

Energy Saving in Households: A Systematic Literature Review

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Abstract

Households emit 72% of all greenhouse gases due to the energy consumption. They are therefore major players in achieving the 1.5°C target under the Paris Agreement. This paper is about reducing household energy demand to mitigate climate change. Short-term voluntary efforts alone will not be enough to achieve the drastic reduction of 1.5°C. Although the renovation of residential buildings is a key energy-saving potential that has not been yet fully achieved, scientists nevertheless agree that greenhouse gas (GHG) reduction targets will only be achieved through the modernization of buildings. In order to achieve energy efficiency goals, it is necessary to understand and guide citizens' behaviour with regard to the energy consumption and savings of private homes. This requires households to have a regulatory framework that supports changes in their behaviour. This systematic review suggests that financial incentives and education could help change consumer behaviour to change energy consumption patterns in households and thus mitigate climate change. However, while the implementation of such a policy would contribute to the reduction of the energy demand and thus GHG emissions, it faces many barriers of the household behaviour. Further in this paper measures to promote energy savings in households, behavioural barriers to their implementation, and policy measures to overcome these barriers are discussed.

Keywords: energy efficiency; energy saving; household's behaviour; climate change mitigation;

JEL Classification: Q47;

DOI: <http://doi.org/10.24818/ejis.2021.04>

1. Introduction

Climate change mitigation is one of the world's key global policy strategies. Globally, energy savings play an important role in achieving climate change mitigation goals, and it is necessary to consider the use of energy efficiency retrofits and their effect on energy demand and improvements in these retrofits through the population to understand their potential as outlined in Hamiltons *et al.* (2016). As the aim announced by the Intergovernmental Panel on Climate Change (IPPC) is to prevent global warming to 1.5°C above pre-industrial levels and the achievement of the environment and energy goals set by the European Commission and also globally, by the Paris Agreement (Masson-Delmotte *et al.*, 2018; European Council, 2014; Adoption of the Paris Agreement, 2015), where countries have been urged to be inspired to make environmentally friendly decisions in all industries. In some countries, such motivational strategies are already being introduced Ahvenniemi and Häkkinen (2020). Promoting energy and resource-saving behaviour is one of the key instruments for reducing the consumption of resources and finding energy and resource efficiency (Liobikiene and Minelgaite, 2021). Promoting energy efficient upgrades provides many advantages, including financial savings, convenience, a feeling of

well-being, lowered pollution, and resource management (Wrigley and Crawford, 2017). Unfortunately, in the limited time available, energy conservation methods alone are unlikely to achieve anything near the energy reductions required, however, energy efficiency, requiring less usage of energy-using products, including private cars, would have to be the basis of all energy reductions. Changes in lifestyles would be required to achieve such reductions, especially for residents of non-OECD countries, as outlined in Moriarty and Honnery (2019). Despite this, a wide variety of policies for climate change mitigation have been implemented internationally and these policies have become one of the main concerns. Scientists and scholars are also debating what the key external advantages are and how to take them into consideration and devise successful climate change mitigation strategies that will be broadly accepted by society in general (Streimikiene *et al.*, 2019).

The real challenge is reducing greenhouse gas (GHG) emissions in the residential sector, as conventional climate change mitigation strategies have not been able to overcome behavioural obstacles because they have targeted primarily fiscal, social, technical, regulatory and/or institutional barriers. Scientists agree that households need to be mobilised to change their everyday habits in order to combat climate change. This includes policies influencing consumer behaviour and improvements in lifestyles (Ramos *et al.*, 2015). A significant number of studies explore the connection between socio-demographic patterns of consumers, norms, and behaviours, and habitual and/or periodic behavioural choices that are energy-efficient, including home appliance choices (Pothitou *et al.*, 2016; Bonan *et al.*, 2020; Lakic *et al.*, 2021; Liobikiene and Minelgaite, 2021). Usually, lower energy consumption leads to lower resource use and lower emissions of local and global pollution, particularly greenhouse gases, but the future contribution and place of households in climate policy is neither well known nor is the priority given to households in current climate policy strategies sufficiently high (Browne *et al.*, 2009; Schleich *et al.*, 2016).

