et al., 2011; Oceja & Fernández, 2017).

Realism: Clarify whether linkages to real planning/governance situations should be established (Reinart & Poplin, 2014). If yes, the degree of realism becomes important and should be specified, e.g. if the game plays out in an existing city.

Narrative: The degree of narrative complexity in the game is linked to the degree of realism of the game (Mannsverk, 2013). The narrative supports players "to develop a deeper and richer understanding" (Medema et al., 2016, p. 7). For example, player goals should be clear and have real-life relevance (Wood et al., 2014). Narratives can range from simple storylines to complex narratives playing a key role in the game (Prieto De Lope & Medina-Medina, 2017).

Data/knowledge management and transfer: Clarify how data and knowledge relevant for planning and policymaking is collected, stored, exchanged and/or explored within the game (Billger et al., 2017; Pasini et al., 2017; Uskov & Sekar, 2014). This includes both data inputs to the game and potential outputs of data after gameplay.

Data and knowledge representation/visualization: Data and knowledge should be represented in ways that make sense for the player (Wood et al., 2014), are suitable for the purpose of the game and are simplified enough to make the game playable (Abt, 1987). This includes the use of indicators (Pasini et al., 2017), level of detailing/photorealism, selection of viewpoints (Billger et al., 2017), and sufficiently realistic visualizations of real contexts (Reinart & Poplin, 2014).

Interactivity: Specify how communication between players and the game takes place: through active interaction (e.g. by moving game pieces or through gloves, gestures), standard interaction (mouse, keyboard, touch screen), specific controls (including virtual reality, VR), or pervasive interaction with real world objects (including augmented reality, AR) (Prieto De Lope & Medina-Medina, 2017).

3.2 Game use

Gameplay: Reaching and engaging players is achieved through satisfaction (enjoyment), motivation (achievable tasks, curiosity) and stimulation (sensorial and/or emotional) (Prieto De Lope & Medina-Medina, 2017). Specify how the game achives this by: being challenging, entertaining and possibly immersive (Medema et al., 2016); by providing clear goals, rewards and feedback on progress or by making players feel that they are part of something (Pasini et al., 2017; Wood et al., 2014); and/or by creating friction (Korn & Voida, 2015). An additional topic is whether the game world is continuous or played in sessions (Montola, 2009; Wendel & Konert, 2016).

Learning/social learning and collaboration: A key learning aspect is how easily the players master the game (Prieto De Lope & Medina-Medina, 2017). The challenge of how to translate that learning into social learning and collaboration that support the serious purpose(s) of the game is closely related to topics already raised under *gameplay* above (Medema et al., 2016). Social learning is further supported by trial and error experimentation in a safe environment (Medema et al., 2016); through possibilities to apply what has been learnt directly inside the game (Wood et al., 2014); and through role play with other players and game facilitators (Medema et al., 2016). Different visualization techniques are appropriate for different purposes or phases of a learning process (Al-Kodmany, 1999). Collective sense-making and critical reflection should be supported to avoid misinterpretation and to identify misleading information (Billger et al., 2017; Medema et al., 2016; Wood et al., 2014).

Links to the wider planning and action context: Games for transformative societal change need systematic links to the wider planning, governance and action context. These types of games may be seen as pervasive games "… that transcend the boundaries between gaming reality and the real world" (Oceja & Fernández, 2017, p. 483), and thus extend the target group (and the learning) to (potentially involuntary) players outside of the game environment, resulting in direct impacts on real-life (Wood et al., 2014). The *target audience* (see below) should include a wide set of stakeholders since, outside the game, "planners have to juggle (…) with the realities of local politics, economic shifts, and the whims of developers" (Gordon et al., 2011, p. 517). If the objective is to induce real change of urban systems, dedicated links are needed, e.g. to planners and planning systems, politicians, developers, citizens, and the wider economy. This is critical since few information and communication technology (ICT) tools for stakeholder involvement have actually affected real life (Houghton, Miller, & Foth, 2014) and there is poor organizational readiness to accommodate digital tools (Billger et al., 2017).

Adaptation of the game: A game can be designed to adapt in relation to the players, depending on e.g. their characteristics, needs, skills, progress, emotions and group structure/relations (Prieto De Lope & Medina-Medina, 2017). Such adaptation involves game challenges/difficulties, rules/mechanics, story/dialogues, graphic appearance and user interaction. A game can also adapt to the evolution of the gameplay, affecting e.g.

levels, content, behaviour of game elements, narrative and guidance (Kickmeier-Rust & Albert, 2012). Additionally, it can adapt to the real-world context operationally (e.g. tasks to be performed), physically (e.g. location, movement), interpersonally (e.g. relationships between players), and environmentally (e.g. surrounding noise) (Prieto De Lope & Medina-Medina, 2017). Information that is relevant personally (or for the organization) can be provided, preferably with real-time/real-life data (Wood et al., 2014). Finally, games may need to adapt to the game device (if digital) (Prieto De Lope & Medina-Medina, 2017), or to the practicalities of the environment (if analogue), such as available space for playing.

Assessment: Assessment of the success of the gameplay can e.g. be carried out by the game itself (automatic), by an observer (manual), or through a combination of these (Prieto De Lope & Medina-Medina, 2017). Determine how this is to be done and how to assess long-term effects of game use on learning and commitment (Aubert et al., 2018).

3.3 Game users

Target audience: Can be defined as an age range or as a particular group of people (Prieto De Lope & Medina-Medina, 2017). Due to the diversity of stakeholders linked to urban planning and governance, with (potentially) conflicting interests, it is vital that the entire range of stakeholders can play or be represented to ensure *links to the wider planning and action context* (see above) (Aubert et al., 2018; Duke & Geurts, 2004; Gordon et al., 2011; Keijser et al., 2018).

Player interaction: A game can be mono-player, multi-player or massively multi-player online role-playing (Prieto De Lope & Medina-Medina, 2017). Interaction between multiple players can take place simultaneously or at different times (Wendel & Konert, 2016) and concerns if/how they can compare their efforts with other players (Wood et al., 2014). Games can be collaborative (a single team), competitive, or a mix of these (competition between teams) (Prieto De Lope & Medina-Medina, 2017) and players can also interact with experts (Reinart & Poplin, 2014). Social issues (sadness, anger, mobbing, toxic behaviour) may arise and competition between teams requires composing teams to be equally competitive (Wendel & Konert, 2016). Game facilitators are often needed (Te Brömmelstroet & Schrijnen, 2010).

Dedication: The time and engagement players are expected to spend need to be understood, in part depending on the gaming experience targeted stakeholders have beforehand, i.e. being inexperienced, casual or hard-core game players (Prieto De Lope & Medina-Medina, 2017).

3.4 Game development

Authorship: Define the person(s) or organization(s) responsible for creating the game and for its future development (Prieto De Lope & Medina-Medina, 2017).

Development methodology: Potential game users should be included in game development to bring contextual knowledge and secure usefulness (Khaled & Vasalou, 2014), similar to action design research (Sein et al., 2011). Involving the game users in the game building process can be achieved through rough prototyping "to sketch out the scope of the problem and to provide a discussion instrument for the comments of

the client and other reviewers" (Meadows & Robinson, 2002, p. 287). This also includes whether to adapt existing games/software, or to develop a tailored game from scratch (Prieto De Lope & Medina-Medina, 2017).

3.5 Game platform

Hardware architecture and deployment: The game can be digital, analogue or a combination of these, e.g. an analogue game with digital support (Solinska-Nowak et al., 2018). For digital games, hardware is about the game device: e.g. computer, tablet or smart phone, and whether to go for 2D or 3D (Prieto De Lope & Medina-Medina, 2017), including whether deployment of the game should be installed on local equipment or be accessed through the Internet (Prieto De Lope & Medina-Medina, 2017). Analogue games can be distributed physically or be downloadable from the Internet for 2D/3D printing (Göbel, Hugo, Kickmeier-Rust, & Egenfeldt-Nielsen, 2016).

3.6 Business model

License: Determine the desired distribution systems. This can be commercial (purchased or paid for by advertisements within the game), free (potentially with the source code free to modify), shareware/trial (free but with restrictions unlocked through purchase), or proprietary (permission needed to distribute or modify) (Prieto De Lope & Medina-Medina, 2017).

Sustainability: A key issue (especially for digital games) is how to maintain the game over time, including updating substantive content (e.g. new technical innovations) and digital software (e.g. apps) (Billger et al., 2017). A plan for long-term maintenance of the game should be part of the design phase.

4 Results Part B: Specifications for a serious game in sanitation planning

In this section, specific issues linked to addressing the sanitation challenge are introduced into the generic game development framework in order to develop a set of specifications for a serious game in sanitation planning. The resulting set of specifications is summarised in Table 2.

4.1 Game design

Application area: Sanitation has been one of the least prioritized areas on the global development agenda, due to high capital investment costs, social taboos and inherent complexity in technology adoption and implementation (Hawkins et al., 2013). Scaling-up to reach the Sustainable Development Goal of sanitation services for all (SDG 6.2) will require major investments (Hutton & Varughese, 2016). There is an emerging paradigm shift in response to the sanitation challenge, viewing human waste as a resource for the recovery of nutrients, water and energy (Guest et al., 2009). In many high-income countries, much of the sanitation infrastructure (sewerage networks, treatment plants) is nearing the end of its life and needs replacement (Selvakumar et al., 2014). Rapidly changing urban areas in the Global South without sanitation infrastructure offer opportunities for rethinking sanitation provision (Larsen et al., 2016). Both these realities open up for systems that can recover resources. Resource recovery involves rethinking not just technical treatment, but also collection systems, user interfaces and managing organizations, where successful resource recovery demands collaboration between individuals, households, service providers and others (McConville et al., 2017b).

Worldview: The importance of universal access to safe sanitation is recognized through its inclusion as target 6.2 in the SDGs (United Nations, 2015). The value of safe sanitation goes beyond public health. The nutritional and caloric value of faecal sludge recovered for agricultural and energy purposes is substantial (Rose et al., 2015). In fact, sanitation geared towards resource recovery can positively influence 14 of the 17 SDGs (Andersson et al., 2016). In addition, sanitation needs to be seen as a human right, so that "the sanitation paradigm will be shifted away from one of charity to one of justice" (Langford et al., p. 346). This brings in sanitation co-production as an alternative to top-down sanitation governance, with service recipients playing key roles (Moretto et al., 2018).

Content: Sanitation is typically seen as a service chain from collection and transportation to treatment and reuse (Tilley et al., 2008). Multiple technologies can be used, and a functional chain depends on proper performance and the connections between each component. Different stakeholders and organizations are involved (see *target audience* below) and, as they are responsible for the functioning of different components of the chain, their perception of costs and benefits of different technologies may vary.

Two different situations are to be considered: a low-income country represented by Uganda and a high-income country represented by Sweden. In Uganda, access to and quality of sanitation are exceptionally poor with only 7% connected to conventional wastewater treatment plants and 73% of the population relying on unimproved latrines (Schoebitz et al., 2016). Only 54% of human waste is treated safely (Schoebitz et al.,

2016) and less than half of that is reused as fertilizer. Expanding centralized sewerage systems to cover all inhabitants is expensive and in many cases impractical or impossible (McConville et al., 2019). Demand is growing to develop innovative decentralized systems that both protect public health and recover resources, while allowing for rapid service expansion (Larsen et al., 2013). In Sweden, about 90% of the population is connected to conventional wastewater treatment plants. However, only 25% of the sludge is used as fertilizer in agriculture (Swedish EPA, 2013). Resource recovery is hampered by concerns about harmful chemicals in the sludge and a resistance to source-separating systems that could improve recycling due to high sunk-costs in existing infrastructure and institutional inertia (McConville et al., 2017a).

