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Original research article

Smart meters and energy savings in Italy: Determining the effectiveness of persuasive communication in dwellings

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ABSTRACT

To secure a sustainable energy development in the residential sector, attitudes and human behavior need to be modified toward more efficient and conscious energy usage. The goal of this research is to assess evaluations and to test the effectiveness in reducing domestic electricity consumption. The aim of the smart monitoring system we evaluate is to provide households with a user-friendly tool that improves awareness of energy behavior in homes, enabling better management via the visualization of consumption and persuasive tailored information on domestic electricity use. In our study, the system was tested on 31 Italian families selected among volunteers all over Italy, participating to the first trial phase from October 2012 to November 2013. A combination of persuasive communication strategies such as graphical real-time and historical feedback based on real data and comparison tools to encourage competitiveness against "similar" households were provided to users through a domestic user-friendly interface. In addition, personalized energy saving prompts were sent via web-newsletters to trial users. The study concludes that energy related persuasive communication is effective in reducing electricity consumption in dwellings on average −18% and up to −57%.

1. Introduction

Extended literature studies [1–5] confirm occupant behavior to be setting the direction for contemporary researches aiming to bridge the gap between predicted and actual energy consumption in residential buildings. Since the stochastic nature of occupant behavior, the mutual influences between human-building-environment cannot be described in a simplistic way, rather it requires appropriate methodologies and techniques able to comprehend, describe and reproduce the leverage of occupant behavior on building operation. In a view of these facts, Stern [6] firstly highlighted a growing interest around the enhancement of an integrative, trans-disciplinary science of human–energy interaction.

Moving toward a model to understand household behavior, the human decision to behave in a certain way is driven by a wide range of internal and external factors [7]. Specifically, in the area of domestic energy consumption, there is a need to take into account the physical, social and cultural factors that influence and/or constrain user's choices and behaviors, such as age, gender, social class, income, geographical position and political differences, aside from information provisions and economic incentives. Moreover, a study conducted in 2003 by Shove [8] shown the domestic energy consumption is influenced by dominant conceptions of comfort, cleanliness and convenience. Interesting examples can be found in the field of domestic energy consumption where, in spite of successive campaigns, the take-up of energy efficiency measures has been disappointing and behaviors have often become more energy-intensive. The most widespread explanation relies on lack of information of the leverage of occupant behavior on energy consumption variations. Human attitudes and behaviors are driven by a complex interaction process: for this reason an interdisciplinary understanding is a pre-requisite for any strategy aimed at changes. Thus, disciplines such as sociology, social psychology, anthropology and building physics are increasingly cooperating for providing findings into behavioral patterns of energy consumption in households.

1.1. Electricity consumption in the residential sector

In 2003 the International Energy Agency (IEA) estimated [9] that, even with a continuation of all existing appliance policy

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measures, the appliance electricity demand in the residential sector will grow by 3000 TWh/year by 2030. Accordingly to a later 2007 projection of the EU Commission [10], the final energy net electricity demand in the European residential sector will grow by 2030 by 3800 TWh/year. The most update 2009 projection lowers the tendency by 3600 TWh/year by 2030.

In a view of these facts, although significant improvements in energy efficiency have been achieved in home appliances and lighting, the average electricity consumption in the EU-25 households has been increasing by about 2% per year during the last 10 years [10]. Some of the reasons for such increase in the residential sector electricity consumption are associated with a higher degree of basic comfort and level of amenities (particularly in the new EU member countries) and also with the widespread utilization of relatively new types of loads whose penetration and use have experienced a very significant growth in recent years.

The introduction of energy labels, implemented with EU Directives in the last ten years, has produced a positive trend in the sales of more energy efficient appliances. Consumers have responded positively to this mandatory information scheme enabling comparison of energy-efficiency of various appliance models through the ranking into the proper energy class (A–G). The introduction of even better energy classes (A+ and A++) and the broadening range of appliances labeled are thought to produce even greater electricity savings. Nevertheless, due to technological limitations in further reduction in energy consumption, nowadays white goods and appliances have reached an asymptote in enhancement of energy efficiency.

