Raise Energy Awareness to Drive a Sustainable Energy Transition in Household

Matteo Nardello
Department of Industrial Engineering, DII,
University of Trento, Italy.
matteo.nardello@unitn.it

***Abstract*—A sustainable energy transition means substantial changes in technology, but also a change in behavior and policies, thus requiring the engagement of both the engineering and the social science communities. In order to achieve the EU 20% reduction on primary energy consumption target by 2020, a change in consumer behavior and energy consumption practices is needed. Providing smart meters and technology for feedback about energy consumption have been considered strategic in current energy policies, as part of the battle against climate change. However, feedback alone does not always lead to energy savings. Beyond information on their own consumption and generic advices, people usually still need more specific guidance about how to change their behavior in an effective and sustainable way. Energy demand is mostly influenced by end user choices and behaviors, making the effectiveness of the adoption of new technologies not effective as expected. This article discusses how technology and electricity consumption feedback alone may not be sufficient to drive a sustainable energy transition. The need of taking into consideration also the socio-economic aspect to understand what motivates consumers' energy consumption is outlined, presenting some ideas to inspire consumers to act beyond their only personal interest and to engage in a transition to a more sustainable-energy usage.**

I. Introduction

The growing industrial and residential carbon footprint are the main actors of the ongoing processes of climate change. While industry's contributions to greenhouse gas emissions can be limited by regulatory legislation introduced by governments, limit and optimizing the energy consumption of domestic households is difficult, as it requires engaging consumers in changing their habits. Actions to increase public awareness, to induce behavior change and to provide education, constitute an important element of policies and programs to support energy efficiency and energy savings. Therefore, local governments started promoting energy efficiency through programs, such as the Energy Efficiency Directive (2012/27/EU) adopted in 2012 to enhance the improvement of energy efficiency in the EU zone [1].

To ease the process of addressing energy usage in the domestic sector, utility companies are replacing the old power meters with new smart meters [2]. These devices are able to report energy consumption in real-time. Moreover, in recent years they are capable of recognizing single appliances consumption with just a single meter for the whole building [3], [4]. With this new source of real-time energy usage data, consumption can be expressed as cost, kilowatt hours (kWh), or carbon dioxide emission (CO2e, the standard unit to quantify greenhouse gas emissions), and reported to the user. This can help to conserve energy with the prospect of saving money, or by promoting environmentally friendly behaviors.

However, the energy saving process is rather complex, leading to irrational methods for dealing with energy conservation [5], that often result in inefficient energy use. First, users have to make sense of the measurement units; Secondly, find out if they are efficient or not. Finally, implement proper actions to reduce energy use.

Despite various efforts to provide information to raise awareness about energy consumption, there is still a lack of knowledge among consumers of the economic potential for energy savings already available thanks to the existing policy measures and technologies. Many factors influence energy consumption in domestic buildings such as building insulation standards, the external meteorological conditions, the number of occupants, living habits and people's attitude towards energy consumption and use of appliances.

Research has shown that a slight change in behavior and life style could result in significant energy savings [6]. Hence, it is important for engineers to understand how their solutions may affect consumers, which behavior changes their solutions involve, and what must be considered when a new technology is administered to consumers [7].

Table I summarizes some of the main barriers [8] in the wide spread of energy efficiency measures discussed in the literature.

This paper will focus mainly on Structural/Technological, Economic and Social barriers. Section II will discuss why the technology alone cannot do all the job. Monetary incentives along with the induced drawbacks are discussed in Section III, while the importance of tailored feedback is examined in Section IV. Section V close this contribution.

II. The technological fix

The transition to a secure, affordable and sustainable energy system, is usually considered a technological challenge. Often a building gives away little about what is going on inside it, in term of energy flows, making difficult for occupants to understand how gas and electricity are used in their homes.

