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Consumer Behavior in Building Energy Use

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Synonyms

Energy behavior; Occupant behavior; User behavior

Definitions

Economic theory of customer preference describes *consumer behavior* as a "set of activities prospective customers undertake in searching, selecting, valuing, assessing, supplying and using of products and services in order to satisfy their needs and desires" (Čavoški and Markovíc 2015).

When it comes to research in the field of energy consumption and energy efficiency, there is a lack of common understanding of what consumer behavior is, since it is strongly related to the technical, economic, sociological, and psychological models applied to understand how and why people perform energy-related actions, and to the disciplines which investigate these actions. Hence, consumer behavior might be referred, among others, as occupant behavior and energy behavior.

Occupant behavior has been referred as a set of "observable actions or reactions of a person in response to external or internal stimuli, or respectively actions or reactions of a person to adapt to ambient environmental conditions such as temperature, indoor air quality or sunlight" (International Energy Agency EBCP 2013). However, this definition does not take into account individual attitudes and reasons which lead to a specific action, which instead have been intensively studied in social sciences.

Energy behavior has been defined as "all human actions that affect the way that fuels (electricity, gas, petroleum, coal, etc.) are used to achieve desired services, including the acquisition or disposal of energy-related technologies and materials, the ways in which these are used, and the mental processes that relate to these actions" (International Energy Agency DSM Energy Efficiency 2014). Energy behavior is the one leading to end-use energy consumption, incorporating two implicit dimensions: the behavior itself and the associated energy consumption (Lopes et al. 2012).

Rather than agreeing on unique terms and definitions, this chapter aims at providing an over-view of the scope, policy implications, and characteristics of the consumer behavior in building energy use, focusing in particular on the household behavior in the residential sector. To the purpose of this work, all the terms above are assumed to embed energy consumption as subject of investigation; therefore, consumer behavior, user behavior, and occupant behavior are used indifferently.

Introduction

Consumer behavior is a key issue in understanding the impact that the society has on the environment. The human preferences and actions have both direct and indirect impacts on the environment, as well as on personal and collective well-being. Energy use is embedded in everyday routines, mostly in a silent way. Since decisions to use energy are generally unconscious, it is difficult to deliberately decide to save energy. Nevertheless, there is a growing awareness of the need to under- stand the human factor as a prerequisite to achieve the goals set at international level by the Paris Agreement and affecting national energy policies, and many researchers call for interdisciplinary knowledge and multidisciplinary efforts to address user behavior and thus unlock its energy efficiency potential.

Climate change is a fundamental societal challenge that brings the reduction of global warming and global carbon dioxide (CO_2) emissions on the top of the governments' agendas. Main contributors to CO_2 emissions are business, trans- port, and the residential sectors. The transport sector alone is responsible for more than 20% of the emissions worldwide. It is clear that demographic (i.e., age, gender, household composition), eco- nomic (i.e., income, employment status), and structural (residence location, working location) factors affect personal transport choices. Changing behavior in relation to transport modes has been studied for many years, although there are few results of the effectiveness of individual behavior change strategies in private mobility. A recent research on the effectiveness of nudges for sustainable consumption behavior (Lehner et al. 2016) has analyzed the impact of nudge mechanisms to influence personal transport behavior. Framing information and providing feedback on transport use and mobility patterns resulted to be effective instruments to influence travel behavior, together with changes in infrastructures and in physical environment, although it has identified the urgency for more large-scale experimentation and piloting in the field of mobility and travel behavior, as there is less research available in this domain than in others (e.g., residential and food sector).

Most of the research on consumer behavior has been essentially focused on the residential sector, investigating the human dimension of energy consumption with reference both to the occupants and to the energy-related behavior of key stakeholders.

Occupant behavior studies have mainly aimed at explaining the gap between theoretical and actual energy consumption in buildings (Steemers and Yun 2009; Yan et al. 2015; Van den Brom et al. 2018), identifying behavioral patterns and house- hold characteristics driving certain behaviors (Van Raaij and Verhallen 1983a; Gram-Hanssen 2010; Ben and Steemers 2018), supporting decision-makers in promoting energy saving behavior (Frederiks et al. 2015).

