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THEMATIC ESSAY

Technological Innovations, Behavioural Interventions, and Household Energy Conservation: Policy Insights and Lessons

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Abstract: The threats associated with climate change and the worsening ecological crisis have led to a growing interest in energy-conservation policies. Policymakers across the globe have been scrambling to find cost-effective and sustainable methods to meet the world's growing energy demands. Traditional policies have so far largely focused on supply-side interventions aimed at encouraging energy efficiency via green innovation and new technologies. However, as several studies have indicated, supply-side policies alone are unlikely to be adequate to achieve the ambitious changes required to make our future sustainable. This review article draws on recent studies in behavioural economics to emphasize the need to reorient public policy towards altering consumer end-uses through behavioural interventions. In an attempt to draw out important lessons for public policy, the article reviews this emerging strand of literature and underlines the complex factors that influence energy consumption in a household. Although preceding studies have primarily focused on developed nations, the output of these studies could guide policymakers in developing and emerging market economies as well.

Keywords: Technological Innovations; Behavioural Interventions; Energy Conservation; Household Decision-Making; Public Policy

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1. INTRODUCTION

The evolution and progress of human civilization have been predicated on its ability to manipulate and use energy. The discovery of fire almost two million years ago gave humans leverage over their environment; it allowed them to not only have better nutrition, a greater variety of food, and longer life spans, but it also enabled them to migrate and adapt to a variety of climatic conditions and perform social tasks, which was crucial for their biological and social evolution (Pausas and Keeley 2009). Similarly, the large-scale use of fossil fuels in the nineteenth century allowed pre-industrial economies in Europe and the United Kingdom to evolve into economic superpowers (Wrigley 2013).

The significance of energy for economics was recognized early on by classical political economists who emphasized the constraints imposed on economies by natural conditions. Notably, Ricardo (1817) highlighted the constraining effect of land supply on growth when he suggested that growth cannot be sustained infinitely in the long run due to the diminishing returns of capital and labour on a fixed supply of land. Similarly, his contemporary, Malthus, famously suggested that there exists a fundamental mismatch between the rate of human reproduction and the world's natural resource base (Wrigley 2013). However, the relationship between economic development and energy use turned out to be far more complex than what classical economists initially predicted. It was the "discovery" of fossil fuels that dramatically changed the nature of the growth–energy nexus (Malm 2016). While "organic economies" that predated the Industrial Revolution primarily derived their energy requirements from "plant photosynthesis"—which was too slow and inefficient to really ignite long-term growth—the Industrial Revolution in Europe emerged in parallel with the radical shift to fossil fuels (Wrigley 2013, 1–10).

The relationship between development and energy consumption has always been complex. Ever since the Industrial Revolution, the world has witnessed ever increasing rates of energy use (Vance *et al.* 2015; Pablo–Romero and De Jesús 2016; Malm 2016). Between 1965 and 2012, it is estimated that global energy consumption grew by well over 200% (IEA 2013). The share of electricity in this estimate, which was recorded to be 19% in 2017, is projected to increase from 20.3% in 2025 to 23.7% in 2040 (IEA 2018). Indeed, even among contemporary developing economies like China and India, which have grown at a tremendous pace over the last few decades—a ravaging hunger for energy has characterized their respective development trajectories (IEA 2020). Given the high estimated demand, it is clear that not only does future growth depend on the ready supply of cheap energy but that the world will face dire environmental consequences from the accelerating use and demand for energy. There is considerable evidence linking growing energy consumption to dangerously high greenhouse gas (GHGs) emissions and the ongoing challenges posed by climate change (Malm 2016; Pablo–Romero and De Jesús 2016). The energy sector is a major contributor of GHGs as more than half of the demand is met through fossil fuels. This renders its total share of anthropogenic GHG emissions 35% as of 2010 (Bruckner *et al.* 2014).

In consideration of this, managing energy consumption and supply has garnered notable importance within national and international policymaking. It is being stressed that nothing less than a paradigm shift in terms of production and consumption will be adequate to reduce the global energy footprint (Fanghella *et al.* 2019). In this regard, growing importance has been placed on increasing energy efficiency in extraction and conversion, shifting towards non-fossil-fuel-based energy (e.g., renewable, nuclear, etc.), and so forth. From the supply angle, the challenge has been to find contemporary and economical methods to meet the current and foreseeable growth in energy demand. The Paris Agreement (2015) was signed by several developed and developing countries, indicating that they are finally taking climate change seriously. There has also been a heightened emphasis on finding alternative, clean technologies for meeting energy requirements. Goal 7 (Affordable and Clean Energy) of the Sustainable Development Goals (SDGs) is committed solely to issues related to energy. It is worth noting that this goal mainly focuses on access to renewable energy and energy efficiency (UNEP n.d.).