Smart electricity meters and home energy communication and management systems are shown as powerful tools for modeling residential end user electricity demand patterns as well as testing ability and potentiality to reduce or adjust domestic consumption. Results of several studies [11–13] underlined that the energy saving potential by improving occupant behavior through persuasive communication is on the average among 15%. In this context, the evolution of the electric power system to include home energy communication and management systems offers more flexibility to energy customers and creates new challenges and needs for energy providers, distributors and appliances utilities. Also, with the aim of better aligning electricity generation and demand, this study is stressing the paramount role of domestic energy users both as passive energy consumer and active energy prosumers (producers and consumers). In this view, the employment of home energy systems in the residential sector is demonstrated as capable to reduce energy bills by shifting peak consumption and managing peak demand [14]. Various optimization strategies and methodologies are proposed for the efficient coordination of domestic appliances. Studies are conducted at the academic, industry and government level both by international and national organizations. A study conducted by Sarah Darby in 2008 [15] presented an interesting literature survey of the persuasive methods that result in positive energy behavioral change.

1.2. Energy saving potential by improving occupant's behavior in dwellings

The electricity energy consumption is rapidly increasing in the last years due to the use of a higher number of electric appliances, reflecting the higher economic status of the householders and their lifestyles. Nowadays, consumption becomes an act of pleasure beyond satisfying basic needs: consequently, our changing lifestyle has dramatic impact on world energy demand. Many serious worldwide problems accompany the increase of electricity use such as global warming, urban heat island, environmental pollution, CO_2 emissions and degradation. Common citizens rarely care about these inconveniences and are often not aware that the energy they consume in their daily domestic activities is so closely related to the climate change issue. Moreover, occupant behavior at home can enormously vary based on different energy related behavioral patterns: accordingly, Andersen in 2012 [16] demonstrated that energy consumption in almost identical dwellings may increase up to a scale of 3. Hence, reducing energy-demand is an important task to face with, not only worldwide, but also at a household level is some way.

With the aim of reducing energy consumption in the residential sector Wood and Newborough [17,18] advanced three general routes to pursue in the residential sector:

i. replacing the existing housing stock with low energy buildings designed primarily to minimize heating and cooling loads;
ii. developing and achieving widespread replication of low-energy domestic equipment (e.g., appliances, lighting)
iii. promoting and achieving "energy-conscious" behavior among householders.

Another possibility, mentioned by studies conducted by Ueno et al. [19,20] is to induce energy saving potential by providing household members with information on actual domestic energy consumption. While the former two technical routes require much money (high capital intense investments) and time (long term results achievement) to accomplish energy improvement, a change of behavioral pattern by energy-saving education of users can save energy without almost any additional investment in infrastructure (low capital intense investments); moreover, the energy-saving effect can appear quickly (short term results achievement).

1.3. Empowering domestic user awareness by energy consumption displays

The concept of displaying energy consumption to domestic consumers in order to promote energy saving behaviors has been suggested since 1970s [21]. Nowadays, home automation technologies allow displaying energy information with the aim of educate, motivate, incentive and persuade domestic users toward energy saving behaviors. Field studies on environmental behavior conceptualized persuasive strategies, pointing out that energy consumer may be influenced by antecedent (general) and consequent (feedback) information. Antecedent strategies announce the availability of positive or negative consequences through information, prompts, demonstration and commitments. Such supply information describes practical ways for reducing energy consumption and could be in the form of brochure, notice, booklet posted through the door, TV programs or Internet sites. Several field studies (Dennis et al., Winnet et al.) [22,23] reported that significant energy savings can be achieved by providing antecedent information about methods of energy conservations. However, antecedent information has proven to be less effective in accomplishing behavioral changes than consequent information.

Consequent strategies provide feedback of positive or negative consequences through prompts, real time visualization, and tailored information. Van Houwelingen and Van Raaij [24] found that the most effective feedback is that which more immediately follows an action. Moreover, Stern [25] argued that it is not the time step differences between days, weeks and months that is important to communicate to users, but that the feedback appears immediately after an action that attempts the goal of energy saving. Stern also stated that the most effective energy information is that which captures the attention of the audience, gains involvement and is credible and useful in the user situation.