Social Computing for Home Energy Efficiency: Technological and Stakeholder Ecosystems

Marc Torrent-Moreno[1], Rafael Giménez[1], Regina Enrich[1], José Javier García[1], and María Pérez[2]

[1] Barcelona Digital Technology Centre, Roc Boronat 117, 08018 Barcelona, Spain
[2] Gas Natural Fenosa, Avenida de San Luís 77, 28033 Madrid, Spain
{mtorrent,rgimenez,renrich,jjgarcia}@bdigital.org,
mperezme@gasnatural.com

Abstract. Many initiatives exist with the goal of providing the required tools to improve energy efficiency of households. Encouraged by public administrations, supported by the private industry, and demanded by an environmentally-aware society, several systems are gaining attention, mainly, energy consumption sensors, smart meters, and energy management platforms. The latter pretend to increase their impact and engagement with emerging social networks focused on energy efficiency matters and applying knowledge engineering disciplines. This paper describes the current home energy efficiency ecosystem, outlines some missing pieces and advances required to achieve its potential outcome, and surveys the existing social media platforms.

1 Introduction

Carbon emissions are one of the major concerns in our society. We can witness different private, public and coordinated initiatives aimed at improving different energy-related aspects around the globe. A primary example is the 'climate and energy package' agreed upon by the European Parliament and Council in December 2008 in order to implement the 20-20-20 targets by 2020, which is encouraging the use of renewable energy sources, enhanced materials and improved energy management systems.

In this paper, we explore existing initiatives and systems where social media is envisioned to play a key role in assisting private users in reducing energy consumption in their households. Energy management systems will enable monitoring and recommend more sustainable practices and, according to existing studies, up to 35 million equipped households can be expected worldwide by 2014 [1].

Of course, these forecasts depend on several factors, most relevant being the timing of smart meter rollouts and early adopter engagement. Here, we will focus on the latter and describe the technological enablers that will assist in increasing consumer commitment, which is a major challenge. Indeed, while the social crowd claims to have become greener and publicly demands a more environmental friendly planet, there is a lack of individual adoption of conservation practices and a lack of knowledge with respect to behaviour or carbon footprint.

The principles and procedures of social media applied to the energy efficiency scenario can provide the engagement capabilities required to effectively integrate

A.A. Ozok and P. Zaphiris (Eds.): Online Communities, HCII 2011, LNCS 6778, pp. 229–238, 2011.

consumers into the service provider strategies. In addition, the performance and reach of these platforms can be enhanced by refining services, contents and interaction according to the user profiling data captured and processed from smart metering devices. The tools provided to customers should supply more information than just how much energy they are consuming, but also how are they doing compared to other customers with the same profile as theirs, whether they are improving and how they can do better by applying personalized recommendations according to their profile, history and preferences. As a result, both user adoption and obtained value from these novel "smart" social media are expected to become major drivers for energy efficiency programs.

Further, the deployment of these platforms would benefit all actors in the play. Customers would save money by reducing their energy consumption and by profiting from time-based pricing. Access to information would lead to increased competitiveness between utilities, which in turn would offer improvements in the services offered. Moreover, utilities would see how their energy efficiency and loyalty programs are widely spread through comments from experiences of customers, providing the feedback necessary to evaluate their degree of success. Knowing how customers behave and what their expectations are could help utilities to design market strategies to flatten the load demand curve by shifting peak demand consumption to off-peak demand periods, thereby avoiding investments in new infrastructures to cover sporadic peaks in demand.

In this paper we first introduce the home energy efficiency ecosystem and identify the goals of the most relevant stakeholders (Section 2). Then, we describe the technological enablers that are required for the short-term success of energy management solutions and those which are envisioned to play a key role in the aim of developing sound solutions capable of bringing energy savings to consumers and achieving long-term user engagement (Section 3). Finally, we survey the existing cloud-based solutions developed to improve energy efficiency at homes, devoting special emphasis on implemented social computing features (Section 4).

2 Stakeholders

In this section we present the main stakeholders involved in the home energy efficiency ecosystem. First, however, we outline the main building blocks of the envisioned system as defined by the market for clarification and further reference.