Technology is given utmost importance in the context of energy efficiency—this stems from the assumption that technological interventions can mitigate environmental damage by reducing the quantity of energy required for output production and by increasing the supply of cleaner sources of energy (Foster 2001). However, what is often overlooked is that the availability of cheap and efficient technologies does not automatically result in their adoption by end-users. There is no apparent reason for entrepreneurs and consumers to choose energy-efficient technologies and appliances just because they are available. In fact, actual adoption patterns and consumer choices are governed by complex social, cultural, and psychological processes. Moreover, as numerous studies have shown, the availability of efficient technologies can generate complex feedback loops, which may inversely encourage rather than reduce energy consumption (Polimeni and Polimeni 2006; Sorrell 2009). From the perspective of public policy, this implies that apart from supply-side interventions, influencing demand-side determinants of energy efficiency is crucial for managing energy use (Parrish *et al.* 2020). Typically, demand can either be influenced by non-price mechanisms or by various price-based incentives such as taxes, subsidies, etc. (Allcott 2011a; 2011b). Previous studies on the effect of monetary incentives on consumption have proved to be inconclusive (Fishman *et al.* 2016) or even negative (Sudarshan 2017; Frederiks *et al.* 2015). Price-based incentives are also much costlier to implement than behavioural nudges (Allcott 2011a; 2011b). More importantly, the adoption behaviours of end-users may not always be driven by the calculus of gains and losses but are instead likely to be shaped by informal institutions, traditions, and past habits and are often shaped by boundedly rational conditions. As a result, standard price-based incentives may not always work as planned or may require complementary non-price interventions (Thaler and Sunstein 2009).

Recent literature on behavioural economics suggests that "nudging" producers and consumers by providing them with information about energy costs, environmental externalities, and other relevant information could have significant implications on their choices. It is in this context that this review paper seeks to centre consumer end-use as an important locus of public action. In contrast to the conventional one-sided emphasis on supply-side interventions, it highlights the growing significance and effectiveness of behavioural interventions in altering the energy choices of households. Although a vast majority of the existing literature focuses on developed nations (Abrahamse *et al.* 2005; Andor and Fels 2018; Brandon *et al.* 2017), the outcomes of these studies are likely to provide policy lessons for developing nations and emerging markets as well, especially considering that policymakers have been making concerted efforts at tackling their growing energy footprints.

Taking into consideration the increasing importance of energy end-use, and the consequent pledge made by several governments during the Paris Climate Convention to reduce their energy footprints, a careful analysis of non–price interventions is extremely important. It is with this intention that the review article is structured as follows. The section following the introduction examines the limits of supply-side interventions aimed at efficiency enhancement through technological upgradation, and the third summarizes the findings from different empirical papers that adopted non-price-based behavioural interventions to influence the adoption of energy-efficient technologies. The fourth section provides the discussion and policy lessons, while the final segment concludes the review.

2. LIMITS OF SUPPLY-SIDE INTERVENTIONS: BEYOND TECHNOLOGICAL FIXES

The risks associated with rising energy consumption have been widely noted in the scientific community; however, there has also been a tendency to consider the related issues—climate change, GHG emissions, etc.—as primarily engineering tasks, i.e., a set of problems that can be solved through technological improvements alone (Foster 2001; Brookes 1990; Geels *et al.* 2017). While it is true that by reducing energy input per unit output and generating energy through clean, renewable sources, technological innovations can play a key role in meeting the growing energy demands of the world economy sustainably, we argue that an exclusive focus on technological fixes is inadequate. For one, despite the consistent improvement in technology over the last several decades, energy demands have shown no signs of decline. Based on this, Vance *et al.* (2015) estimate that efficiency increases alone may not effectively influence the energy demand–supply matrix, since energy efficiency would have to grow at historically unprecedented proportions in the coming years to meet the growing needs of the global population. Further, even if efficiency successfully improved to that magnitude, there is no guarantee that it would result in a reduction in the rate of energy consumption. For although technological improvements may result in the use of fewer inputs for a given level of output, this change may also generate complex backward and forward reactions that may spur producers to use more energy or consumers to increase their demand of energy-intensive goods (Foster 2001). In the long run, the incentives of economies of scale may push producers to increase production of the said good, and, consequently, demand greater amounts of energy (Brookes 1990). If this increase in production is accompanied by declining prices, it may give rise to additional pressures on energy use as a direct result of rising consumer demand as well.