Energy efficiency can be defined as: "achieving the same services and performance while using a technology with a lower energy demand" [9]. A fundamental change in energy consumption habits is needed, moving to a better exploitation of renewable energies to meet emission reduction targets.

TABLE I
SOME OF THE MAIN BARRIERS THAT SLOW DOWN THE ADOPTION OF ENERGY EFFICIENCY MEASURES

Barriers	Definition	Reference
Structural barriers		
Lack of Standards	Lack of energy efficiency standards and common norms	[10]
Energy price volatility	Uncertainties of future energy price, limit the propensity to invest in efficiency measures	[10], [11]
Economic Barrier		
Lack of capital	High upfront investment cost of energy efficient technologies	[11], [12], [14]
Lack of information	Lack of information regarding the outcomes and benefits of efficiency measures	[12], [13]
Behavioral barriers		
Satisfaction	Users decision are driven by satisfaction. i.e. minimum effort principle	[15]
Other priorities	Users tend to prioritize other expense instead of in efficiency measures	[10], [11], [15]
Lack of knowledge	Limited understanding or education about energy efficiency	[10], [15]
Risk Tolerance	Users tend to avoid the prospect of a loss even with the prospect of certain gains	[12], [15]
Free-riding effect	Users seek benefits without having to pay	[15]
Social barriers		
Social comparisons	People tend to follow the social norm.	[10], [15], [14]
Trust	People seek information and judgment from those that they trust.	[15], [14]

One of the proposed policies to reduce greenhouse gas emissions is to stimulate the adoption of energy efficient technologies by households [16], as the domestic sector alone accounts for about a quarter of global greenhouse gas emissions.

Increase energy efficiency of residential building and houses is not a simple process. It can be achieved by implementing different measures:

1) the integration of renewable resources, like solar panel (fig. 1a) for both energy production and water heating;
2) the adoption of more energy-efficient domestic appliances, like condensing boiler, heat pump and LED lighting system;
3) the introduction of monitoring devices to report real-time energy consumption (fig. 1d), like smart meters along with Human Interface Device (i.e., portable display or smartphone apps [17];
4) the improvement of building efficiency, like the adoption of glazing windows (fig. 1c), or wall insulation (fig. 1b).

One further step to increase energy efficiency can be made by the introduction of District heating (fig. 2), that use the heat generated in a centralized location and distributed through a system of insulated pipes, for providing residential and commercial heating [18].

A. *Widespread limiting factors*

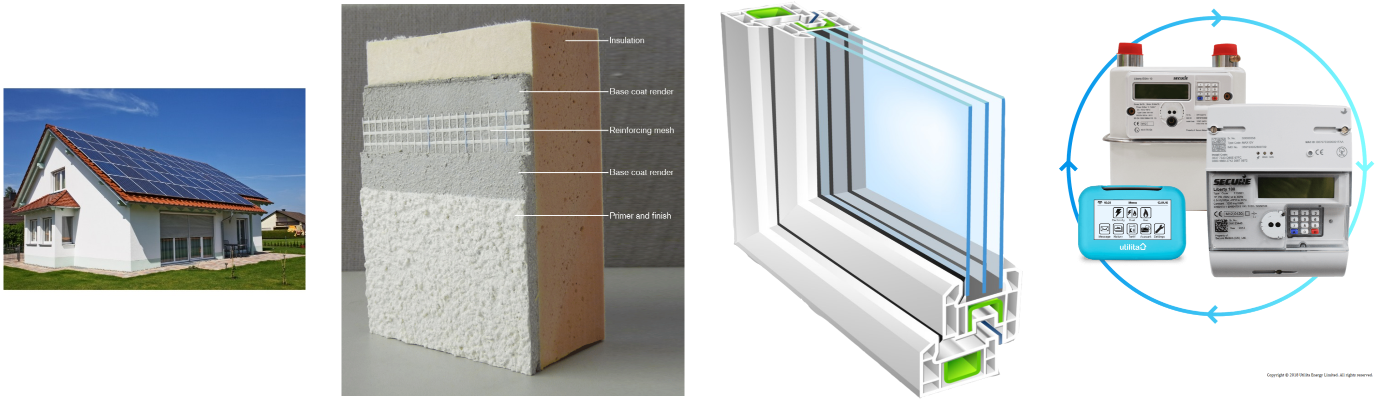
Although all the technologies discussed above are already available on the market, the desired level of energy efficiency in households has not been achieved yet. This can be partially attributed to how the technologies are administered and assimilated by the end user. An example are programmable thermostats that can lead to energy waste when not operated as designed by the manufacturers. As shown in [19], only a minority of householders fully understand programmable thermostats controls, with the final result of a higher energy demand.