As we can observe in Fig.1, we can identify three main building blocks: the utility is the energy provider (in this paper we focus on electricity, although it could also refer to gas, water, or a combination of any) which distributes electricity and commercializes the service (although companies distributing and commercializing could be different, it is not relevant within the scope of this paper). The utility owns the IT infrastructure required for billing and CRM purposes, i.e., includes all consumers' relevant data and profile, as well as the communication and energy distribution channels up to the smart meter. AMI (Advanced Metering Infrastructure) is the chosen term to name the smart meter and the communication channel up to the utility which enables remote readings. Further, new generation smart meters, located at the consumers' buildings, can include an additional communication interface that provides real time readings to the HAN (Home Area Network).

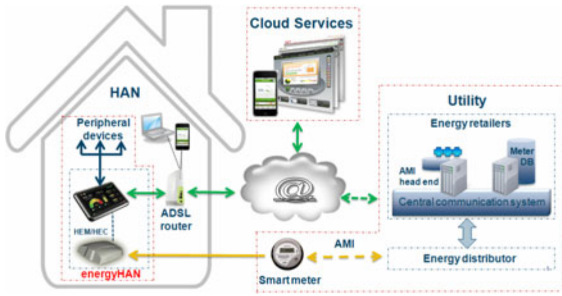

Fig. 1. Envisioned building blocks in the energy efficiency ecosystem

The energy HAN refers to the sensor network installed at home capable of monitoring relevant parameters of energy consumption (including devices' energy consumption as well as temperature, presence, etc.) and includes the energy management devices acting as energy hub. The energy HAN should be also capable of obtaining real time readings from the smart meter and contains a gateway to the internet (e.g., through the consumer's ADSL or 3G router) in order to connect to cloud-based services.

Cloud-based services are offered by an energy management platform implemented in the cloud, which extend those implemented in the home equipment. Obtaining real-time and detailed readings from user's energy consumption, these platforms enable key features such as data analysis and visualization, social computing for direct user interaction, and personalized utility services, among others.

Derived from the building blocks introduced above, we can, at first sight, differentiate the following stakeholders in the home energy efficiency field, each of them pursuing their own different goals:

Utility. Having the AMI being deployed in many countries (and to be soon in many others) to enable remote readings, utilities see the next step in implementing a direct, bidirectional and constant communication channel with their clients. Their interest in implementing this channel together with encouraging social media platforms is twofold. On the one hand, they can develop a new customer relations model based on better knowledge of the customer, including personalized services and loyalty programs. On the other hand, it will allow the building of more accurate demand estimations, which in turn allow for optimization of wholesale energy purchase. Early alliances with HAN manufacturers and cloud-based platforms will guide the direction of future business models and potential approaches to consumers. In a second phase, utilities pretend to develop better energy management strategies, including demand response programs and pricing policies. Further, these strategies will aim for the incorporation of renewable energy sources as well as the integration of electric vehicles.

HAN Provider. Current first-generation energy HAN systems are commonly composed of a clamp sensor, which monitors the aggregated energy consumption at home, and an optional energy management display. Both can exchange data wirelessly and send it to a cloud-based platform through the home internet connection. A dedicated home display offers the advantage, when compared to interacting with a cloud-based service through a computer, smartphone or TV, of being at the optimal place to quickly check the current energy consumption state or tariffs before switching on another appliance and triggering an alarm. Although a simple sensor can already differentiate some consumption patterns in an aggregated curve, e.g., identifying home appliances being used, a better consumption pattern will be acquired and consequently a higher saving potential will be achieved with a larger amount of sensors at the house, i.e., monitoring not only appliances independently but also relevant parameters such as temperature or humidity. Note that these independent sensors can also be actuators and therefore the user (or eventually the energy management unit or even the utility) could remotely control their usage depending on the current power consumption levels and tariffs. HAN providers' sole objective is the sale/installation of its products, either directly to clients or in partnership with a cloud-based service provider and/or a utility.