Space heating represents the largest share of household consumption. In 2016 in EU, household consumption for space heating, water heating, and electrical appliances accounted, respectively, for 65%, 15%, and 14% of the total consumption. Therefore, occupant behavior related to space heating has been investigated in various empirical studies, among others (Gram-Hanssen 2010; De Meester et al. 2013; Engvall et al. 2014; Ren et al. 2015; Santangelo et al. 2018).

Behavior related to electricity consumption has also gained attention in a number of studies (Grønhøj and Thøgersen 2011; Abreu et al. 2012; D'Oca et al. 2014a) while ventilation and window opening behavior (Andersen et al. 2009; Fabi et al. 2012; D'Oca et al. 2014b), domestic hot water (DHW) (Feng et al. 2017; Mora et al. 2017), and water saving behavior (Martínez-Espiñeira et al. 2014; Hayles and Dean 2015) have been so far less investigated. Few studies have attempted to study many occupant behaviors at the same time (Stazi et al. 2017) (for a more complete research review on impact of occupant behaviors on building energy analysis refer to Delzendeh et al. 2017).

Occupant behavior in office buildings and tertiary sector have been studied as well (Masoso and Grobler 2010; Yan and Hong 2018), although they have received so far slightly less attention than the housing sector.

Finally, some researchers argue that key stake- holders (i.e., building designers, operators, managers, engineers, occupants, industry, vendors, and policymakers) need to be aware and educated on the relevance of the human factor to their particular perspective, in order to integrate the human dimension in their daily actions (D'Oca et al. 2018; Santangelo and Tondelli 2017).

Consumer Behavior Embedded in Different Regulatory Levels: A Policy Framework

Policy-makers are currently facing the challenge to design and implement effective housing renovation strategies both for the public and the private housing stock, able to support not only the technical and physical renovation, but also a change of paradigm in energy consumption. The more the energy efficiency of buildings is, the greater is the impact of household behavior (Andersen et al. 2009; De Meester et al. 2013; Santangelo et al. 2018); therefore, there is a growing belief that the implementation of energy efficient measures should better cope with household needs and the ability and willingness of occupants to undertake changes in their daily behaviors.

Policies and regulations at different territorial levels are struggling to encourage decision-makers to include information to users as a prerequisite to implement effective energy efficiency strategies and to lower energy consumption.

At international level, understanding the human factor in energy consumption is a topic which got an increasing attention in the last decade. The Organisation for Economic Cooperation and Development (OECD) conducted a survey in 2011 to get an insight into the factors affecting people's behavior towards the environment and on what policy measures really work to enable changes at the household level (OECD 2014). The International Energy Agency (IEA) identified occupant behavior as one of the six driving factors of energy use in buildings (International Energy Agency 2016), while the World Business Council for Sustainable Development recognized that occupant behavior can have as much impact on energy consumption as the efficiency of equipment in reducing energy consumption (World Business Council for Sustainable Development 2007). The Habitat III New Urban Agenda has recognized the role of sustainable consumption to ensure environmental sustainability (art. 14c) and the national, subnational, and local governments as key actors to promote energy conservation and efficiency, and to develop sustainable, renewable, and affordable energy and energy-efficient buildings (art. 75) (United Nations 2017).

At European Union level, the building sector is the largest single energy consumer. The European Commission has recognized the importance of buildings performance towards climate change mitigation and has set regulations to help promoting the use of smart technology in buildings and to accelerate buildings renovation. Currently, about 35% of the buildings are over 50 years old and almost 75% of the building stock is energy inefficient, while only 0.4–1.2% of the buildings are renovated each year, depending on the country. This renovation rate is clearly not enough considering that half of the residential stock was built before 1970, prior to the first thermal regulations. Therefore, the increase of the renovation rate of existing buildings has the potential to lead to significant energy savings and the residential sec- tor is the one which offers the greatest potential. Improving the energy efficiency of buildings can also generate other economic, social, and environ- mental benefits. Better performing buildings pro- vide higher levels of comfort, wellbeing, and health for their occupants. The revision of the Energy Performance of Buildings Directive (EPBD) and Energy Efficiency Directive (EED), just entered into force on the beginning of July 2018, aims at accelerating the cost-effective ren- ovation of existing buildings and promoting smart-ready systems and digital solutions in the built environment, therefore providing consumers with more accurate information about their consumption patterns.