Tackling the widespread problem from another side [20] highlights how users are still reluctant to adopt automated energy management infrastructure due to the additional hardware required by the sensing system. Moreover, users also concerned about what can happen if the system fails or begin hacked.

In addition to these limiting factors, the perceived hassle and inconvenience of installing energy efficiency measures have a great impact on the willingness of people to act, even when the cost barrier is removed by government incentives. This is the case of wall insulation works as shown by a survey conducted in the UK [21]. Authors observed that one major practical and psychological barrier is physical disruption and redecorating as one of the most commonly reported barriers to wall insulation projects. The ‘hassle factor’ plays a key role for the non-adoption of energy efficiency measures and may explains why many people who show an initial interest in retrofit measures drop out before the work begins.

The costs and benefits of policy interventions to influence consumer energy efficiency behavior are still much debated. Any new technological improvement has a social dimension that shapes the outcome of its adoption, both in terms of effectiveness and widespread. This has led to a slower rate of diffusion of energy efficiency investments, compared to the rate needed to ensure the expected energy savings.

The engineering approach usually lacks an analysis that includes more social and organizational understanding of energy systems and the right way to provide both advices and technology for improving the efficiency in household. For this reason, it is important to move to an approach that recognizes complexity and pays attention to communicating how and why technology works, that combines intuitive design, expertise and learning through experience in order to address the social



(a) (b) (c) (d)

Fig. 1. Different technologies for improving energy efficiency in buildings. (a) PV panels. (b) Wall insulation. (c) Triple glazing windows. (d) Gas and electricity smart meters with HID for providing feedbacks to users

dimension effectively.

This adoption problem has been defined as ”energy efficiency gap” [14], [13], [22].

III. Understanding monetary incentives

Monetary incentives to promote the reduction of energy consumption in the domestic sector are often the first strategy implemented by governments and policy makers. Energy prices play an important role in electricity consumption. Monetary incentives are divided into two categories, bringing either direct or indirect benefits to end-users.

Direct incentives are economic incentives provided by policy intervention targeted in promoting the adoption of new technology, like the installment of heat pumps, solar panel or energy-efficient appliances. Two type of investments can be highlighted with regard to energy efficiency measures: energy efficient appliances and energy efficient retrofits. Investments in energy efficient appliances are defined as the purchasing of higher class (i.e., A+) energy efficient appliances; while energy efficient retrofit investments refer to major structural improvements to the house typically involving changes or upgrades to the building structure, such as wall insulation and double glazing, or changes to the heating and hot water system.

Indirect incentives promote pro environmental behaviors, like curtailment behaviors [23].

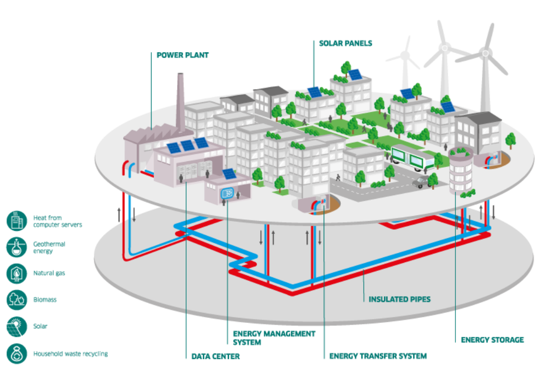


Fig. 2. District heating example

These are the daily and habitual habits of households that can reduce the energy demand. They can focus to consume less of something, by doing things in a different way, with less environmental impact, or whether or not to do something.