Cloud Services Provider. We have witnessed the launch of a few cloud-based services in the last couple of years, which are reviewed in Section 4. These can obtain real readings from home sensors or through web forms filled by the user. Developed by energy HAN manufacturers or third parties, their goal is to provide an appealing user interface with engaging features that achieve real energy savings. The most advanced aim is to analyze the user's consumption patterns and identify behavioural improvements through AI (Artificial Intelligence) techniques. Further, social computing features help engage and assist users with tips from other users, from experts or even automatically from the system. The business model behind these platforms varies, depending on whether they are standalone systems, if they are part of a complete solution including an energy HAN, or if they are deployed in partnership with a utility. Indeed, while as a social network advertising can be a direct source of revenue, the high interest of utilities in acquiring and managing the data (including user conversations) encourages both parties to discuss joint initiatives.

Public Administration. In accordance with sustainable planet goals, governments are establishing more concrete actions and policies which are relevant for this field. Although some, such as the US and several European countries, have begun enforcing the adoption of smart meters, their position with respect to additional policies is still unclear. It would definitely encourage the adoption of energy HAN systems and boost the engagement of users if they would take further actions such as enforcing communication interfaces between meters and energy HAN, imposing time of use pricing, subsidizing equipment, and providing incentives for consumption reduction.

Consumer. When referring to their energy consumption, users have two main motivations: saving money in their monthly bill and reducing carbon emissions. However, since these savings will not always be very significant or will not be achieved without compromising on daily comfort, easy access and utilization as well as appropriate engagement methods are essential requirements. Currently, early adopters fit the profile of tech-savvy, ecologically-aware consumers and are interested in features such as real-time monitoring and remote access to the energy systems. However, when aiming at the mass market, solutions will have to provide more appealing interfaces, be extremely easy to use, and probably be integrated in a single product. Note that present-day consumers are in control, i.e., they can contract any utility, HAN provider and service that they wish, independently of each other. However, one dealer integrating the complete solution would certainly encourage its adoption by the mass market. According to [1], 81% of these would pay at least $150 for energy management equipment if they could achieve up to 30% savings, and more than 52% are willing to spend $5/month if they can save up to 10%.

Additionally to those described, the interest of other entities is witnessed which see energy management as a potential killer application for home control systems. These entities, which could help boost energy HAN adoption, are mainly providers of home networking, domotic and security systems as well as telecom operators.

3 Technological Enablers

Although the future looks promising and the benefits are clear, we are still some steps away from achieving the maximum potential outcome of a complete solution. Indeed, several ICT building blocks still require advances in terms of standardization or technological enhancements. In the following section we describe the state of the art and current trends of the main ones: namely, smart metering and energy HAN systems, knowledge engineering capabilities, human-computer interaction technologies, and social engagement strategies.

3.1 Communication Interfaces between Smart Meters and the Energy HAN

The smart meter is a key component of new AMI deployments. As such, communication aspects from the smart meter toward utilities backend systems are clearly defined and standardized by institutions such as NIST in USA, or by Mandate 441 of the European Commission. Also, although different communication technologies are implemented in existing energy HAN products, such as Z-Wave or HomePlug, ZigBee seems to be the current trend for these networks.

With respect to the communication between both systems, i.e., the smart meter and the energy HAN, although a large percentage of current solutions implement ZigBee, it still remains as an unresolved challenge how best to cover multiple scenarios, from small houses to large apartment buildings. Along this line, standardization efforts like those fostered by EU commission mandate 441 and the CENELEC TC 205 working group will further strengthen the "smart metering – HAN" as an enabler for innovative energy efficiency applications and services.

3.2 Knowledge Engineering

The transformation of raw data into knowledge supporting the operation of expert systems plays a central role to realize the full potential of the described platforms. Although there's no a unique vision on the technical approaches to fulfill the lifting from data to knowledge, the concept of knowledge engineering is regularly used to embrace all the involved disciplines. In the following section we have depicted those which are more relevant in the scope of this paper, ranging from traditional data mining techniques to those closer to artificial intelligence such as user profiling and recommendation, with a special focus on the semantic technologies as the state-of-the-art framework for knowledge acquisition.