Household Behavior: One Issue, Several Approaches

Whether consumer behavior is based on long-lasting practices or new ones, it is overall influenced by both personal characteristics and the societal context. Macrolevel factors such as technological developments, economic growth, demographic factors, institutional factors, cultural developments (so-called TEDIC factors) influence consumer behavior at the broader level, while microlevel factors such as motivation, opportunity, and ability (MOA factors) shape user behavior at the individual level (Abrahamse et al. 2005).

Investigating consumer behavior towards energy efficiency and sustainable energy consumption requires a deep understanding of both the human factor and the technological asset, and the integration of both qualitative and quantitative methodologies. A brief review of the two main approaches – based on social science theories and on technological disciplines – is presented below. Both rely on modeling as key approach that helps explaining the reality and informing the users, but it is even more important for informing and guiding the policy-makers to assess scenarios and to take decisions (for a more comprehensive over- view see Wilson and Dowlatabadi 2007; Lopes et al. 2012).

Social Science Approach

From the economic point of view, one of the first behavioral theories is the rational choice model, also called utility-based decision model. It is grounded on the microeconomic theory of utility maximization given certain preferences. Consumers are assumed to behave rationally, but in order to weigh the costs and benefits of various options, they need information on the possible actions or goods they can choose from. However, after having been largely applied in the 1970s, this model has progressively been replaced by others, since it has been demonstrated that behavior embeds a number of inconsistencies, and consumers do not make consistent rational decisions even if all the information is provided (Wilson and Dowlatabadi 2007; Lopes et al. 2012). Moreover, people make decision not only considering short- term monetary paybacks, but also mentally assessing other nonmonetary positive or negative elements, but they account the two assessments separately, resulting in nonrational decisions.

Technology adoption and attitude-based decision models explain the relationship between innovations and behavior. The Diffusion of Innovation (DoI) model assumes a linear progression of knowledge, awareness, intention, and behavior that results in the adaptation of technologies; the theory of cognitive dissonance is based on the assumption that consumers struggle to behave coherently and to keep consistency between their knowledge, attitudes, and actions; in the theory of planned behavior (TPB), attitudes are formed from the personal belief about a behavior as well as the evaluation of its outcomes. While these theories have been successfully applied to explain human choices in a wide variety of contexts, their application in energy efficiency and sustainable energy consumption has been limited (Kowsari and Zerriffi 2011).

Social and environmental psychology has started from the 1970s to explore behavior in relation to residential energy efficiency. According to the ecological value theory, people with egoistic and self-interested values are less likely to perform pro-environmental behaviors than those who have pro-social values. However, having pro-environ- mental attitudes is not a sufficient condition for acting in an environmentally friendly way. The value- belief-norm (VBN) theory proposes a causality relation between personal values, ecological world- view, adverse consequences for valued objects, perceived ability to reduce threat, and pro-environ- mental personal norms. The three causal variables that lead from values to personal norms that activate environmental behavior are beliefs. As a consequence, information can play an important role in influencing beliefs, which in turn can change pro-environmental norms that finally lead to environ- mentally significant behaviors (Kowsari and Zerriffi 2011). However, decision models that exclude contextual factors often fail to adequately explain energy-related behavior when it involves high-effort, high-cost, and high-involvement decisions (Lopes et al. 2012). Hence, context has been included in the attitude-behavior-external conditions (ABC) model, where attitudes are considered to lead to behavior change only if contextual variables (physical, financial, legal, or social) provide either incentives or disincentives.

However, contrarily to the previous models, sociology approaches generally argue that energy use is not a consequence from choices of a single person, but it results from the social context. Sociologists and anthropologists believe that human behavior is social and collective, and that energy models that intend to include behavioral dimensions should consider the social context of individual actions. Therefore, in the residential sector, they consider the household as the meaningful unit of analysis.

Finally, practice theory focuses on the collective structures of practices and on what guides the practices people perform in their everyday lives, where energy consumption is not a practice in itself, but it is a consequence of all the different energy-related activities that people do at home (Gram-Hanssen 2010). Therefore, these considerations are particularly important when it comes to frame the intervention strategies to energy conservation and behavioral changes.