Context of use: Although resources for planning and infrastructure development are limited in Uganda, there is flexibility for both formal and informal actors to be involved (Murungi & van Dijk, 2014; Nastar et al., 2019). It is foreseen that technical equipment (devices, Internet access) and workshop spaces (size, sitting arrangements) may lack in quality. In Sweden, resources are available for planning and infrastructure development. However existing organisation structures are highly institutionalized and pose significant barriers to change (McConville et al., 2017a). Workshop venues typically are of high technical and spatial quality, and there may be expectations that a game takes advantage of these qualities.

Genre: Collective strategic choices (Friend & Hickling, 2005) should be supported, based on visualization and simulation, e.g. of nutrient flows, money and organization. The game should include role-playing, since such games have proven useful for knowledge development, social learning and joint capacity building among stakeholders managing water and land resources (Camargo et al., 2007; Farolfi et al., 2004; Pahl-Wostl, 2002; Prat et al., 2009).

Realism: Games for urban and environmental planning are useful for developing locally specific actionable learning, as well as, insights built across multiple or more generic contexts (Höök & Löwgren, 2012; Schouten et al., 2017). The sanitation game should thus be possible to use in more or less realistic sanitation situations, where the story of the game can play out in a recognizable urban context, convincingly linked to a real planning process (Reinart & Poplin, 2014).

Narrative: The narrative should contain the interlinked parts of the sanitation service chain and the diversity of stakeholders, and should have real-life relevance (Wood et al., 2014), yet not at the cost of becoming overly complicated (Abt, 1987). The narrative should also be adaptable to allow players to recognize their own sanitation situation and relate to their own sanitation experiences in order to create links to real sanitation planning processes.

Data/knowledge management and transfer: Based on the water sector, Borri et al. (2016) argue that knowledge should be managed in ways that support micro-learning and co-evolution of innovations by distributing knowledge among many stakeholders. Furthermore, data on the sanitation service chain, system solutions, environmental/health effects and costs need to be included (Schütze et al., 2019). Such data should be adaptable to local circumstances and be possible to interlink across scenarios, simulations, and player responses through a database (Sewilam et al., 2017). Consequently, performance and consequences of different sanitation management practices and system solutions should be simulated to illustrate the implications of choices made in the game, and to collect data on these choices.

Data/knowledge representation and visualization: As a social-ecological system, sanitation comprises a high degree of complexity (Jiménez et al., 2020). There is a need to strike a balance between ambitions to represent and visualize this real-world complexity and delivering an understandable and playable game (Abt, 1987; Savic et al., 2016). The level of abstraction in the visualization of the content should be sufficient (Reinart & Poplin, 2014) for appreciating that it concerns a recognizable urban area and for understanding the components of the sanitation chain and accepting them as relevant. Visualization can be both analogue and digital, and should include the pros and cons of the sanitation system resulting from the gameplay, to make it possible to draw conclusions.

Interactivity: Given the need for a collaborative approach to transformational sanitation planning (Kemp et al., 2007), dialogue between players is key and gameplay should take place through active interaction (see above, Prieto De Lope & Medina-Medina, 2017).

4.2 Game use

Gameplay: As stakeholders may have conflicting perspectives, the game needs to be both engaging and develop trust by having fun and reflecting together (Gordon & Baldwin-Philippi, 2014) in a safe environment (Medema et al., 2016). Drawing on Uskov and Sekar (2014), goal setting should provide a sense of progress towards sustainable sanitation, where the quest is to overcome sanitation obstacles through collaboration among stakeholders to forge a new sanitation system. Introducing a game element that creates friction (Korn & Voida, 2015) should illustrate prevailing conflicts in sanitation planning (Hawkins et al., 2013) in a meaningful way, e.g. by including an element of competition between players (Uskov & Sekar, 2014).

Learning/social learning and collaboration: To support the social learning that is needed for transformative sanitation planning (Pahl-Wostl, 2002) the game should be realistic, challenging, immersive, entertaining, engaging and provide feedback (Medema et al., 2016). Social learning should bring understanding of i) "positive interdependences" (we can only succeed as a group), ii) "individual accountability" (individual results affect both the group and the individual), iii) "face-to-face promotive interaction" (helping, supporting, encouraging and praising), iv) use of "social skills" (leadership, decision-making, trust-building, communication and conflict management), and v) "group processing" (discussing and reflecting on progress and working relationships) (Johnson & Johnson, 1999, p. 70-71, see also Wendel & Konert, 2016).

Since collaboration between stakeholders is key for implementing resource recovery and changes in the service chain (Pahl-Wostl, 2002), trust-building and motivation to collaborate become a primary learning goal, achieved by e.g. trying out different roles and experimentation in a benign setting (Medema et al., 2016). As sanitation comprises social taboos (Black & Fawcett, 2008) and sociotechnical complexity (McConville et al., 2017b) a game needs to support collective sense-making and critical reflection among stakeholders (Devisch et al., 2016; Mannsverk, Di Loreto, & Divitini, 2014). In addition, it should include possibilities to apply what has been learnt in the next round of gameplay (Wood et al., 2014). Finally, it is important to carefully consider where, in the different phases of a sanitation delivery process, the gameplay will take place since

this affects if/how collaborative learning can support empowerment and inclusiveness (Moretto et al., 2018).

Links to the wider planning and action context: Overcoming the sanitation challenge requires transformative societal change in how resources are used in the sanitation service chain and likely even in the technologies and organizations within this system (van Welie et al., 2019). It may not be necessary for the game to be pervasive (Oceja & Fernández, 2017), yet it should allow players to make direct connections to their own work. Also, as only few of all potential stakeholders will play the game, the linkages between the gameplay and the realities of the wider group of stakeholders (planners, politicians, users) not playing the game become critical; both those engaged in sanitation and those involved in the provision of other urban infrastructure. It is essential that data, outcomes and learnings from gameplay can be communicated to this wider set of stakeholders through dedicated communication links (Wood et al., 2014), ultimately leading to double-loop learning (Argyris & Schön, 1996), affecting the mode of operation of involved institutions and supporting wider diffusion of novel sanitation (Geels, 2005).

Adaptation of the game: Since driving forces affecting sanitation typically are context specific (Isunju et al., 2011) there is need for adaptation to local contexts in both Global South (Hendriksen et al., 2012; Okurut et al., 2015) and Global North contexts (Krantz, 2012; Schramm et al., 2017). Furthermore, to be successful, sustainability innovation in sanitation planning, especially regarding decentralized systems, cannot be based simply on technologies but needs to bring in "daily discourses, community knowledge, practices and the localised contexts" (Fam & Mellick Lopes, 2015, p. 752). Sanitation entails local factors linked to "inequalities in health, gender, caste, religion, education and work" (McFarlane, 2019, p. 2) that need to be considered in the game. As the sanitation game is to be played in very different contexts, adaptation is also about making it adaptable to each sanitation workshop situation, e.g. regarding what sanitation stakeholders are taking part and where it is being played (Prieto De Lope & Medina-Medina, 2017).

Assessment: Assessment should focus on if and how playing a sanitation planning game leads to a transition towards innovative sanitation systems and resource recovery. It should focus both on the developed sanitation system and on the resulting learning and collaboration. For example, resource recovery potentially resulting from the game can be assessed by simulation and visualization of resource flows for different combinations of sanitation system components, based on, e.g. material flow analysis (MFA), life cycle assessment (LCA), life cycle costing (LCC), multi-criteria decision analysis (MCDA) (Schütze et al., 2019) and investment and life-time costs (Roefs et al., 2017).

Collaboration and learning linked to sustainable sanitation are difficult to assess since "the design of teamwork, a component which is central to collaborative learning, is still not very well understood" (Wendel & Konert, 2016, p. 227). However, assessment can look at the frequency and quality of different types of behaviours, such as coordination (communication, situational awareness, leadership, assertiveness, decision making, mission analysis, adaptability) and cooperation (laughter and excitement together, helping, complementing each other, waiting for each other, working out strategies) (Bowers et al., 1992).

4.3 Game users

Target audience: Historically, water and wastewater management has been controlled by municipal authorities and technical departments. Transitioning to resource-recovering sanitation means bringing together a wider set of stakeholders in new partnerships and involving them in sanitation planning and implementation processes (Andersson et al., 2016), i.e. all those having a stake in how sanitation systems are designed, implemented and operated, as well as, an interest in the services and products of such systems. These include e.g. households, real estate owners, construction companies and developers, collection and emptying enterprises, treatment utilities, solid waste companies and, in particular, the end-users of recovered products (agricultural and industrial actors). A transformative sanitation planning game needs to accommodate all these stakeholders, either through playing the game itself or by being part of the interlinked *wider planning and action context* (see above). University students within the field of sanitation constitutes an additional target group that would benefit from the game in their education (McConville et al., 2017).

Player interaction: As a diverse set of sanitation stakeholders (see *target audience*) should engage in processes of collaborative learning (see *learning/social learning and collaboration*), multiplayer interaction is of particular interest with its possibilities to let players engage socially through competition (as individuals), cooperation (in groups) or collaboration (taking advantage of complementary skills, knowledge, abilities and resources (Wendel & Konert, 2016). Since sanitation is permeated with conflicting perspectives (see *gameplay*) social issues should be taken care of by an active game facilitator (Te Brömmelstroet & Schrijnen, 2010).

Dedication: As diverse stakeholders (see *target audience*) will play in an inclusive setting (see *gameplay*), the game needs to be readily playable by players with no previous experience from gaming and/or sanitation. As many of the stakeholders suffer from heavy workloads in their daily activities, their time for engaging in novel ICT activities (such as serious games) is limited, even when highly relevant for their responsibilities and interests (Houghton et al., 2014).

4.4 Game development

Authorship: In the Global South, sanitation tend to have a low priority among both local authorities and international donors (Monney et al., 2015). As there are few serious games linked to sanitation, it seems feasible to assume that business opportunities are slim and that a public body needs to initiate and manage game development. Public agencies (such as those responsible for sanitation planning) are typically strapped for resources. This leaves university researchers, resourced through public or private funding, as a viable resource for initiating game development.

Development methodology: Being a matter of systemic change, development of an inclusive sanitation planning game should be a joint activity since the ambition is "to co-evolve [the] understanding of a social–ecological issue (…) and co-produce appropriate knowledge to serve a common purpose" (Roux et al., 2017, p. 712). It needs to involve representatives for future players in game development to secure contextual knowledge and usefulness (Khaled & Vasalou, 2014). An action design approach (Haj-Bolouri et al., 2017; Sein et al., 2011) would be useful, involving relevant stakeholders and carried out in iterative cycles of design, testing and evaluation. Haj-Bolouri et al. (2017) point out that when game development takes place within a research project,

also the researchers become stakeholders and there is a need to balance two (sometimes conflicting) perspectives: the specific problems of developing a sanitation game and the research problems linked to this game development. In comparison with client-driven projects, research-driven initiatives need to meet additional implementation and organizational obstacles (Billger et al., 2017).

4.5 Game platform

Hardware architecture and deployment: When playing a collaborative game in a workshop format aimed at social learning, all players need to be able to see the game board and interact both with the game and with each other (Devisch et al., 2016; Reinart & Poplin, 2014). Bearing in mind the different *contexts of use* in low and high-income countries (see above), both digital and analogue game formats need to be considered. Games for use in low-income settings need to bear in mind the reduced access to large displays and stable Internet/wifi and that tablets/smart phones based on iOS operating systems are typically not available. Tablets are possible to use, however, as they may be limited in size it may be problematic to properly view all game elements. Larger digital table displays would work, but are uncommon in low-income countries. Projectors are more accessible.

