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Supporting Interventions to Reduce Household Greenhouse Gas Emissions: A Transdisciplinary Role-Playing Game Development

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Abstract

Background. Designing interventions for conserving the **food, energy, and water nexus** at household level poses a significant challenge due to the complex interplay between **human behaviors, technologies, and policies**. Games show potential to increase **awareness** for environmental issues and influence behaviors towards more sustainable practices.

Aim. By bringing together scientists and practitioners in the game design process, a **transdisciplinary (TD) approach** is seen as a promising way to integrate available knowledge and establish ownership of the problem and solution options. Few gaming literature, however, looked at combining the two approaches in addressing resource conservation issues.

Method. We present a systematic account of the TD approach process of developing a **role-playing game (RPG)** - called HomeRUN (Role-play for Understanding Nexus).

Results. We documented our experiences in terms of challenges as well as the benefits of the TD approach. **Interacting disciplines** in this process include psychology, economics, engineering, climate, sociology, and computer science. Inputs from each discipline combined with feedback from social actors that

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include city government, utility companies, and community members facilitated continuous improvements of the RPG design.

Keywords

climate change, development, environment, learning, role-playing game

Introduction: Research Context, Problem, and Approach

Households consume a considerable amount of food, energy, and water (FEW) resources. In the U.S., households consume 80% of direct and indirect energy used and are responsible for a similar share of CO₂ emissions (Bin & Dowlatabadi, 2005). Food systems contribute between 19 to 29% of the total anthropogenic greenhouse gases (Vermeulen, Campbell, & Ingram, 2012). Nearly 5% of total GHG emissions in the U.S. comes from the water sector (Griffiths-Sattenspiel & Wilson, 2009). These facts highlight the opportunity for household actions to reduce GHG emissions by reducing FEW resource consumption (Wilkinson et al., 2009).

To inform effective interventions, researchers need to deal with a challenge of knowledge production: which knowledge is needed and where the knowledge comes from. A transdisciplinary (TD) approach brings social actors from outside academia (e.g. industry, government, NGOs, and community members) into the research process (Lang et al., 2012). By such an inclusion, the approach can potentially facilitate (i) integrating the best available knowledge, (ii) reconciling values and preferences, and (iii) creating ownership for problems and solution options. In this way, a transdisciplinary research will result in co-production, which stands for “*simultaneous production of knowledge and social order*” (Guston (2001, p. 401).

In projects involving academics and social actors, scientists are mostly concerned about the credibility of the research (i.e. whether the methodology is valid and reliable) (Cash et al., 2003). In contrast, practitioners and stakeholders are more concerned about the saliency of the project (i.e. whether the outcomes have some practical relevance). Adopting a TD approach for game development may alleviate such concerns.

In addition to the TD approach, gaming has been proposed as another promising form of knowledge co-production (e.g. Smeds, 1997). Games offer an environment where behavior can immediately be observed, allowing for experimentation in a safe situation, and enabling transfer through reflection or so-called debriefing after the actual gameplay (Kriz, 2003; Mayer & Veeneman, 2003; Wenzler, Willems, & van't Noordende, 1995).

In facilitating knowledge co-production, gaming can potentially overcome traditional barriers when it comes to knowledge transfer between academics and practitioners. This article presents a gaming approach in the context of influencing household FEW consumptions and discusses our experience in developing a role-playing game (RPG) using a TD approach. First, we introduce the context of household FEW nexus,

role-playing game, and transdisciplinary concept. Second, we describe the TD process of the game development as well as some key characteristics and elements of the final game design. Lastly, we reflect on what we learned and discuss challenges and benefits of adopting TD approach in game development.

Household Food-Energy-Water (FEW) Nexus

The challenges to reducing FEW consumption are mainly due to lack of awareness and a disconnect between consumption choices and impacts (Arthur, 1989). Household consumption decisions can be disconnected from environmental impacts due to the complexity of interactions in the FEW nexus. Specifically for household, the embedded energy and GHG emissions of food can be highly variable based on specific agricultural production practices such as irrigation and fertilizer use; energy use by refrigeration and different modes of transportation across the supply chain; and energy sources used for food storage and preparation in the household. GHG emissions and the impacts of water withdrawals embedded in household energy use can also vary significantly by location, season, and in some cases even time of day (Heller & Keoleian, 2015; Jones & Kammen, 2014). The level of environmental impacts is also highly dependent on the types of food consumed by households. Based on per kilocalorie of food produced, ruminant meat (i.e. beef, goat and lamb/mutton) produce impacts 20–100 times higher than those of plants, whereas milk, eggs, pork, poultry, and seafood have impacts 2–25 times higher than plants (Clark & Tilman, 2017).

