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OVERVIEW

Domestic energy consumption and climate change mitigation

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In this overview, we use domestic energy use as a lens through which to look at climate change mitigation. First, we provide a brief overview of research on domestic energy use, covering four main disciplines: engineering, economics, psychology, and sociology. We then discuss the results of empirical studies that examine how households may be encouraged to reduce their energy use and help mitigate climate change. We include research findings in three key areas: technological innovations, economic incentives, and informational interventions. We outline the effectiveness of each of these approaches in encouraging domestic energy conservation and provide instances where such approaches have not been effective. Building on this established body of knowledge on direct energy consumption (i.e., electricity, gas, and fuel consumption), we highlight applications for addressing indirect energy consumption (i.e., energy embedded in the products households consume) by discussing its implications for sustainable food consumption as a climate mitigation option. We conclude this overview by outlining how research from the four disciplines might be better integrated in future research to advance domestic energy conservation theory and empirical studies.

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1 | DOMESTIC ENERGY CONSUMPTION AND CLIMATE CHANGE MITIGATION

Scientists are now more certain than ever that humans are responsible for climate change and unless emissions of CO_2 are reduced dramatically, we risk severe, pervasive and irreversible impacts from changes to the climate (Field, Barros, Mach, & Mastrandrea, 2014). Domestic energy use accounts for a significant portion of global greenhouse gas emissions, primarily through combustion of fossil fuels. Globally, about a quarter of total final energy demand (i.e., energy consumed by households at point of use) can be attributed to the residential sector, with a general increasing trend since 1970 (Johansson, Patwardhan, Nakićenović & Gomez-Echeverri, 2012).

Households use energy directly (through lighting, heating) and indirectly. Indirect energy use refers to energy embedded in the production, transportation, and disposal of consumer goods and services (Reinders, Vringer, & Blok, 2003). Life cycle assessment (LCA) research has quantified an increasing number of these indirect energy impacts in household goods such as food, clothing, or electronics (Duan, Eugster, Hischier, Streicher-Porte, & Li, 2009; Peters et al., 2010; Woolridge, Ward, Phillips, Collins, & Gandy, 2006). Bin and Dowlatabadi (2005) find that the average U.S. household in 1997 emitted 40% of CO_2 emissions from direct energy activities (household energy use and personal travel) and 60% from indirect energy use. A study of 11 EU countries observed that the proportion of indirect energy consumption can vary between 36 and 66%, depending on

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the country (Reinders et al., 2003). Therefore, to address the issue of climate change mitigation via household consumption, it is necessary to expand our focus beyond direct energy use.

A major source of indirect energy consumption comes from food consumption. Recent studies indicate that the proportion of energy use dedicated to food production is substantial. For example, estimates of total U.S. energy used to produce food range from 8–16% (Canning, 2010; Cuéllar & Webber, 2010) depending on how the boundaries are drawn around the energy input analysis of the food (i.e., higher estimates include energy used by consumers who drive to buy food; Cuéllar & Webber, 2010). The opportunity for reductions in indirect energy consumption via food has also garnered more attention as empirical research has documented that developed nations waste 13–25% of food brought into the home. Environmental groups such as World Resources Institute and Natural Resources Defense Council have begun to focus on food systems, including consumption, as a realm to target for reducing waste and shifting consumption for greenhouse gas reductions.

Households can make significant contributions to climate change mitigation through efficiency and curtailment behaviors for both direct and indirect energy emissions (Gardner & Stern, 2008). Efficiency behaviors are actions or measures that result in less energy being used for a given level of energy service (e.g., insulating a building, installing light-emitting diodes [LEDs]). Direct energy efficiency behaviors typically involve the one-off purchase and installation of an appliance or device, and imply a financial cost (e.g., home retrofits, energy efficient appliances). For indirect efficiency behaviors, such as food consumption, this means choosing food that has been produced using less energy intensive means (i.e., climate friendly agriculture) or switching to foods that provide similar nutritional value (i.e., calories or protein content) with fewer greenhouse gas impacts. Curtailment behaviors are actions that result in less service or utility (e.g., lowering thermostat settings, switching off lights) or buying less food to avoid overeating or food waste. Direct and indirect energy curtailment behaviors tend to be low or no cost but need to be done frequently to achieve energy savings (e.g., lowering thermostat settings, switching off lights, and purchasing smaller portions of food) and can involve the loss of amenity associated (e.g., less heating, less lighting, and less calories). In this overview, we include research on direct household energy (i.e., gas, electricity, and fuel use) for the provision of useful services (e.g., lighting, heating) and conservation efforts to provide insights into how this may apply (or not apply) to addressing indirect energy use, specifically food, in households.

Evidence suggests that there is potential for households to reduce direct and indirect domestic energy use. A recent survey of U.S. households indicates that greenhouse gas emissions from household direct energy consumption could be reduced by up to 20% through the adoption of efficiency and curtailment behaviors (Dietz, Gardner, Gilligan, Stern, & Vandenbergh, 2009). One analysis of household carbon footprints that accounts for direct and indirect energy consumption suggests that food makes up 10–30% of a household's carbon footprint (or indirect energy footprint; Jones & Kammen, 2011). A modeled five person household in St. Louis can save $1,400 per year and reduce its carbon footprint by almost 3 tCO2e/year by reducing overeating and waste from food and reducing the amount of meat, dairy, and nonessential food items consumed (Jones & Kammen, 2011, p. 4093). However, studies indicate that it can be difficult to encourage the adoption of both direct and indirect energy behaviors. Commonly used policy instruments such as the provision of information and the use of financial incentives have had mixed success and uptake (Abrahamse, Steg, Vlek, & Rothengatter, 2005; Stern et al., 1986).

A number of factors contribute to growing domestic greenhouse gas emissions, including population growth, income, urban settlements in different climates, technology adoption and use, cultural factors, and individual behaviors (Fouquet, 2010). Interdisciplinary perspectives on energy consumption studies are necessary because of the complex interplay of these individual, technological, economic, and social drivers of domestic energy consumption. This includes a better integration of social science research in the realm of domestic energy use (Sovacool et al., 2015; Stern, 2014). Interdisciplinarity refers to an integration of knowledge, theoretical frameworks, and/or methodological approaches from different disciplines (Max-Neef, 2005). In interdisciplinary research, theories or methods from one discipline are complemented by those from other discipline(s) and—by proxy—the research is collaborative in nature. Interdisciplinary research can provide a more integrated theoretical and empirical understanding of the ways in which the various drivers of energy use interact. It can also guide practical policy recommendations for climate change mitigation via reductions in domestic energy consumption. However, interdisciplinary energy research is largely lacking.

