Evaluating Current Systems and Exploring the Potential of Social Networking Platforms to Increase User Engagement with Eco-Feedback Systems

N. Mohammadi[1], T. Bulbul[2] and J. E. Taylor[3]

[1]Department of Civil and Environmental Engineering, Virginia Tech, 200 Patton Hall, Blacksburg, VA 24061; neda@vt.edu
[2]Department of Building Construction, Virginia Tech, 430-C Bishop-Favrao Hall, Blacksburg, VA 24061; tanyel@vt.edu
[3]Department of Civil and Environmental Engineering, Virginia Tech, 131-B Patton Hall, Blacksburg, VA 24061; jet@vt.edu

ABSTRACT

For infrastructure energy efficiency to reach its full potential, new and improved ways for occupants to engage with their energy use are needed. Despite the recent advancements in eco-feedback systems, strategies to increase motivation and user engagement in these systems remain primitive for a number of reasons. Improving the efficiency of user driven energy conservation actions requires improvements in the delivery of energy consumption feedback, and methods that trigger occupant engagement with infrastructure data within eco-feedback systems. One approach to achieve increased engagement is through integrating feedback solutions with social networking platforms. This will enable feedback systems to address a larger population and to utilize persuasive engagement approaches such as: customized awareness, engagement motivations, and time/location sensitive alerts. In this paper, we explore potential interactions between the occupants, infrastructure, and eco-feedback systems to examine the relevance of exploiting social media to increase user engagement in energy conservation actions. We examine the applicability and effectiveness of four eco-feedback systems from an occupant engagement perspective and identify gaps in these interactive systems. Finally, we propose a dynamic and interactive approach to feedback to enhance infrastructure energy efficiency.

INTRODUCTION

Renewable energy developments and energy efficiency efforts designed to address today's environmental challenge of reducing CO_2 emissions are effective once in correspondence with each other. On one hand, renewable energy technologies are increasing the amount of alternative clean energy resources available. On the other hand, energy conservation actions are critical to slow down the energy demand growth; otherwise, CO_2 emission goals will fall into an ascending trend (Prindle et al. 2007). The infrastructure occupants play a significant role in stabilizing energy demand and, as a result, reducing the associated environmental impacts. Hence, a number of eco-feedback systems have been developed to provide feedback to the occupants on their energy consumption behavior. These systems intend to increase the occupants' awareness, thus trigger energy efficient activities through user engagement. The level of occupant engagement with such eco-feedback systems is fundamental to meeting the goals of these systems to reduce energy consumption. Yet, it can be the case that, despite the delivered eco-feedback, occupants still may refuse to cut down certain electricity use during peak demand hours (Strengers 2011).

These behaviors reinforce the importance of occupant engagement, and the necessity for providing continuous motivation in designing eco-feedback systems. However, the existing eco-feedback systems present evidence of user disengagement in their results (Strengers 2011; Pereira et al. 2013). For instance, despite the attention to the user-interface design in increasing the occupants' engagement (Jain et al. 2012), basic desktop energy monitoring systems are often ignored or discarded when the novelty and attractiveness of the system dissipates (Pierce et al. 2010). Also, a lack of sufficient occupant interaction with these systems adds to disengagement results and thus inefficiency of energy conservation actions. Studies have shown significant decreases in user interactions with an eco-feedback system when examined over longer time periods (Pereira et al. 2013). Pereira et al. concluded that after nearly one year of eco-feedback system deployment, no further significant increase or decrease in electricity consumption was exhibited.

Nevertheless, integrating the existing web-based eco-feedback systems with social networking platforms, can potentially offer significant improvements in occupant engagement, due to the possibilities that social affordances of these platforms enable. Online social networks are in use across the globe on a regular basis, and they have great potential in raising awareness and energy behavior change (Foster and Linehan 2013). Social networking platforms in this paper refer to those mobile social networking websites that enable time/location-based services to enrich social networking; such as Facebook or Twitter.