Overall, an analogue game board would secure wide usability. Such games are more cost-effective, portable and can more easily be adapted to different themes and situations (Wonica, 2017). Wonica (2017) argues that these attributes make analog games ideal for informal learning settings. However, the need for simulating flows of resources and costs for different system solutions (see *assessment*) points towards including a digital component. Such software would be safer to have installed locally and based on e.g. Microsoft Windows and/or Android to secure wide usability and avoid malfunctions due to poor Internet connections. However, more advanced digital components would presumably make the game more attractive in high-income settings, such as in Sweden.

4.6 Business model

License: The game is intended to be widely used in sanitation planning contexts with different constellations of stakeholders and varied resources available. It needs to be easily accessible and the procedure for acquiring the game needs to be simple and low-cost. A license-based business-model is not relevant for an analogue game, which is better simply sold as an item. However, as a main objective is to reach a wide dissemination to promote sustainable sanitation, it is preferable that game rules, game board and game components can be downloaded for free.

Sustainability: As funding opportunities are limited for sanitation games (see *authorship*), the issue of maintaining and updating the game needs to be resolved before launching it. Resources need to be set aside for maintenance in a shorter time perspective. Out of 29 possible business models for games (Perry, 2008), the most relevant would seem to be a combination of freeware with donationware where people/organizations may sponsor the game's long-term sustainability (and potential upgrades/additions) based on its objectives of universal health and environmental benefits.

Table 2 Specifications for a serious game in sanitation planning.

Categories	**Game Specifications**
1. Game design	
Application area	- Shares knowledge about the potential of resource recovery from sanitation and supports attitude-change and collaboration between players - The focus is on Nitrogen, Phosphorus and Potassium but also includes water and energy
World view	- The main message is that resource recovery in sanitation is a good thing, and that stakeholders need to work collaboratively towards that end - Circular economy is beneficial - Promotes equity of benefits & costs regarding access to sanitation for all, universal health protection
Content	<u>System:</u> - Contains possibilities to design and optimize the service chain of technologies, where multiple technologies exist at each level of the chain - Two main but very different sanitation contexts are covered: Sweden and Uganda, taking into account the varying organizational structures, infrastructural setup and availability of resources in the different contexts <u>Roles:</u> - Multiple stakeholders along the service chain with their different perceptions regarding, e.g. needs for health, comfort, environmental performance and economic gain - Takes into account organizational structures as well as cultural and political aspects
Context of use	- A wide set of stakeholders can play the game, both formal and informal actors - Contextual conditions affecting the stakeholders and their possibilities and/or inclinations for gameplay should be taken into account, e.g. available technical and spatial resources, organizational structures, and level of stakeholder involvement/engagement
Genre	- The overall genre is a strategy game for developing viable scenarios and coalitions - It is a role-playing game - The game also contains an element of simulation, e.g. of nutrient flows, money, organization
Realism	- Includes a degree of realism of the visualizations, based on recognizable examples of urban environments to select among but does probably not contain existing urban areas. Visualizations are thus not fully adaptable to real situations.
Narrative	- Includes a simple but realistic storyline with clear goals, and provides enough information on the whole sanitation system (the sanitation service chain) and its challenges, so that players can relate to their own situation - Has a narrative that can be reshaped (by game leaders) to fit local situations for real-life relevance

Data/ knowledge management and transfer	- Data is managed by the game, such as the performance of different sanitation solutions/systems in the two main situations (Uganda and Sweden) - Data used in the game is possible to revise by game leaders to fit a specific context - Supports exploration and communication of data by simulating implications of system choices made in the game regarding possibilities to recover multiple resources and achieve environmental and health benefits from wastewater, as well as potential negative impacts - Collects data from the players, such as opinions and choices made
Data/ knowledge representation and visualization	- Includes sufficient representation and visualization of key features to make the players recognize, trust and accept the content and the game components as relevant, but is still simple enough to be widely playable - Illustrates the sanitation system through both analogue and digital symbolic building blocks - Contains a local perspective (e.g. local map or key features of existing area) - Visualizes the pros and cons of the sanitation system resulting from the role play, to make it possible to draw conclusions from the game results
Interactivity	- Facilitates communication with other players takes place through dialogue - Active interaction with the game takes place through both analogue and digital means
2. Game use	
Gameplay	- Gameplay is characterized by: > Enjoyment to, in a fun and entertaining way, learn about sanitation > Safety, breaking down barriers between stakeholders (roles) in a relaxed atmosphere > Motivation to put together a new/better sanitation system; a quest to overcome challenges and get rewards > Friction and conflicting/competing agendas > Community-building to build coalitions for action
Learning/ social learning and collaboration	Supports both individual and collaborative learning, where detailed objectives include: > To entice learning by being challenging, entertaining, engaging and realistic > To stimulate curiosity to try different things by providing opportunities for experimental learning > To provide a platform for exchange and exploration of ideas, perceptions and positions, and possibilities to reflect on and apply what is being learnt in a subsequent round of the game > To increase the collective understanding of system complexity (correlations and interdependencies) > To create understanding and respect for other stakeholders' perspectives by supporting interaction and providing opportunities to try out different roles > To encourage inclusiveness, cooperation, collaboration and trust among players/coalitions to attain a purposive transition towards sustainable sanitation

Links to the wider planning and action context	- Influences two sets of stakeholders: a) directly those playing the game and b) indirectly the wider set of stakeholders taking decisions on sanitation systems - Has the capability to engage with and include "a practical situation" from which players can relate to their own context - The game environment and output are designed to be capable of feeding data and learnings directly into ongoing planning/development, e.g. through dedicated links to the real world - The game should support learning among a wider set of key stakeholders who have not played the game themselves by: > Providing examples of feasible system solutions in support of resource recovery and circular economy > Showing that collaborative approaches to resource recovery are feasible, productive and transformational
Adaptation of the game	- Is adaptable so new information can be added and game play adjusted – by a game leader before and during game play – to match the local situation, e.g. it is possible to: > Adjust names of locations so that players can recognize themselves/their situation in the game > Add content relevant to a specific city and/or planning process > Add/change roles to fit social, cultural, institutional and/or organizational circumstances and to make it more relevant or dynamic > Adjust to different types of workshop settings
Assessment	- Makes it possible to assess the outcomes of the game based on the following aspects: > The level of resource recovery achieved in the developed sanitation system > Level of collaboration and joint learning experienced by the players > Level of innovation in the developed sanitation system
3. Game users	
Target audience	- Includes the collective of all those needed to be involved in a transition towards sustainable sanitation, e.g., urban/regional planners, wastewater/water planners, health sector, regulators/politicians, funders, engineers/technicians, households, citizens, community organizations, consultants, building developers, builders, sanitation entrepreneurs, researchers, farmers, food industry, food markets - Accommodates these stakeholders as being part of two main groups: those playing the game itself and those being part of the interlinked wider planning and action context
Player interaction	- Is a multiplayer game, where the number of players is 3-7 - Has social learning and collaboration as a main goal, with a facilitator in place to deal with social issues arising from player interaction - Include player roles defined as the key stakeholders among those involved in sanitation

Dedication	- Is accessible to inexperienced gamers and people with different backgrounds, where some have only basic insights into sanitation collection and treatment systems (e.g., water, nutrients, pathogens) - Requires a time commitment of maximum two-hour sessions (preferably shorter), and possible to play in multiple shorter session (maximum one hour)
4. Game development	
Authorship	- Has a public body as author, such as a university research group funded through public or private funding
Development methodology	- Makes the game development a joint initiative between stakeholders in the sanitation service chain and the game developers - Is based on a co-creation development process with at least 2-3 iterations with stakeholder feedback - Addresses implementation issues with the stakeholders during the development process
5. Game platform	
Hardware architecture and deployment	- Is a predominantly analogue game that can be augmented digitally, e.g. for simulation of game results - The analogue part of the game is possible to play independently anywhere without the digital components - The digital parts will function on local equipment (Microsoft Windows and/or Android), possible to use without Internet connection
6. Business model	
License	- Is freeware, possibly as open source but proprietary (permission needed to distribute or modify) - Both analogue and digital components are freely available for downloading
Sustainability	- Has a plan and allocated resources for maintaining the usability of the game for a minimum of three 3 years from completion - Provides a framework for donations to secure long-term sustainability, as well as upgrades and/or additions

5 Results Part C: The sanitation planning game prototype

The final prototype sanitation planning game is a role-playing analogue board game, consisting of hexagons forming a playing area that can be laid out and reshaped to fit local land use (see Image 1 and Appendix B Game Rules). The objective of the game is to build and optimize sanitation systems and to feed and keep the inhabitants of the city healthy.

Image 1 *The final board game prototype.*

Four players take on roles as housing, treatment, farming and private contractors, each with their own actions, responsibilities and hidden agendas (see Images 2 and 3). As game pieces representing different technologies for housing, treatment and farming are placed on the board by the players taking turns, their choices result in an emergent sanitation system.

Image 2 *Game testing in Sweden. Photo: Jennifer McConville.*

The game contains a certain element of competition (i.e. it is possible for a player to win the game by collecting points in accordance with the role's agenda), but there is also an everybody-lose-together mechanism (i.e. the game wins), triggered by famine, disease and contamination. Different types of resources linked to the sanitation service chain are represented by six-sided dice that are turned to illustrate their conversion as they pass through the sanitation system, including the possibilities for disease. Unforeseen events transpire through chance cards that bring some excitement to the game, but also allow for adding contextual conditions and to reshape the game narrative. The game includes content and visualizations tailored to the specifics of Sweden and Uganda to facilitate adaptation to local contexts.

Image 3 *Game testing in Uganda. Photo: Jennifer McConville.*

A digital add-on based on Microsoft Excel makes it possible to feed game results into a spreadsheet in parallel to playing (see Image 4). This add-on simulates the degree to which the players succeed in providing sanitation services for all urban residents and recover nutrients/provide food security, or whether they have to rely on imports of food and fertilizers. The results from the add-on can be brought up during gameplay to support decisions or presented after the game for post-game analysis and reflection.

Image 4 *The digital Microsoft Excel add-on.*

Results Part D: A first assessment of the sanitation planning game

The prototype was piloted with a group of students to assess the fulfilment of the specifications. All of the players felt that the game at least partly achieved its goal of sharing knowledge about resource recovery from sanitation, supporting attitude change and collaboration between players (*Application area*). Based on the written feedback from the students it was clear that the game highlighted potentials for resource recovery and promoted collaboration. As one student said, "*the game really pushes you to start thinking of the excreta as a resource*." Another wrote, "*The fact that each person has a different role is beneficial to understand how people should collaborate in real situation. It is interesting to see the game from a different point of view each round. We can share knowledge about sanitation talking with the others playing because everyone can explain his own point of view about a decision.*"

Many students (11 of 14) also appreciated that the game made them think about the interconnectedness of larger urban planning processes by visualizing urban growth and trade-off between infrastructure developments and environmental and health consequences (*Realism & Data and knowledge representation*). For example, one student stated that, "*You have to think about the significance of each action you will do during the game to achieve the final goal of a good and healthy city with as much as possible green houses with green treatment systems*." Students were less certain that gameplay supported attitude change. Half of the students pointed out that they already had a positive attitude towards resource recovery and they believed that more information and repeated interactions would be needed to truly change attitudes. Despite the already positive attitude of the students, results from the pre- and post-game survey did find slight increases in positive attitudes towards resource recovery and reuse of treated human excreta in the post-game survey.