The paradoxical effects of efficiency improvements were noted in the late nineteenth century itself, when a pioneer of neoclassical economics, William Stanley Jevons, suggested that technological improvements may increase energy consumption rather than decrease it. He asserted that the cheapening effect these technologies have on the final product could unintentionally lead to higher consumer and producer demand than before (Jevons 1906 [1865]). Though originally propounded by Jevons to explain how steam technology led to increased consumption of coal, this paradox has been the subject of a large body of contemporary literature that underlines the very same unintended consequences of efficiency on energy demand. Several studies have emphasized these rebound effects in the context of both micro-level and macro-level data (Polimeni and Polimeni 2006; Aydin *et al.* 2017; Fowlie *et al.* 2018). To expound, Davis *et al.* (2014) conducted a study on the cash-for-coolers subsidy that was rolled out by the Mexican government to enable households to replace old air conditioners and refrigerators with newer, more efficient models. They reported that in some cases, energy usage increased as a result of the subsidy. The authors also found that the additional features included in the new appliance models may have driven consumers to use them more "than one would have expected based on the pure price response" (Davis *et al.* 2014, 229). In the Netherlands, Aydin *et al.* (2017) found that the rebound effect for energy efficiency is around a third for homeowners and around two-fifths for tenants and is reported to be higher for lower wealth quantiles; further, they note a positive relation between the rebound effect and wealth. Newman and Kenworthy (2000), similarly, point out how the expansion of roads and freeways, often justified as a means of reducing traffic congestion, may, in reality, incentivize more automobile use than predicted, thus paradoxically contributing to more traffic congestion.

In a slightly different setting, studies have noted how the increasing share of renewable sources may have complex effects on the price of electricity, which could in turn increase the overall household demand for energy, leading to a reduction in potential environmental savings. Velez–Henao *et al.* (2020) refer to this as the environmental rebound effect. More precisely, in an attempt to diversify the energy system, the Colombian government adopted a policy promoting the use of wind, solar, and other sources of renewable power. The empirical analysis by Velez–Henao *et al.* (2020) shows the environmental rebound effect offsetting the potential environmental saving. In a similar context, Bahinipati and Viswanathan (2019a) observe that large-scale adoption of irrigation-efficient technologies may not reduce groundwater extraction in water-stressed regions in Gujarat, India.

It is worth noting that although rebound effects are crucial determinants of energy savings, some studies have documented relatively modest energy savings in contexts where there are no rebound effects as well. For example, evaluating a nationwide energy-efficiency programme, Fowlie *et al.* (2018) studied a sample of 30,000 households in the US and reported that energy savings tend to be much lesser than the investment costs associated with energy efficiency. Estimates also suggest that actual energy savings are significantly lesser than the predicted values. Although indicative of a rebound effect, the authors find no strong evidence for the hypothesis. However, it must be noted that even in such cases, the central distinction between technological innovation and ultimate adoption remains crucial.

Even if technological improvements are made at the desired rates—and we assume away the complex rebound effects that they may give rise to—an equally important issue is the challenge of getting producers and consumers to adopt green and efficient technologies. The mere existence of efficient technologies does not mean that they are diffused and put into use by default, especially in decentralized market economies.

To put things into perspective, technology adoption is usually described in rather simple terms in the standard economic literature. One of the central tenets of traditional neoclassical economics is that monetary incentives are crucial determinants of consumer and producer behaviour. Based on the assumption that the typical economic agent is a "lightning calculator of pleasures and pains", the traditional, textbook model of choice tells us that economic agents, be it consumers or entrepreneurs, make choices by balancing their costs and benefits and ultimately only use those alternatives that maximize their net rewards (Veblen 1898, 389). Given that prices are crucial to these calculations, changes in price can have powerful effects on what actions people take. For example, as natural resources diminish and their prices increase, standard models tell us that economic agents are likely to shift towards technologies that use these inputs less intensively (Velthuijsen and Worrell 2002). Thus, it has been argued that the introduction and diffusion of the steam engine in eighteenth-century Britain were largely driven by the fact that not only were labour costs high, but coal and capital costs were low, incentivizing firms to switch towards labour-saving, energy-intensive technologies (Allen 2012). Or as put by Allen (2012, 23), "People respond to price incentives. The timing of the shift to coal, and the invention of technologies to expand its use, reflected the prices of coal, labour, and capital."