This overview focuses on the potential for the domestic sector to contribute to climate change mitigation. This overview has two broad aims: (a) bring together theoretical and empirical research from four key disciplines in the area of direct energy consumption and (b) distill key learnings from this research that may be used to inform research on indirect energy consumption. We use food consumption to illustrate the ways in which interdisciplinary approaches might be employed to reduce our greenhouse gas emissions associated with food choices. We have chosen food as a case study because recent analyses identify food as embedding high levels of greenhouse gas emissions. We start by providing an overview of some of the key frameworks and methods used in the study of domestic direct energy consumption in four disciplines, that is, engineering, economics, psychology, and sociology. We highlight the contributions made by these disciplines in understanding domestic energy consumption through illustrative examples. We move on to discuss recent developments in interdisciplinary research. We highlight where the disciplines may complement each other and suggest where we think (more) interdisciplinary work could be possible. We conclude this overview by discussing how interdisciplinary perspectives can address greenhouse gas emissions through food consumption.

2 | FRAMEWORKS FOR UNDERSTANDING DOMESTIC ENERGY CONSUMPTION

Academic work on domestic energy consumption can broadly be classified into four categories: (a) energy use as an issue of technology and buildings, (b) the economics of energy use, (c) individual behavior and energy use, and (d) social constructions of energy use. Here, we briefly outline these perspectives. More extensive reviews of these different perspectives can be found elsewhere (Shwom & Lorenzen, 2012; Wilson & Dowlatabadi, 2007).

Engineering and building sciences focus on the energy use (and energy efficiency gains) associated with technological innovations and building design. Research in building design examines how the energy efficiency of buildings can be improved, such as LEED-certified buildings, or *Passivhaus*, a building design standard that results in homes that require less energy for heating and cooling. However, building design standards that depend on technological and design specifications may not be as effective as believed. For example, the European Union policy titled Energy Performance of Buildings Directive (EPBD) requires energy labeling for all existing residential buildings (graded in labels A through G). Studies in the Dutch housing sector, using energy consumption data, found that the worst graded buildings used far less energy than modeled and the best graded (A, A+, and A+++) buildings used more energy than modeled (Majcen, Itard, & Visscher, 2013). There can be considerable variations in demand for energy use even when factors such as housing type or sociodemographic characteristics are taken into account (Lutzenhiser, 1993). Energy use can vary substantially even in physically identical homes. This suggests that an important source of variation in energy demand stems from variations in how the technologies are used and highlights the role of household behaviors and routines. Engineering and related sciences also examine how technology and technological innovations can contribute to domestic energy conservation via an increased efficiency of domestic appliances, that is, how to get the same or more output, with less energy input required, such as energy efficient lighting. The assumption is that households will save energy when they implement these technological innovations. However, the ways in which individuals in households use these technologies are often not considered in this line of research—a point to which we will return later.

While engineers and building scientists consider changes to the building envelope and technological innovations as key drivers of energy conservation (and emission reductions), economists focus on the effect of price signals on people's decision-making. Economists view individuals as rational decision makers, balancing costs (e.g., initial cost of an energy efficient appliance) and benefits (e.g., expected energy and financial savings of the appliance) and who choose the option with the highest expected utility. The reasons why households do or do not invest in energy efficient technologies may be explained in terms of imperfect information (i.e., consumers do not know of all available options), market failure, or what is known as "behavioral failures" (i.e., lack of uptake). Economic research focuses on the role of energy prices, upfront cost and/or payback periods (i.e., discount rates) associated with energy efficient upgrades and retrofits (Wilson & Dowlatabadi, 2007). Economic research indeed finds that a higher cost of energy is generally associated with higher adoption rates of energy efficient appliances (Anderson & Newell, 2004). Research in this field also uses economic modeling to estimate the relationships between socioeconomic drivers, such as dwelling type, household size, and income, and household energy consumption (Wyatt, 2013).

To elicit the factors that give insight into the rational decision-making process, economists make use of choice experiments. In a choice experiment, people are given scenarios that have different sets of characteristics and they are asked to indicate their preferred option (stated preference), or their willingness to pay (WTP) for different options. The choices people make and the associated trade-off between scenarios reflects the relative importance of the characteristics of each scenario (e.g., perceived costs versus perceived benefits). Choice experiments have been used to examine people's WTP for renewable energy (Scarpa & Willis, 2010), energy efficient appliances (Ward, Clark, Jensen, & Yen, 2011; Ward, Clark, Jensen, Yen, & Russell, 2011), and energy efficient retrofits (Banfi, Farsi, Filippini, & Jakob, 2008; Chau, Tse, & Chung, 2010). A UK study found that while consumers highly valued renewable energy, this value was not necessarily large enough to compensate for the high initial capital costs of renewable energy technologies (Scarpa & Willis, 2010). A Swiss study found that WTP for home retrofits varied significantly for different energy-efficiency measures, with the highest WTP for improved air conditioning and ventilation systems (Banfi et al., 2008). Economic studies thus provide insights into the trade-offs people make in their decisions relating to energy consumption.

Behavioral economics integrates economics and insights from psychology about individual decision-making (Pollitt & Shaorshadze, 2011). Research findings from behavioral economics include work on so-called nudging (also known as choice architecture). Nudging refers to a change in the default option, which is assumed to result in behavior change. For example, if a utility company were to start offering "green" (i.e., from renewable sources) electricity to their customers, they could offer this to households as a default, and provide households with the choice to opt-out, or they could provide households with the choice to opt-in. The assumption is that when people need to "opt-out," the uptake of this scheme would be higher, compared to when people need to "opt-in." A more in-depth review of the economics and behavioral economics literature and energy efficiency can be found elsewhere (Gillingham, Newell, & Palmer, 2009).

