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This paper proposes a set of criteria for evaluation of serious games (SGs) which are intended as effective methods of engaging energy users and lowering consumption. We discuss opportunities for using SGs in energy research which go beyond existing feedback mechanisms, including use of immersive virtual worlds for learning and testing behaviours, and sparking conversations within households. From a review of existing SG evaluation criteria, we define a tailored set of criteria for energy SG development and evaluation. The criteria emphasise the need for the game to increase energy literacy through applicability to real-life energy use/management; clear, actionable goals and feedback; ways of comparing usage socially and personal relevance. Three existing energy games are evaluated according to this framework. The paper concludes by outlining directions for future development of SGs as an effective tool in social science research, including games which inspire reflection on trade-offs and usage at different scales.

Keywords: domestic energy demand; serious games; evaluation framework; feedback mechanisms

1. Introduction

With the roll-out of smart meters and in-home displays (IHDs) completed in a few countries and underway in many more (reaching approximately 70% of European households by 2020; JRC 2014), the question of how householders engage with this step change in feedback about their energy usage is becoming more pertinent. Strengers' (2013, 51) ironic depiction of 'Resource Man', 'a data-driven, information-hungry, technology-savvy home energy manager' challenges the expectation that every user will be keen to read the numeric data on an IHD and take the time to understand and deconstruct their energy consumption. Conflicting reports exist about the

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interests that users maintain in IHDs; Snow et al. (2013) and Hargreaves (2012) find them to be moved out of sight over time, while Schwartz et al. (2014) and Burchell, Rettie, and Roberts (2014) report that use persists over the medium term. Therefore, the quest continues to find the best ways to display and communicate energy use information to the bill payer AND other energy consumers in the building (household members and office staff) so as to encourage and enable them to better manage and ideally reduce their energy use. The aim of this paper is to assess the potential for serious games (SGs) to increase energy literacy among users and potentially encourage reductions, aided by a proposed set of tailored criteria. Already, some IHDs take on aspects of gamification, whereby features of games such as points and goals are transposed to non-gaming environments, with comparative performance indicators (e.g. neighbourhood average; E.ON 2014) being a popular form of nudging. There is growing evidence that some people respond better to 'playful' formats of information feedback (e.g. Lucero et al. 2014). This trend of gamification of data displays is a wider phenomenon, as is the growing trend of using digital games for learning, simulation and demonstration.

SGs are primarily designed for education (Michael and Chen 2006) and are widely used in public engagement in a number of fields, including environmental and cultural (e.g. Froschauer et al. 2010; Petridis et al. 2011). As members of the growing research community that studies how citizens view and engage with the socio-technical configurations of our energy system, we seek to develop a better understanding of the (potential) role of SGs in the research agenda on energy transitions. Drawing on existing SG evaluation frameworks, we propose a set of criteria for evaluating energy games and the extent to which these address different aspects of energy literacy. We apply these criteria to evaluate three existing games, selected due to their representation of three categories of energy game: 'switch-off', 'city mayor' and real-time data games; and, in two cases, the presence of academic papers about their design. This helps us to identify gaps in current energy SG provision and, in the discussion, reflect on the value of such games for experimental research-led interventions regarding energy consumption.

2. Background

2.1. *Energy literacy and user feedback*

The 'double invisibility' of energy (Burgess and Nye 2008) makes conscious thought about its consumption difficult, through both the challenge in knowing the number of units used, and the inconspicuousness of energy consumption within everyday actions. A focus on practices and routines offers one potential way to begin tackling this difficulty, but in a multi-person household or workplace the bill payer has limited control over energy use (Goulden et al. 2014). A non-bill paying majority may include people who use more energy than the payer, for example, teenagers (Bell et al. 2013), and/or who may have lower motivation to save energy, for example, employees (Carrico and Riemer 2011). It is a multi-faceted challenge for the whole household to learn how to use display units and monitoring devices (Hargreaves 2010, 2012). The units of energy consumption are not intuitive for many people (KWh was called 'kilowattevers' by a participant in Costanza, Ramchurn, and Jennings's 2012 study) but the usual alternative of communicating energy use in financial terms may not interest those who are not paying or who can easily afford it. Indeed, a recent study of Dutch households found that a lack of energy awareness was highest in younger, wealthier households (Brounen, Kok, and Quigley 2013). Energy *literacy* in fact implies a stage beyond knowledge acquisition: learners should have the ability to digest and critique information they receive, and make informed decisions about their actions (St. Clair 2003). In order for this to happen, constructivist and transformative learning is important – the former being where a route from current knowledge to new information is paved through applications to real life and the latter being where we are encouraged to reflect upon problematic perspectives and mindsets (Hein 1991; Mezirow 2009). Schwartz et al. (2014) suggest that IHDs should take into account different levels of existing energy literacy and provide a range of entry points into using home energy management systems (HEMS). This would be enhanced by attempts to engage all members of a household in ways that are interesting and relevant to them.