In a more contemporary example, Davis *et al.* (2014) have noted how incentives for large-scale appliance replacement motivated around 1.9 million households in Mexico to exchange old refrigerators and air conditioners between 2009 and 2012. Observing incentivizing programmes in India, Bahinipati and Viswanathan (2019b) observe that a pecuniary benefit, along with the removal of the ban on groundwater extraction, has played a major role in the diffusion of micro-irrigation technologies in water-scarce regions in Gujarat. Studies have also noted the importance of Pigouvian taxes to correct the market distortion caused by environmental externalities. Previous studies have suggested imposing a carbon tax based on the social cost of carbon to generate revenue and reduce GHG emissions (Paul *et al.* 2013). Obviously, following the demand law, raising electricity prices could reduce household demand, with the size effect varying according to elasticity.[1] Paul *et al.* (2013) present evidence of changes in the electricity demand and the technology mix due to the carbon tax in the US. In the context of the European Union and the United Kingdom, Platchkov and Pollitt (2011) observe the role of price in driving energy demand, i.e., lesser demand is associated with a high price, including tax. Regarding India, Filippini and Pachauri (2004) calculated that price elasticity varies between –0.29 to –0.51, indicating a decline in the energy use of urban households, approximately 0.3–0.5%, with a 1% increase in the price index.

Given the widespread prevalence of the view that choice is determined by efficiency concerns alone, which underplays the distinction between technological innovation and diffusion, it is not surprising that much of the policymaking discussions on mitigating climate change and conserving energy use focus on technology while missing broader, psychological, cultural, and social structures that determine the use and adoption of such technologies in the first place (Foster 2001; Geels *et al.* 2017). However, as several studies indicate, the issue of adoption is far more complex than it is made out to be, and decentralized decision-making does not always lead to superior, more efficient technologies being adopted, even if they are available in the agents' choice set.

In the context of eighteenth- and nineteenth-century Britain for instance, Malm (2012; 2016) notes that the adoption of the coal-powered steam engine over alternative energy sources like water was not driven by a loss–benefit calculus alone, but also by the desire to bring workers under their control. Or as Malm (2012, 113) puts it, "As a prime mover based on a fossil fuel, rather than on water flowing through particular spots determined by the contours of landscapes, it granted capital the power to search out the cheapest and most disciplined labour." To take another classic example—it is well recognized that mass transit in the US is far weaker than private transport, partly due to the influence of powerful "automobile–oil–rubber" lobbies (Whitt and Yago 1985, 37–65; Newman and Kenworthy 2000, 15–25). More than an individual choice based on cost and benefit alone, the diffusion of the automobile was a result of hidden state subsidies, enormous volumes of cheap credit, provision of roadways, and an entire cultural industry built around automobile consumption, all of which played a pivotal role in building up mass demand for automobiles instead of public

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[1] The results of these studies must be considered in light of their contexts, because, as Chen (2017) notes in a study based in Taiwan, the demand curve for energy consumption could be inelastic. Thus, in the complete absence of substitution options, electricity prices play an insignificant role in household decision-making.

transport (Mattioli *et al.* 2020). Similarly, historical institutionalists and new institutionalists who emphasize the importance of path dependence suggest that technological diffusion is often dictated by past historical events. Once technologies are chosen, even when feasible and more efficient alternatives exist, the choice tends to be self-perpetuating, creating inertia towards the status quo (Puffert 2008). More recently, randomized experiments have been used to analyze technology adoption practices, and studies have found evidence of organizational and cognitive barriers that may prevent optimal technology adoption practices in the context of developing countries (Hanna *et al.* 2014). Hanna *et al.* (2014), for example, studied the technology choices of Indonesian seaweed farmers. The study found that while farmers are generally aware of important aspects of the farming process, a large proportion failed to notice the importance of pod size in determining output, despite high rates of literacy and long years of farming experience.

Inversely put, efficiency need not always dictate the choices that agents make, especially in uncertain and complex systems. This is as true of consumer choices as it is of those made by producers. A growing literature has emerged on the so-called "energy paradox" or "efficiency gap", which points to the non-adoption of feasible and affordable energy-conserving technologies and appliances by consumers (Sallee 2014; Allcott *et al.* 2014, 72–88; Allcott and Greenstone 2012, 3–28). Studies suggest that consumers' reluctance to choose energy-saving options, despite the massive savings that could accrue in the long run, stems from complex behavioural factors that underlie how people make decisions when faced with informational asymmetries of various kinds and fundamental uncertainties (Alcott and Mullainathan 2010). While the hard sciences are useful to develop technologies, it is observed that cost-effective behavioural interventions drive households to save energy (Alcott and Mullainathan 2010). Given that technological fixes alone may not provide a way out of the current conundrum facing the global economy—and given that a large proportion of the energy demand emanates from the residential sector—this line of analysis stresses the need to find ways to reduce energy consumption directly by influencing the demand-side determinants of technology adoption (Parrish *et al.* 2020). It emphasizes the need to understand the non-monetary determinants of end-use, which it argues can be as powerful a tool to alter energy consumption as any technological fix; it is to these studies that we turn in the next section.