Student feedback regarding gameplay was also overwhelmingly positive. The students strongly agreed (12 of 14) that they enjoyed working with the other players collaboratively in the game and that they felt comfortable and free to express their opinions in the game setting (13 of 14) (*Gameplay*). Most of the student (8 of 14) commented positively on the communication and collaboration that arose between the different roles in the game (*Learning and collaboration*). As one student said, *"I think it gives each individual actor the ability to share ideas and communicate with another to create a good sanitation management*." The students found that the game could show concepts for system planning, but that it was not directly transferable to the real world (*Links to wider planning*), e.g. "*the game is very good at showing the big patterns of reuses, but it is of course much more complicated in reality.*"

The second level of assessment focused on to what extent the produced game was able to fulfil the game specifications presented in *Results Part B*. Below, some of the lessons from the application of the specifications will be highlighted (see also the right-hand column in Table 3).

For the specifications regarding *Game design*, it was a challenge to balance softer values (such as fluid and enjoyable gameplay) and technical realities. The game clearly conveys the message that resource recovery in sanitation is beneficial, but fails to include its nexus with water and energy (*Application area*), and to clearly bring on board the equity dimension of sanitation (*Worldview*). As the game is a simplification of the complex sanitation system and its service chain, more detailed system design and

optimization was not possible without overly complicating the game. Thus, we felt that we were only partly able to achieve the *Content* that we originally desired in the game. Although the board hexagons and chance cards can be arranged to mimic local contexts, the game cannot easily be adapted with more specific local information, such as by using a local map as background image (*Context of use; Realism & Data and knowledge representation*).

All in all, possibilities to truly reflect local conditions and stakeholder roles are limited. Although the issues of organizational structures and cultural aspects were much discussed during gameplay, these aspects were not included in the game itself in order to keep the roles simple and enable gameplay. The simplifications also impact possibilities to communicate data to players, to collaboratively explore data, and to collect data from players' opinions and choices (*Data and knowledge management and transfer*). Still, the level of detail and simplification also seems to support understanding, playability and dialogue across a wide set of stakeholders (achieves *Interactivity*). As the game is somewhat detached from real and local sanitation challenges, its potential of developing locally viable scenarios and stakeholder coalitions needs more attention. The digital Excel add-on provides opportunities for basic simulations of some resource flows and impacts, but suffers from the same level of simplification as mentioned above, and thus does not really fulfil the needs for players to explore these simulations in an interactive manner.

When it comes to *Game use*, gameplay seems to be characterized by enjoyment, stakeholder cohesion and incentives to improve sanitation provision (*Gameplay*). As confirmed by the students and others involved in the co-design process (Billger et al., 2020), individual and social learning, experimentation and understanding of different perspectives, and stakeholder collaboration all seem to be supported by the game. Still, the game does not contain any dedicated channels to influence or share the learning with the wider set of stakeholders that is not directly playing the game nor any concrete outputs with real-life and local applicability, such as contextualized proposals for resource-recovering sanitation systems (*Links to wider planning context*). Thus, the game probably will have little direct impact on real and ongoing sanitation planning and system development. Still, by being somewhat adaptable to local situations and/or new information, local relevance possibly can be strengthened. Apart from the simulations provided by the digital add-on, the game does not contain any mechanisms for *Assessment* of game outcomes.

Regarding the specifications for *Game users*, we were able to meet most of the specifications. The game supports multiplayer collaboration that does not require any previous gaming experiences in game sessions that do not take too long to play. Still, the two-hour game session does not include time for post-game discussion, which is highly recommended to include. The game is accessible to the design *Target audience*, including the diverse collective of people needed to be involved. As one of the students wrote, "*I think that the game also would be great to play for less experiences people, for example politicians, to give them a clear view of how important sanitation systems are. I think that the game would be an eye opener for people who are not in the sanitation area*." Still, the reduction of game roles into 'housing', 'treatment' and 'farming' may exclude other key stakeholder roles, although the 'private contractor' wild card might be adaptable to include a wider set of stakeholder roles in the game.

For *Game development*, we were able to fulfil the criteria set in the specifications. Development was driven by the research team, but included significant joint game development with especially the Ugandan stakeholders through the whole development

process. Adjustments were made to the game through a series of iterations, including stakeholder feedback from Uganda. We did find that participation of Swedish stakeholders was weak. So depending on the context, it may be difficult to follow the co-creation approach taken in this case. Although the co-creation process itself can support learning, it is worth noting that it is time consuming and that this should be made clear at the start of the design process.

The *Game platform* is largely analogue, where the digital add-on would benefit from further development. Still, the strength of the combined analogue/Excel game platform is its robustness in playing environments with more fragile physical and technological settings, such as informal settlements in Uganda.

Finally, the *Business model* is to distribute the game as freeware, i.e. the analogue game as a downloadable document for local printing and the digital add-on as a simple spreadsheet. A limited number of boxed games will also be produced and sold for an at-cost price. The sustainability of the game regarding costs for e.g. updates or expansions is thus not satisfied.

*Table 3 Summary of specifications for a serious game in sanitation planning. The right-hand columns show an assessment of how well the prototype fulfilled the specifications: Y = fulfilled; P = partially fulfilled; N = not fulfilled; * = in digital add-on*

Categories	**Game Specifications**	**Fulfilment by prototype Y**	**P**	**N**
Game design				
Application area	- Shares knowledge about the potential of resource recovery from sanitation and supports attitude-change and collaboration between players	X		
	- The focus is on NPK recovery but includes water and energy		X	
World view	- Main message: resource recovery in sanitation is good, and stakeholders need to work collaboratively towards that end	X		
	- Circular economy is beneficial	X		
	- Promotes equity of benefits and costs regarding access to sanitation for all, universal health protection			X
Content	System:			
	- Contains possibilities to design and optimize the service chain a service chain of technologies, where multiple technologies exist at each level of the chain		X	
	- Two very different sanitation contexts are covered: Sweden and Uganda, taking into account the varying organizational structures, infrastructural setup and availability of resources in the different contexts		X	
	Roles:			
	- Multiple stakeholders along the service chain with their different perceptions regarding, e.g. health, comfort, environmental performance and economic gain		X	
	- Takes into account organizational structures as well as cultural and political aspects			X
Context of use	- A wide set of stakeholders can play the game, both formal and informal actors	X		
	- Contextual conditions affecting the stakeholders and their possibilities for gameplay should be taken into account, e.g. available technical and spatial resources, organizational structures, and level of stakeholder engagement		X	
Genre	- A strategy game for developing scenarios and coalitions		X	
	- A role-playing game	X		
	- Contains an element of simulation, e.g. of nutrient flows		X*	
Realism	- Visualizations include a degree of realism, based on recognizable examples of urban environments to select among, but does probably not contain existing urban areas. Visualizations are thus not fully adaptable to real situations.		X	

Narrative	- Includes a simple but realistic storyline with clear goals, and provides enough information so that players can relate to their own situation		X	
	- Narrative can be reshaped to fit local situations for relevance		X	
Data/knowledge management and transfer	- Data is managed by the game, such as the performance of different sanitation solutions/systems in the two main situations (Uganda and Sweden)		X*	
	- Data used in the game can be adapted to fit a specific context			X
	-Supports exploration and communication of data by simulating implications of system choices made in the game regarding possibilities for resource recovery and impacts on health and the environment		X*	
	- Collects data from the players, such as opinions and choices made			X
Data/knowledge representation and visualization	- Includes sufficient representation of key features to make the players recognize, trust and accept the game components as relevant, but is still simple enough to be widely playable	X		
	- Illustrates the sanitation system through both analogue and digital symbolic building blocks		X*	
	- Contains a local perspective (e.g. local map or key features of existing area)		X	
	- Visualizes the pros and cons of the sanitation system resulting from the role play, to make it possible to draw conclusions from the game results		X*	
Interactivity	- Facilitates communication with other players through dialogue	X		
	- Communication with the game uses both analogue and digital means		X[1]	
Game use				
Gameplay	- Gameplay is characterized by:			
	> Enjoyment to, in a fun and entertaining way, learn about sanitation	X		
	> Safety, breaking down barriers between stakeholders (roles) in a relaxed atmosphere	X		
	> Motivation to put together a new/better sanitation system; a quest to overcome challenges and get rewards	X		
	> Inspiration to develop a common vision and make it happen	X		
	> Community-building to build coalitions for action		X	
	> Friction and conflicting/competing agendas	X		

[1] Partially fulfilled for the board game, but not for the digital add-on

Learning/social learning and collaboration	- Supports both individual and collaborative learning, where detailed objectives include: > To entice learning by being challenging, entertaining, engaging and realistic > To stimulate curiosity to try different things by providing opportunities for experimental learning > To provide a platform for exchange and exploration of ideas, perceptions and positions, and possibilities to reflect on and apply what is being learnt in a subsequent round of the game > To increase the collective understanding of system complexity (correlations and interdependencies) > To create understanding and respect for other stakeholders' perspectives by supporting interaction and providing opportunities to try out different roles > To encourage inclusiveness, cooperation, collaboration and trust among players/coalitions to attain a purposive transition towards sustainable sanitation	X X X X X X		
Links to the wider planning and action context	- Influences two sets of stakeholders: a) directly those playing the game and b) indirectly the wider set of stakeholders taking decisions on sanitation systems - Has the capability to engage with and include "a practical situation" from which players can relate to their own context - The game environment and outputs are capable of feeding data and learnings directly into ongoing planning and development, e.g. through dedicated links to the real world - The game should support learning among a wider set of key stakeholders who have not played the game themselves by: > Providing examples of feasible system solutions in support of resource recovery and circular economy > Showing that collaborative approaches to resource recovery are feasible, productive and transformational		X X X	X X
Adaptation of the game	- Game is adaptable so new information can be added and gameplay adjusted – by a game leader before and during gameplay – to match the local situation, e.g. it is possible to: > Adjust names of locations so that players can recognize themselves/their situation in the game > Add content relevant to a specific city and/or planning process > Add/change roles to fit social, cultural, institutional and/or organizational circumstances and to make it more relevant or dynamic > Adjust to different types of workshop settings	 X	 X X X 	
Assessment	- Makes it possible to assess the outcomes of the game based on: > Level of resource recovery achieved in the developed sanitation system > Level of collaboration and joint learning experienced by the players > Level of innovation in the developed sanitation system	 X* 	 X 	 X

Game users				
Target audience	- Includes the collective of all those needed to be involved in a transition towards sustainable sanitation, e.g., urban & regional planners, wastewater & water planners, health sector, regulators & politicians, funders, engineers & technicians, households, citizens, community organizations, consultants, building developers, builders, sanitation entrepreneurs, researchers, farmers, food industry, food markets		X	
	- Accommodates both those playing the game itself and those interlinked through the wider planning and action context			X
Player interaction	- Is a multiplayer game, where the number of players is 3-7	X		
	- Learning and collaboration is a main goal, with a facilitator in place to deal with issues arising from player interaction	X		
	- Player roles are the key stakeholders involved in sanitation	X		
Dedication	- Accessible to inexperienced gamers and non-experts in sanitation planning	X		
	- Requires maximum two-hour sessions (preferably shorter), and possible to play in multiple shorter session (max. 1 hour)		X	
Game development				
Authorship	- Has a public body as author, such as a university research group funded through public or private funding	X		
Development methodology	- Game development is a joint initiative between stakeholders in the sanitation service chain and the game developers	X		
	- Is based on a co-creation development process with at least 2-3 iterations with stakeholder feedback	X		
	- Addresses implementation issues with the stakeholders during the development process	X		
Game platform				
Hardware architecture and deployment	- Is a predominantly analogue game that can be augmented digitally, e.g. for simulation of game results		X*	
	- The analogue part of the game is possible to play independently anywhere without the digital components	X		
	- The digital parts will function on local equipment (Microsoft Windows and/or Android), possible to use without Internet	X*		
Business model				
License	- Is freeware, possibly as open source but proprietary (permission needed to distribute or modify)	X		
	- Both analogue and digital components are freely available for downloading	X		
Sustainability	- Has a plan and allocated resources for maintaining the usability of the game for a minimum of 3 years from completion			X
	- Provides a framework for donations to secure long-term sustainability, as well as upgrades and/or additions			X