Goal setting (Becker 1978) and continuous and comparative feedback (e.g. Van Houwelingen and Van Raaij 1989; Opower 2013) have been noted to be effective forms of household energy use feedback (Abrahamse et al. 2005). However, critics note that current industry efforts to provide feedback through smart-metering and IHDs still lack focus on specific behaviours that they aim to modify (Froehlich, Findlater, and Landay 2010), and also that they make insufficient effort to ensure that feedback is presented in a way which allows people to make decisions appropriate to their own lives (Schwartz et al. 2013). A number of papers propose energy feedback design interventions which go beyond standard IHDs, for example, using an *Energy AWARE clock*, or a *Power Aware Cord* to visualise energy use (Pierce, Odom, and Blevis 2008; Broms et al. 2010). An ongoing problem for all such endeavours is how to stop HEMS, however novel, simply drifting into the background once their novelty wears off (Van Dam, Bakker, and van Hal 2010). The success of gamification in ongoing engagement with energy use (Simple Energy 2014 report savings of over 10% resulting from their gamified interventions) along with games' ability to engage reluctant young learners and allow for repeated practice of performance over time (Prensky 2007) means that SGs may help to keep energy conservation in the forefront of players' minds. There is an absence of long-term trials of games, though Lieberman (2001) reports regular interaction with an SG for a full six-month trial.

2.2. *Purposes and characteristics of SGs*

At the most basic level, a game has three ingredients: a set of rules, the possibility to win (against oneself or others) and 'fun'. Given the focus of this paper we will not dwell on 'fun', other than to acknowledge that it is a key ingredient for participation. SGs add a fourth ingredient: learning. SGs can have a range of purposes, from advertising and 'edutainment' to training and personal development (SGU 2011). Increasing participants' knowledge is one of the main aims of SGs and central to the more pedagogically focused field of game-based learning: seen as highly relevant to so-called digital natives (Prensky 2007). Some SGs are explicitly designed to encourage behavioural change, with several notable success stories reported from the health sector (e.g. Lieberman 2001; Kato et al. 2008; Knight et al. 2010).

A number of academics have used SGs as a tool to engage participants with resource and planning issues. Examples include participatory decision-making with farmers (Fisher et al. 2012) and inclusive urban development (Mayer et al. 2005). Such games may be played by single users or in group settings, and are used to assist participants in learning and decision-making, and/or aim to change behaviours. SGs tend to be characterised by feedback loops and re-runs, so that players can compare their results with previous runs or (in a group setting) with each other. Finally, SGs are often more effective if they simulate more closely the lived experience of the participants (Khaled and Vasalou 2014). This tailoring can be achieved through collaborative game design with the participants, an activity which by itself yields valuable new knowledge for the researcher. This knowledge may relate to the resource landscape, existing patterns of use and the decision options available to different individuals. While the format of games can vary greatly, and it is possible for some types of games to develop both material (e.g. board games) and computer versions, computer SGs offer easy tailoring, keeping scores for re-runs, storing diagnostics, adjusting for different numbers of players and processing and displaying real-world data. These are potential important benefits for energy SGs that draw on smart meter data.