It is widely thought that households need to adjust their behaviour in order to reduce the challenges created by rising fossil oil consumption levels (Steg, 2008). Therefore, in this article, the energy saving measures in households and the behavioural barriers that hinder the implementation of these measures were reviewed and systematized.

2. Energy Savings in Households

In order to contribute to climate change mitigation for households, scientists accept that reducing GHG emissions is one of the main priorities (Gambhir *et al.*, 2014; Fawzy *et al.*, 2020). Levesque *et al.* (2019) presented the scenario results for final energy demand at the global level, where authors claim, that in 2050, by the Reference scenario, the final energy demand will increase by 62% and in 2100, this model accentuated the doubling of the demand compared to 2015 (+126%). Since most of the energy comes from buildings heating/cooling systems and the use of electrical appliances, therefore it is discussed later in this paper.

2.1. Reducing energy demand through renovation and „Green buildings“

It is estimated that existing buildings have the most substantial energy saving potential, which has not been fully achieved yet (Felius, 2020). Levesque *et al.* (2019) indicate that building reconstruction where the use of insulating materials in buildings decreases the

need for electricity and people are able to pay extra for it. It should be stressed, though, that the willingness to pay (WTP) for energy savings is closely related to the owners' income, and household owners are often putting an extra willingness to pay value on the most visible (such as aesthetics) but non-energy expenditure advantages and householders who claimed that they were less acquainted with the idea of green buildings were able to pay a lower price premium than those who have more knowledge about it (Gambhir *et al.*, 2014; Levesque *et al.*, 2019; Zalejska-Jonsson, 2014; Collins and Curtis, 2018). After the review of referring studies, measures to promote buildings renovation are summarised and presented in *Table 1*.

Table 1. Benefits of renovation and willingness to pay of consumers for more energy efficient buildings

A measure to promote buildings renovation	Basic insights into researches	References
Willingness to pay for residential energy efficiency improvements and for green apartments	<ul style="list-style-type: none"> • For low-energy buildings, the reported willingness to pay is around an additional 5 percent, a fair investment decision; • Customers are prepared to pay a premium for features they know and can see the possible advantages; • Can be singled out three categories to clarify the free-riding application standard that may or may not have: i.e. 'Free-riders', 'Partial free-riders' and 'Dependents'; • Higher costs decrease the likelihood of selecting a retrofit alternative, but it is more conceivable that households that have undertaken a retrofit in the past select a more costly renovation means in comparison to the households upgrading for the first time by energy efficiency retrofit; • In less energy-efficient homes, the adverse cost impact on the renovation option is much greater compared to more energy-efficient homes. 	Zalejska-Jonsson (2014); Collins and Curtis (2018)
Communicating the benefits of renovation	<ul style="list-style-type: none"> • In order to optimize the co-benefits of energy-related renovation steps, all of the key components of the building envelope should be changed to a minimum energy efficiency based on local climate conditions; • Prepared methods for the successful application of the greening of existing buildings (GEB). The studies state that, even without the support and encouragement of the local government for this GEB strategy, continued long-term green knowledge and implementation might not be sustainable; • By increasing the efficiency of the building, emissions of pollutants from fuel wood and cattle dung used for space heating can be reduced; • Waste products, locally available materials, can be used as cost-effective building insulation. 	Ferreira <i>et al.</i> (2017); Leung (2018); Bhochhiboya, <i>et al.</i> (2010)
Changing consumer behaviour and energy demand regulation	<ul style="list-style-type: none"> • Household behaviour change measures can generate significant energy savings, leading to lower greenhouse gas emissions, reducing national targets for reducing greenhouse gas emissions and improving the well-being of the country's population; • In the reference scenario, the adoption of low consumption practices could save as much as 61 percent of the energy consumed by 2100; • As a local initiative, demand side management and renewable energy have great potential to alleviate the effects of climate change. 	Bhochhiboya <i>et al.</i> (2010); Levesque <i>et al.</i> (2019).