Furthermore, many consumers are unaware that end-use heating of water is a significant component of household energy consumption and the energy and nutrients flowing through the built-environment water cycle (water withdrawal, treatment, and distribution; and wastewater treatment and disposal) are generally unaccounted for in household consumption decisions (Attari, DeKay, Davidson, & De Bruin, 2010). These rather hidden elements of the system can be revealed by a thorough systems analysis, leading to a comprehensive model of FEW nexus, which is also the starting point for the development of the RPG in such complex system (Grogan & Meijer, 2017). The TD approach contributes to a clear view of the FEW nexus, as it provides different perspectives, from different disciplines and domains, informing a rich game development.

Role-Playing Games (RPGs) for Reducing Household FEW Consumptions and Impacts

In our study, we developed and explored the effects of an RPG in affecting human behavior. We define RPGs as a sub-genre of serious games, whereas serious games are to facilitate learning higher order skills (Charsky, 2010) and understanding of complex problems. RPGs are “*digital games that strongly emphasize narrative, alternating action with episodes of exploration and dialogue, and with intricate reward mechanisms*” (Cornillie, Clarebout, & Desmet, 2012, p. 49). An immersive role-playing

experience can give participants a strong feeling of connection to the real context and a deep understanding of the issue in play (Gordon & Schirra, 2011). RPGs make use of the concept of role-taking, as introduced in the sense of a cognitive activity by sociologist Mead (1934, 1982). In general, RPGs serve three functions: 1. they can enhance a group's cohesiveness by building upon a shared narrative, 2. they encourage complex problem-solving, and provide a learning opportunity, and 3. they offer participants a safe space to alternate personas, by taking over different roles (Bowman, 2010). Especially the second characteristic of RPGs is the one that we aim to utilize and explore in our study. In game terms, this is understood as an activity of perspective-taking, or enabling an individual to contemplate a different point of view than usual (Peng, Lee, & Heeter, 2010), which can lead to a difference in behavior over time. RPGs further help players to identify with certain roles or concepts. Furthermore, role-playing stresses the fact that expected behavior related to a particular role is adopted by the player (Peng et al., 2010).

We developed an RPG called HomeRUN (Role-play for Understanding Nexus) to improve our understanding of consumers' decision making rationale by uncovering insights regarding couplings between provisions of climate impact information and actors' conservation decisions. By allowing the players to take over the role of household owners, the RPG evaluates the effects of information, technology options, and policies on consumption and conservation decisions.

Transdisciplinary (TD) Approach for Role-Playing Game Development

For informing our RPG development, we use the following TD definition:

"Transdisciplinarity is a reflexive, integrative, method-driven scientific principle aiming at the solution or transition of societal problems and concurrently of related scientific problems by differentiating and integrating knowledge from various scientific and societal bodies of knowledge." (Wiek, Farioli, Fukushi, & Yarime, 2012, pp. 26-27)

This definition emphasizes that transdisciplinary research needs to comply with several requirements: (a) focusing on societally relevant problems, (b) enabling mutual learning processes among researchers from different disciplines (from within academia and from other research institutions), as well as actors from outside academia, and (c) aiming at creating knowledge that is solution-oriented, socially robust and transferable to both the scientific and societal practice (Gibbons, 1999). Concerning the latter, it is important to consider that transdisciplinarity can serve different functions, including capacity building and legitimization (Scholz, 2011).

To make the TD approach operational, some key design principles have been offered in the literature to guide its application (Lang et al., 2012; Pohl, 2008; Wiek et al., 2012). These principles cover various aspects including team formation, problem definition, methodological framework, and solution generation (Table 1).

Table 1. Transdisciplinary Design Principles for RPG Development.