SGs can build upon existing social science research-related interventions (for increasing energy literacy and encouraging reductions in energy use) in several ways. A virtual world can allow people to test out knowledge, apply it in different scenarios and see the potential consequences of actions and changes (Froschauer et al. 2010) (e.g. in a virtual home) in a more visual and easily understandable way than an IHD. De Freitas and Oliver (2006, 254) also discuss how immersing oneself in an 'internal representational world' can support critical reflection on real-life behaviours. We would suggest that an SG may therefore act to bring relevant practices into consciousness and make individuals wilfully connect these with energy consumption. Depending on the game design, it may also provide accessible visual metaphors for energy (as opposed to numeric or graphical data displays) that help it to become less abstract to the majority of people who do not see their everyday routines, like cooking or cleaning, as 'energy behaviour' (Burgess and Nye 2008). Additional motivation for energy use reductions can be provided through comparisons, challenges and rewards. Orland et al. (2014) argue that the social bonds and practical behaviour changes encouraged by their game *Energy Chickens* helped to motivate players more than other feedback mechanisms. Indeed, we believe that SGs offer the opportunity for whole households to deliberate and participate in energy management, which is something not offered by other feedback devices.

3. Criteria for energy SGs and their evaluation

Following this discussion, what is it that energy SGs could or should be doing? We examine existing frameworks and criteria to evaluate (any) SGs, to then develop a framework tailored for energy SGs.

3.1. *Reviewing existing SG evaluation frameworks and criteria*

The assessment of SGs may focus on the evaluation of the game or of player performance (Bellotti et al. 2013). Table 1 summarises the key aspects of three SG evaluation frameworks that are most relevant to and most strongly inform our criteria for an energy SG, and that therefore do not dwell on player performance or technical aspects (see Göbel, Gutjah, and Hardy 2013) or on the higher education student course context (see Nadolski et al. 2008). The Four Dimensional Framework (De Freitas and Oliver 2006) is strongly focused on pedagogy and learner support. However, it also argues the benefit of an immersive game world representative of real life. While the EGameFlow scale (Fu, Su, and Yu 2009) is focused on learner enjoyment, it contains aspects of goals and feedback which should feature in any SG evaluation. Finally, Mayer et al. (2014) consider impacts on understanding and behaviours in the short, medium and long term, which are important for maintenance of energy use reductions.

Discussion about the value and content of these frameworks continues. For example, Bellotti et al. (2013) stress a need for more tools to measure aspects such as higher order thinking and soft or social skills, while Mayer et al. (2014) call for more systematic consideration of SG evaluation, for instance, through a greater number of operationalised models. Our paper adds to the debate on SG evaluation by developing a set of criteria which is tailored to games about

Table 1. Comparison table of frameworks and criteria to evaluate SGs.

Key paper	Name	Elements of framework/constructs for operationalisation
e.g. De Freitas and Oliver (2006)	Four Dimensional Framework	Context, learner specification, pedagogical considerations and mode of representation
Fu, Su, and Yu (2009)	EGameFlow	For example, clear goal, feedback, challenge, immersion, social interaction and knowledge improvement
Mayer et al. (2014)	Generic conceptual framework for evaluating SGs	Pre-game elements include socio-demographics, attitudes, behaviours and skills; in-game elements include game play and experience; post-game elements include player attitude, knowledge, skills and behaviour

energy consumption and reflects the largely informal nature of energy education at home and the social nature of its use. Energy SGs may be tailored towards use at home, work or in an educational setting; collaborative use or solo play; and for players of a wide age range. This makes their purpose different from SGs which help to deliver a taught course. Our set of criteria acts as a heuristic framework to understand what existing games do and in what ways they could be advanced, but can also be used for the design of further games.

3.2. *Defining and justifying the criteria for an effective energy SG*

Table 2 presents a list of criteria for an effective energy SG, drawn from the literature and organised in four categories; one that is specific to energy literacy, and three generic categories for SGs related to personal behaviour identified in Section 2.2: feedback, social comparison and customisation for personal relevance. These 4 categories, and the 21 criteria contained within them are discussed in detail below. There is some overlap between categories, in particular Columns 1 and 4. However, the criteria in Column 1 relate to actions and challenges which happen in real life (such as energy management in homes and cities), while the criteria in Column 4 focus on how presentation of data encourages the player to connect *personally* with the game. The criteria indicated as 'core' we consider essential for any SG aiming to increase energy literacy. Without clear goals and feedback, and encouragement to reflect on learning and real-life behaviours, it is unlikely that an energy SG will leave a player feeling knowledgeable and able to reduce their real-life consumption. We believe that attention should be paid to as many of the additional criteria as possible for an energy SG to be engaging and incite personal energy use reductions.

3.2.1. *Energy literacy and application to real-life energy use/management*

Attention to this category is essential to ensure critical learning takes place, and the player can relate this to real-world situations.