Incorporating social networking platforms in existing eco-feedback systems will enable rich communications, and perhaps the capability of influencing a larger population. Their time/location-based sensitivity, can allow the spread of customized awareness and persuasive messaging to the occupants at the right time and location. It has been well-established that feedback provided closest in time relative to an action has the highest effect (Ester 1984). Social networking platforms will permit providing the users customized goal-setting arrangements based on their social orientation. Since every user is connected to his/her own familiar social network, the positive energy conservation influences of peer networks (Peschiera and Taylor 2012) can also be increased. Likewise, there will be less difficulty in propagating energy efficient normative behavior.

This paper assesses a number of existing well integrated eco-feedback technologies from an occupant engagement perspective to understand the current state of the art in employing social networking platforms to increase user engagement in energy conservative actions.

BACKGROUND

Currently, computerized consumption eco-feedback systems are among the most successful channels of infrastructure-occupant energy interactions and awareness delivery systems (Fischer 2008). However, there appears to be a disjunction between the disciplines that are pursuing this solution. This, results in disintegration of these systems in terms of the actual goals intended to be met. Such disintegration relies on either not having appropriate infrastructure energy data integrated into their systems (Grevet et al. 2010); or, having presented very small-scale post user evaluation studies for their system performance and implications. These efforts are often limited to interviews and pilot studies (Petersen et al. 2009; Petkov et al. 2011). Such disintegration will lead to further engagement issues with the users.

Eco-feedback systems emerged as an area of research in the area of Human Computer Interaction (HCI). Yet, the literature in this area (e.g., Foster et al. 2010 and Froehlich et al. 2010) has focused on the interface design and individual interactions with the software. These endeavors are essentially accomplished independently from the long-term social impacts on energy consumption behavior. The true influence of the system within the social network that they are influencing is neglected. In order for eco-feedback systems with energy efficiency goals to operate effectively, they need to appropriately integrate with ambient intelligent systems that make the infrastructure data available. This integration requires an interdisciplinary approach which combines knowledge from different domains. Stated in this way, addressing the problem of user engagement in these systems, is in fact a combination of several factors. In the first step, the system needs to have an integrated approach in the design, its implementation, and the resulting data collection, analysis and feedback. Once that is achieved, we can then study those systems in terms of new features and media, through which they can be more effective. In order to explore the disengaging factors in the existing eco-feedback systems which can be addressed through social networking platforms, we examined several of these systems in detail.

The following section will compare four of the most well-integrated eco-feedback systems in the literature, from an occupant engagement perspective. In this selection, we have only considered those eco-feedback systems that are integrated with energy sensor data, and whose social networks' influences were studied. We will call these systems 'integrated eco-feedback systems'. We narrowed our selection based on their application medium, and the type of energy which has been monitored. *Watt's Watts* (Gulbinas et al. 2013; Jain et al. 2012) is a web-based system, designed to provide near real-time feedback to the users within a social network environment. *ECOIS* (Ueno et al. 2006) is an on-line interactive energy consumption information system for motivating energy-saving in residential buildings. *Oberlin College* (Petersen et al. 2007) is a college dormitory wide energy feedback system which provides different resolutions of socio-technical feedback, combined with incentives to encourage students for improved energy behavior. Among these systems was also *EnergyWiz* (Petkov et al. 2011), an eco-feedback system with a user-friendly interface which was designed to address the initial steps of motivation-specific design of energy-related application. Despite the shortcomings of this system in its user evaluations, we concluded that due to its rich user interface design and user interaction features it should be included in our study.

ECO-FEEDBACK SYSTEMS EVALUATION

Four web-based integrated eco-feedback systems for residential buildings that are intended to trigger electricity consumption behavior changes of their occupants are shown in Table 1. We evaluated the occupant engagements of these systems based on the following engagement factors: 1- Adoption rate (study participants, study period), 2- User customized motivation, 3- User-interface design consideration, 4- Feedback frequency, and 5- Availability of user interaction features. The number of users for eco-feedback systems, and the duration of the study (Pereira et al. 2013), determines the fast/slow adoption of positive energy consumption behavior. A study (Fischer 2008) exploring the effects of feedback on electricity consumption, and users' reactions and attitudes found that in cases with no energy savings, the billing feedback was provided