6 Discussion and conclusions

The starting point for the development of a comprehensive design framework for a serious game supporting planning and governance processes in urban transformation was Prieto De Lope and Medina-Medina's (2017) taxonomy. This taxonomy was helpful. However, we found it lacking in specific areas, which have been further elaborated on in this study, including key additions. First, instead of starting with authorship and hardware, we restructured the taxonomy to start with *game design* – especially the serious purpose of the game, its worldview, its content and its context of use. This allowed us to introduce a different type of logic into the design process. If a serious game is to be co-designed with affected stakeholders, it seems essential to start game development through deliberation based on societal needs and the domain expertise of the stakeholders (Khaled & Vasalou, 2014), and also by discussing what values should be reflected in the game (Fisher, 2017). Second, shifting the focus to the purpose and content of the game, i.e. to promote transformative environmental planning that leads to increased resource recovery, contributed to identifying necessary amendments to Lope and Medina-Medina's (2017) original sub-categories and to the addition of new sub-categories based on complementary reviews of the serious games literature. Third, the application and prototyping of specifications focusing on a serious game on sustainable sanitation provided a tentative assessment of the usefulness of this framework. We found that, after some iterations and adjustments, the specifications were found to be sufficient for providing a starting point for the actual design of a sanitation planning game.

It is evident that the resulting game did not meet all the expectations as expressed in the theoretical framework and the extensive list of specifications. A significant number of trade-offs were necessary when confronted with different types of realities, such as ease and clarity of gameplay and available funding and time resources. Still, the framework and detailed specifications made it possible to manage these trade-offs in an informed and considered manner, avoiding coincidental and nontransparent decisions in the game development process. Furthermore, the first instance of evaluation of the game could be carried out in a systematic and transparent manner.

The objectives of the present study were to shape a generic design framework for development of serious games in urban planning and governance, to develop a set of specifications for a serious game for sustainable sanitation planning, and to develop and assess such a game. Although we feel that the presented specification framework has come a long way in responding to these objectives, we would not dare to claim that it is comprehensive, or that the resulting game is the perfect outcome. An obvious limitation is, of course, that the relevance and completeness of the framework needs to be assessed by putting it to work in new or expanded game designing processes, with subsequent real-life application and evaluation in sanitation planning. Also, even if we have prototyped and tested a sanitation game developed based on these specifications, this game is in need of further testing in real-life settings on both Global South and North sanitation planning settings. We would like invite the serious game community to apply and further develop the proposed specification framework to improve its relevance and applicability, in sanitation planning as well as in other fields of urban transformation.

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Appendix A: Prototype assessment questions

Questionnaire: Pre-game play

Contact Information

1. Kindly enter your initials or nickname: *

……..

2. What is your age? *

Mark only one oval.

- ◯ <20
- ◯ 20-29
- ◯ 30-39
- ◯ 40-49
- ◯ 50-59
- ◯ >60

3. What is your gender? *

Mark only one oval.

- ◯ Male
- ◯ Female

4. How many years experience do you have working with sanitation? *

Mark only one oval.

- ◯ No experience
- ◯ < 5
- ◯ 5-10
- ◯ 15
- ◯ 16-20
- ◯ > 20 years

5. In what way are you involved in sanitation? *

6. Why do we need sanitation services?

7. Who needs to be involved in sanitation services?

8. Please indicate how strongly you agree or disagree with the following statements:

Mark only one oval per row.

Statement	**Strongly Disagree**	**Disagree**	**Neither Disagree Nor Agree**	**Agree**	**Strongly Agree**
Lack of sanitation services makes people sick.	⬭	⬭	⬭	⬭	⬭
Sanitation services have no impact on our environment.	⬭	⬭	⬭	⬭	⬭
Sanitation services contribute to economic growth in our country/city.	⬭	⬭	⬭	⬭	⬭
Sanitation services are important for providing local jobs.	⬭	⬭	⬭	⬭	⬭
Provision of sanitation services has no impact on people's happiness.	⬭	⬭	⬭	⬭	⬭

9. Please indicate how strongly you agree or disagree with the following statements: *

Mark only one oval per row.

Statement	Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
Sanitation services are a top priority.	⬭	⬭	⬭	⬭	⬭
There are other issues that should be prioritized over sanitation	⬭	⬭	⬭	⬭	⬭
The main purpose of a sanitation system is to dispose of waste.	⬭	⬭	⬭	⬭	⬭
Human excreta contains resources that can be recovered.	⬭	⬭	⬭	⬭	⬭
Treated human excreta can be used to fertilise crops.	⬭	⬭	⬭	⬭	⬭
Recovering nutrients from human excreta will make us less reliant on imported fertilizer for food production.	⬭	⬭	⬭	⬭	⬭
We should recover more resources from sanitation systems.	⬭	⬭	⬭	⬭	⬭

10. Please indicate how strongly you agree or disagree with the following statements: *

Mark only one oval per row.

Statement	Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
Untreated human excreta poses a health risk.					
Human excreta can be treated so that it does not pose a health risk.					
I would buy fertilizer recovered from treated wastewater, such as sludge from a wastewater treatment plant.					
I would buy fertilizer recovered from treated human excreta, such as composted faeces or sanitized urine.					
I would eat food that was fertilized with cow manure.					
I would eat food that was fertilized with treated wastewater, such as sludge from a wastewater treatment plant.					
I would eat food that was fertilized with treated human excreta, such as composted faeces or sanitized urine.					
I think that my friends or colleagues would eat food that was fertilized with cow manure.					
I think that my friends or colleagues would eat food that was fertilized with treated wastewater, such as sludge from a wastewater treatment plant.					
I think that my friends or colleagues would eat food that was fertilized with treated human excreta, such as composted faeces or sanitized urine.					

Questionnaire: Post-game play

Contact Information

1. Kindly enter your initials or nickname (same as in the pre-game survey): *

……..

2. Please indicate how strongly you agree or disagree with the following statements:

Mark only one oval per row.

Statement	Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
I enjoyed working with the other group members during today's workshop.	⬭	⬭	⬭	⬭	⬭
A leader emerged in the group during the game.	⬭	⬭	⬭	⬭	⬭
I felt welcome to express my opinions freely to other group members during the game.	⬭	⬭	⬭	⬭	⬭
I felt that I was really part of the group during the gameplay.	⬭	⬭	⬭	⬭	⬭
I experienced personal friction and personality clashes within the group during the game.	⬭	⬭	⬭	⬭	⬭
I would feel comfortable working with the members of the group in the future.	⬭	⬭	⬭	⬭	⬭

3. What aspects of sanitation services did you feel were highlighted in the game?

4. Who do you think needs to be included in the next planning workshop for sanitation services?

5. Did playing give you any new insights/ideas on how to develop sanitation planning?

6. Please indicate how strongly you agree or disagree with the following statements:

Mark only one oval per row.

Statement	**Strongly Disagree**	**Disagree**	**Neither Disagree Nor Agree**	**Agree**	**Strongly Agree**
Sanitation services have no clear link to public health.	⬭	⬭	⬭	⬭	⬭
Our local environment is polluted due to lack of sanitation services.	⬭	⬭	⬭	⬭	⬭
Provision of sanitation services are a drain on our national/city economy.	⬭	⬭	⬭	⬭	⬭
Sanitation services do not provide local jobs.	⬭	⬭	⬭	⬭	⬭
People will be happier if they have proper sanitation services.	⬭	⬭	⬭	⬭	⬭

7. Please indicate how strongly you agree or disagree with the following statements: *

Mark only one oval per row.

Statement	Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
Sanitation services are a top priority.	⬭	⬭	⬭	⬭	⬭
There are other issues that should be prioritized over sanitation.	⬭	⬭	⬭	⬭	⬭
The main purpose of a sanitation system is to dispose of waste.	⬭	⬭	⬭	⬭	⬭
Human excreta contains resources that can be recovered.	⬭	⬭	⬭	⬭	⬭
Treated human excreta can be used to fertilise crops.	⬭	⬭	⬭	⬭	⬭
Recovering nutrients from human excreta will make us less reliant on imported fertilizer for food production.	⬭	⬭	⬭	⬭	⬭
We should recover more resources from sanitation systems.	⬭	⬭	⬭	⬭	⬭

8. Please indicate how strongly you agree or disagree with the following statements: *

Mark only one oval per row.

Statement	Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
Untreated human excreta poses a health risk.	⬭	⬭	⬭	⬭	⬭
Human excreta can be treated so that it does not pose a health risk.	⬭	⬭	⬭	⬭	⬭
I would buy fertilizer recovered from treated wastewater, such as sludge from a wastewater treatment plant.	⬭	⬭	⬭	⬭	⬭
I would buy fertilizer recovered from treated human excreta, such as composted faeces or sanitized urine.	⬭	⬭	⬭	⬭	⬭
I would eat food that was fertilized with cow manure.	⬭	⬭	⬭	⬭	⬭
I would eat food that was fertilized with treated wastewater, such as sludge from a wastewater treatment plant.	⬭	⬭	⬭	⬭	⬭
I would eat food that was fertilized with treated human excreta, such as composted faeces or sanitized urine.	⬭	⬭	⬭	⬭	⬭
I think that my friends or colleagues would eat food that was fertilized with cow manure.	⬭	⬭	⬭	⬭	⬭
I think that my friends or colleagues would eat food that was fertilized with treated wastewater, such as sludge from a wastewater treatment plant.	⬭	⬭	⬭	⬭	⬭
I think that my friends or colleagues would eat food that was fertilized with treated human excreta, such as composted faeces or sanitized urine.	⬭	⬭	⬭	⬭	⬭

Post-game writing reflection question

1. Describe any new ideas you got from the game.
2. Do you think that the game influenced you with regards to how you view sanitation services or excreta management? *In what way?*
3. If you were in charge of urban sanitation planning, what would you propose to do with sanitation services in the future? *Why? Describe how you would go about achieving this vision.*
4. What did you think about the gaming activities?
5. The game aims to share knowledge about resource recovery from sanitation and supports attitude-change and collaboration between players. Do you feel that it achieves this goal? *In what way?*