Psychological research focuses on understanding perceived barriers and enablers of domestic energy use behaviors with the aim to better understand how to change these behaviors. While economists focus mainly on price signals and perceived costs and benefits (i.e., self-interest), psychological research also includes altruistic motivations, such as values, beliefs, and norms. In psychological research of energy use, the unit of analysis is the individual and theoretical frameworks focus on understanding the relationships between individual attitudes, values, and beliefs on one hand and domestic energy use and conservation on the other (Abrahamse & Steg, 2009; Klöckner, Sopha, Matthies, & Bjørnstad, 2013). Theoretical models range from those that focus on self-interest (akin to economic thinking), such as the theory of planned behavior (Ajzen, 1991) and models that focus on the role of environmental concern and altruism, such as the value-belief-norm theory (Stern, 2000). Studies have found that while energy consumption is largely driven by sociodemographic characteristics, such as income and household size, energy conservation behaviors are mostly related to individual-level variables such as attitudes (i.e., opinions) toward energy conservation (Abrahamse & Steg, 2009; Gatersleben, Steg, & Vlek, 2002), identity and values (i.e., guiding principles in people's lives; Abrahamse & Steg, 2011; Sahin, 2013), and habits (i.e., routine behaviors; Huebner, Cooper, & Jones, 2013). Research also suggests that different behaviors are related to different behavioral determinants. For example, a recent study found that efficiency behaviors were related to sociodemographic variables, while curtailment behaviors were related to environmental attitudes and concern (Karlin et al., 2014).

While the focus in psychology is mostly on individual-level motivations, household and society-level influences are part of sociological analyses of domestic energy consumption. Sociological perspectives help energy consumption studies move past individualistic approaches that focus on rational action or personality driven behaviors to more nuanced understandings of how individual agency and social structures interact to influence the consumption of energy. Agency refers to how much power an individual has to act in a given context, while social structure refers to the sets of formal and informal rules (institutions) that pattern relations and actions within a society. The sociological perspective has actively debated how social structures are balanced with the agential choices consumers make in influencing energy consumption. Early approaches focused on highlighting how sociodemographics (such as social class, ethnicity, life cycle stage, gender, education, and occupation) that psychology had identified as important predictors of energy consumption were actually group identifiers. The various sociodemographics represented groups of people who had different activities, housing, and technology and thus different energy consumption profiles (Lutzenhiser, 1992; Rosa, Machlis, & Keating, 1988). An early attempt to integrate how social groups and technological infrastructure interact was Lutzenhiser's 1992 paper on cultural perspective on energy use that highlighted how technology can be theorized as material culture and that its forms coevolve with culture. He argued that while people's technological adoption and energy use had been explained by "needs, comfort, and convenience," a cultural approach highlighted the social construction of those meanings and preferences by different groups (Lutzenhiser, 1992). Another study highlighting the coevolution of technology and culture is Hughes's historical analysis of electrification of Western societies (Hughes, 1993). In the study, he highlights how cultures and institutions within and across nations influence the decision-making of managers, inventors, and engineers which in turn shapes the development of the electric system. For example, he points to the absence of regulation in the early years (1880–1930) and the prevalent views of private utilities that electricity should be paid for by end users as shaping where and when electrification happened. The values that guide decision-making are embedded in the system making them "evolving cultural artifacts rather than isolated technologies" (p. 465) and these systems subsequently shape consumption (Hughes, 1993).

A more recent social theoretical strand that seeks to explain how social and technological factors interact to shape household energy consumption is practice theory (Shove & Pantzar, 2005; Shove & Warde, 2002; Spaargaren, 2011). Practice theory bridges the gap between cultural and technology lock-in and agency by moving away from a behavioral approach and taking the social practice as unit of analysis. Social practice theory does not focus on individual choices to undertake a specific behavior, but instead focuses on common activities that are routinely undertaken in daily life. These common activities are called social practices and they are relatively stable and identifiable objects (Shove & Walker, 2007) that consist of an "organized constellation of actions—an integral bundle of activities" (Schatzki, 2002, p. 71). Examples of practices include: eating, walking, cleaning, and driving, which all have significant energy implications.

An important point that social practice theory emphasizes is that energy consumption isn't actually about energy at all, but rather about using energy in activities that serve a purpose in our lives. In this sense, practice theory is well suited to address both indirect and direct energy consumption. Practices are constituted by people who are interacting with their material world (our household technologies or grocery stores and kitchens for example) in a spatially and temporally patterned way. A practice is made up of three elements: competence, meaning, and material. Competence is the understanding and ability to perform an activity. Meaning is the social significance of performing that activity at a given time. The material includes the physical technology or infrastructure and body needed to perform the activity (Shove, Pantzar, & Watson, 2012). The implication of social practice theory is that energy consumption is a part of these social practices and thus the social practices are the unit of change, not the household or the individual, if one wants to change household energy consumption.

The four disciplines have made important theoretical contributions to the study of direct energy consumption. Each discipline has its own emphasis on how energy consumption occurs and what influences consumption, that is, the role of technology (engineering), the rational decision maker (economics), individual attitudes and behavior (psychology), and the role of social structures, institutional arrangements, and practices (sociology). We now turn to empirical evidence from the four disciplines on understanding and changing direct domestic energy consumption.

3 | EMPIRICAL STUDIES ON DOMESTIC ENERGY CONSERVATION AND CLIMATE CHANGE MITIGATION

3.1 | Understanding energy consumption

Empirical studies on energy consumption at the household unit of analysis can be categorized into two groups. One group of studies are explanatory and seek to account for variation in energy use patterns between households. These studies collect data on energy behaviors or consumption of a sample of individuals or households and the various characteristics of the person or household with those energy use patterns or behaviors. These studies can be qualitative and provide detailed insight on households' decision-making and lifestyle practices (Lorenzen, 2012; Schelly, 2014; Shove & Southerton, 2000), or they can be quantitative correlating various demographic, attitudinal, or technological characteristics and behavioral and consumption outcomes (Guerin, Yust, & Coopet, 2000; Poortinga, Steg, & Vlek, 2004). Quantitative studies that seek to understand the human factors of energy consumption are often survey based. These surveys usually have sample sizes of under 1,000 individuals or households and often measure self-reported energy behaviors rather than measured behaviors or actual consumption. More recently, large datasets on home energy consumption have become available as utilities modernize and implement smart meters. However, these "big data" sets are rarely available in conjunction with detailed information about the household occupants.

Qualitative methods used in research on energy consumption can include interviews, direct observation, participant activity logbooks or diaries, or textual analysis (Schelly, 2016). These methods can provide "thick" descriptions of everyday life and thus provide insight about exactly how households consume energy and their understandings of various contextual factors that shape their behavior. They have most often been utilized in conjunction with practice theory described above that focuses on the reproduction of daily life and its energy implications. For example, qualitative research has shed light on how viewing people's decision to retrofit a home from a singular decision-making framework fails to account for how the readiness to retrofit flows from an ongoing process of dwelling (maintenance and repair of one's home in everyday life) (Fyhn & Baron, 2017). Other qualitative work has focused on people's practices when they were working from home (the competencies, meanings, and materials of those activities) and potential energy consumption implications (Hampton, 2017). These qualitative studies often include a smaller number of people, with in-depth ethnographies often ranging from 5 to 10 households or individuals and interviews ranging from 10 to 50 individuals. These studies seek to identify the less obvious and previously untheorized factors that influence energy consumption through in-depth research that allows people to focus attention on what is important to them.