Ontological Modeling. Within computer science, ontologies provide an exhaustive and explicit conceptualization of a given domain that fosters the transfer and processing of information between systems. In the specific domain of the described platforms, the rich domain conceptualization enabled by an ontology offers a powerful framework for the development of semantic recommender systems by increasing the understanding of the user and social dynamics [2]. From the basis of the existing ontologies for user modeling (SUMO, GUMO [3], UbisOntology), social graphs (XFN and FOAF) and social media content (SIOC Core Ontology), modeling the target domain requires an extension of those to correlate specific topics related to energy efficiency such as climate, building characteristics, household appliances and household composition.

User Profiling. User profiling techniques provide the basic background for profitable and sound performance of recommender systems. Through user profiling techniques systems can map the interests, preferences and wants of users and match the generated recommendations on a systematic and model-based basis. As previously stated, semantic modeling based on ontologies provides the most powerful framework today to maintain and exploit user profiles. Techniques for user profiling are grouped under two basic models: implicit and explicit. In the depicted scenario user profiling based on customer attributes is also connected to the characterization of the consumption behavior based on consumption data mining, and the identification of proper refinement mechanisms for created models arises as one of the main challenges.

Data Mining. As previously stated, the discipline of data mining is highly relevant for systems based on the processing of massive amounts of data such as those described here. In the context of energy platforms data mining is useful to reinforce user models according to the different consumption patterns found in the data. The most common techniques used in data mining are decision trees, nearest neighbor classification, neural networks, rule induction, and K-means clustering [4]. Some open research challenges deal with finding out which works best for profile representation, how to categorize variables, how to normalize them or which is the distance function which defines if two users are similar concerning energy efficiency.

Recommenders and Semantic Reasoners. In the described system, recommender engines provide the computational capabilities to select and present information that is interesting to the user. Recommender engines compare stored user profiles to some key attributes in the information to predict the "rating" that a user would assign to an item he doesn't know. The performance and accuracy of recommender engines is crucial for user engagement in energy management platforms. The integration of context-awareness into recommendations, the enhancement of system scope by adding learning capabilities supporting changes in consumer's behavior, and the ability to collect data from disseminated and heterogeneous data sources are some of the main open challenges being addressed by research in the area today.

Social Media Tracking. The application of information retrieval techniques to social computing provides a great potential for knowledge acquisition from user-generated content, but these techniques must be properly adapted to the specific features of the social data: scalability, real-time, content duplication and lack of structure. As above mentioned, the central corpus of knowledge acquisition methods for social media can be expressed as applied adaptations of some of the traditional information retrieval techniques: data harvesting or web scraping, filtering, opinion and sentiment mining, activity tracking, and pattern detection and learning on similarity metrics [5].

3.3 Human-Computer Interaction

The relevance of Human-Computer Interaction (HCI) as a success factor for social computing platforms is increasing in accordance with the growing complexity of contents and activities these systems deliver. Providing an optimal user experience as a tool to elicit of the level of participation is the final goal of HCI in social computing. At the same time, recommender systems such as the ones depicted in this paper also pose some specific challenges to the discipline of HCI. Together with good algorithms, recommender systems must provide usable and intuitive interfaces for presenting suggestions and capturing opinions [6]. The visual representation of reputations and trust levels is also a challenging aspect addressed by research today [7]. In addition to that, the heterogeneity of the devices shown in the energy efficiency scenario also introduces some issues to HCI. Devices with constrained computational capabilities and reduced interface capabilities are highly useful in multiplying the information displays which the system offers to the user, but technologies must be adopted to fit those specific device requirements.

3.4 Social Engagement

Although it should not be specifically considered as a technological research area, the strategies for user engagement are a subset of the interaction design with a highly relevant impact on social computing.

Modern approaches on user engagement agree on the need for a consistent design of the reputation and reward policies, the development of a shared culture among the platform users and the deployment of a consistent behavior from the platform administration side. Techniques and mechanics inherited from game play are performing today as those displaying best results to raise user engagement. In a phenomenon known as gamification, this approach makes technological platforms more engaging by encouraging desired behaviors. Well-known techniques such as achievement badges, leader boards, or the delivery of virtual currency are in the state of the art of the user engagement through gamification.