TD Design Principle	Significance
Collaborative research team	Ensure all relevant expertise and experience are represented in RPG development process
Shared understanding of the research problem	Ensure that the resource conservation problem is well defined in terms of scope/boundary, objectives, research questions, and success criteria
Shared methodological framework for collaborative knowledge production and integration	Clarify tasks and roles for scientists and practitioners and ensure the generated solution options (change in behavior, policy and technology) address the defined problem.
Integration and implementation of the co-created knowledge	Ensure that the solutions generated are implementable and project results are integrated into existing body of knowledge

The Transdisciplinary Connections Between Social Actors and Scientific Disciplines

The core development team involved in the RPG development consisted of a systems engineer, a sustainability expert, and a computer scientist. To form an interdisciplinary team, we identified the scientists’ disciplines and social actors that are relevant to the problem of household FEW consumptions (Table 2). The different scientific disciplines include psychology, economics, engineering, and climatology. The sectors involved in TD research include science, the private sector, public agencies and civil society (Pohl, 2008).

Cognitive, educational, and social psychology as disciplines contribute to the understanding on how humans think, learn, and influence each other (Grogan & Meijer, 2017). Furthermore, psychology can help us in understanding how actors act in relation to each other and to their environment. Perspectives from economics can especially help us in our case to design and research the choices of players in the RPG. Each contributing scientific discipline is addressed in the following sections.

Systems Engineering

Engineering complex systems such as the FEW nexus faces several challenges, as such systems comprise out of a large number of interrelated actors, with multiple relationships between them (De Bruijn & Herder, 2009), as well as different values and interests included. Engineering systems aims to use methods such as simulation, modeling and gaming in order to change the system into a preferred state. Insights from this field help us to understand and model the complexity of the underlying problem for the RPG.

Table 2. Relevant Disciplines and Actors Related to Household FEW Consumption.

Scientific Disciplines	Social Actors
Systems Engineering	Private sector: Utility companies (electricity, water, and gas)
Behavioral economics	Public agencies: City government
Psychology	Civil society: local communities
Climate science	

Behavioral Economics

Insights from the field of behavioral economics for game design are useful for guiding the valuation of decision utility. In particular is the so-called warm-glow phenomenon (Evren & Minardi, 2017). This refers to an experience where people get satisfaction from philanthropic activities such as charity, recycling, voting, and volunteering due to the feeling of having done the right thing. This approach provides an alternative to the assumption that humans are only motivated by self-interest.

From the game-theoretic discipline point of view, Bolton (2002) argues that game theory can provide lessons for constructing RPGs. In our application, we use game theory to construct a payoff matrix that ties one player decision to the decisions of other players. For example, if only a single player decides to reduce her carbon footprints while the rest do not then collectively everybody will suffer the same consequences (e.g. higher resource prices due to drought).

Psychology

Psychology contributes to theories about behavioral intentions to reduce household consumption. In particular, it is important to factor in people’s motives in their decisions and behaviors. Recent evidence shows that people’s well-being improve when they are engaged in behaviors that benefit the environment (e.g. charity and carbon offset) (Venhoeven, Bolderdijk, & Steg, 2016). Environmentally friendly behaviors result in more positive self-image (“feel good”). As more people see themselves as pro-environment, they will engage in more environmentally friendly behaviors that will lead to a self-reinforcing dynamics.

The insights from this field led to several modifications in the game design. First, they justified the inclusion of environmentally friendly behaviors into the game. We call this type of behavior “build wonder”. Second, we incorporated the feel-good factor into the aggregate measure of players’ payoff. Third, we applied a communications-based tool that uses information or social norms to shift consumption behaviors.

Climate Science

Climate science plays an important role in the RPG design because it informs the link between GHG emissions and climate conditions in terms of rainfall and

air temperature. These climate scenarios, in turn, affect the household costs and availability of water (g. due to drought), energy (e.g. due to the need for more air conditioning), and food (e.g. due to flood) in the game.

Social Actors

Our experience in engaging social actors concerns two aspects: (1) policies of the actors informing the development of the RPG and (2) interests of the real actors in the results of the game. We considered specific contributions and interests of three actors: utility companies, city government, and local communities.

Utility Companies

Contributions to the RPG development. Utility companies provide water, gas, and electricity services to households. These companies interact directly with customers and are therefore well-positioned to influence consumption behaviors. We looked at the practices of utility companies on what kind of messages they use to influence consumption. For game development, these practices serve as reference points for what has been tried out and what the leverage points are for interventions.

Interests in the game results. Utility companies have different initiatives to help homeowners reduce their electricity and water consumptions. For example, by stating the fact that heating and cooling is the biggest home's energy user, they offer a discounted check-up service for air conditioning system before summer starts. They campaign for reducing heating energy by setting the thermostat to 68 degrees Fahrenheit (20 degrees Celsius). Energy bills for electricity and gas show information on monthly usage and a comparison with the previous year's consumption.