3. NON-PRICE BASED INTERVENTIONS: INSIGHTS FROM BEHAVIOURAL ECONOMICS

Behavioural economics incorporates insights from psychology into the study of economic decision-making. It is rooted in standard neoclassical economics in the sense that the analysis begins with the individual, but it seeks to make these models more realistic by relaxing their stringent assumptions about human behaviour (Kahneman 2003; Thaler and Sunstein 2009). In particular, this strand of literature shows that in the context of limited information, uncertainties, and risks, people take actions that are not always optimal. More importantly, their behaviour is not merely a pathology that is to be assigned to the margins of theory but is a persistent and repeated response to the highly complex situations they are faced with. Despite generally being brushed off by standard models, this behaviour can constitute the predictable, albeit irrational, response of human beings to the uncertainties that they face. These modes of behaviour can be explained by applying psychological theories on human behaviour to the economics of decision-making. In the following paragraphs, we outline the findings of papers that aim to investigate the effectiveness of nudge-like interventions in bringing down energy use at the household level. The paper surveys studies that investigate how households can be induced to reduce their energy use, either by encouraging them to cut down their energy use in absolute terms or by persuading them to make investments in energy-efficient technologies. Inducing households to do either requires targeted policies, and the following studies note the role of behavioural interventions in promoting these measures (Andor and Fels 2018).

In this context, recent literature on household decision-making suggests that people repeatedly underestimate the energy savings that they can make from adopting efficient or clean technologies, which results in "the low adoption of energy-efficient technologies despite potentially large saving" (Alcott and Taubinsky 2013, 2). Economists have started to stress on how behavioural factors can act as barriers to optimal decision-making. It has been pointed out that to calculate the costs and benefits of alternatives, a consumer requires a certain level of literacy and a familiarity with numeracy (Blasch *et al.* 2019). Energy labelling and star ratings are two mechanisms that help increase energy literacy levels, apart from conducting programmes and implementing non-price-based policies (Jain *et al.* 2018a; 2018b). Further, even in cases where cognitive barriers are not significant, it has been argued that consumers and producers simply do not make use of the available information and thus underestimate the hidden costs of their actions (Kahneman 2003; Allcott and Greenstone 2012). This is what Sallee (2014) refers to as "inattention bias", which she defines as the unwillingness of decision-makers to find and incorporate relevant information while making choices due to the perception that the cost of such an exercise far outweighs its benefits. This is particularly true in the case of inter-temporal choices, where agents are required to make decisions that not only impact them in the present but across several other periods as well.

In a slightly different context, Leard (2018) uses a household-level survey to show how inattention among automobile buyers leads them to undervalue fuel costs. His results demonstrated how estimates of savings vary between attentive and inattentive buyers. Even when choices are less complex in terms of temporality, the sheer abundance of choices often pushes consumers to make decisions based on rules of thumb, heuristics, and past habits, all of which make them less likely to change their consumption patterns even when such shifts may be beneficial (Abadie and Gay 2006). Such inertia, or what has been called a "status quo bias", may arise when consumers deem search costs to be high when their choices are shaped not only by economic factors such as prices and income but also by existing endowments or when faced with considerable uncertainty with regards to future demand/price (Kahneman *et al.* 1991, 193–206). Thus, previous studies have uncovered a persistent tendency on the part of residential consumers to stick to incumbent electricity providers, leading to greater concentration in markets that could potentially hurt consumer welfare (Brennan 2007). In a study of Swiss households, Alberini *et al.* (2013) find that price-related uncertainty tends to make families stick to the status quo when it comes to decisions regarding investments in energy-saving home renovations.