Table 1. Eco-feedback Systems Evaluation

Eco-feedback system	Study participants	Study period	User motivations (Customized)	UI design consideration	Feedback frequency	Availability of interaction features
ECOIS (2006)	nine residential-houses of a married couple with 1–3 children	40 weekdays before and after installation	N/A	N/A	Email distribution, Daily/10 day comparison graphs	Urge to press [yes], [I will try], [Neither] buttons
Oberlin College (2007)	1162	2 Weeks	University-wide competition	Usage graphs and gauge, Mini-movies for energy data explanation (layman terms)	Data update every 20s, last day, last week time series graphs	N/A
EnergyWiz (2011)	17 individuals (semi structured interviews)	N/A	Challenge, Norm-comparison, One-on-one comparison, and Ranking	Motivation-specific design	Live Data feature	Mobile application, Enabled performance comparison with contacts from social networking sites (Facebook-enabled)
Watt's Watts (2012)	43	6 Weeks	Built-in Incentives: prize redemption through reward points	UI design with four components: Historical comparison, Normative comparison, Rewards and penalization, Incentives, and	24h, to date, last week (through graphic modes)	Energy audit tool for specific applications and devices

Disaggregation

too infrequently. This caused the users to feel disconnected from their positive behavior. Research has shown that feedback must be given frequently to be effective (Ester, 1984). The interface design plays a critical role in triggering positive energy consumption behavior (Jacucci et al. 2009).

Observations Evaluating the eco-feedback systems of Table 1 from an engagement perspective, we first note that most of the eco-feedback user evaluations have been implemented within small scale communities and over short periods. The adoption rate and success of these systems cannot be simply expanded to a larger population. Studies involving a small number of participants and over longer durations (Pereira et al. 2013), has observed a significant decrease in user interactions. This may suggest another reason for motivation dissipation. Individuals adopt positive behavior when they are part of a larger community and are able to compete against their own selected networks. Limiting the number of occupants—as was the case in three of the four studies we examined–will likely impede the adoption of positive energy consumption behaviors, especially in the longer term.

Another influencing factor in establishing user engagement is the frequency of feedback, which has been improved over the years from daily email distributions in *ECOIS*, to near real-time and live data in *EnergyWiz* and *Watt's Watts*. However, nowadays the real engagement challenge is not to provide live data to the users but rather to make the data meaningful. We can only increase the user's engagement with continuous real-time data if it is provided at the right time and location (e.g., during peak hours of consumption). Despite some efforts to introduce user interactions for these systems, e.g. an energy audit tool in *Watt's Watts* and performance comparison tools in *EnergyWiz*, the number of interactive features is still limited and not necessarily customized towards the user's personal motivations.

User motivations such as 'challenge' and 'ranking' in *EnergyWiz*, mini movies for energy explanation in the *Oberlin College* competition project, or prize redemption through rewards points in *Watt's Watts* are following a 'one size fits all' design approach which may cause user engagement to dissipate over time. Studies have concluded that receiving points for reduced energy consumption will appear ineffective in the long term; and the users will accomplish their acceptable minimum after a certain point (Petkov et al. 2011). The four existing eco-feedback technology designs also are limited in that they provide the same feedback to all users regardless of their motivational level and individual willingness to take energy conservative actions. People are motivated differently (He et al. 2010), and thus customized motivations are required to increase engagement.

Discussion These observations revealed a number of disengagement factors in four existing integrated eco-feedback systems. However, much of these issues can be addressed by integrating existing eco-feedback systems with social networking platforms. With pervasively available sensor technologies, infrastructure energy data such as disaggregated energy consumption of electricity, lighting, CO_2 emissions, temperature, etc. can be presented to the occupants through social networking platforms.

With the availability of mobile social media (Facebook, Twitter) which have time-location sensitivity affordances, real-time and customized awareness can be delivered to users; changes can be tracked and used to trigger increased engagement. Mobile social media can connect the occupants to the infrastructure energy data, and allow further interactions by customized, compelling, and persuasive alerts. Therefore, social networking platform-based eco-feedback systems would enable tapping into an expansive population of occupants when raising awareness, and encouraging positive behavior.