(1) Realistic and meaningful tasks within a game connect the player to a real-life context (Froschauer et al. 2010). An SG has little use unless the player can apply what they have learned to real-world situations (Mayer 2012).

Table 2. A framework for evaluating what SGs can do to progress energy literacy.

Energy literacy and application to real-life energy use/management	Goals and feedback	Social comparison/community	Personal relevance, customisation and timeliness
1. **Clear application of game goals to real-life energy use/management** 2. **Encouragement to apply learning outside the game** 3. **Encouragement to reflect on learning and real-life energy-using behaviours (e.g. bring energy-using practices into consciousness, encourage active thinking about energy use)** 4. Engages the player with energy issues at a range of scales (local/city, national and global) 5. Player encouraged to be critical of the information they receive about energy use and issues (one aspect of energy literacy) 6. Communicates energy use through ways that are significant to the player, for example, meaningful units, visual metaphors, units of choice to player 7. Player encouraged to see energy in a nexus context with other resources (e.g. water–energy–food linkages and trade-offs)	8. **Clear goals of gameplay (Fu, Su, and Yu 2009)** 9. **Clear connection between activities and learning** 10. **Sufficient feedback on progress provided in the game (Fu, Su, and Yu 2009)** 11. **Engaging methods of feedback, for example continuous; user encouraged to make goals or pledges** 12. **Opportunities to apply learning inside the game environment (Fu, Su, and Yu 2009)** 13. Opportunity for the player to see/compare their progress (e.g. their current behaviour to past behaviour)	14. Opportunity for the player to compare their behaviour/ progress with others (e.g. through a leaderboard or forum) and potentially engage in social learning 15. Encourages people to feel ‘part of something’, for example, a community	16. Information is personalised, or personally relevant information 17. Runs on personally relevant real-life, real-time data 18. Helps the player meet their own personal energy goals (e.g. environment, comfort and saving money) 19. Engages people with their energy use in the medium or long term (Mayer et al. 2014) 20. Allows the player to test out different scenarios relevant to their own life (in the home, workplace or a different environment) and receive feedback 21. Data are presented in a way which allows people to make decisions appropriate to their own lives

Note: Numbers refer to individual criteria, and bold text indicates core criteria.

(2) Further to Criterion 1, the game should not only highlight real-life applications but enable and motivate them (such as through facilitative feedback; Dunwell, de Freitas, and Jarvis 2011). ‘Scaffolding’ (a concept borrowed from cognitive psychology theory) is required to allow the player to link what they learn in the game to their actions in the real world (e.g. energy-using behaviours) (Dunwell, de Freitas, and Jarvis 2011, 45).

(3) Taking these criteria a step further, immersion in an ‘internal representational world’ can support reflection on real-life behaviours (De Freitas and Oliver 2006, 254). By encouraging critical reflection on when energy is used (e.g. specific behaviours and lifestyles) we can begin to address its ‘double invisibility’ (Burgess and Nye 2008).
(4) Framing energy consumption as carbon emissions could encourage behaviour changes at a broader scale than simply reducing usage at home, and a sustainable citizen connects the responsibilities of citizenship at different scales (Desforges, Jones, and Woods 2005; Spence et al. 2011).
(5) A constructivist approach to the SG design gives the learner an active role in their learning, forming their own associations (Froschauer et al. 2010). While becoming ‘literate’ in something is not essential for an SG, we argue that being encouraged to think critically and make informed decisions will encourage a sense of agency to manage energy more sustainably.
(6) In terms of learning, communication should suit the learner’s preferences (Ainsworth 2008). For energy, this is meaningful units that resonate with the user (Spence et al. 2011).
(7) By making connections to the water–energy–food nexus, the player gains a greater understanding of the trade-offs involved and wider implications of increasing energy demand (Hellegers et al. 2008).

3.2.2. *Goals and feedback*

This category, core to the effectiveness of SGs, is a common feature of evaluation (see below).