City Government

Contributions to the RPG development. To support water conservation and efficiency upgrades, the City of Tempe, AZ has been offering some incentives. Residents, for example, can receive a rebate of 50% on the purchase price (up to \$75) of a new high-efficiency toilet that flushes 1.28 gallons (4.85 liters) per flush. The City recognizes the fact that more than half of indoor water consumed at household comes from baths, sinks, washing machines, and other kitchen appliances. The relatively clean wastewater from these sources (i.e. grey water) can be reused for landscape irrigation.

Interests in the game results. Insights from the RPG would be relevant in informing mechanisms to formally coordinate public information and education programs offered by the city and its partners regarding sustainability for homeowners. In addition, RPG can provide a platform for the cities to test their incentive policies for FEW conservation.

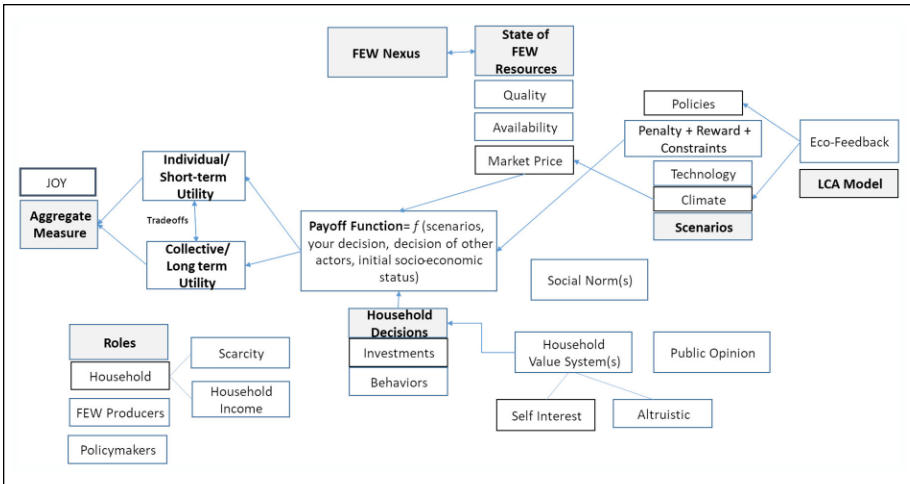


Figure 1. HomeRUN RPG design framework that reflects the transdisciplinary nature of game development.

Local Communities

Contributions to the RPG development. To learn some of the best practices on how households and a community can reduce their environmental footprints, the design team visited Prairie Crossing, a conservation community in Grayslake, Illinois. The homes within the community use 50% less energy for heating, cooling and hot water compared to similar dwellings in the area. For RPG design, such an example informs what can be realistically achieved in terms of reduction in household energy consumption.

Interests in the game results. The RPG can, as stated above, contribute to a strong community cohesiveness, by providing a shared term of reference. Playing the game in the community can strengthen the willingness to change behavior towards reduced FEW consumption on community level.

RPG Design Framework From a Transdisciplinary Perspective

In the design of serious games as the RPG in our study, it is first important to understand the real system (Grogan & Meijer, 2017; Harteveld, 2011). Our overall framework for designing the FEW nexus RPG is shown in Figure 1. The framework shows key RPG elements and their connections. Household decisions consist of investments in upgrades in the water (e.g. low flow showerhead) and energy (e.g. solar panel) system. They also include a change in behavior that results in either reducing carbon emissions (e.g. reducing meat consumption and purchasing green electricity) or increasing them (e.g. take a vacation involving air travel or long car trips). The payoff

of each decision will depend on factors such as their initial socio-economic status, scenario regarding policy, technology, and climate as well as the decisions made by other households. Following Duke's design specifications of serious games (1980), we further detail specific questions on each RPG element and requirements from the perspective of transdisciplinary approach (Table 3). After that overview, we briefly explain how we answered the respective question in our game design and describe some key characteristic of the final game.

The table shows how the game elements as defined by Duke (1980) are translated into specific questions towards the design of the RPG, and what requirements are connected to it from a TD approach.