The examined platforms could be improved if they enabled goal-setting that is based on social orientation. It has been studied that pro-social individuals are more easily persuaded in taking targeted actions when assigned a goal, whereas, pro-self individuals who are more effective through self-set goals (McCalley and Midden 2002). If mobile social platforms were to be integrated with eco-feedback systems, then the positive effects of peer networks for encouraging energy conservation behavior could be expanded. Peer networks would no longer be limited to peers from the same building. Competitive peer network effects can be developed with the individuals' own family and friends' circles, perhaps even from different locations with different types of energy feedback. Utilizing social networking platforms can increase user engagement and interaction through social affordances such as 'like' and 'share' within the users' customized networks.

Social networking platform-based eco-feedback systems have great potential in improving successful self-reporting of energy saving systems like StepGreen (Grevet et al. 2010) in support of a city-wide social visualization system. This system can be integrated with real infrastructure data to reduce the effort involved with self-logging actions, and thus increase user engagement. Persuasive mobile applications are already being used in the area of human sustainable mobility, through persuasive mobile applications which track the CO_2 emissions of the users' journey, and provide them with persuasive and personalized challenges that lead to energy conservative actions (Froehlich et al. 2009; Jylha¨ et al. 2013). Such intelligent transportation systems can be expanded to ambient intelligent infrastructure, in order to ensure energy behavior change at a larger scale. In summary, the persuasive power of social media should be directed towards increasing user engagement in order to increase the effectiveness of energy efficiency interventions involving eco-feedback.

CONCLUSION

This paper contributed an evaluation of selected integrated eco-feedback systems from a user engagement perspective. We found that three of the four eco-feedback systems examined a small number of users, and all studies took place over a short time period, or were limited to interviews Although adoption was found to be strong in these cases, given the results of Pereira et al. (2013) over a long time period, it is likely that adoption of positive energy consumption behavior would be less optimistic than suggested by smaller scale, shorter duration studies. Tapping into larger social networking platforms may result in increasing user participation and decreased user disengagement. Utilizing social networking platforms may increase users' engagement and interaction through social affordances such as 'like', 'share', or 'retweet' within the user's customized networks. The examined eco-feedback system designs assumed a 'one size fits all' perspective toward user interface design. And, yet, the same interface may not appeal to all users equally and may result in motivational loss and disengagement. Employing social networking platforms may improve the delivery of personalized and location/time-sensitive feedback to the users for increased engagement. These platforms have already attracted attention. For example, *Wattsup* is providing socially enabled feedback through Facebook, which allows social comparisons of domestic energy using standalone energy monitoring devices *(*Foster et al. 2010). Also, *EnergyWiz* allows challenging a Facebook friend on a weeklong energy saving competition. These examples are illustrative of the potential direction for eco-feedback system design.

We suggest future eco-feedback system researchers employ tailored feedback using mobile social media platforms to impact users' energy efficiency behavior. Considerable efforts are being made in the area of HCI in developing applications to promote energy efficiency for infrastructure. However, there are limitations in understanding the essence of the problem due to the fact that studies in this area tend to focus within a single discipline. Improving infrastructure energy efficiency is necessarily an interdisciplinary effort which requires collaboration from computer science, civil engineering, sociology, psychology and other disciplines to ensure achieving the overarching goal of reducing energy consumption and the associated greenhouse gas emissions generated in its production.

REFERENCES

Ester, P. (1984). "Consumer behavior and energy conservation." Ph.D. thesis,Springer, Springer.

Fischer, C. (2008). "Feedback on household electricity consumption: a tool for saving energy?." Energy efficiency, 1(1), 79-104.

Fogg, B. (2008). "Mass interpersonal persuasion: An early view of a new phe- nomenon." Persuasive Technology, Springer, 23–34.

Foster, D., Lawson, S., Blythe, M., and Cairns, P. (2010). "Wattsup?: motivat- ing reductions in domestic energy consumption using social networks." Proceed- ings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries, ACM, 178–187.

Foster, D. and Linehan, C. (2013). "'liking'carbon: can social media play a role in carbon management?." Carbon Management, 4(1), 1–4.

Froehlich, J., Dillahunt, T., Klasnja, P., Mankoff, J., Consolvo, S., Harrison, B., and Landay, J. A. (2009). "Ubigreen: investigating a mobile tool for track- ing and supporting green transportation habits." Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, ACM, 1043–1052.