(8) Clear goals of gameplay can be considered a central aspect of any successful SG, included in the criteria of Bellotti et al. (2013) and Fu, Su, and Yu (2009).
(9) Every mechanical feature of an SG should be well connected to the learning goals (Bellotti et al. 2013), and this criterion also features in the EGameFlow scale (Fu, Su, and Yu 2009). Connecting activities within the game and learning makes gameplay feel meaningful.
(10) Fu, Su, and Yu (2009) put forward the criterion of sufficient feedback, and it is important in order for the player to know their progress and gain guidance towards better performance (Kapp 2012).
(11) Feedback should not be overly critical, excessive or irrelevant (Dunwell, de Freitas, and Jarvis 2011). Engaging energy feedback might include progress towards targets for reductions and actionable ways to improve performance.
(12) Fu, Su, and Yu (2009) evaluate opportunities to apply learning inside a game, and Wang, Shen, and Ritterfield (2009) report a positive effect on players who experience the impacts of their decisions within a game.
(13) The opportunity for the player to see or compare their progress is not essential, but allows for the player to improve on their game performance, and ideally their real-life energy conservation, over time. Also, while some types of player like to compete with fellow players, others prefer to compete with themselves and this can be equally motivational (Bryant and Fondren 2009).

3.2.3. *Social comparison/community*

This category can be seen as important for environmental games because a major potential route to motivation for behaviour change is through engaging with others.

(14) Comparison to others through social norms can be an effective way of motivating energy conservation efforts (e.g. Dolan and Metcalfe 2013). A leaderboard is a simple way of making a solitary play experience feel social, and encouraging competition (Kapp 2012).
(15) Social interaction is recommended in SGs, whether through online collaboration or real-world communities (Fu, Su, and Yu 2009), and energy conservation projects have attributed success to participants feeling 'part of something' (e.g. Burchell, Rettie, and Roberts 2014).

3.2.4. *Personal relevance, customisation and timeliness*

This category is relevant for any effort targeting personal consumption and habits.

(16) Data or advice which a player knows is personalised will mean they can be sure of its relevance to their life. This also connects to the concept of instrumentality, and instilling the notion that the player themselves can make a difference by saving energy (Spence et al. 2011).
(17) Few games have worked to engage players using their real-time data (Orland et al. 2014 is one exception) but we argue that doing so helps to ensure personal relevance and connection to real-world actions and potential change.
(18) Besides being able to select actions they are capable of doing, allowing a player to save energy according to their own priorities will increase buy-in. It is well known that appealing to personal motivations is pertinent to behaviour change attempts (Defra n.d.).
(19) A critique of many types of interventions for behaviour change is that they are not tested or are ineffective in the long term. There have been calls for efforts that address medium- and long-term engagement with energy consumption (e.g. Van Dam, Bakker, and van Hal 2010; Snow et al. 2013) and an energy SG could also work to address this gap (Mayer et al. 2014).
(20) Besides the opportunity to trial ideas, a virtual world which provides feedback may encourage a player to replicate actions in real life (Froschauer et al. 2010).
(21) In terms of allowing the player to make decisions appropriate to their own life, a person may wish to select energy curtailment actions over efficiency actions, for example (Steg 2008). The greater the degree of agency a player has within a game, the more enjoyable and productive the play will be (Bryant and Fondren 2009).

4. Applying the criteria

We have conducted an extensive search for online energy SGs. Beyond quizzes (a one-off, minimalist SG), we found three broad types: 'switch-off', 'city mayor' and real-time data games. We apply our framework to an example game of each of these three types.

The game *Energy Hogs*[1] belongs to the 'switch-off' category; the player is seeking to track down the 'energy hogs' in a virtual home and banish them through adopting more efficient behaviours, switching off appliances or making sustainable purchases. *Energy Hogs* meets only two of the goals and feedback criteria and two of the energy literacy criteria, with a number of those considered 'core' not addressed, and contains no social comparison or personal tailoring at all (Table 3). However, the player is directed to the *Hogbusters Handbook* and *Scavenger Hunt* activity in order to apply the facts that they have learned to their home. Options for extending the game, based on our framework, include letting players choose their own energy-saving goals and finding ways to achieve them within the virtual home, or drawing connections between these behaviour changes and the wider environment.

Table 3. Energy SG criteria met by *Energy Hogs* (grey boxes), based on game play.