4 Current Solutions

There are many ways in which the combination of resource consumption data and social networks can be leveraged to influence the behavior of occupants and managers. The use of social media solutions as a way to reach end users and provide value-added services towards energy efficiency (whether in homes, offices, or any other scenario) is relatively new. The main objective is to empower, engage, educate, and motivate users toward smarter resource usage, both individually and within a community as a whole. In general, these social media-based energy efficiency solutions are based on appealing graphical user interfaces that allow users to introduce energy consumption and specific user profile data, keep track of their energy consumption, or receive valuable feedback based on this information. Integration with other social networks such as Twitter or Facebook is a common mechanism used to foster interaction between users, make data even more visible and accessible, and finally promote the use of the tool within a larger community.

At the time of writing, several solutions are either available on the market or nearing launch. The main ones and their distinctive features are as follows:

Welectricity is a free stand-alone web service with a community of users from 72 countries, which is based on a dashboard that let users compare their energy consumption with that of others with similar profiles and keep track of their energy efficiency goals as well as other features.

Building Dashboard Network is a cloud-based platform released in 2010 by Lucid Design Group, which claims to be the first social network for buildings. It is focused on the use of evolvable tools that promote individual behavioral changes towards community-wide energy and water use and conservation goals. It is currently deployed in commercial, institutional and residential buildings, mainly located in the USA and Canada.

Microsoft Hohm is a free online application based on the use of advanced analytics licensed from Lawrence Berkeley Labs and the US Department of Energy, developed to provide personalized energy-saving recommendations to users based on their profiles and consumption data which they provide (or which is obtained through integration with third-party hardware solutions).

PeoplePower Energy Services Platform is a software platform based on a broad range of data mining, analytics, and reporting tools, designed to work in conjunction with an embedded hardware platform intended to provide energy monitoring and control capabilities to virtually any electronic device.

Google Power Meter is a cloud-based tool designed to be easy to integrate and to use data provided either by utilities, smart meters, or third-party energy monitoring devices. The platform is able to learn the energy consumption habits of a user, as well as to derive community-level patterns used to provide personalized useful tips, engagement, and motivation tools among users.

Enerbook is a web-based social network created by the Portuguese company ISA as a complement to ISA's iMeter in-house solution for energy efficiency monitoring and control. The portal provides iMeter users a set of evolving social networking tools to enable interaction and sharing of experiences.

Current solutions comparison. In Table 1 we present a summary and comparison of the main characteristics of the social media solutions analyzed. We focus our comparison in four key areas: energy data source (to provide an idea of how the solution obtains the data used), user-focused features (either personalized tools for a specific user or tools provided to enable social interactions between users), deployment responsibility (whether the service is integrated in the utility's back-end, or is a standalone service), and the current state of the solution in the market.

Although it is too early to identify which will be the most adopted solution, it is clear from the results obtained from first deployments of these solutions that social community tools and the integration with other successful social networks will play a key role in current and future energy efficiency solutions. The use of user profiling techniques, a reliable source of data, and powerful data processing mechanisms will allow these solutions to offer users better functionalities and services. However, there is still a large margin for improvement, particularly in the current knowledge engineering mechanisms that are the heart of these energy efficiency social tools.

Table 1. Feature comparison of existing cloud-based energy management services including social computing features

	Welectricity	Building dashboard	Microsoft Hohm	People Power	ISA's Enerbook	Google Power Meter
Energy data source						
From users	✓	✗	✓	✗	✗	✗
From utility	✗	✗	✗	✓	✗	✓
Own BEM/HAN solution	✗	✓	✗	✓	✓	✗
Integration with 3rd parties BEM/HAN solutions (monitoring)	✗	✓	✓	✓	✗	✓
User focused features						
Explicit user profiling	✓	✗	✓	✓	✓	✓
Implicit user profiling	✗	✗	✓	✓	✗	✓
Real time feedback (user awareness)	✗	✓	✗	✓	✓	✓
User motivation features	✓	✓	✓	✓	✗	✓
User's energy "coaching" (Personalized advises, tips)	✓	✓	✓	✓	✗	✓
Other services (BEM/HAN device's local/remote control)	✗	✗	✗	✓	✓	✗
Social community tools (Competitions, experience sharing)	✓	✓	✓	✓	✓	✓
Third party social networks connectors (facebook, twitter, etc)	✓	✓	✗	✓	✗	✗
Deployment responsibility						
Integration within utilities' backend	✗	✓	✓	✓	✗	✓
Stand alone service provider	✓	✓	✓	✓	✓	✓
Current state						
Commercial use	✓	✓	✗	✗	✓	✓
Under development	✗	✗	✓	✓	✓	✗
Controlled trials	✗	✗	✗	✗	✗	✓