Saving electricity is composed of various activities that reduce the amount of energy consumed, like not using the air conditioner, drying clothes outdoors on the line instead of using the dryer, or using the public transportation services instead of private vehicles.

Either actively or passively, households make decisions regarding how to use their major energy systems, most of the time, without knowing the impact of their decisions. For example, they select the temperature of the water of the washing machine. Decide the dishwasher cycle to use; The internal temperature of their home in the winter and in the summer and whether to leave lights turned on and appliances in standby or turn them off. Curtailment efforts require changing strong habits that people are generally comfortable with and hence are often seen as a personal sacrifice.

Indirect incentives can also aim to move the time of energy usage to match the availability of renewable resources or to off-load the grid during peak hours, in order to remove the need of switching on additional power plants to cope the energy demand. This is usually achieved by providing dynamic energy prices, based on grid level or the time of the day.

A. Money incentives effectiveness

Although there are limitations to the effectiveness of monetary incentives, some studies have founded that they may sometimes be an effective tool to foster the reduction of energy consumption in the domestic sector. A survey conducted by Albertini and Bigano [24] evaluated the effects of monetary incentives on the propensity to replace the heating equipment with a more efficient one. The study was based on the data collected in 2013 during a two-month online survey, with a total of 3025 completed questionnaires collected. Authors have pointed out how there is a direct relation between the amount of incentives received and the likelihood of replacing the heating system. Results have shown an increase of 3% in

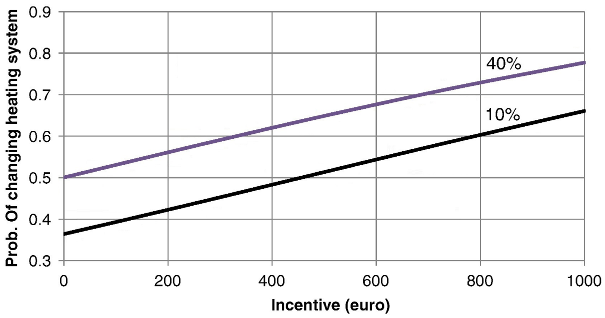


Fig. 3. Relation between the willingness of changing heating system in regards to the given incentives. Purple curves refers to a saving equal to 40% while the black one to 10%

the willingness every 100-euro incentive increase as depicted in figure 3, that show the relation between incentives and probability of changing heating system, both with 10 and 40 percent of proposed energy saving. Authors has also highlighted the theoretical CO2 reduction in relation to the saving (figure 4).

This behavior is also confirmed by a 2011 study that reported how of nearly 5000 southern California households with solar panels, approximately 1500 participated in third-party ownership programs, where the up-front cost for the installment of the related equipment were reduces thanks to incentives offered by commercial companies.

Another interesting study comes from Japan [25]. Authors have shown how the percentage of energy saved can be further increase if, along with monetary incentives, users are given social comparison feedback showing energy use compared to that of neighbors.

B. Money incentives downsides

It is commonly assumed that providing financial aids to support people in tackling possible risk and costs increases the probability they will invest in energy projects. This hypothesis is supported by the fact that if you ask people directly what motivates them most, they will mention monetary incentives. Financial incentives can indeed have positive effect on public acceptability, especially when large investment is needed.

However, this type of incentives does not always meet the expected effect, especially when the amount is small in respect to the effort required by the user. Monetary incentives must be carefully tailored, in order to consider the private costs and benefits of the promoted behavior. When private costs in terms of effort and comfort are relatively high (i.e., building isolation projects), also the proposed benefits need to be high as well. If people focus exclusively on the private cost versus benefits, they may not be likely to engage in the change.