In summation, due to certain psychological biases and limitations to cognitive resources, agents often fail to make choices predicted by utility maximization. These behavioural factors also affect energy consumption patterns either directly or indirectly. To put things in perspective, traditional literature has a lot to say on market failures and their effects on consumer welfare, but it has been relatively silent on failures stemming from consumer behaviour itself. Behavioural economics, instead, stresses how individuals—driven by complex psychological dynamics—fail to take optimal actions. This issue can be explicated by comparing it to the established idea of externalities. Traditionally, externalities lead to a non-coincidence between privately optimal actions and socially optimal ones, arising from the external costs/benefits that agents impose on one another. Behavioural economics, however, points us towards the possibility that agents may impose costs upon themselves by acting in ways that do not correspond with their long-term interests. All of this has crucial implications for public policy. If psychological factors affect consumer choices and behaviours, standard monetary incentives and punishments may not be enough to control under-investment in energy-saving appliances. If at all, when such incentives are applied without heeding underlying consumer preferences, there is a chance that it will backfire. As has been argued by Frey and Jegen (2001, 589–611) and others, external motivations of this sort may "crowd out" intrinsic motivations, including pro-environmental ones (Frederiks *et al.* 2015, 1383–1394). Under these conditions, it becomes incumbent for policymakers to consider the psychological dimensions of consumer behaviour while developing energy-related policies.

Generally speaking, behavioural policy interventions can take on myriad forms. Unlike price-based instruments, however, these interventions seek to influence consumer preferences directly or indirectly through what are called "nudges". These usually involve a comprehensive set of interventions ranging from providing energy-saving information, goal-setting, and a peer comparison model of energy consumption, which allows households to compare their consumption with their neighbours (Sudarshan 2017, 320–335). While the distinction between nudges and traditional price-based instruments is often blurred, the idea behind nudges is derived from the notion of "libertarian paternalism", i.e., the idea that interventions be designed to not overtly constrain consumer sovereignty and gently push them to adopt privately optimal alternatives (Hansen 2016, 155–174). They are, in Galle's (2014, 839) words, "innocuous little speed bumps" that decision-makers can opt out of at minimal cost. More generally speaking, Hansen (2016, 158) states that

A nudge is a function of (I) any attempt at influencing people's judgement, choice or behaviour in a predictable way that is motivated because of cognitive boundaries, biases, routines, and habits in individual and social decision-making posing barriers for people to perform rationally in their own declared self-interests and which (2) works by making use of those boundaries, biases, routines, and habits as integral parts of such attempts.

Nudging, like behavioural interventions, is considered to be an inexpensive approach to altering energy use (Allcott and Mullainathan 2010; Allcott *et al.* 2014; Brandon *et al.* 2017). Based on 38 natural field experiment studies, Brandon *et al.* (2017) concluded that behavioural interventions reduce energy consumption by 35–55% even after the end of treatment. Another study by the European Environment Agency (2013) summarized that various behavioural interventions (e.g., feedback, target-setting, etc.) could save energy up to 20%.

Often, providing consumers with relevant information regarding energy use through easy and relatively cost-effective means is an effective method of nudging them towards energy conservation (Andor *et al.* 2020; Brülisauer *et al.* 2020; McCalley and Midden 2002; Tyagi *et al.* 2020). In a field experiment involving graduate students at the National University of Singapore, Brülisauer *et al.* (2020, 111742) tested three treatments: (i) sharing information on energy use by air conditioners relative to total use, (ii) sharing information on the neighbour's electricity consumption, (iii) sharing information on three unknown residents' electricity consumption. The study reported that providing appliance-specific feedback reduces the level of consumption—i.e., the electricity consumption by air conditioners reduced by 17%. Similarly, Andor *et al.* (2020) conducted a field experiment in Germany, wherein the sample households were asked to install appliance-specific smart meters. The results suggest that electricity consumption was reduced by 5%, and a further reduction was observed during peak hours, of approximately 10–15%. Such a reduction could be augmented if appliance-level feedback is provided—the study estimates that such an intervention could potentially generate around €570–600 million per annum in consumer surplus for households in Germany (Andor 2020). In a similar context, several studies have shown how energy labels allow consumers to easily process information and make informed choices by taking into consideration the energy efficiency of household appliance models (Sammer and Wüstenhagen 2006; Shen and Saijo 2009; Jain *et al.* 2018a; 2018b).