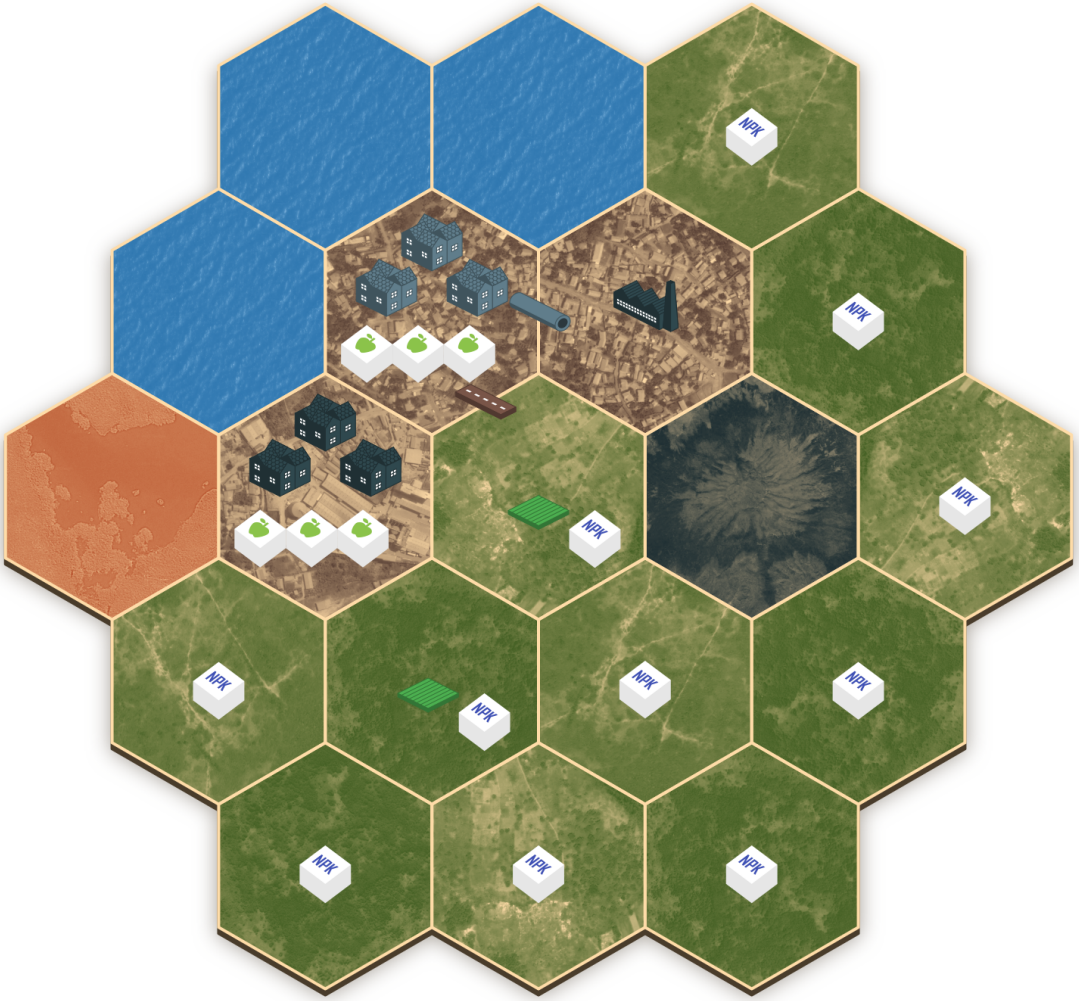
Appendix B: Game rules

Game Rules

Poor sanitation and mismanagement of fertilizing nutrients have major negative impacts on the lives of millions of people around the world, including disease and pollution of our waterways. However, with proper management, we can reduce disease and recover valuable fertilizing products, water and energy. Safe management of sanitation waste can thus protect health and the environment, as well as increasing food security. The game aims to share knowledge about resource recovery from sanitation and supports attitude change and collaboration between players.

Basic concept

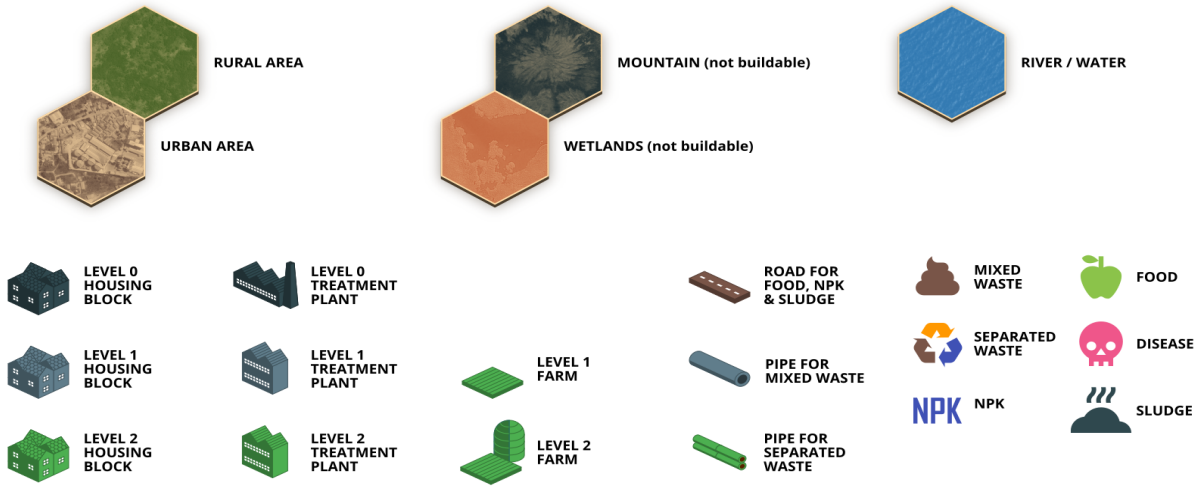
- Four players play both against each other and against the game.
- A game consists of 4 rounds, and takes approximately 2 hours.
- **Housing blocks** in the game need **Food** and produce **Waste** (**Mixed** or **Separated**). **Treatment plants** in the game treat **Waste** and convert it into **Sludge** or **NPK** (fertilizer). The **Farms** use **NPK** to make **Food** that is sent to the **Housing blocks**. To do this, **Roads** and **Pipes** are needed for transportation.
- The player with the most points at the end wins, provided that the players have not collectively lost against the game, e.g. there is too much **pollution**, **disease** or **hunger**. Players gain points based on chosen **Infrastructure cards** during the game.



Set-up

Set up the game by laying out the **hexagons** as shown in the picture above (this can be changed to match local conditions) and place the following infrastructure as shown:

- **3 Housing blocks (level 0)** on one **Urban hexagon** + **3 resource dice showing the Food symbol**
- **3 Housing blocks (level 1)** on one **Urban hexagon** + **3 resource dice showing the Food symbol**
- **1 Treatment plant (level 0)** on one **Urban hexagon**
- **2 Farms (level 1)** on **2 different Rural hexagons** + **1 resource dice for each showing the NPK symbol**
- **1 Road transportation** (brown) between one of the **Farms** and an **Urban hexagon**
- **1 Mixed Waste transportation** (grey) from a **Housing area** to the **Treatment plant**
- **Every Rural hexagon gets 1 resource dice showing the NPK symbol**



Pass out the roles (players may choose or randomly be assigned): **Housing role**, **Treatment role, Farming role,** and **Independent contractor role**. Each player also takes a **Hidden agenda card**. The **Hidden agendas** give players extra points for **Infrastructure cards** that have corresponding symbols, and therefore affects strategy for each player (see page 4).

Give each player **1000 coins (Ć)** and give **500 Ć** to the **City budget.**

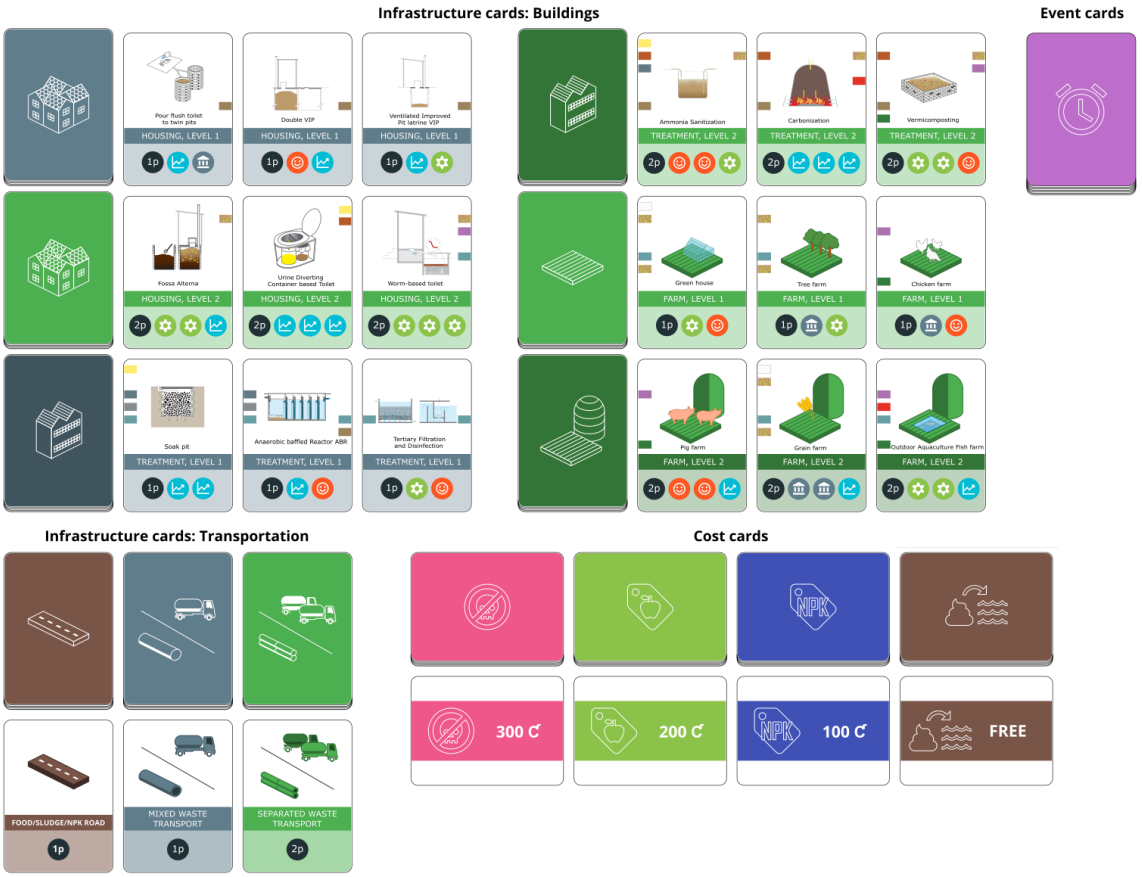
Place the different **cards** on the board, see picture on the next page.

- 6 piles with the **Infrastructure type: Houses, Farms & Treatment**, with 3 cards of each face up.
- 3 piles with the **Infrastructure type: Transportation,** face up.
- 4 piles with the **Cost cards**, one of each card face up.
- 1 pile of the **Events cards**, face down.

Set a **timer** for 10 minutes and start the timer when you are prepared to start playing.

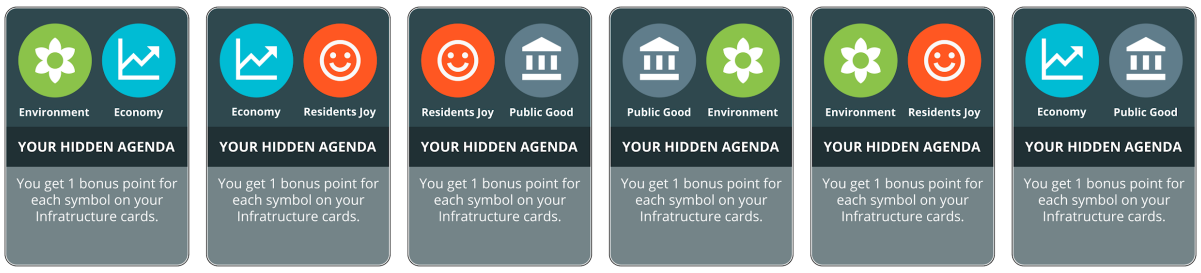
The cards in the game

There are four kinds of cards in the game: **Hidden agenda cards** that give each player their own agenda, **Event cards** that are drawn when the alarm rings. **Infrastructure cards** used for building actions and finally, **Cost cards** that describe the costs of joint decisions.