3.2 | Changing energy consumption

The second group of studies we examine here are those that are intervention-based and have produced researchable change strategies. These studies look at individual or household consumption over time and evaluate the impacts of an intervention such as a change in technology, pricing, or information. In these studies, researchers have collected data on self-reported behaviors or energy consumption before and after implementation of an intervention. Occasionally, these studies are natural experiments where conditions change in the real world (i.e., the oil crisis of 1973 and the associated sharp increase in oil prices). More often, these studies are designed to investigate effective approaches to increase energy conservation or renewable technology adoption.

As discussed above, a growing body of research seeks to understand energy consumption through the lens of social practices. This research implicates that the focus of change should be on social practices and the broader institutions that organize them. Shove argues that the narrow focus on household consumption change that emerges out of technological, economic, and psychological approaches is one that propels a certain set of policies that are not likely to lead to truly sustainable consumption (Shove, 2010). To change energy consumption via social practice theory, efforts must focus on forming new less energy intensive practices, reproducing those practices and maintaining those new social practices while destabilizing and eventually getting rid of greenhouse gas intensive social practices. To create and reproduce green social practices, we must know how to recruit practitioners to these new greener practices and get others to defect from other unsustainable practices (Hargreaves, 2011). Thus, the focus of practice theory is "not on the people who do the enacting, but on the practice that they reproduce/transform" (Shove, 2014). Social theorists who have evaluated behavior change programs using ethnographic approaches thus focus on how the patterns of everyday life align or misalign with the targeted behavior (Hargreaves, 2011).

What does social practice theory mean for interventions to change household behaviors? The household is not irrelevant to social practice theory as the practitioners are household members and many social practices are embedded in the household's daily rhythms and material realities. Social practice theory has been used to provide insight on in situ household consumption dynamics. While examples of these energy efforts are limited, some geographers working on reducing food waste have built on social practice theory to develop new approaches to change consumption practices in households (see Box 1). This is an area where direct energy researchers may adopt new tools from food consumption researchers.

However, social practice theory also suggests that to increase the adoption of green household practices, there needs to be broader action outside the household that creates structures that support competence, meanings, and material needed for those green household practices. This "stronger" version of social practice theory suggests to find more systemic levers to changing consumption in households. For example, Shove (2014) highlights how state policies like urban planning for communities can lead to different transportation practices. But it is not just material infrastructure. Another example Shove provides are the efforts of the Japanese government to create new practices around comfort to reduce energy demand in workplaces. The air conditioning was turned down in the summer, the heat down in the winter, and workers were encouraged to wear short sleeves in the summer and layers in the winter through a campaign. The convention was modeled by leaders like the Japanese Prime Minister. Information provision was one part of this effort and thus could be thought of as an informational intervention, but social practice theory suggests it must be more than simply information. While this review focuses on household level change, the authors agree that more systemic change is needed to aggressively advance the changes in direct and indirect energy consumption needed to address climate change.

The following section identifies three commonly used approaches that have sought to shift household direct energy use: (a) technology change, (b) pricing, and (c) informational interventions. The section brings together empirical research from engineering, economics, psychology, and sociology.

3.2.1 | Technology change

Research from engineering and building sciences seek to change energy use through technological innovations, such as home retrofits, building codes, or mandatory energy efficiency standards for appliances. The notion that technological innovations are key to energy efficiency and conservation is central to much research in domestic energy conservation (also known as a "technological fix"). This work, for example, includes studies of the effectiveness of home retrofits and the adoption of energy efficient appliances on direct domestic consumption.

Various evaluation studies find that households who have received home retrofits (e.g., insulation, efficient boilers) achieve significant energy savings. For example, an evaluation study of Ireland's Home Energy Saving scheme found that households who had implemented retrofits had reduced their energy consumption levels by an average of 21%, compared with a control group (Scheer, Clancy, & Hogain, 2013). Heating-related energy savings of around 15% were observed in a study

BOX 1

ADDRESSING INDIRECT ENERGY CONSUMPTION THROUGH CHANGING FOOD CONSUMPTION

The food system is resource intensive, driving a large amount of water, land, and energy use. Research from environmental sciences has quantified the environmental impacts associated with households' food consumption choices. For example, a study of food consumption using LCA found that plant-based meals have a lower environmental impact compared with meat-based meals, and estimates that voluntary dietary changes could reduce indirect energy use by 30% (Carlsson-Kanyama, 1998). Another analysis found if households in high-income nations adopted national recommended diets (e.g., the WHO recommends an average of 80 g of meat per person per day) instead of the average diet they could realize 13–25% reductions in greenhouse gases. The reductions in greenhouse gases emerge from households reducing calories to the recommended amount (about 54% of the effect) and a change in the composition of food constitutes the other 46% (i.e., less protein, more vegetables; Behrens et al., 2017).

But how do we encourage this shift in diets? What are effective interventions for indirect energy via food consumption and how is it different than what we know about interventions for direct energy consumption? There is a long-standing and extensive literature on efforts to change people's food choices for health reasons (Abraham & Michie, 2008), but focusing on how sustainability considerations can change consumer choices is relatively new. Research from sociological and psychological studies suggest that factors such as demographics, values, attitudes, culture, geography, and identity play a role in shaping food choices, such as organic and local food choices, the consumption of Fair Trade products, shifting to a plant-based diet and reducing food waste (de Boer, de Witt, & Aiking, 2016; Evans, 2012; Hartmann & Siegrist, 2017).