Efficiency behavior often take large investments, which are covered by energy saving only after a long period of time. An example is the pay-back period of a solar system that may be 10 years or more, making the consequent monetary savings perceived as not worth the effort, as most people prefer receiving money now, compared to receiving a higher amount in the future.

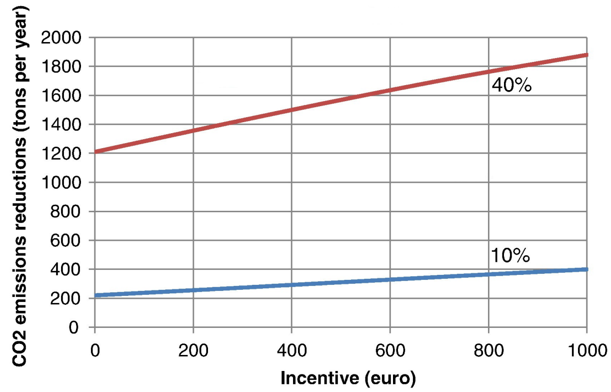


Fig. 4. Estimated CO2 reduction per year, respectively with 10% and 40% proposed saving

Another downside of providing financial incentives for reducing fossil-energy usage is that doing so may threaten households' intrinsic motivation to engage in efficiency behavior they would have engaged in anyway. Research has found that offering an extrinsic reward in the form of monetary incentive tends to reduce intrinsic motivation for that behavior. These effects are especially pronounced among consumers who care about the environment. This is confirmed by [26] that highlight how the willingness to enroll in a residential energy saving program, is higher when emphasis is given on environmental benefits instead of monetary benefits.

Another study suggesting that financial incentives may not be the best way to promote energy conservation is [27]. Authors show that providing households specific, tailored and scientifically verifiable information about the associated environmental and health effects of their electricity consumption, can motivate behavioral changes about daily electricity consumption. This was particular effective on families with children, who achieved up to 19% energy saving with respect to the control group.

IV. ENERGY FEEDBACKS

Across the world, the initiative to switch from the old power meter to smart meters into residential home are gathering momentum, as proved useful to both end user and utility company. Smart meters integrate the ability to send accurate meter readings directly to energy providers, that can use this information for energy grid management, with the final goal to meet environmental and security of supply objectives. The same fine-grained data can also be used to provide to end-user advices for improving their energy consumption.

One the other end, smart meters, allows consumers to monitor their electricity consumption using an associated In-home-display (IHD) or companion app, helping them to have more control over their energy usage and spending.

The idea is that providing consumers with IHD based feedback along with tailored advices from the utility company, will allow users to gather information they need to: 1)Promote overall energy consumption reduction; 2)Move the consumption away from periods of peak demand: 3)Respond flexibly to periods of oversupply.