The hidden agenda

Every player has a **Hidden agenda** that is connected to the kind of persona you are playing. Some players will be concerned about the environment, others favor economic development, while others are concerned about happiness of residents or public good. The different kinds of personas in the game are:



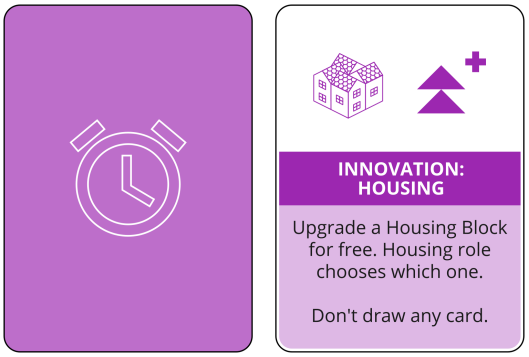
Environment/ Economy	Economy/ Residents joy	Residents joy/ Public good	Public good/ Environment	Environment/ Residents joy	Economy/ Public good

In the game, players are given extra points if they choose to build **Infrastructure cards** that match their **Hidden agendas**. These agendas remain with the player throughout the game, i.e. they do not rotate with the roles. Multiple players may have the same agenda symbols, which means that some **Infrastructure cards** will be of interest for more than one player. Thus, the players are advised to keep their agendas secret.

Event cards

Each time the alarm rings an **Event card** is drawn. These cards may influence the game in a positive or negative way. Positive cards often concern one player and can be saved until later, but negative cards apply immediately. Most often the effect of the card applies to the current round, but some of them describe a one-time action. **Follow the card instructions**.

If the alarm rings after all players have finished their rounds and are playing together the card is applied at the start of the coming round, if a positive card is drawn it is given to the player that will play that role the coming round.



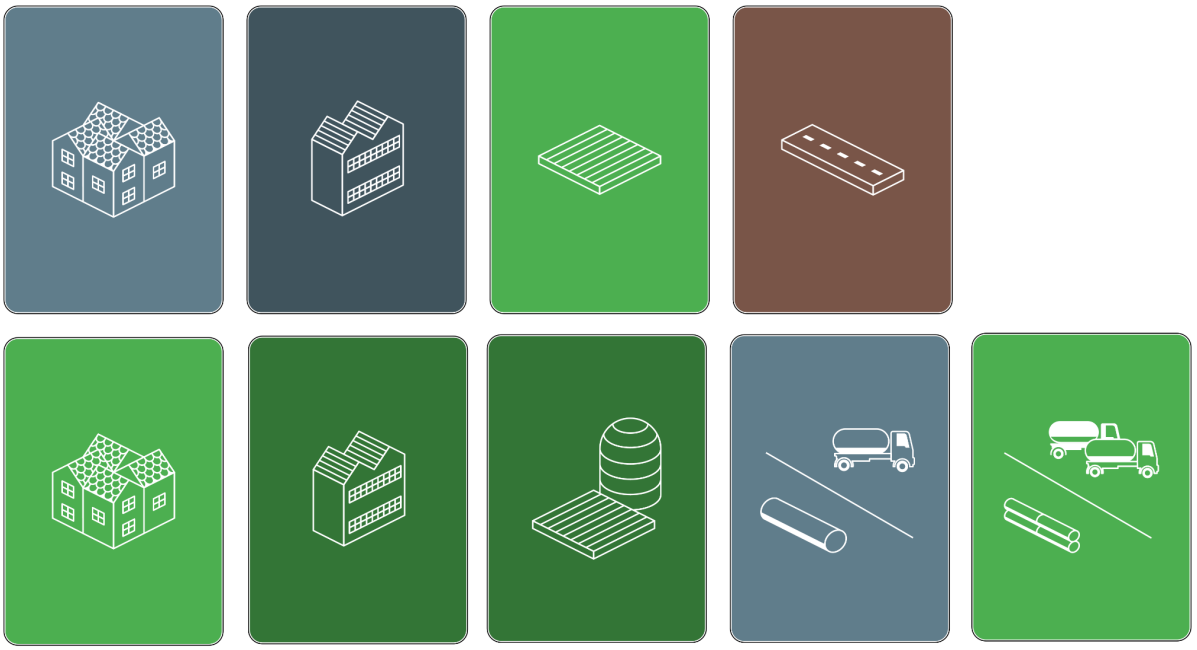
Event cards

The timer

The timer is used to indicate when an event card should be drawn. The timer is immediately restarted for ten more minutes after it rings.

Infrastructure cards

These are the cards that each player gets when he/she makes a building **Action.** The cards give each player points that are counted at the end of the game (see page 9).

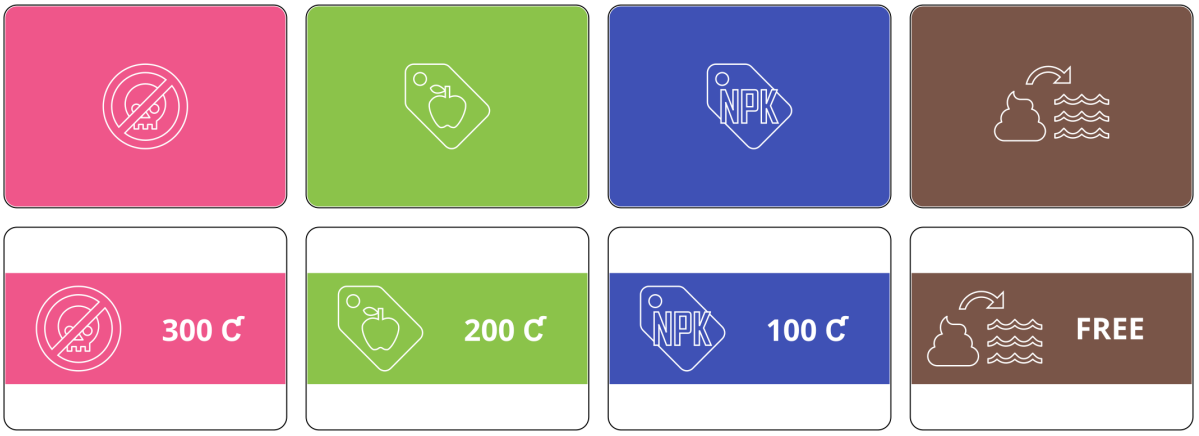


Infrastructure cards

Cost information cards

Shows the cost of different **Political decisions**, which are carried out after discussion between all players at the end of every round (see page 8). There are four possible political decisions and these cards show the cost of each decision. One cost card per decision is lying face-up on the table during the game. The costs are changed/shuffled after each round:

- Vaccination. The cards show the cost per unit of **Disease** removed (200-400 Ć).
- Import **Food**. The cards show cost per imported **Food** resource (200-300 Ć).
- Import **NPK**. The cards show cost per **NPK** resource imported (100-200 Ć).
- Dump **Waste** in the water. The cards show cost per dumping action (0-100 Ć).



Cost cards

Game Round

The **Housing role** always plays first, followed by the **Treatment role**, the **Farming role** and last the **Independent contractor role**. During their turn, each player will **1) build actions, 2) fetching resources, 3) converts resources and 4) send resources**. *Note: a player must complete their turn before the next player can start their turn.*

Build Actions

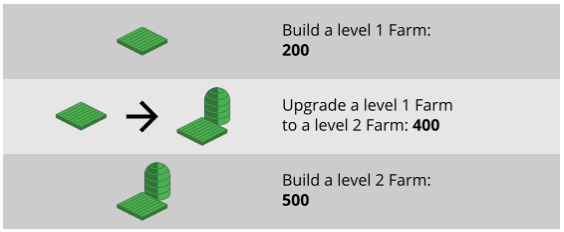
Each player can make up to **3 build actions** per turn.

- **Housing** role can build and upgrade **Housing blocks** and build any **Transportation infrastructure**.
- **Treatment** role can build and upgrade **Treatment plants** and build any **Transportation infrastructure**.
- **Farming** role can build and upgrade **Farms** and build any **Transportation infrastructure.**
- **Independent** contractor role can do **all build actions**, but for a higher price.

Housing role unique build actions:

Treatment role unique build actions:

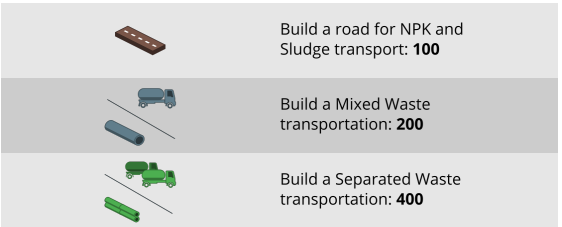
Farming role unique build actions:



Independent contractor role unique build actions:

Standard cost:		Contractor cost:
100	→	200
200	→	300
400	→	600
500	→	800

Transportation infrastructure (all):



For every **action**, the player may choose an **Infrastructure card** related to the **action (building** or **transportation)**. E.g. Upgrading a **level 1 Housing block** to a **level 2 Housing block** gives the player a **level 2 Housing block card**, building a **road** gives a **Road card** (brown), replacing the level 0 **Treatment plant** gives the special card for this, etc. Players receive points for the cards that they build. All obtained **Infrastructure cards** are shown face-up in front of respective players. The cards are personal for the player and *are not rotated* with the roles.

Fetching, converting & sending resources

After each player has performed their **3 build actions** they first choose if they want to **fetch** any resources into the hexagons that are connected to their responsibility area. Next, they can **convert** resources related to their responsibility area and finally they **send** the resources they converted if they want. **Movement** of **resources** requires **Transportation infrastructure**. Movement of **Food, Sludge** and **NPK** requires **Roads** (brown) and movement of **Mixed Waste** and **Separated Waste** requires **grey** or **green Transportation,** respectively**.** Resources can be moved through an unlimited number of hexagons, as long as there are transportation connections (roads/pipes) between them. **Resources** that are not used/treated or cannot be transported, remain on the board in the hexagon where it is produced.

Resource actions for each role:

- The **Housing role** should **convert Food to Waste** in each **Housing block** (exactly one **Food** should be converted to **Waste** at each **Housing block** each round). The **Food** should be converted to **Mixed Waste** (from Level 1) or **Separated Waste** (from Level 2) depending on the housing type. The **Waste** may then be sent to **Treatment plants**, provided that **Transportation infrastructure** exists (grey or green transports).

- The **Treatment role** checks if there is **any Waste that can be fetched** to a **Treatment plant** and chooses if he/she wants to do so. Then he/she **converts Mixed Waste into Sludge** at Level 1 **Treatment plants** and **Separated Waste into NPK** at Level 2 **Treatment plants**. **Sludge** can be moved to the **Dump-hexagon** (see below) or a **Farm**, provided that **Roads** exist to these places. If the **Sludge** is to be sent to a **Farm**, this must be determined in consultation with the **Farming role**. Note: Only **four units** of **Sludge** can be stored in the same hexagon as a treatment plant,, then it must be moved if the plant is to work the next round.
    - **The Dump hexagon:** One hexagon may be selected by the players to be a **Dump**. This hexagon should be determined as soon as **Sludge** starts to accumulate. Any hexagon may be chosen and an unlimited amount of **Sludge** can be dumped there as long as there are roads from the plants producing it. Nothing else may be built on this hexagon.
    - **The 0-level plant**: For each unit of **Waste** (max 4 units each round) that are sent to the level **0 Treatment plant**, the Treatment role roll the dice (the dice with red warning signs and green check marks), if the conversion is successful the **Waste** becomes **Sludge**, otherwise the **Waste** is moved to a **Water hexagon**, causing pollution.