Technological and/or Engineering-Based Approach

Energy modeling is used to quantify energy consumption mainly to inform the building design sector or to support policy-makers in assessing the effectiveness of different scenarios. Focusing on the bottom-up approach (Lopes et al. 2012), rather than on the top-down approach, which is unable to distinguish individual behavior, these models make use of input data as household characteristics and building – or group of buildings – characteristics, to assess the energy consumption embedded in certain behaviors or to cluster the users according to recurring behavioral patterns.

The statistical approach relies on statistical data collection, requires large samples, and embeds the risk to not adequately deal with the socio-technical factors (e.g., how householders use domestic appliances or how they react to changes in the dwelling as a result of energy performance measures) (Lopes et al. 2012), although the added value is that it can lead to results generally valid at regional/national level.

The engineering approach makes use of building energy simulation programs (e.g., EnergyPlus, DeST, ESP-r) to assess the impact of certain behaviors in building energy performance. Indeed, it has been demonstrated that occupant behavior is a major factor contributing to observed gap between the theoretical and actual energy consumption of buildings. Due to the stochastic nature of human behavior, to achieve better predictions of building energy performance, models of human-building interaction have increasingly been integrated into building energy simulation algorithms. Such approaches typically rely on mathematical equations representing the relationship between specifically exercised energy-related behaviors (i.e., opening windows, drawing blinds and shades, operating artificial lights, using electrical equipment) and some physical variables of the indoor and outdoor environment, specific to a particular building setting (D'Oca et al. 2018). The appropriate model resolution depends on the problem that is being addressed, therefore before developing a model to describe occupant behavior, it is necessary to clarify the resolution for the spatial, temporal, and occupant resolution dimensions (Yan et al. 2015). A single model is unlikely to be generic enough to cover all solutions at different scales.

Determinants of Consumer Behavior in Residential Sector

A number of studies both from social and technical fields have been performed in the last decades with the aim to investigate the determinants of user behavior and to identify energy consumption patterns. While social science usually adopts both qualitative and quantitative methods to perform its studies, the scholars preferring a technological approach use extensively quantitative methods. They consist mainly of data collection through surveys and interviews (Andersen et al. 2009; Gram-Hanssen 2010; Engvall et al. 2014; OECD 2014), reading from smart meters (Grønhøj and Thøgersen 2011; D'Oca et al. 2014a) and statistics (Schaffrin and Reibling 2015; Guerra-Santin and Silvester 2016), used individually or combined one to the others. The mostly applied research instruments rely on theoretical framework and behavioral models (Van Raaij and Verhallen 1983b; Abrahamse et al. 2005; Stephenson et al. 2010) in the field of social science, and mostly on simulation tools (D'Oca et al. 2014b; Yan et al. 2015) and statistical analysis and data mining techniques (Steemers and Yun 2009; Ren et al. 2015) for the engineering science.

Several researches have categorized consumers and their energy and environmental attitudes to different behavior patterns. Starting from the 1980s, Van Raaij and Verhallen (1983a) focused on the definition of five energy-related behavioral patterns (i.e., conservers, spenders, cool, warm, average) and verified that the average difference between the two extreme usage levels accounted for 31%.

The large survey conducted in 2011 by the Organisation for Economic Cooperation and Development on people's behavior towards the environment (OECD 2014) has identified three clusters of environmental attitudes, labeled environmentally motivated, environmental skeptics, and technological optimists. The environmentally motivated comprise just under half of the pooled sample; they gather together people who believe that environmental problems are real and express a willingness to make compromises in their life- style to solve them, with the least need for reciprocation from others. Environmental skeptics believe that environmental issues are overstated and do not wish to pay for government environ- mental policies, although they do report a general willingness to make compromises for the benefit of the environment. Technological optimists share the belief with the environmentally motivated cluster that environmental problems are real and appear willing to make lifestyles compromises to solve them, but they show a greater belief in the potential of technological progress to solve environmental problems.

By investigating the effect of thermostat and window opening behaviors, D'Oca et al. (2014b) grouped residential occupants into active, medium, and passive energy users. While the active users change the heating set point to get warmer or cooler, the passive ones do not and better tolerate some level of discomfort.