In household energy renewal decisions, high heating bills and low thermal comfort in apartments have been major variables, but inadequate public funding and unwillingness to borrow are also one of the key barriers for this decision (Streimikiene and Balezentis, 2020). At the end of the century, energy consumption from activities in buildings will decrease by 11 percent relative to the level of 2015, instead of a 126 percent increase. New practices for the use of hot water, insulation and the increased use of powerful air conditioners and heat pumps are driving the decrease in energy demand (Levesque *et al.*, 2019). *Dubois et al.* (2019) note that household living conditions (demographics, home size) have a significant effect on the household ability to reduce their footprint, even more than the position of the country or city. Important factors driving the CO₂ emission curve upwards are having children and purchasing a new home. Thus, if individuals were motivated and understood the advantages of the "Green Building" gained during this time, these emissions could be minimized (*Dubois et al.*, 2019). Therefore, there is a great need for government initiatives and education during this time. Furthermore, Dietz *et al.* (2009) found that, if the most successful non-regulatory approaches are used, the realistically achievable national emission reduction could be approximately 20 percent in the household sector within 10 years.

Individual homeowners who are considering energy-efficient rehabilitation of their houses, including acts such as roof insulation, walls, installation of recuperative ventilation and investments in renewable energy sources, have financial incentives accessible. In many countries, fiscal incentives have been implemented to enable households to pursue energy-saving renovations (Al-Mansour, 2011; Risch, 2020).

2.2. More energy efficient devices for households' electricity savings

The two approaches to reducing energy use are to maximize the efficacy of all energy-using devices, or to minimize their use by some means (Moriarty and Honnery, 2019). Moreover, many studies concentrate on the effects of different determinants and/or ability to pay for different types of appliances when energy efficiency labelling is implemented (Newell and Siikamkj, 2014; Harajli and Chalak, 2019). The information on the average cost of electricity significantly increases the probability of consumers preferring a more cost-efficient appliance. Research findings emphasize that by including monetary information on annual energy use, informed and rational choices of appliances can be improved. Firstly, with the duty of electrical equipment manufacturers to include details in the form of a monetary calculation on the future energy consumption of the device. A second approach will be to inform customers about the energy usage of various appliances and how to find the most powerful appliances, by the use of brochures and energy awareness courses in schools (*Blasch et al.*, 2019).

Policy-making mechanisms such as shifting the perceived psychological advantages of consumer use of energy-saving products through public ads will help make customers "feel good while doing well" socially and environmentally (Xianchun *et al.*, 2020). *Table 2* presents in more detailed an overview of research about the incentive to choose a more economical device in households.

Table 2. Choice of energy efficient appliances in households

Reason to choose a more economical device	Basic insights into researches	References
The choice to buy energy efficient appliances due to governments decisions	<ul style="list-style-type: none"> • Details on annual energy costs significantly increases the probability of customers selecting the more (cost-)efficient appliance; • The provision of monetary information on annual energy use will improve the informed and rational choice of appliances; • A stronger government call for electricity savings is influencing to greater energy savings in households. 	Blasch <i>et al.</i> (2019); Mizobuchi and Takeuchi (2016)
The choice to buy energy efficient appliances due to the households pro-environment behavioural	<ul style="list-style-type: none"> • Environmental outlook and care, as well as psychological benefits, have a strongly positive effect on the behavioural desire of respondents to purchase devices that conserve electricity; • Age and family size both associate strongly and favourably with the decision to buy an energy-saving appliance; • More successful involvement in energy saving is correlated with an altruistic approach; • More power was saved by households who owned energy-efficient air conditioners than those that did not; • The rebound effect may negate the energy-saving effects of energy-efficient appliances. Researches show, that “Additional-purchase households” showed significant energy savings, whereas “replacement households” did not. 	Xianchun <i>et al.</i> (2020)

In recent years, energy certificates or mark programs have grown rapidly, particularly in the building sector, but also for residential appliances and vehicles (Ramos *et al.*, 2015). However, it could be a very important tool to promote energy savings in household data on the use of electricity by households (feedback). Ramos *et al.* (2015) claims that consumers may be involved in reducing their energy usage if they are conscious of the way they use energy and of its cost. Darby (2006) research shows that immediate feedback decreased energy consumption by 5 to 15 percent from a monitor or meter. Another way to provide insight is by bills that provide statistics on the usage of household electricity and how it equates with others (Ramos *et al.*, 2015).