- The **Farming role** may **fetch NPK and Sludge** from **Treatment plants** or rural hexagons. **NPK** is then **converted into Food.** The Farmer may choose to attempt to convert **Sludge into Food.** In this case, a conversion dice is rolled for each **Sludge** unit (the dice with disease signs and green check marks). If successful (green check) the **Sludge** becomes **Food**, otherwise the **Sludge** becomes **Disease** (disease sign on dice). Finally, the **Food** is **sent** into the Urban hexagons.

- The **Independent contractor role** must first choose one of the other characters to play the actual round. They may perform the same actions and conversions as the chosen role. Note however, that **Treatment plants** and **Farms** have limits on how many conversions they can do each round and these may not be exceeded (see below). For example, if the treatment role has used a Level 1 **Treatment plant** to convert 2 **Wastes** and the **Contractor** decides to play the Treatment role, the **Contractor** cannot use that particular plant again.

Limits in the game:

- Every **Housing block** uses 1 resource, e.g. 1 **Food** (turning to 1 **Waste – Mixed** or **Separated** depending on the housing type)
- **Max 4 Housing blocks** can be located in one urban area hexagon.
- **Max 4 resources of the same type** are allowed in the same hexagon (land or water), except in the hexagon for dumping **Sludge**, which has no limit.
- **Max 2 Treatment plants per Urban area hexagon.**
- **Treatment plant level 0** (existing plant) has capacity for 4 **Waste** (but 50% risk of non-treatment).
- **Treatment plants Level 1 & Level 2** have capacity to treat 2 **Mixed Waste/Separated Waste.**
- **Max 1 Farm** (level 1 or 2) per rural area hexagon**.**
- **Farm level 1** can produce **2 Food from 2 NPK** or **Sludge** (with risk).
- **Farm level 2** can produce **4 Food from 4 NPK** or **Sludge** (with risk).

Joint Political Decisions – All players together

After all players have taken their turn, all players discuss which (if any) of the following **Political decisions** that are needed. All joint decisions are paid with the **City budget**. If the **City budget** is not enough, the players may add from their **own coins**.

- **Import Food: all Housing blocks** that have not received **Food** from the **Farms** *must* import **Food** (see the cost on the cost information card for Food import).
- **Import NPK:** (optional) to prepare for the next round **NPK** may be bought and placed on a **Farm** hexagon of the players' choice (see the cost on the cost information card for **NPK** import).
- **Vaccination campaign against Disease** - if there is any **Disease** on the board, the players can pay to remove it from the game board (see the cost on the cost information card for vaccination).
- Manage **residual Waste** – for any untreated **Waste** remaining on the board there are two options. *NB: Both **Mixed** and **Separated Waste** remaining on the board are considered **residual Waste** until they are **converted** through treatment.*
    - Option 1: **Dump** it in a **Water hexagon** (see the cost on the card for **Dumping**)
    - Option 2: **Leave it** (and risk contamination and **Disease**)

Control for disease

Roll the **dice** once for each remaining **Mixed Waste** or **Separated Waste** on the board and once for each **Water hexagon** containing **4 Waste** units (the dice with disease signs and green check marks). There is a 1/3 risk that **Waste** turns into **Disease**, otherwise it remains as **Waste**.

The Game plays

Check is any of the **Losing Conditions** are met, **if yes, the *game is over***:

- The **Water** is fully **polluted** (4 **Waste** units in all the **Water hexagons**).
- There are 4 or more **Disease** units on the board.
- There is not at least one **Food unit** per **Housing block** in the Urban areas (e.g. people are hungry).

Before next round

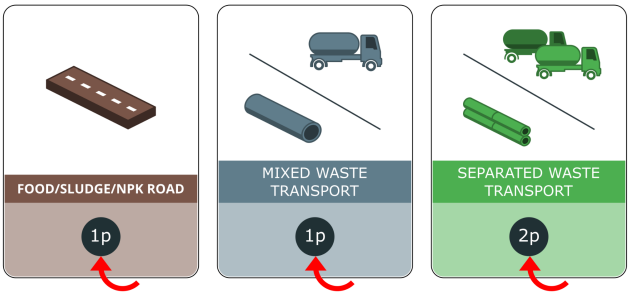
- Change all **cost information cards.**
- **Rotate all roles to the left** (NB: order of play remains the same, **Housing role** starts followed by **Treatment role**, **Farming role** and **Independent contractor role**). Each player keeps all their **Hidden agenda**, individual cards and money that was not spent.
- **For every 3 Housing blocks on the board, place 1 new level 0 Housing block.** If all existing **Urban areas** are full (max 4 **Housing blocks** per hexagon), then a new hexagon is converted from **Rural** to **Urban** (flip it over). Players can decide together which hexagon that should be turned into **Urban area** (NB: it is not possible to build on **Wetland/Mountain** hexagons). If there are no free **Rural** hexagons, or if the players decide to do so, a **Farm** can be converted into **Urban area**.
- **Every player gets a new budget 1000 coins and the City budget gets 500 coins**. Unspent money from the previous round is kept by each player (not rotated with the role).

Game end

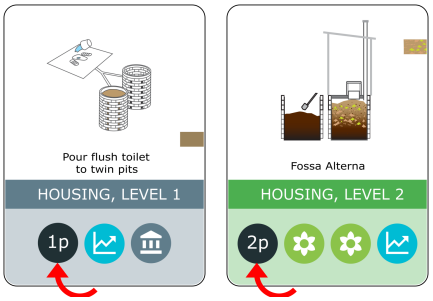
The game is over if any of the **Losing conditions** are met at the end of any of the four rounds. Provided that the players have not lost, the game is over after four rounds. At the end of the game points are counted to determine a winner. **The player with the most points wins.**

Players count their points as follows:

- **Transportation infrastructure** gives 1 or 2 points, depending on the level.
  For example:



- **Infrastructure cards** give 1 point per level, e.g. level 1 cards give 1 point, level 2 cards give 2 points.
  For example:



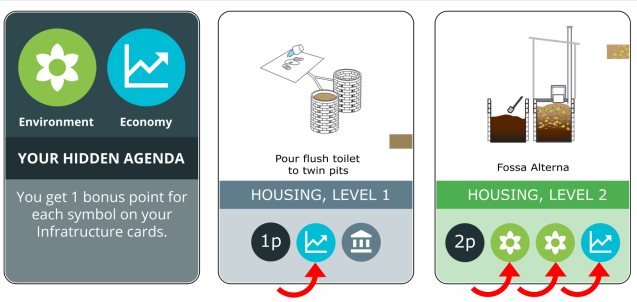
- In addition, each **Infrastructure card** gives points to the player based on their **Hidden agenda**. On each card, count all the **symbols** that match the player's hidden agenda.
  For example:

For example: A player with the Environment/ Economy agenda get extra points for all cards with corresponding symbols

The Housing level 1 card rewards the player 1 extra point Economy symbol but no point for the Public Good symbol.

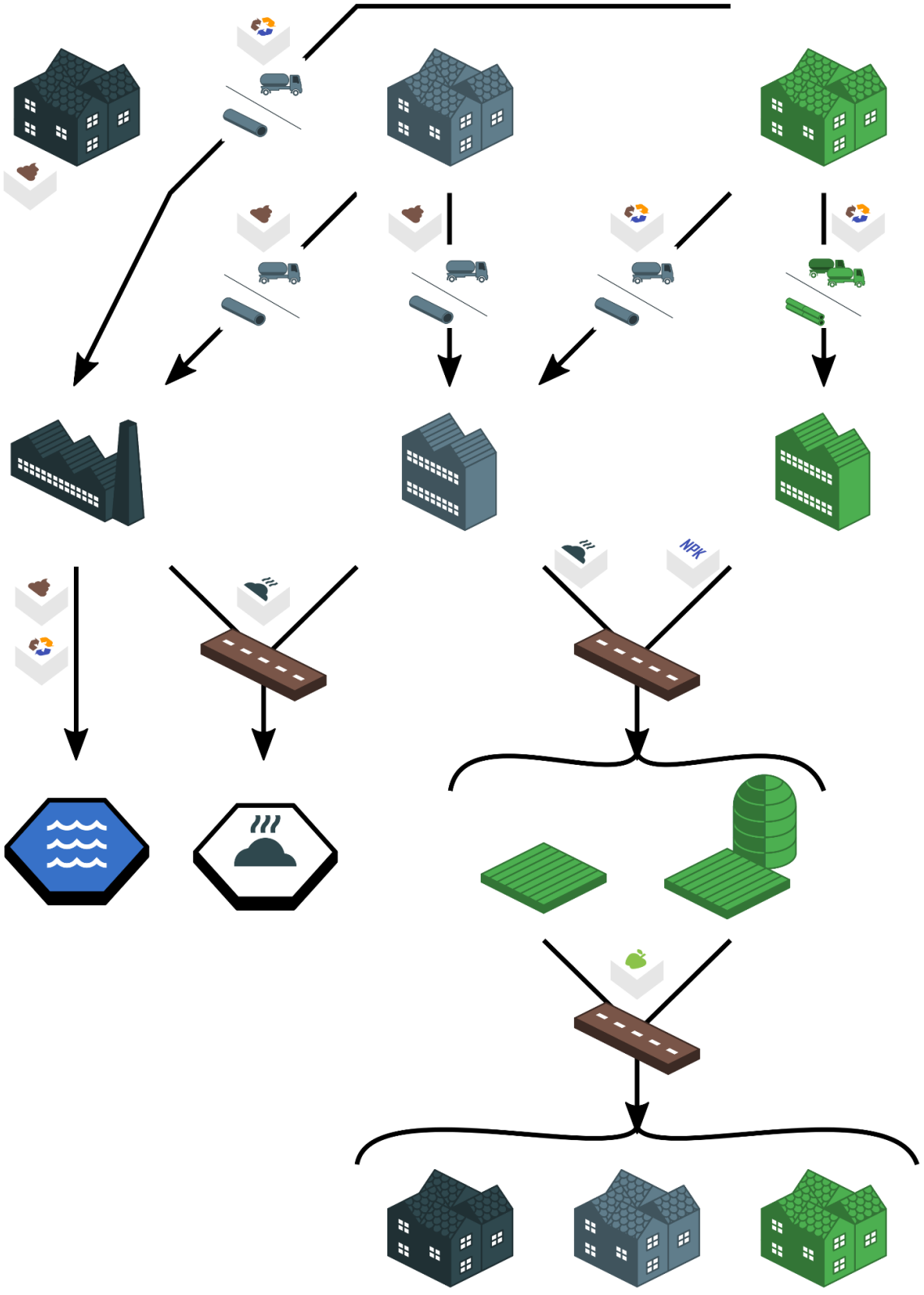
The Housing level 2 rewards the player 2 extra points for the Environment symbols and 1 point for the Economy symbol.

In this example, the player gets a total of 7 points including the level points (dark circles).



Conversions and movement of resources

This figure illustrates the possible movements and conversions of the resource dice.



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