Turning to household characteristics (i.e., demographic, socio-economic, and building-environmental factors), some links have been identified in the literature. Based on self-reported behavior of 145 households in the Netherlands for 1 year, Van Raaij and Verhallen (1983b) argued that life-style influences energy-related attitudes and behavior: family size and composition next to the presence or absence from home for work or leisure all have a direct effect on user behavior and energy use. Income, educational level, and employment showed also to be related to energy use. Two decades later, Poortinga et al. (2003) discovered differences in acceptability of energy-saving measures related to age, household type, income, and education level.

However, the influence of some factors is strongly linked with the local/regional/national conditions (Guerra-Santin and Silvester 2016). Among them, income remains one of the most controversial factors. On the one hand, income has been shown to be a determinant of energy consumption in Mexico due to the inadequate thermal insulation of the buildings where low-income households mostly live (Romero et al. 2013). On the other hand, a study performed in the Netherlands showed no relationship between income and energy consumption (Guerra-Santin et al. 2009). Income is also one of the factors determining the prebound effect (i.e., the lower than expected energy use in old inefficient dwellings due to a lower comfort level accepted by the occupants). While high-income households have higher overall energy consumption, low-income groups spend a larger share of their income on utility costs (Schaffrin and Reibling 2015).

Some studies have shown that ownership has a positive influence on energy saving (Andersen et al. 2009; Martinsson et al. 2011; Guerra-Santin and Silvester 2016), while gender has also turned to be a significant determinant, with women more environmentally conscious than men (Carlsson-Kanyama and Lindén 2007; OECD 2014) and the proportion of women in the house giving a reduction in energy use for heating, assuming all other factors being equal (Engvall et al. 2014). Not surprisingly, the heating patterns vary depending on the age of households and employment status (Guerra-Santin and Silvester 2016), with older and retired people staying at home during daytime hours, therefore with the heating system on for longer than other family groups.

Strategies to Inform the Users and Support Behavioral Change

Individual needs correct information for saving energy. Without an appropriate frame of reference, users cannot determine whether their energy consumption can be reduced or not.

Strategies to promote efficient behavior can be divided into two groups, psychological strategies and structural strategies (Steg 2008). While the former (e.g., education, information) are aimed at influencing directly the user, the latter (e.g., new appliances, infrastructures, services) are aimed at changing the context in which decisions are made, to make energy conservation more attractive. Policy instruments should translate these strategies into practices. According to Linden et al. (2006), four main categories of policy instruments can be identified, namely, information, economic, administrative, and physical instruments. Focusing on information, it has been recognized the importance of tailored information (Van Raaij and Verhallen 1983b; Abrahamse et al. 2005) in delivering changes in energy-related behaviors and knowledge.

Feedback plays a significant role in raising energy awareness and changing consumer attitudes towards energy consumption. The main feedback categories are descried below.

Direct feedback is the more immediate and easier accessible means to get on demand information. It is particularly useful for illustrating the impact on energy use of a specific behavior pat- tern or device in real time. Feedback can be provided by a smart meter with In-Home Displays (IHDs) monitor or a clearly visible energy meter. By direct feedback measures, energy consumption information is available in real time, all the times. Nevertheless, the effect of the direct feed- back depends on how regularly users read the information, and also the literature emphasizes the importance of frequent feedback in order to effectively influence user behavior.

Indirect feedback is the one that has been processed in some way before being delivered to the users, as the case of informative energy bills. Consumers have no direct access to the real time consumption of a certain behavior pattern, and can only respond to previous consumption behavior. This means that there is a time-delay between energy consumption and the moment feedback reaches consumers. The means for providing direct feedback can vary from more informative and also more frequent bills, information on web platform and email. As indirect feedback, it can include analysis of data collected over longer period, and it is more suitable for showing longer-term effects. As for the direct feedback, the effect of indirect feedback depends on how frequent the feedback is available for consumers and on how simple are the information, as the highest motivation to absorb them, occurs at their time of arrival. The range of savings achieved through indirect feedback (2–10%) tends to be lower than the one reported in direct feedback studies (5–15%), while the combination of different informational feedback may lead to an increase of energy savings up to 20% (Barbu et al. 2013). Frederiks et al. (2015) found that advising individuals that people similar to them (e.g., peers, neighbors) are using less energy or taking certain energy-saving actions, in addition to conveying social approval of such actions, will most likely motivate them to conform to these positive energy-saving attitudes and to reduce their consumption accordingly. The use of the energy bills in heating, domestic hot water, and electricity saving measures may seem obvious. They are the occupant factsheets on how much energy they consume. The energy bill can also be used as a communication tool for saving tips, but for being an important saving measure, the information must be easy to understand for those it is aimed at.