Key Characteristics of HomeRUN RPG

From a thorough systems analysis, it comes clear that understanding why a behavioral change towards reduced FEW consumptions is important is a complex challenge, as many factors influence the individual consumption, and consumption patterns are also based on a variety of interrelated factors. We have had to narrow the complexity down to some key characteristics of the RPG that are highlighted below. In the following, we provide information regarding target audience, objectives, and technical aspects of the HomeRUN game (Table 4).

Below, we briefly summarize how we answered the questions in the game design process based on Duke (1980).

Roles – The RPG must represent the roles of house owners as human players. One question was whether to represent a diverse population of households in terms of income level and location. The next consideration was whether other roles would be represented by human players or simulated. The roles in HomeRUN now include both producers of FEW resources (e.g. farmers, utilities) and policymakers (e.g. city government).

Scenarios – The plot of HomeRUN involves several decision trade-offs. Household players need to decide among alternative actions. These involve different upgrading and investment decision in the food, energy, and water sector. To reflect what happens in reality, they can also spend their resources on resources consuming activities. These include going for energy-consuming vacations involving air travel or long road trip, eating more meats, and buying consumptive goods (e.g. food, car air conditioning, and refrigerator). We called this kind of actions “indulge”. In contrast, they can neutralize their carbon footprints by, for example, paying for a carbon offset fee. We called this kind of actions “build wonder”. The last alternative decision is a do-nothing option that in effect will keep the status quo.

Furthermore, the players should consider the timing of their decisions. Saving resources for later use on more expensive energy upgrades might yield more benefits when there is a policy (e.g. carbon cap and trade scheme) that allows selling of excess carbon credits. Another consideration is the individual versus collective impacts of household decisions. Some households may act “selfishly” triggering extreme weather events (e.g. drought and extreme temperature) that would affect everyone.

Table 3. Transdisciplinary Considerations for RPG Elements.

RPG Elements	Considerations	Transdisciplinary Requirements and Guideline
Roles -- characters assigned to players with prescribed patterns of behavior	Whose roles should be represented? What attributes and value systems are assigned to the roles? Which roles should be played by humans and which roles would be simulated by computers?	Recognize the diversity of actors whose value system need to be represented. Include relevant "stakes" needed to tackle the sustainability problem
Scenarios -- the plot of the game	What are key trade-offs for household decisions? What are relevant scenarios regarding technology options, climate, and policies? In what ways can one household decision affect others?	Scenarios are designed to represent plausible evolutions of technologies, policies, climate as well as value conflicts among stakeholders Scenarios should be validated by social actors, a face validity to the least
Rules -- to govern what players should do in a variety of circumstances	Which circumstances are relevant? What should these rules base on? How should these rules be imposed?	Recognize that the private sector, public agencies, and civil society organize knowledge and action according to individual time scales, categories, priorities
Pulse -- event/ problem introduced during the course of the game to focus players' attention on a single aspect of the problem	What particular aspects of the problem need to be addressed by the players? What kind of information related to the problem should be given to the players? When and how often should the information be shared?	
Models -- representations of real-world phenomena	Which real-world phenomena should be represented? What are the appropriate level of details and realism of the models?	Recognize the role and contribution that each scientific discipline can provide to better represent the system of interest
Accounting system -- a set of fixed procedures to deal with player decisions	What is the winning criteria for the game? What formulas to capture the outcomes of players' decisions? Which game data to record for further analysis?	
Indicators -- aspects of the accounting system chosen to emphasize for the participants.	Which performance indicators are shown to the players? Different aspects of indicators: individual vs. collective, one sector vs. aggregate sectors	Indicators that are (1) scientifically sound and (2) acceptable and comprehensible by social actors
Symbology -- the physical representation of graphical user interface (GUI)	How would the GUI be represented to the players?	Symbology that is realistic, intuitive, and appealing to social actors

Table 4. Some Key Characteristics of HomeRUN RPG.

Target audience	The game target includes a number of main stakeholders including home dwellers (both owners and renters), policymakers (especially the city government), utility companies, and college students
Objectives	<u>Research:</u> Improve understanding of consumers' decision making rationale and evaluate the effects of <u>Policy:</u> Explore the effect of information, technology options, and biophysical setting (e.g., water-abundant or water-scarce locale) on decisions. <u>Policy:</u> Raise awareness for the need of reduced FEW consumption, and promote sustainable consumption behavior
Mode of use	Educational: Raising awareness and encourage higher skill learning by understanding the complexity of the problem
Duration of play	The game consists of ten rounds of play with each round representing a period of one year in real life. Each round last for 75 seconds. The total duration of the game including briefing, pre- and post-survey ranges 1-1.5 hours.
No. of game user	The game is designed to be played by four players.
Represented role	Players of HomeRUN take over the role of a house owner who has to make certain decisions with regard to FEW consumptions.
Household type	The current RPG version models average U.S household in terms of household size and income level. This model is used to calculate the feedback of the game on the players' decisions.
Development software platform	The RPG is developed using Unity, which is a cross-platform game engine developed by Unity Technologies. The game is currently only available for Windows OS and can be played on PCs and tablets.