Froehlich, J., Findlater, L., and Landay, J. (2010). "The design of eco-feedback technology." Proceedings of the SIGCHI Conference on Human Factors in Com- puting Systems, ACM, 1999–2008.

Grevet, C., Mankoff, J., and Anderson, S. D. (2010). “Design and evaluation of a social visualization aimed at encouraging sustainable behavior.” System Sciences (HICSS), 2010 43rd Hawaii International Conference on, IEEE, 1–8.

Gulbinas, R., Jain, R. K., Taylor, J. E., Peschiera, G., and Golparvar-Fard, M. (2013). “Network eco-informatics: Development of a social eco-feedback system to drive energy efficiency in residential buildings.” Journal of Computing in Civil Engineering.

He, H. A., Greenberg, S., and Huang, E. M. (2010). “One size does not fit all: applying the transtheoretical model to energy feedback technology design.” Proceedings of the SIGCHI Conference on Human Factors in Computing Sys- tems, ACM, 927–936.

Jacucci, G., Spagnolli, A., Gamberini, L., Chalambalakis, A., Björkskog, C., Bertoncini, M., Torstensson, C., and Monti, P. (2009). "Designing effectivefeedback of electricity consumption for mobile user interfaces." PsychNology Journal, 7(3), 265-289.

Jain, R. K., Taylor, J. E., and Peschiera, G. (2012). “Assessing eco-feedback interface usage and design to drive energy efficiency in buildings.” Energy and buildings, 48, 8–17.

Jylhä, A., Nurmi, P., Sir ́en, M., Hemminki, S., and Jacucci, G. (2013). “Matkahupi: a persuasive mobile application for sustainable mobility.” Pro- ceedings of the 2013 ACM conference on Pervasive and ubiquitous computing adjunct publication, ACM, 227–230.

McCalley, L. and Midden, C. J. (2002). “Energy conservation through product-integrated feedback: The roles of goal-setting and social orientation.” Journal of economic psychology, 23(5), 589–603.

Pereira, L., Quintal, F., Barreto, M., and Nunes, N. J. (2013). "Understanding the limitations of eco-feedback: A one-year long-term study." Human-Computer Interaction and Knowledge Discovery in Complex, Unstructured, Big Data,Springer, 237-255.

Peschiera, G. and Taylor, J. E. (2012). "The impact of peer network position on electricity consumption in building occupant networks utilizing energy feedback systems." Energy and Buildings, 49, 584-590.

Petersen, D., Steele, J., and Wilkerson, J. (2009). "Wattbot: a residential electricity monitoring and feedback system." Proceedings of the 27th international conference extended abstracts on Human factors in computing systems, ACM, 2847-2852.

Petersen, J. E., Shunturov, V., Janda, K., Platt, G., and Weinberger, K. (2007). "Dormitory residents reduce electricity consumption when exposed to realtime visual feedback and incentives." International Journal of Sustainability in Higher Education, 8(1), 16-33.

Petkov, P., Ko ̈bler, F., Foth, M., and Krcmar, H. (2011). “Motivating domes- tic energy conservation through comparative, community-based feedback in mobile and social media.” Proceedings of the 5th International Conference on Communities and Technologies, ACM, 21–30.

Pierce, J., Fan, C., Lomas, D., Marcu, G., and Paulos, E. (2010). “Some consideration on the (in) effectiveness of residential energy feedback systems.” Pro- ceedings of the 8th ACM Conference on Designing Interactive Systems, ACM, 244–247.

Prindle, B., Eldridge, M., Eckhardt, M., and Frederick, A. (2007). “The twin pillars of sustainable energy: Synergies between energy efficiency and renewable energy technology and policy." Washington, DC: American Council for an Energy-Efficient Economy.

Strengers, Y. A. (2011). "Designing eco-feedback systems for everyday life." Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, ACM, 2135–2144.

Ueno, T., Sano, F., Saeki, O., and Tsuji, K. (2006). "Effectiveness of an energy-consumption information system on energy savings in residential houses based on monitored data." Applied Energy, 83(2), 166–183.