Research using interventions to shift people's food choices from a sustainability perspective is an emerging area. Mirroring the direct energy consumption approaches, researchers have focused on technological advances that can provide more sustainable food such as climate friendly agricultural practices, cultured meat tissue, or plant-based protein substitutes (Tuomisto & Teixeira de Mattos, 2011). However, unlike energy where there are institutional mechanisms for reducing energy use like building codes or energy efficiency standards, there is no mandatory regulation of energy use in agricultural production or food consumption. In fact, the agricultural sector is often exempt from emissions trading schemes, removing incentives to produce food in more climate-friendly ways. There has been some research on a meat (and dairy) tax to discourage its consumption and decrease environmental impacts (Säll & Gren, 2015), but no nations have adopted one (Nordgren, 2012). Thus, decreasing the impacts of food consumption depends on encouraging voluntary producer and consumer uptake. To investigate how to encourage these options, researchers have turned to informational interventions. For example, psychologists have tested the effectiveness of messages raising awareness of the climate impacts of meat consumption and intentions to consume meat. This research provides insights on how to best communicate ("frame") the problem of indirect energy use and climate impacts (Graham & Abrahamse, 2017). Others, such as behavioral economists, have utilized nudging (e.g., making the vegetarian option the default) to successfully increase the consumption of plant-based meals (Campbell-Arvai, Arvai, & Kalof, 2014).

Unlike direct energy consumption where households often face expensive technological lock-in, consumer choices to decrease food energy impacts via reducing waste or decreasing meat and dairy consumption are more easily taken from a cost perspective. While "sustainably farmed" meat is more expensive than conventional meat, plant-based meat substitutes, grains, and beans can be equal to or cheaper in price and commonly found in most grocery stores in most developed countries. We suggest that food consumption instead faces much more of a cultural lock-in by way of traditions, preferences, food fads, and cooking know-how. Social practice theory and sociology in general provide many insights on how our food provisioning systems and our lives structures food consumption (Delormier, Frohlich, & Potvin, 2009; Mackendrick, 2014). Shove notes that the term "obesogenic environment"—coined in health promotion literatures—captures the nonindividual factors influencing overconsumption; but that there is no equivalent in the energy literature (Shove, 2010).

Perhaps because of this presence of nonindividual factors in the food literature, food studies, unlike energy studies, have developed approaches out of the social practice theory literature for interventions. Sahakian and Wilhite use case studies of changing food practices (putting Oklahoma City on a diet, local foods in Geneva and going from bottled water to tap in London's restaurants) to highlight how social practices can be changed via demonstration projects and social learning (Sahakian & Wilhite, 2014). An innovative technique that has emerged to focus implementing more sustainable household consumption practices is the use of living labs, or in this case HomeLabs. Davies and her colleagues first generated potential new practices using a "practice oriented participatory (POP) backcasting approach" where 80 stakeholders from across society were asked to imagine alternative sustainable practices for personal washing, home heating, and eating in 2050. The participants generated what skills, stuff, understandings, and rules would be needed for those more sustainable practices (Davies & Doyle, 2015). The researchers then chose some of the food practices implemented as new practices in five homes that were conceptualized as living labs. Households were given materials and information such as food growing kits and lessons on food preparation, portions, and storage to reduce waste. Homes were visited by researchers once a week where they conducted semistructured interviews and home waste audits at weeks 1 and 5. The research found that the introduction of bundles of materials and information that addressed the practice of sustainable eating was successful (Devaney & Davies, 2016). Living labs where new practices are introduced and evaluated are a social practice-oriented intervention-based research approach that is a fertile area for future research, though expensive and difficult to scale up.

evaluating the effect of the provision of insulation in English households (Hong, Oreszczyn, Ridley, & Grp, 2006). A randomized controlled trial conducted in New Zealand found that providing homes with insulation and a choice of either a heat pump, wood burner, or flued gas heater encouraged energy demand reduction. The study found that energy consumption was significantly lower in insulated homes compared with the control group, and health outcomes for residents improved (Howden-Chapman et al., 2007). Other research on the role of technology examines the role of energy-efficient appliances in contributing to household energy conservation. Studies estimate that programmable thermostats can help reduce household energy use by 5–15% (Peffer, Perry, Pritoni, Aragon, & Meier, 2013). Reductions in electricity use can also be achieved when households replace incandescent bulbs with compact fluorescent (CFL) or LED lighting.

As described earlier, technological fixes do not necessarily result in expected reductions in direct energy consumption. This suggests that, for example, household behavior is important to consider when implementing technological innovations or that economic analyses of household expenditure patterns of energy services may be useful. For example, there is evidence to suggest that the uptake by households of retrofitting and weatherization schemes is not always as high as expected. Further, economic analyses suggest that energy savings are not always as high as economic models would predict (Fowlie, Greenstone, & Wolfram, 2015).

An analysis of the findings of the aforementioned New Zealand study found that actual energy savings from insulation were one third of the projected energy savings derived from an economic model (Grimes et al., 2016). And while some studies find that the installation of programmable thermostats results in energy savings, other studies have found only small or no difference in energy consumption levels between homes with programmable thermostats and those with manual thermostats (Meier, Aragon, Peffer, Perry, & Pritoni, 2011; Peffer et al., 2013; Peffer, Pritoni, Meier, Aragon, & Perry, 2011). This suggests that households may not use (or may not know how to use) these thermostats in ways that reduce energy consumption. There is ample opportunity for more interdisciplinary research here. For example, a UK study found that people were more likely to take up energy efficiency innovations (e.g., insulation, heating controls, in-home energy displays) when they had sought out information about these innovations from people they knew (McMichael & Shipworth, 2013). This illustrates what economic and engineering studies could gain by incorporating insights from psychology about the role of social influence (e.g., social norms) and insights from sociology about the role of the broader social context (e.g., the role of local community groups in facilitating uptake of innovations). We return to this point in the concluding paragraphs.

3.2.2 | Economic incentives

The use of price signals can take various forms, for example, via a subsidy on energy efficient appliances at the point of sale, or by providing a rebate after purchase. For example, an economic analysis of a rebate scheme on the purchase of heat pumps in Maryland, USA, observed a reduction in electricity usage of about 5% (Alberini & Towe, 2015). Other work focuses on modeling a number of variables of interest, such as price elasticity, and the demand for energy at different tariffs (e.g., off peak versus on peak). And still other work takes advantage of natural experiments that have occurred. For example, researchers have analyzed energy use changes during price spikes. While all homeowners received messages to conserve during the oil crisis, researchers found that those using oil heat during the 1973–1974 oil crisis (where prices increased 200%) increased end use efficiency by 14.4% as opposed to those who were heating with natural gas (where the price stayed relatively constant) and only increased end-use efficiency by 5% (Peck & Doering III, 1976). Similarly, following 60 days of increasing prices in electricity costs during the California energy crisis, homeowners reduced their energy use 13% while it rebounded just as quickly once the regulators instituted price caps (Reiss & White, 2008). Overall, a review of the empirical literature (Lijesen, 2007) finds that price elasticity for electricity demand is generally low.