Rules – Players choose one or a combination of actions in each round. This can be done as long as there is sufficient money to fund the decisions. Major investments such as installing a solar panel can only be done once. Other actions such as eating local food or taking a vacation can be chosen repetitively.

Pulse – Several events and problems that can be introduced during the course of the game. In our case, these pulses involve effects on households investment and behavioral decisions. First pulse is the supply of information regarding average carbon footprints. Such a message will draw attention to how well one performs relative to other players. Second pulse is a policy event that will reward or punish certain decisions. For example, a carbon cap-and-trade policy will give a financial reward to those whose carbon emissions are below the allowance. Third is a pulse representing extreme weather events. The weather scenarios include “heat wave” (string of hot days), a “drought” (string of days with no rain), and a “storm” (extreme rain events).

Models – The GHG emissions impacts will be informed by a life cycle assessment (LCA) model. We use some impact assessment outcomes based on an LCA model that was developed by University of Berkeley in the U.S (<http://www.coolcalifornia.org>). The so-called Calculator for Households & Individuals tool provides a rough estimate of carbon footprints from (1) household activities for travel (road and air), (2) services (e.g. health, education, home maintenance & repair), and (3) consumptions on energy, food, water, and goods such as clothing, furniture, appliances, and devices.

Indicators – Several key indicators that are considered include different metrics to represent extreme weather events. The idea is to produce probability distributions for each metric for each of the three climate scenarios. The probability distributions will illustrate the likelihood of the occurrences of heat waves, droughts, and extreme rain events. To capture the cumulative payoffs of household actions and decisions, we devise an indicator called “Joy”. The aggregated measure is supposed to include financial, environmental, and psychological aspects of the payoffs.

Symbology – Evolution of the Game Graphical User Interface (GUI)

During the course of the design process, we have modified the graphical user interface to respond to feedback from different actors. The following snapshots illustrate how the GUI has evolved. A significant change in the GUI was made as a result of feedback from our social science team. Initially, the different homeowners’ actions and decisions were grouped according to FEW categories (Figure 2a). The feedback was that the players can better relate to the options if they are grouped according to types of activities they typically do at home. These activities include getting something to eat, getting oneself entertained, and getting things cleaned up (Figure 2b).

Reflection on Transdisciplinary Challenges and Opportunities

The process of designing an RPG has been an iterative one as we were going through conceptualization and prototyping. In such a process, the TD nature of the RPG strongly manifests. The design process highlights some challenges surrounding trans-disciplinary RPG development and strategies for dealing with them (Table 5).

Collaborative Problem Framing and Building a Collaborative Research Team

Integration of disciplines added perspectives in the way we look at the complex interactions between technology, behaviors, climate impacts and policies. Some of the interactions have been formal and regular (i.e. within the research project team). Others were more informal and ad-hoc. As a result, we have less control in verifying and getting follow-up feedbacks. The challenge in this regard is to effectively involve



Figure 2. Evolution of game graphic user interface. (a) FEW categories as options for actions. (b) Types of activities as options for actions.

people from different fields. The interest of such team members can be maintained by giving specific updates at regular intervals about the project.

The further challenge is to reconcile the different perspectives. This challenge can be dealt with by being proactive through open discussions. A multi-disciplinary development team often poses a challenge, as ideas coming from one discipline tend to overlook considerations from the other. For example, climate scientists tend to overlook how people take into account short-term costs and future impacts in interpreting

Table 5. Challenges to the TD Research in the RPG Setup With the Outline of Strategies and Benefits.