Behavioural economics offers evidence that people show systemic and consistent decision-making behaviours that differ from the principles of the philosophy of rational choice. (Della Valle and Sareen, 2020). The following section discusses the nudge and boost tools that explain, how behavioural economics can increase justice for energy.

3. Nudge and Boost Interventions for Consumer's Behaviour Change

Up till now, in much of the discussion of behaviourally informed methods have been stressed "nudges," that is, interventions intended to guide individuals in a certain direction while retaining their freedom of choice. Nevertheless, the behavioural psychology also promotes a different kind of non-fiscal and non-coercive action, namely, "boosts" (Hertwig and Grüne-Yanoff, 2017). *Table 3* provides more detailed information on these interventions and their use.

Table 3: "Nudge" and "Boost" interventions and their roles

Aspect	"Nudge" intervention	"Boost" intervention
Description	A cost-effective mechanism to redirect behaviour without alternatives being foreclosed or economic incentives being modified. Many peoples' choices are influenced by an intuitive system that relies on associative memory, which automatically and often unconsciously encourages heuristics of choices and decisions. Thus, the basis of this intervention is to guide individuals in the direction of the policy, eliminating the shortcomings of cognition or motivation of the intuitive system.	Interventions that extend the decision-making competences of people alike target the individual's skills and knowledge, the available set of decision tools, or the environment in which decisions are made.
Intervention target	Behaviour	Competence
Role of intervention	<ul style="list-style-type: none"> • Encouraging people to provide feedback on their needs and issues; • To direct the conduct of the chooser away from the conduct indicated by the cognitive impairment and towards to ultimate aim or desire; • To encourage successful information campaigns, e.g. by leveraging timely moments; • A nudge does not affect those characteristics that individuals have clear preferences about (e.g., income, comfort, etc.), but rather those characteristics that individuals will usually claim not to care about (e.g., position in a list) 	<ul style="list-style-type: none"> • Empowering people by expanding (boosting) their skills and thereby helping them achieve their goals (without making undue assumptions about what those objectives are); • To empower people in a number of contexts with the skills that they should apply. As the first crucial step towards finding out one's choice, to help everyone understand statistical knowledge; • Growing a sense of self-efficacy by building capacity that allows for a broad spectrum of behaviours.

Source: Thaler and Sunstein (2008); Grüne-Yanoff and Hertwig (2016); Della Valle and Sareen (2020)

The nudge strategy steers action without taking the detour of refining new skills, instead, it skilfully harnesses cognitive and motivational deficiencies to prompt behaviour change involving automatic enrolment, while the boost method invests in building on the skills of people and improving them (Hertwig and Grüne-Yanoff, 2017). In *Table 4* the main tools of nudge and boost interventions that can help to achieve the desired goal are singled out.