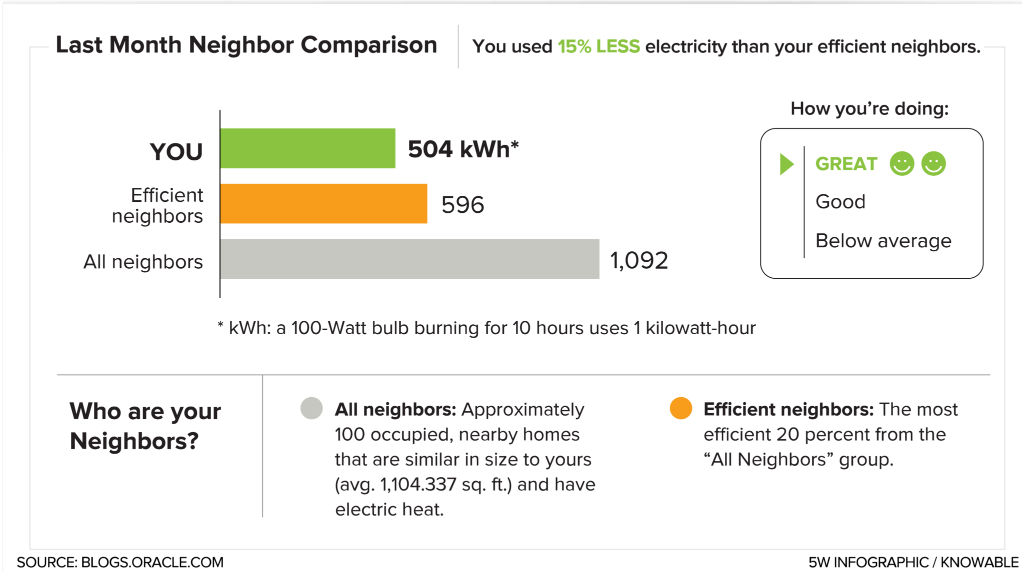


Fig. 5. Example of home energy reports along with social comparison feedback and desirable behavior provided by OPOWER [28]

Nilsson et al. [29], have analyzed the potential barriers in reducing the energy consumption by only providing IHD, concluding that the use of a display as such does not necessarily contribute to electricity savings. They have highlighted the need to include individual and specific feedback to household instead of generalized tips and information applicable to all, and how the information visualized should be simple and easily accessible, with simple diagrams and vivid color symbols.

To maximize the outcomes of IHD, the study indicates the need to provide end-user with the tools they need to understand energy feedbacks. This requires teaching end-user what energy units mean, along with the functionalities provided by the technical device. Moreover, a clear illustration of the connection between their behaviors and energy consumption and between energy consumption and related costs must be given.

A. *The importance of tailored energy feedbacks*

A multitude of studies have examined the extent to which feedback can reduce energy consumption whether they are delivered via an IHD or other means. This because it is crucial to understand how interventions can be designed to effectively reduce household energy consumption.

One strategy proven effective at promoting energy saving is providing social norm communications [30]. An example is reported in the report in figure 5, a report generated by OPOWER.

OPOWER [28] generates energy efficiency reports, which utilities then send to customer along with the monthly bills. A colorful bar graph compares the recipient's monthly energy consumption to his/her neighbors'. No names are used: the comparison is based on the average usage of 100 neighbors with similar-sized houses. A second chart compares the recipient's use to his or her most energy-efficient neighbors'. Those who do well get a smiley face; those at the top of their energy class get two. These information about the energy behavior of neighbors tend to motivate people to adapt their energy consumption to be in line with others. The classic example are solar panels. When they are installed in a neighborhood, there tends to be a spur on solar panel adoption, independent of income or population characteristics. This behavior is confirmed by [31] where energy consumption feedback was combined with additional information about the socially desirable behavior. Half of the consumers were provided with plain social norms feedback, while the other received additional information about the socially desirable behavior. Results have shown that the group receiving both information saved the most energy.

V. Conclusion

The current energy system is under transformation. New technologies promising great energy saving are becoming every day more popular among prosumers.

Unfortunately, the expected improvements in energy efficiency are lower than the outcomes enabled by the already available technology. Consumers choices and behaviors are to a large extent driven by cognitive biases and other unpredictably irrational tendencies. They are influenced by the people around them and usually evaluate things in relative rather than absolute terms. Moreover, they prefer lower value certainties over higher-value risks. We still need a better understanding about which incentives and other strategies may influence prosumers energy behaviors and under which circumstances. It is clear that a new approach that takes also into consideration the social e phycological impact of energy efficiency measures will be needed to match the energy reduction targets. Thus, it is important to consider all these aspects when developing strategies to encourage renewable and sustainable energy use and to motivate pro-environmental behavior.

ACKNOWLEDGMENT

The author would like to thank the financial support for this work provided by the student grant program of the IEEE Smart Cities initiative.

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