Studies using economic modeling also estimate the occurrence of so-called rebound effects. A rebound effect refers to an (unanticipated) counterbalancing or even a complete canceling out of initial energy efficiency gains. As energy efficiency improvements lower the effective cost of an energy service, rebound effects describe how the resulting savings may be reinvested in consuming more of the energy service (direct rebound) or more of another energy-intensive good or service (indirect rebound) (Greening, Greene, & Difiglio, 2000). For instance, an economic modeling study on heating-related energy use in Austria (Haas & Biermayr, 2000) found that energy savings following home retrofits were much lower than what one would expect based on the energy saving potential calculated by engineering models. A German evaluation study on the adoption of energy-efficient lighting (Schleich, Mills, & Dutschke, 2014) found that households altered their behavior in response to the lower costs associated with lighting services of energy-efficient light bulbs, by letting bulbs burn for longer periods of time, or by increasing the luminosity of bulbs. Recent reviews of the literature on rebound effects (Dutschke, Peters, & Schleich, 2013; Sorrell, Dimitropoulos, & Sommerville, 2009) indicate that while there appears to be evidence of the occurrence of rebound effects, there is still much debate about the ways in which rebound effects are manifested in the home and "what people actually do when they rebound" (Winther & Wilhite, 2015, p. 596). There are competing explanations, not driven by economics or price signals that may explain why researchers observe an increase in energy use. Moral accounting or moral licensing suggests that people may track their "good" and "bad" behaviors and that using the air conditioner more often may be a consequence of the logic that they have done something virtuous (install an efficient air conditioner) and now they can "indulge" and be as cool as they would like. This kind of rebound is particularly important as we think about addressing indirect and direct energy use (Sorrell & Dimitropoulos, 2008).

Behavioral economics focus on the use of nudging (discussed earlier on in this paper), which refers to a change to the default option. For example, a German study found that households were more likely to use "green" electricity (i.e., from renewable sources) when the default option was to opt-out rather than to opt-in (Pichert & Katsikopoulos, 2008). A number of large-scale randomized control trials have been conducted with various forms of nudging to encourage energy conservation (Allcott & Mullainathan, 2010). While a number of studies find nudging an effective tool to encourage behavior change, it has also encountered critique. Nudging raises issues around ethics (e.g., changing the default without people knowing about it). Nudging also does not necessarily take into account people's motivations and the question remains whether the use of nudging results in sustained changes over time and in different contexts (i.e., when the "nudge" is removed; Stern, Dietz, Gardner, Gilligan, & Vandenbergh, 2010).

3.2.3 | Informational interventions

"Informational interventions" is an umbrella term that encompasses a range of interventions that rely on voluntary behavior change, such as information and feedback provision. Information provision is one of the most widely used interventions to encourage domestic energy conservation. It can involve general information about consumption levels, the impacts of those consumption levels (e.g., households' contributions to greenhouse gas emissions and climate change, its economic costs, or its health impacts), or it can consist of solution-focused information (e.g., home energy saving tips). The assumption is that through information provision households become more aware of the problem or knowledgeable of possible solutions, which spurs behavior change. Research in psychology has examined the effectiveness of information provision via field studies. In such studies, energy consumption levels after an intervention are compared to a baseline measure of energy consumption, often compared to a no-intervention control group. These studies suggest that information alone is generally not effective in encouraging domestic energy conservation.

Research on feedback provision has focused on providing information about the amount of energy use (Darby, 2006; Ehrhardt-Martinez, Donnelly, & Laitner, 2010). These studies make a distinction between indirect feedback which provides information about energy use after the fact (i.e., a bill or a weekly report) and direct feedback that is close to real time. These studies increased in number in the 1990s with the evolution of in home display technologies and moved forward again with the advent of advanced smart meters. Advanced smart meters provided the opportunity for two-way communication between the home and the utility. The utility can read the energy use patterns and the home can be provided information on use and cost real time. Early studies found modest changes in energy use with feedback (3–8%). Interventions with real-time energy information are more effective in yielding savings. Interventions that provide detailed energy use information, for example, at the appliance level, also increased saving over more general house level feedback (Delmas, Fischlein, & Asensio, 2013; Karlin, Zinger, & Ford, 2015).

More recently, research in psychology has focused on the ways in which information and feedback can be conveyed (or framed) to enhance their effectiveness. Message framing refers to the way information is conveyed which directs the audience's attention to certain aspects of a message (Chong & Druckman, 2007). In one set of interventions, researchers focus on how the impacts of energy consumption are framed. Information about energy conservation tends to be framed in terms of monetary incentives (e.g., amount of money saved) or environmental benefits (e.g., reduction in carbon emissions). Studies suggest that the framing of an energy conservation message can affect people's response to this message (Schwartz, de Bruin, Fischhoff, & Lave, 2015; Steinhorst, Klöckner, & Matthies, 2015). For example, a recent study (Asensio & Delmas, 2015) in Los Angeles compared the effectiveness of feedback provision about energy savings when this was framed either in terms of monetary savings (i.e., you have saved this amount on your energy bill) or public health outcomes (i.e., you have contributed this amount to air pollution in Los Angeles). Compared to a no-information control group, the public health message resulted in significant reductions in energy consumption, while the monetary feedback group increased their energy consumption (which was contrary to expectations and to what economic theory would suggest).

Energy conservation studies also examine the role of social influence in encouraging behavior change (Abrahamse & Steg, 2013). One line of research examines the effect of framing information and feedback messages in terms of making social norms salient. Social norms refer to our perception of what is "normal," or what society expects of us, which can guide behavior (Forgas & Williams, 2001; Schultz, Nolan, Cialdini, Goldstein, & Griskevicius, 2007). The assumption is that households will be motivated to save energy when they know that other people are also doing this. In one of these studies (Nolan, Schultz, Cialdini, Goldstein, & Griskevicius, 2008), households in San Marcos, California received a message that either emphasized monetary savings, social responsibility, environmental considerations, or social norms ("77% of San Marcos residents often use fans instead of air conditioning to keep cool in summer.") Compared with the other messages and a control group, households who had received social norm information reduced their electricity usage the most.