Table 4: The main Nudge and Boost tools

“Nudge” intervention	“Boost” intervention
<ul style="list-style-type: none"> • Change in Default Options The default option is the option that remains when individuals are faced with a choice and do not actively choose a different option. Thus, by leaving the preferred option as the default option, the goal can be achieved more successfully because individuals are more likely to behave passively. (As example, Opt-out green electricity offers or smart grid trial. In an opt-out contract, consumers are given the environmentally friendly choice as a default). • Social Norms and Comparisons Since people are social beings, social beings influence human actions. Therefore, posing good environmental decisions as social norms will inspire people to conduct environmentally friendly activities more frequently. (e.g., Comparison of energy bills with others). • Increasing Information Salience and Simplification Salience is critical in promoting environmental goals because individuals have short attention spans in pursuing environmental objectives. Having data as transparent and easy as possible will impact what product a customer can buy. (e.g. Energy use feedback: Detailed energy bills, metering and displays or energy labelling of appliances and buildings). • Changes to the physical environment Changing the physical environment can impact the behaviours of individuals. As example, in order to promote more sustainable behaviour, design for sustainable behaviour aims to change the physical environment (e.g., the fridge can be built so that it is harder to hold the door open). 	<ul style="list-style-type: none"> • Foster competences Boost intervention is aimed at increasing people's competencies and knowledge, so as to change their behaviour (for example, to improve saving behaviour). It can be used for increasing the ability to connect with one's future self and to teach simple rules of procedure. • Instil or strengthen statistical skills Usually, people make choices that are related to probabilistic alternatives and effects and can thus not be reliably predicted (for example, the decision to switch to a more energy-efficient household appliance). However, on the basis of statistical evidence, individuals also make bad decisions. Thus, policymakers should also support measures that shift the representation of statistical information from probabilities to natural frequencies and from numerical to graphical representations to improve statistical literacy skills. • “Rules-of-thumb” provision To strengthen one's own situation through training in procedural routines related to energy and financial capital. In order to simplify decision processes, individuals can be fitted with strategies which can therefore save cognitive energy.

Source: Mont *et al.* (2014); Sunstein (2015); Hertwig and Grüne-Yanoff (2017)

Nudge and Boost interventions can be successful in achieving policy goals and saving public expenditure, especially in areas that are difficult to regulate through conventional policy interventions, such as energy consumption (Allcott, 2011).

Energy efficiency policies are in many cases effective in reducing energy use in the residential sector, but many researchers (Jensen, 2008; Allcott and Mullainathan, 2010; Yohanis, 2012) have identified a significant contribution of information and behavioural problems to the energy efficiency paradox in this sector. Thus subsequently, this article discusses the behavioural barriers implementing energy saving policies in households.

4. Behavioural Barriers to Combating Climate Change in Households

Although consistent public policies and business investment are required, it is unlikely that household energy usage will be reduced by simply modernizing buildings or using more sufficient appliances in order to meet the Paris climate targets. Studies of household energy use have shown a high variability in energy use among similar households, suggesting that the third decisive agent is occupants, and their behaviour can be as important as building physics. In addition to efficiency, including the concepts of adequacy in the design of policies for good quality of life will lead to reducing energy consumption: energy efficiency and energy adequacy are complementary approaches to energy saving (Samadi *et al.*, 2017; Poncin, 2020; Trotta *et al.*, 2018). van Sluisveld *et al.* (2016) claim, that in the end-use sectors, lifestyle changes are the most important, which can lead to approximately 15 percent CO₂ emission reduction potential.

Table 5: Policies that may help address behavioural barriers in the households

Behavioural Barriers	Policy category	Explanations
<ul style="list-style-type: none"> • Uncertainty on renovation costs/benefits and payback period; • Environmental concern / low priority; • Lack of trust in governments' policy; • Lack of trusted information and experience; • Time constraints and the capability to use data; • Resistance to change, negative perception of new technologies; • Customs, habits, and relevant behavioural aspects; • Lack of understanding on saving potentials; • Lack of a 'culture of saving' 	The supply of information	Replacing consumer discouragement with information on future savings, such as audits or labelling of products; Low-cost methods for motivation and persuasion, also known as "nudges"; Programs that require customers to concentrate on losses rather than gains, or pressure customers to set a target.
	The economic tools	Higher prices of electricity; Taxation with high consumption of energy; Subsidies, grants, deductions from taxation, tax benefits and credits, rebates and assurances; The devices or thermometers for set-back; Energy efficient, flexible heating infrastructure incentives.
	The regulative tools	Measures specifying the steps to be taken to achieve particular goals in the area of environmental quality: <ul style="list-style-type: none"> • Certificates of energy performance; • Minimum building efficiency standards; • Mandatory billing of heating energy at regular intervals; • Duty to integrate information into formal education
	Communication	Campaigns for information (projects for protests, group programmes); Convey best practices; Report on the direct link between greenhouse gas reductions and the use of space heating.
	Direct spending on government	Infrastructure funding, such as smart meters, subsidies
	Instruments of procedure	Voluntary contracts with corporations, colleges, etc.