Energy audits are also an additional means to provide detailed information on energy demand and saving potential. They generally include the evaluation of the thermal characteristics of the building, its existing heating, ventilation and air conditioning (HVAC) system, and the appliances in use. Although the energy audit report does not address user behavior directly, it can be successful in raising awareness on energy issues, a prerequisite for changing behavior and consumption practices.

Providing a household with information tends to result in higher knowledge levels, but not necessarily in behavioral changes or energy savings (Steg 2008). Information alone is unlikely to motivate changes. Information is also unlikely to result in sustained behavioral change beyond the life of a given campaign, since enthusiasm for new behavior or actions tends to decrease in time if no reinforcement of such initiatives is provided. Although the limits of information strategies, informing the users is recognized an important first step in prompting people to change their behavior, and an important element in the implementation of policy instruments to lead to reduction of energy consumption in buildings.

Directions for Future Research

Consumer behavior is hugely complex, shaped by many factors, some of which are intrinsic to the individuals, others depend on the building characteristics and more generally on the local environment where people live. Research has shown that occupants can use three or more times as much energy for heating as their neighbors living in dwellings with similar characteristics (Steemers and Yun 2009; Gram-Hanssen 2010), and energy savings through behavioral factors can be as high as those from technological ones (Lopes et al. 2012), thus giving to the occupants the possibility either to reinforce the savings from energy efficiency measures, or to waste them. However, the difficulty to quantify behavior has also contributed to limit the integration of the human factor in energy efficiency policies and building renovation strategies, with a consequent overconfidence in technology.

In order to change the consumer behavior, the tools adopted can be divided in two main groups: disincentive and incentives through laws and regulations, and informative tools for increasing occupant knowledge and awareness. Both approaches require effective policy instruments to support all the stakeholders involved in the implementation of energy efficiency measures to deliver such change. Indeed, the role of policy instruments for energy efficiency should be further studied in order to effectively address the behavioral patterns of different user groups. Urban planning is one of the disciplines that has recently started to focus on the human factor as a driver for the effective implementation of urban renovation programs. Understanding and tackling user behavior by embedding renovation measures and incentives to lead to behavior change in urban planning tools could contribute to bridge the gap between the provision of energy efficiency measures in policy and regulations and their actual implementation (Santangelo and Tondelli 2017).

Furthermore, the majority of research on consumer behavior focuses on single buildings and there are only a few studies that investigate the urban scale impacts (Delzendeh et al. 2017). Future research should aim at assessing the impact of occupant behavior on a larger scale, considering urban renovation rather than single building retrofit.

Consumer behavior issue is going to face future challenges as soon as a new disruptive technology is taking over. As argued by Lopes et al. (2012), when it comes to the ongoing transformation of electric grids into smart grids, the latter will provide a completely different technological context, changing the customer–utility relations and raise significant challenges to user behavior. Although it is expected that smart grids will increase energy awareness levels and encourage more efficient energy behaviors, in order to ensure an adequate implementation of smart grids, energy behavior research should be developed at the same time as the technological framework.

As illustrated above, many different energy- related behaviors have been investigated so far, with the heating pattern as the most studied. Future investigations about the interrelationship between different energy behaviors are needed, which will generate more realistic assumptions in building energy performance (Delzendeh et al. 2017). For being able to address the complexity of the human factor in energy consumption, the social effects, technical characteristics, and building performance simulation models, the role of economic, taxes and incentives as well as the policy instruments should be further investigated in combination one with each other. Integrating quantitative and qualitative approach still remain an effort to make in order to better understand behavior determinants and the drivers for changing it. A higher integration would be also beneficial among different research fields, with many scholars advocating for more collaboration among different disciplines. Although some studies have already applied multi- disciplinary approaches (Stephenson et al. 2010; Yan and Hong 2018), much more effort has to be taken in order to better understand determinants of behavior and drivers to behavioral changes.

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