Another form of social influence is social comparison. Social comparison refers to the tendency to compare one's own performance with that of other (similar) people (Festinger, 1954). Applied to domestic energy conservation, households receive information about how their own energy consumption compares with other households (e.g., of similar size or in the same neighborhood). Large-scale randomized control trials in the United States (Allcott, 2011; Allcott & Mullainathan, 2010; Ayres, Raseman, & Shih, 2013) have observed energy savings of around 2%, compared to a no-intervention control group (note that in some of these studies, social comparison is referred to as a "nudge"). However, studies done in the United Kingdom (Harries, Rettie, Studley, Burchell, & Chambers, 2013), the Netherlands (Abrahamse, Steg, Vlek, & Rothengatter, 2007), and Australia (Kurz, Donaghue, & Walker, 2005) found no statistically significant differences in energy consumption levels between households who had been given social comparison feedback and those who had not. Other studies indicate that households with energy consumption levels that are above the average ("the norm") decrease their energy consumption following social comparison feedback and that households with below average energy consumption levels tend to increase their energy consumption (Abrahamse et al., 2005; Schultz et al., 2007). This suggests that the use of social comparison needs to be carefully implemented to work most effectively.

4 | TOWARD AN INTERDISCIPLINARY RESEARCH AGENDA

Collaborative, interdisciplinary energy research is lacking (Schmidt & Weigt, 2015; Sovacool et al., 2015). Above, we have identified general disciplinary approaches to understand and change energy consumption. It quickly becomes apparent that the factors these approaches focus on are often interactive and vary in strength of influence across contexts. To advance studies of changing energy consumption, we must advance a more interdisciplinary approach that integrates theories and methods from different disciplines to examine these factors simultaneously. Our call for (more) interdisciplinary research is not new (Lutzenhiser, 2014; Sovacool, 2014). But despite such calls for interdisciplinary research, there is still an underrepresentation of the social sciences in energy research. Recent debates among scholars from different disciplines (Felder, 2016; Valentine, Sovacool, & Brown, 2017) about energy research have highlighted some of the challenges involved. Schuitema and Sintov (2017) outline some of these challenges (and possible solutions) for interdisciplinary energy research. The practicalities of doing interdisciplinary research involve understanding different disciplinary perspectives and viewpoints, which can sometimes be so fundamentally different that a research team might spend large amounts of time explaining how they approach energy research before they can start "doing" the energy research. Interdisciplinary energy research may also require compromises and as a result, the research may not always be performed to the "ideal" disciplinary standards (which can have implications for publishing the findings). There are funding implications too, with interdisciplinary projects often having multiple components, meaning they can be more expensive and slower to complete. However, if energy research is to yield useful insights into sustainable energy transitions, we must overcome these challenges. We have outlined what each discipline brings to the table; now we focus on how they can usefully complement each other to advance research on domestic energy consumption and climate change mitigation.

Energy research can benefit from a better integration of technical, individual, sociocultural and economic factors. For example, technological and engineering approaches often do not take into consideration how individuals in households "use" technological innovations; or how mechanical cooling has become "integrated within, and integral to the 'proper' accomplishment of different kinds of practices" (Shove, Walker, & Brown, 2014, p. 1516). Some initial interdisciplinary work exemplifies the need to integrate these insights. One example is a study of in-home heating of low-energy homes in Sweden (Isaksson & Karlsson, 2006). The study combined quantitative methods from engineering, focusing on the physical parameters of thermal comfort in the building (temperature, humidity), with quantitative (surveys) and qualitative methods (interviews) from the social sciences about occupants' perceptions of heat and comfort in their home. Among other things, the findings suggest a difference between the objective measure of in-door temperature and occupants' perceptions of warmth and comfort. An interdisciplinary study in Mexico examined the uptake of energy efficient cook stoves (Masera, Díaz, & Berrueta, 2005). The study used an integrated approach: it examined stove performance in controlled laboratory as well as field settings, monitored health impacts and assessed users' attitudes and preferences. One of the key recommendations to come from this study is to consider the dissemination of efficient cook stoves as a process that requires an understanding of the technical aspects as well as sociocultural and economics factors.

While engineering focuses mostly on technology without taking people's perception into account, similarly, psychological studies of energy consumption focus mostly on individual perceptions and behaviors, without necessarily taking the social, institutional, or environmental context into account. The often-used tools of information and feedback provision can be rather generic (e.g., a door hanger with information about a social norm), and these interventions would benefit from contextualizing this information, or making it more personally relevant (e.g., tailored to households). Interesting work is being undertaken on the use of visualization tools, making information about energy conservation more personally relevant and context specific. For example, drawing on theories and methods from the physical sciences and psychology, a UK-based group of researchers examined the effectiveness of thermal imaging to encourage home retrofitting (Goodhew, Pahl, Auburn, & Goodhew, 2014). Thermal imaging is a technique that uses infrared radiation that allows heat loss of an object to become visible. Compared with a control group, householders were more likely to install draught proofing measures and more likely to reduce energy consumption after seeing the thermal images of heat escaping their homes. A Dutch study (Abrahamse et al., 2007) combined insights from environmental sciences, psychology, and computer science to communicate the environmental impacts of energy saving options via an online platform. This provided households with tailored (i.e., relevant to their specific context) information about energy conservation. It also provided them with insights about how much of a difference these changes could make in terms of climate change mitigation (the feedback was communicated to households in terms of monetary savings as well as emission reductions). Compared to a no-information control group, households who had received information (combined with goal setting and feedback) significantly reduced their direct energy consumption (by 8%).