Altering intrinsic preferences can, as studies have shown, serve as a powerful mechanism to reduce energy demand. However, individual choices are made in social contexts. Institutional scaffolding, social practices and mores, kinship and familial ties, broader class conflicts, and state interventions can shape the dynamics of how individuals make choices. Recognizing the social contexts within which individuals act is important as it widens our understanding of the forces that drive energy transitions and thus broadens the scope of policy interventions aimed at energy transitions (Stephenson *et al.* 2015; Klaniecki *et al.* 2020; Geels *et al.* 2017). Behavioural economists, while being rooted in methodological individualism, partially recognize the social nature of decision-making and emphasize how "behavioural choices by individual agents (as well as their objective functions) can (either positively or negatively) be affected by other players' preferences, material well-being, intentions and/or behavioural choices" (Zarri 2010, 563). In this context, a widely commented upon nudge involves the use of social norms in the form of peer comparisons. OPOWER's experiment with home energy reports (HERs) is one example of how non-price-based interventions can positively reinforce energy savings by nudging consumers (Allcott 2011a; 2011b). To change households' use of electricity, utility companies in the US recruited OPOWER to inform consumers regarding their energy usage. Electricity bills along with HERs were sent out to 600,000 households as a randomized control trial. Each HER had two major components: a peer-comparison module and an action-step module. The reports were sent to the treatment groups at varying frequencies ranging from monthly to quarterly, and their energy usage was compared with control groups. The results uncovered by Allcott (2011b) suggest that the effect of HERs was "equivalent to an 11–20% short-run price increase or a 5% long-run price increase" (Allcott 2011b, 1083). Moreover, Allcott and Rogers (2014) emphasized that the OPOWER intervention could result in long-term changes in energy-related decisions when treatments are repeatedly applied. Specifically, energy consumption declined immediately after HERs were received, but it then slid back to pre-treatment levels. However, in the long run, when "the intervention is repeated, people gradually develop a new 'capital stock' that generates persistent changes in outcomes" (Allcott and Rogers 2014, 3005). This capital stock, Allcott and Rogers (2014) note, includes energy-saving appliances that consumers invest in but also new habits that consumers imbibe and incorporate into their decision-making process.

Similarly, Brandon *et al.* (2019) evaluated the effectiveness of two nudges implemented on 42,100 households in Southern California by OPOWER—which involved the provision of peak energy reports (PERs) and HERs to households. All households were randomly sorted into four mutually exclusive groups and received one out of four options—i.e., only HER, only PER, both HER and PER, and no correspondence (control group). While the "only PER" group reduced energy consumption by 2–4%, consumption plummeted by 7% when both PER and HER were implemented together (Brandon *et al.* 2019, 5293–5298). Corresponding observations were reported by papers published in the 1980s. Midden *et al.* (1983), for instance, reported that providing the information alone is ineffective and that comparative feedback is more effective in reducing electricity consumption than individual feedback. Likewise, Hutton *et al.* (1986) found that households in the US and Canada reduced consumption by 4–5% when they received information along with feedback.

4. DISCUSSION AND POLICY IMPLICATIONS

The primary aim of this review is to underscore the importance of behavioural interventions as an alternative tool for encouraging household energy conservation. It has been established that the residential sector plays an important role in meeting energy-related goals; yet, studies show that consumers may not make sustainable choices of their own accord even when such alternatives are economically beneficial to them. In this regard, studies indicate the importance of reshaping how people make decisions. A series of studies that have emerged over the last few years suggest that public policies aimed at altering energy consumption are likely to be effective if they leverage the behavioural dimensions of decision-making. That is, if they directly alter how people make choices—"nudging" consumers into making sustainable choices. While much of this emerging body of literature has been primarily focused on developed nations, these studies hold important lessons for developing nations as well. In this regard, three issues, in particular, are worth emphasizing.

First, although energy-conservation goals require new technologies and policies to scale up efficiency, several studies have found that technological fixes alone may be insufficient. For one, a mere improvement in energy efficiency may increase rather than decrease demand due to complex rebound effects. Moreover, the mere availability of better technologies is not likely to result in their widespread adoption due to behavioural factors at the consumers' end. It follows, therefore, that any policy that aims at mitigating the negative effects of growing energy consumption must emphasize the importance of directly altering consumer end-use as well.

Second, if consumer end-use is to be directly influenced, traditional monetary incentives such as taxes, subsidies, and so on may be of limited use as stand-alone tools. Not only are policies such as Pigouvian taxes likely to face implementation difficulties from a political point of view, but the carrot–stick approach may fail to leverage important dimensions of human behaviour that could be directed towards pro-environmental ends. Pecuniary incentives, on the contrary, end up having complex feedback effects and may crowd out potential pro-social behaviours of households. In such contexts, "nudge"-like interventions such as goal-setting, commitment, information, peer-group comparison, appliance-specific information, and so on, may prove to be potent measures to alter energy use. There is considerable evidence of their effectiveness in recent studies (e.g., Allcott 2011b; Brandon *et al.* 2019).

Third, while individual behaviours provide an important site of action for policymakers seeking to reduce energy use, there are reasons to want to move beyond the epistemic focus on individuals and broaden the scope of analysis. Individual decisions regarding energy use are deeply embedded in societal-level processes.

Individuals do not seek to 'consume' energy for its own ends, but rely on it to facilitate everyday practices such as commuting to work, being comfortable at home, or laundering clothes. These energy-using practices have become embedded in contemporary social life, and rely on complex and embedded infrastructures such as national road networks, the domestic building stock and national electricity grids. (Hampton and Adams 2018, 215).