Energy literacy and application to real-life energy use/ management	Goals and feedback	Social comparison/ community	Personal relevance, customisation and timeliness
1	8	14	16
2	9	15	17
3	10		18
4	11		19
5	12		20
6	13		21
7			

The second game category could be called ‘city mayor’. It examines the various resource decisions (exploitation or conservation) within a particular geographical setting that includes a city and its rural hinterland, with the aim being to balance economic and environmental objectives. Renewable energy production is a key component, but it sits within a nexus of other resources like clean air and water. Our example game, *Super Energy Apocalypse: Recycled (SEA:R)*, features zombies and a ruined world as a metaphor for the ill effects of human interventions (Doucet and Srinivasan 2010). *SEA:R* utilises real data on the US energy economy but is not customised or tailored to the player and does not relate to everyday energy use. The goal of playing the game is to appreciate the relationship between resources, generation, transportation, the economy and pollution (Doucet and Srinivasan 2010). The developers found that players performed better in a post-test of knowledge than a pre-play test, though the results were not quite statistically significant (Doucet and Srinivasan 2010).

SEA:R pays attention to three of the four categories (Table 4) (with six of the eight ‘core’ criteria addressed) but there are opportunities to develop further in each one. Goals and feedback are incorporated within this game (as they would be in almost all SGs), but the fact that the game is not about personal energy behaviours means it is not attempting to connect the player with their individual energy use decisions at home or at work. Equally, it is not straightforward for the player to apply what they have learned outside the game environment. However, the game certainly encourages thinking about sustainable energy choices more broadly (and the fact that there is no easy solution), while cleverly not coming across as an ‘educational game’. The game is played individually but social comparisons (with other players) are enabled by an online leaderboard. Our criteria highlight that *SEA:R* is an effective game for increasing energy literacy in terms of engaging players with information about local, national or global scale energy resources and making decisions. Integration of personal energy usage in some way could increase motivation and agency among players further, showing how they personally can apply their new knowledge.

Real-time energy games involve multiple players and actual energy data related to the players, obtained through smart meters. Extensively reported in Orland et al. (2014), the *Energy Chickens* game stands out in that it covers three of the customisation/tailoring criteria. The game, which involves maintaining the health of a virtual pet chicken through making personal energy savings, runs on actual energy consumption data measured through plug-load sensors of personal office appliance use. The researchers found that self-reported energy consciousness increased and measured energy usage decreased, with some individual level persistence following a 12 week trial

Table 4. Energy SG criteria met by *SEA:R* (grey boxes), based on Doucet and Srinivasan (2010) and game play.

Energy literacy and application to real-life energy use/management	Goals and feedback	Social comparison/ community	Personal relevance, customisation and timeliness
1	8	14	16
2	9	15	17
3	10		18
4	11		19
5	12		20
6	13		21
7			

Table 5. Energy SG criteria met by *Energy Chickens* (grey boxes), based on information from Orland et al. (2014).

Energy literacy and application to real-life energy use/management	Goals and feedback	Social comparison/ community	Personal relevance, customisation and timeliness
1	8	14	16
2	9	15	17
3	10		18
4	11		19
5	12		20
6	13		21
7			

(but no overall statistical indications of persistence, potentially due to social influence and lack of employee control over equipment use) (Orland et al. 2014).

Table 5 shows that a greater number of the criteria we suggest fit with a game like *Energy Chickens*, and all of the 'core' criteria are addressed. We can see that goals and feedback are clearly communicated through the game, and social comparison/community is also a clear focus. Real-time personal consumption data are utilised, which is still rare among energy SGs despite being highly advantageous for engaging players with their personal energy consumption. Moreover, the fact that the game is used in an office environment makes it a social game, bringing in aspects of discussion, comparison and competition. 'Graph' view allows the player to see their progress over time, while 'Mountain' view allows them to compare their performance with others in the office. Interestingly, being used in a workplace means that any energy savings from behavioural change are of financial benefit to the employer rather than to players. There is the opportunity for the player to try out different ways of saving energy and measure the impact of this through their virtual pet, but only based on the data being collected at their workstation. Supplying the player with information about the energy usage of other office appliances or those in the home could help them make informed decisions about other opportunities to save energy, thus additionally increasing agency and energy literacy.

5. Discussion

Having developed a set of criteria to guide and evaluate energy SGs, its application to three different types of existing energy games has shown that none of these is covering the entire spectrum of possible criteria for effectiveness. The application shows that *Energy Chickens* is more advanced in comparison to the other games, due to its use of real-time personalised information and community aspects.