Source: Faber *et al.* (2012); Cattaneo (2019)

Consumption habits, misunderstanding of economic returns, different purchase choices, decreased trust in local and national public administration, low cost-effectiveness of expenditure, lack of attractive products and services, comfort priority are correlated with behavioural barriers. Most of the time, these barriers are due to knowledge shortages that have both an impact on improving energy efficiency and on adopting energy-efficient technologies (Cagno *et al.*, 2013; Risholt *et al.*, 2013; Moglia *et al.*, 2017; Bagaini *et al.*, 2020). *Table 5* provides behavioural barriers, which hinders the implementation of energy saving targets in households and measures to address them.

Consumer behaviour in a market, as complex as energy efficiency in housing, is difficult to measure robustly, and considerable analysis is still needed to solve very relevant questions, such as how these failures affect energy efficiency, how behavioural and market failures relate to them, or whether they can be corrected by learning or repetition (Shogren and Taylor, 2008). Human behaviour, along with the physical characteristics of the home, environment, number and demographic profile of residents, household income, lifestyle, and possession and use of appliances, is one of the key factors that can affect domestic energy consumption (Jensen, 2008; Yohanis, 2012; Pothitou *et al.*, 2014). Finally, it is proposed that public understanding of energy conservation and environmental issues be improved to promote the promotion of energy saving alternatives (Jia *et al.*, 2018).

5. Conclusion

Promoting energy-saving behaviour is one of the key instruments for reducing the consumption of resources and finding energy efficiency. This systematic review has shown that changes in household energy consumption would allow substantial reductions in energy demand to be achieved. However, in terms of energy efficiency alone, it is unlikely that energy consumption can be accomplished within a short period of time. Instead, by saving electricity and using less energy-consuming equipment, the most of energy needs should be minimized. This literature review has also revealed that building renovation and the use of insulating materials in buildings minimize the need for electricity and people are prepared to pay extra for it. It should be stressed, however, that the possibility to pay for energy savings is closely related to the owners' income, and household owners are often putting an extra WTP value on the most visible (e.g., aesthetic) but non-energy investment benefits. Based on collected information from the review, it can be argued that monetary information on the annual energy consumption of the appliance could help to choose more economical appliances in households.

However, considering observations into insights of behavioural economic, it is important to emphasize that economic intervention is not adequate to offset climate change, and that household choices are systematically separate from the principle of rational economic choice. To understand the energy efficiency paradox in households, it is important to address behavioural failures. The lack of awareness about energy prices is one explanation for these behavioural failures. Thus, information on households' use of energy, bills of household's electricity and their comparison with others (neighbours) could contribute to energy savings. Therefore, a significant recommendation is to concentrate on removing obstacles to climate change reduction while formulating policy on climate change. Based on the information gathered from the review, it could be concluded that lifestyle changes will be needed to improve climate change mitigation, especially for non-OECD people. In addition, behavioural insights have also been taken into account in recent years in

addressing complex issues such as reducing household energy demand and changing household energy consumption manners. Nudge and Boost are the most common forms of soft interventions and two contrasting approaches to the application of reasoning and decision-making psychology to enhance policy.

However, though changing household behaviour, it can result in substantial energy savings, leading to lower emissions of greenhouse gases and while the implementation process, it faces many behavioural barriers. In this systematic review, the following behavioural barriers which hamper the achievement of energy demand reduction targets are identified: 1) Uncertainty on renovation costs/benefits and payback period; 2) Environmental concern / low priority; 3) Lack of trust in governments' policy; 4) Lack of trusted information and experience; 5) Time constraints and the capability to use data; 6) Resistance to change, negative perception of new technologies; 7) Customs, habits, and relevant behavioural aspects; 8) Lack of understanding on saving potentials and 9) Lack of a 'culture of saving'.

In promoting energy savings in households, the choice of residential renovations and energy-saving appliances, policymakers should focus on economic incentives as well as public education. In order to increase the public energy-saving awareness and environmental concern, it is recommended to facilitate the promotion of energy-saving options, which can help to meet greenhouse gas reduction targets and to improve the well-being of the population.

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