TD Principle	Challenges and Realization	Strategies
Collaborative problem framing and building a collaborative research team	Need to maintain contact and commitment. Interactions occurred on an ad-hoc basis. Reconcile and integrate different actors perspectives.	Initialize a study to understand the problem. Create a team structure that enables participation.
Co-creation of solution-oriented and transferable knowledge through collaborative research	Efficiently and effectively involve people from different fields. Development of a solution-oriented strategy within the scheduled time frame.	Pro-active in initializing actions to stimulate research and communications
Integrating and applying the co-created knowledge	Iterative RPG modeling and playtesting to ensure the goal of the study is met. Tracking the scientific and social impacts.	Comparative studies to derive generalizable results.

scenarios with regard to temperature and extreme weather events (something that an economist would point out). Such a discrepancy can be reconciled and tested with the help of a prototype. Thus, regular RPG prototype testing helps to keep the project well understood by the TD team. A detailed study to understand the problem with the help of flowcharts, system diagrams and visuals helps to integrate the knowledge. A structured team that establishes shared rights and obligation from the start of the TD project helps to develop a sense of ownership in the TD team and hence maintains a better flow of the work.

Co-Creation of Solution-Oriented and Transferable Knowledge Through Collaborative Research

One challenge in co-creating knowledge within the scheduled time frame is translating a disciplinary concept and implementing it into a game feature. Such concepts may be difficult to visualize and sometime certain ideas may seem simple in theory but they cannot be implemented or embedded into the RPG by the developer. For example, the idea in which each individual player establishes his own utility function and hence the impact of his decisions to wellbeing (joy) is appealing in theory. But in practice, the idea may require each player to do an additional step outside the game by conducting a survey and feedback the result into the game before the game starts. To deal with this challenge, the designers need to stimulate experimentations within the team and constantly update the prototype to playtest new elements.

Integrating and Applying the Co-Created Knowledge

The feedback from initial testing indicates that players can identify some strategies through which they can maximize their game scores. The absence of a single dominant strategy for the game can have two implications. First, the diversity of players' insight can be used by real actors (city or utility) to shape their resource-conservation programs by providing customized measures. For example, players who form their strategy based heavily on reducing impacts of food consumption can be targeted with messaging highlighting the actual impacts of food production. Second, players themselves can take the lessons from playing the game into real life to adjust their consumption behaviors. One key challenge is to track the scientific and social impacts of this kind of TD projects. One strategy is to conduct a longitudinal study using mixed methods to track and evaluate the impacts. Another strategy is to conduct a comparative study of projects with similar goals to derive some generalizable insights.

Concluding Remarks

A role-playing game has been developed to better understand factors that drive households in their behaviors and decisions regarding food, energy, and water resources – the FEW nexus. Gaining these insights is important for designing effective interventions to reduce households' greenhouse gas emissions footprints. The process of designing the RPG has been an iterative one through conceptualization, prototyping, and play-testing stage. In such a process, the trans-disciplinary nature of the RPG strongly manifested. Interactions among the disciplines involved include psychology (on effect of games), behavioral economics (on valuation of decision utility), systems engineering (on technology scenarios and life cycle impacts), and climate science (on climate scenarios). The TD approach showed to be a challenging, yet powerful process of designing an RPG as subtype of a serious game to understand a complex problem, as it aims at integrating multiple perspectives that can shed light on the interrelated factors of such complex issue as the FEW nexus.

The digital RPG game as introduced provides feedback to the group of four players engaged in a session, but does not include a debriefing phase yet. Debriefing is seen as an important phase in the use of serious games (Peters & Vissers, 2004). The process of playing a game itself can help players to better understand a certain situation. Yet, reflecting on what has been learned during a game, and discussing options of how to translate the lessons learned back to real life could add value to the process of game play. This is especially true when a debriefing is well structured, as proposed by Kriz (2010). The RPG of our study is currently used for raising awareness for the need of energy reducing actions. Future work will be dedicated to explore the effect of the game on actual behavioral change. As this requires a stronger impact than creating awareness, a debriefing phase will also be designed, implemented, and evaluated. This will help when using the game to explore the choices of players, thus when the RPG is used as research instrument. In this case, a debriefing phase could not only improve

the feedback to the players, but protect the game itself as well as validate the interpretations of the game play's results (van den Hoogen, Lo, & Meijer, 2016).

As we acknowledge that one might feel our recent study being limited to the design decisions of the RPG, our future work will focus on game play sessions with a larger group of players. Such, we will be able to analyze the behavior and derive decision patterns to inform interventions towards behavioral change processes of lower energy consumption in households, using a digital role-playing game including a debriefing phase.

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