We had to augment criteria from existing frameworks to reflect the need for energy SGs to develop energy literacy among players and increase the visibility of energy use. *Energy Chickens* performed better than *Energy Hogs* and *SEA:R* because the framework centres on the idea that the player should become more able and motivated to conserve energy at home or at work after playing an energy SG. *SEA:R* shows that games without an explicit purpose to modify personal energy consumption could also help people learn about energy use and issues more broadly (and become more energy literate), although the actual impact on behaviours is uncertain. The lack of personalisation in *Energy Hogs*' game tasks (choosing units, goals or testing scenarios) also makes it difficult for the player to engage with their real-life energy consumption, as shown through application of the criteria.

It is important to reflect here that we base our conceptions of the 'effectiveness' of these games on our own gameplay (where possible) and the literature, rather than testing the extent to which the games helped a group of testers reduce their energy consumption. Therefore (in this paper), we cannot reflect on the actual success of the games in changing behaviours. However, initial indications from Orland et al. (2014) and Doucet and Srinivasan (2010) suggest that with further development, SGs could be effective in reducing energy consumption, following successes in the health sector (e.g. Kato et al. 2008).

Pre- and post-game engagement (which in a research project could take the form of interviews, community workshops, personalised information or household challenges, for instance) could allow gaming experiences to meet more of the criteria on our checklist which may not currently be met by playing the game alone. These engagement activities are easy to combine with various social science research methods, creating conditions for shared learning but also blurring the lines between primary research and (educational) outreach.

6. Opportunities for further research and development

Achieving long-term change in energy consumption is difficult: interventions such as continuous feedback (Van Houwelingen and Van Raaij 1989) and information alongside rebates (Gonzales, Aronson, and Costanzo 1988) have had limited bearing or even a negative effect on long-term energy-using behaviours. SGs offer an interesting alternative intervention, one which has the potential to be more engaging even for non-bill payers, but further research into their effectiveness is needed (Orland et al. 2014), especially in the longer term.

Our framework projects a vision for a successful game as one that encourages a diverse group of people in an office or household environment to become energy literate, make informed decisions and take control of their energy use. But also beyond the framework we need to appreciate the limitations of (existing) SGs. Players have a limited agency in the real world, so should a game flag up these limits? While this could be discouraging, it may also open up conversations with others – for example, between children and parents, landlords and tenants, employee and employer – thus invoking ripple effects beyond those directly engaging with the game. This under-researched area deserves further attention.

SGs have the potential for different age groups to not only play and enjoy the experience, but to learn with and from one another. It is possible to develop material energy games (e.g. board or card games) alongside their digital counterparts, in order to encourage engagement from people of all ages. Parallels can be drawn between existing research activities and types of SG (e.g. scenario building as a research activity and playing 'city mayor'-type games). A number of world and UK future energy scenarios have been developed (e.g. National Grid 2013; World Energy Council 2013), but energy SGs could provide a virtual environment for local and personally relevant scenarios to be developed and deliberated among families, neighbours and colleagues. The criteria we propose could also be applicable, with some adaptation, to games used as research-based interventions in other sustainable consumption debates, such as water literacy and conservation, or sustainable transport choices.

7. Conclusions

We have argued that SGs offer a potentially productive area for exploration by social scientists interested in energy behaviour change and energy demand reduction at an individual and collective level. Several SGs have already been developed in this domain, but there is a need for more research on their effectiveness. Energy SGs have their own specific criteria to meet in terms of making energy use more visible, comprehensible and personally relevant, and encouraging players to become more energy literate. While excellent frameworks exist to evaluate SGs generally, these were insufficient for the evaluation of the potential effectiveness of an energy SG. This paper proposes a set of criteria for reviewing the effectiveness of energy SGs that can also identify options for further development of games that increase energy literacy and potentially help to reduce consumption.

The criteria emphasise the need for personally relevant information which players can apply to their real-life energy decisions, clear and actionable feedback related to each player's own goals, and ways of comparing progress. We do not expect games to replace IHDs but there is a place for further energy SGs to be developed which focus on changes an individual – particularly one not paying the bill – can make in the context of their household and community. These could potentially be linked to games or scenarios at broader geographical scales, and also inspire broader reflections on the connections and trade-offs between energy, water, food and the environment.

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Note

1. http://www.energyhog.org/ (accessed 25 September 2014).

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