Scope for more interdisciplinary empirical research could lie in an examination of the rebound effect from an economic and behavioral and/or social practice perspective. For example, a Norwegian study (Winther & Wilhite, 2015) examined the rebound effect in relation to heat pumps, through the lens of a social practice approach. Interview findings suggest that people tended to expand the time the home was heated, compared to before a heat pump had been installed, but there were many differences between households in their knowledge of and use of the heat pump. Such insights could be combined with an economic analysis (i.e., a quantification) of a rebound effect. Another area where more interdisciplinary work could be done is an examination of the role of social influence. Studies from psychology focus on the role of individuals (e.g., "environmental champions" who could influence other people in their social network) in encouraging adoption rates (Carrico & Riemer, 2011; Weenig & Midden, 1991). This psychological work could be complemented with disciplinary approaches that consider the role of social networks at a larger scale, such as the work on spatial clustering of innovations from geography (Noonan, Hsieh, & Matisoff, 2013). Other lines of research use economic modeling to examine the uptake of technological innovations under different scenarios (McNeil & Letschert, 2010), including the role of social networks (Bale, McCullen, Foxon, Rucklidge, & Gale, 2013). These different theoretical and methodological approaches in the study of social networks and domestic energy conservation offer of possibilities for more interdisciplinary work in this area. Given the success of interdisciplinary projects to change heating and efficiency behaviors, such interdisciplinary approaches could also be applied to emerging energy changes, such as the rapid transition of energy grids and what this might mean for energy consumers. Energy grids are moving toward what has become known as "distributed generation," whereby multiple energy generation units are located more closely to energy consumers. Such energy grids may yield significant benefits in terms of energy efficiency and reduced carbon emissions, especially when the electricity comes from renewable sources. In a review of distributed generation systems, Wolsink (2012) outlines that research in this area might benefit from a more sociotechnical approach, because "most technical studies apply implicit and largely unfounded assumptions about the participation in and contribution of actors" in these systems (p. 822). Examples from sociology, geography, and psychology include studies into the meanings and dynamics of community renewable energy, the increasing role of the electricity prosumer—both consuming and producing electricity—in the electricity market, and the use of nudging to engage consumers with smart grid technologies (Darby, 2010; Toft, Schuitema, & Thøgersen, 2014; Walker, Devine-Wright, Hunter, High, & Evans, 2010).

To advance energy consumption studies, strong Interdisciplinary theoretical frameworks are needed. There are two promising integrative approaches emerging from energy studies. One is the "energy cultures" framework, which views energy behavior as primarily arising from the interactions between norms (individual and shared expectations about what is "normal behavior"), material culture (physical aspects of a home including the form of the building and energy-related technologies), and energy practices (energy-related actions; Stephenson et al., 2010). These, in turn, are directly shaped by broader influences, such as efficiency standards, subsidies, energy pricing, and social marketing campaigns. The energy cultures framework has been applied in a number of studies to explore the interrelated dimensions of domestic energy consumption and it has informed interdisciplinary research projects (Stephenson et al., 2015). The second theoretical framework, the "sociotechnical systems" approach emerges from sociotechnical theories of innovation or transition and seeks to understand what role consumption plays in the evolution of sociotechnical systems (Twomey & Gaziulusoy, 2014). These theories focus more on how sociotechnical systems evolve across time and act as sources of change. They are applied to issues such as how to escape "carbon lock-in" and have evolved to account for multiple levels of sources of change (bottom up and top down) to address how system change occurs. The focus is on evolution of material culture and technological dimensions of energy consumption as its unit of study and seeks to place these within a broader systems approach that accounts for culture and institutions.

5 | CONCLUSION

Research on domestic energy consumption spans the engineering and social sciences. First, the research contributes to our understanding of factors that shape domestic energy consumption. And second, research strands explore how households may be encouraged (through the use of interventions) to adopt efficiency and curtailment behaviors to help mitigate the effects of climate change. In these concluding paragraphs, we suggest some avenues for future research.

Significant energy savings can be achieved via the adoption of efficient devices and appliances. This is broadly consistent with the notion that efficiency behaviors tend to make more of a difference in terms of achieving energy savings (and climate change mitigation), compared to curtailment behaviors. At the same time, studies in the area of individual and social behavior highlight that it is important to understand how people use and interact with energy efficient appliances. For example, energy-efficient light bulbs can theoretically help reduce energy use, but the question remains whether people have the skills and knowledge required to make efficient use of energy saving features. Rebound effects suggest that changes in practices (e.g., leaving lights on for longer) could result in lower energy savings than what economic models would predict. Psychological research tends to focus on curtailment behaviors and we have provided a number of illustrative examples of research in this area, while research on how to encourage efficiency behaviors is relatively scarce. For example, how could efforts to improve energy efficiency be designed to minimize rebound? There is scope for a broader emphasis on focusing on energy consumption behaviors that have a high environmental impact, such as efficiency behaviors, perhaps in collaboration with other disciplines such as engineering or building sciences.

Many studies in this overview have been conducted from a monodisciplinary perspective, and there is scope for much more interdisciplinary work in these areas. A number of interdisciplinary studies have been conducted, such as collaborative work between psychology and physical sciences on the use of thermal imaging, or collaborations between environmental sciences and psychology on the provision of feedback about the climate impact of energy-related behaviors. The research area of human-technology interaction also includes interdisciplinary approaches to study the interplay between technological innovations and human behavior. However, more interdisciplinary empirical studies are needed to better understand the ways in which technologies and household behaviors are produced and reproduced and become embedded routines. More collaborative work can also be done in the area of communicating the climate change impacts of domestic direct and indirect energy use to households. There is an underrepresentation of the social sciences in energy research. But perhaps more problematically, there is hardly any uptake from social science research into energy policy. While decades of research have shown that the provision of incentives and information are not always as effective as assumed, they are commonly used policy instruments to change energy consumption. Insights from the social sciences can help improve these policy instruments, through economic analyses of consumer responses to price hikes, or via psychological research on how to (more) effectively frame information about energy conservation.

A necessary consideration for the future of energy research is that this overview highlights that most of the research in the household energy domain appears to focus on direct energy consumption, that is, the use of gas, electricity, and fuel. As of yet, not many empirical studies focus on households' indirect energy consumption (see Box 1). It is important to examine how to encourage the adoption of behaviors related to indirect energy use, such as sustainable food choices and minimizing food waste. Studies from environmental sciences suggest that indirect energy use (such as meat consumption) can have high environmental impacts. Targeting the indirect energy use of households could therefore have significant benefits in terms of climate change mitigation. Households may not necessarily be aware of these environmental impacts and this provides opportunities for (interdisciplinary) research to examine how to effectively communicate information about the climate impacts associated with indirect energy use, such as food choices. This could consist of collaborations with environmental sciences (using LCA approaches to quantify these impacts), food and agriculture sciences (developing new technologies such as nonmeat alternatives), and psychologists and sociologists (understanding individual attitudes and perceptions as well as cultural lock-in).

Last, there is scope to expand the research base on the ways in which households might adapt to climate change. The effects of climate change on domestic energy use will be different for households in different regions; for example, there will be increased demand for cooling in some areas, while other areas will face water shortages. Regional variations are important to consider in climate change adaption research. Changes in temperature or rainfall may affect electricity prices (e.g., droughts affect electricity generation from hydroelectric dams) and affordability of energy services, and this is likely to be different for different regions. Households' adaptive responses to climate change will likely become a growing area of importance and further work is needed in this area. Future research could focus on households' perceptions of climate change adaptation and engagement in adaptation behaviors.

CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

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