5 Conclusions and Outlook

Social media platforms are envisioned as key components for the successful adoption and long term engagement of consumers with household energy management systems. Such systems can benefit many actors in the play, from customers to utilities. On the one hand, private users would be assisted by service providers or other peers in the goal of reducing energy consumption, would obtain enhanced and personalized services, and would earn social acknowledgement. On the other hand, utilities would have access to data that would allow them to build loyalty programs as well as implement improved demand response and pricing programs.

Currently, several cloud-based solutions exist that aim at monitoring user energy consumption and incorporate social media features. However, these could be further improved with knowledge engineering algorithms which would assist analysis and recommending engines that could, in turn, improve user acceptance and engagement. Furthermore, not only product-based improvements, but also business models and the way consumers will be approached (e.g., which stakeholder will sell and install the energy management system) need to be well defined. The complete service must be easy to contract and use in order to avoid user disappointments which would make it difficult to achieve large penetration rates.

Early alliances among stakeholders will define future business models encompassing relationships between utilities, energy HAN manufacturers, and cloud-based service providers. Currently, utilities are very active in stimulating the market and positioning themselves, even though technology may not be ready for the mass market. Obviously, the role of the public administration will be key in the development of this sector, with the ability to encourage it by enforcing communication interfaces between smart meters and HAN, subsidizing energy management equipment, or providing incentives for energy reduction.

Further, a second generation of energy management systems is envisioned which will offer automation features to further optimize consumption rates and could be capable of identifying both malfunctioning devices (which are not efficient any longer) or suggest new and more efficient ones. Moreover, other aspects such as the introduction of renewable energy sources and the integration of the electrical vehicle into the house grid may drive the smart energy management system to become an indispensable device in every household.

Acknowledgments. The authors would like to thank Greg Gladman for his insightful comments which significantly contributed to the final state of this paper.

References

1. Hatler, M., Gurganious, D., Chi, C.: Smart Energy Homes A Market Dynamics Report. In: Onworld Study, Onworld (2010)
2. Sheth, A., Nagarajan, M.: Semantics-Empowered Social Computing. IEEE Internet Computing 13(1), 76–80 (2009)
3. Heckmann, D., Schwartz, T., Brandherm, B., Schmitz, M., von Wilamowitz-Moellendorff, M.: GUMO – The General User Model Ontology. In: Ardissono, L., Brna, P., Mitrović, A. (eds.) UM 2005. LNCS (LNAI), vol. 3538, pp. 428–432. Springer, Heidelberg (2005)
4. Berthold, M.R., Hand, D.J.: Intelligent Data Analysis. Springer, Heidelberg (2003)
5. Appan, P., Sundaram, H., Tseng, B.: Summarization and Visualization of Communication Patterns in a Large-Scale Social Network. In: Ng, W.-K., Kitsuregawa, M., Li, J., Chang, K. (eds.) PAKDD 2006. LNCS (LNAI), vol. 3918, pp. 371–379. Springer, Heidelberg (2006)
6. Knijenburg, P., Bollen, D., Schmidt-Thieme, L.: Workshop on User-Centric Evaluation of Recommender Systems and Their Interfaces. In: RecSys 2010. ACM, New York (2010)
7. Egger, F.: Interface: How to Maximize Perceived Trustworthiness? In: Proceedings of the International Conference on Affective Human Factors Design, pp. 317–324. London Academic Press, London (2001)