Previous studies, have, therefore, emphasized the multi-level determinants of energy transitions and how altering energy use requires broad-based changes in "energy cultures", infrastructure, markets, and institutions in addition to changes in user behaviour (Stephenson *et al.* 2015, 117–123; Geels *et al.* 2017, 463–479; Klaniecki *et al.* 2020, 111092). Moreover, transitions in energy use are likely to have contradictory effects on stakeholders and are thus likely to be deeply conflictual processes, which unless managed, could have consequences for long-term energy usage patterns (Siciliano *et al.* 2018). Behavioural economics provides an interesting vantage point to address some of these issues; but even while several strands within it recognize the crucial ways in which the social environment matters, much of the existing work is wedded to the methodological individualism of neoclassical orthodoxy and thus undertheorizes the links between social structure and individual agency (Frerichs 2018). Given that energy consumption is deeply embedded in everyday cultural practices (Geels *et al.* 2017; Klaniecki *et al.* 2020) and is affected by social provisioning processes (Mattioli *et al.* 2020), and given that individual choices are inescapably enmeshed in complex power struggles that are ongoing within society, there is considerable room to build epistemic bridges between the sociological and behavioural strands of the energy transition debate (Hampton and Adams 2018). Doing so is particularly crucial to extend the geographical scope of behavioural studies, which have thus far been restricted to the developed world. In non-Western contexts, the distinction between public and private spheres is less clear, and conceptions of possessive individualism often co-exist along with strong collective identities. Here, the social environment within which decision-making occurs is likely to have a far more salient influence than elsewhere. Perhaps—precisely because of these realities—the behavioural turn in economics has not been extensively extended to the developing world yet. In fact, a striking feature in most of the studies mentioned thus far is the dearth of research in the context of developing nations.

Concerning India, in an empirical study, Suryawanshi and Jumle (2016) used a primary survey to highlight the role of socio-economic variables in determining household energy-conservation behaviour. Tyagi *et al.* (2020) surveyed the effectiveness of behavioural interventions in developed countries and discussed their applicability in the context of developing countries. Sudarshan (2017) adopted a nudging approach to assess household energy consumption behaviour in Delhi and found that informational interventions helped reduce energy consumption by 7%. However, the analysis also found that households did not reduce their energy consumption when they were given both information as well as pecuniary benefits—which indicates that monetary benefits crowd out non-price-based behavioural interventions. Further, a tariff is observed to be more significant in the case of nudged households (Sudarshan 2017). These results correspond with a field experiment conducted by Chen *et al.* (2017), which found evidence of pro-environmental preferences in urban India. Their study found that non-pecuniary information regarding the health and environmental effects of energy consumption can significantly reduce energy consumption. While the studies cited here all seem to suggest the effectiveness of behavioural interventions, Prabhu *et al.* (2013) paint a more complex picture. They studied a large-scale programme launched in rural Kerala to greater awareness about energy efficiency. The study revealed that sustained campaigns, training classes, and local government involvement can play an important role in raising awareness regarding energy use. The study also highlighted, however, that habits and preferences for the status quo exerted a strong inertia on energy-related decisions and acted as a barrier to the adoption of energy-efficient lifestyles.

5. CONCLUSION

The consensus that a fundamental shift in energy-use patterns is crucial for building a sustainable future is undeniable and has been widely recognized. That such a shift requires a paradigm change in energy efficiency facilitated through innovative and radical new technologies has also been widely commented upon. What is often not taken into consideration, however, is the potential role of demand-side factors that influence how end-users make decisions regarding energy use. Many existing policy frameworks emphasize the role of supply-side technological solutions in achieving energy transitions and realizing low-carbon futures. However, recent studies in behavioural economics suggest that influencing consumer choice through behavioural nudges can play an important role in this regard. Given these reflections, there is an immediate need to design policies that aim at reducing consumer end-use through innovative behavioural programmes, especially in the context of developing and market economies. Rather than thinking of energy sustainability solely in terms of supply-side solutions, it is becoming increasingly incumbent on policymakers to propose holistic, multi-dimensional solutions that seek to tackle demand-side as well as supply-side determinants of energy use.

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Availability of data and materials This is a review paper, and all the materials used in this study are included in the article.

Author contribution SSR collected all the papers required for this review article, and these papers were distributed equally among CSB, RAS, and SSR to read and summarize the main arguments and findings. CSB and RAS authored the original draft. All authors have read and approved the final manuscript.

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