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Transforming energy use

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Connecting individual energy-related perceptions and behaviors to the larger climate system is a daunting task. What can individuals do to change the system itself? How do we perceive how much energy different activities use? Are there ways to improve our perceptions? How do we use behavioral science to motivate climate mitigation and adaptation policies? In this article, I review a body of work focusing on answering these questions. I discuss perceptions and motivations to transform energy use, and highlight some research projects of interest. In the policy area I discuss how behavioral science has aided and has still to be integrated into decarbonization policies. I end with several open research questions for the field.

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Mitigating and adapting to climate change is challenging. Changing individual behavior is nowhere sufficient to address the problem, but individuals are vital to mobilize system-wide changes from demanding and accepting decarbonization policies to transforming consumption behaviors [1–3]. From the individual-level perspective, climate change is a social dilemma, where private interests are at odds with collective interests [4], where the problem feels geographically and temporally distant [5••], and where many do not know what actions they can take to help [6]. These are simply a taste of the psychological challenges that climate change brings to bear, and there are many more [7,8]. Much of our global greenhouse gas emissions responsible for climate change come from the energy sector (∼73%) [9]. Thus, tackling the climate problem means tacking our energy problem: how do we transform our energy use, that is, decarbonize our global energy system which is primarily based on fossil fuels?

As individuals, there is a lot we can do to decrease our personal energy use (such as weatherizing our homes [10]) and to help decarbonize of our energy system (such as electrifying our personal vehicles [11] which will be vital to move away from gasoline). Other than personal consumption, what we do effects other people's behaviors via social norms and can influence policy makers. For successful pathways to decarbonizing our energy system, we will need an all of the above strategy: large-scale infrastructure projects, such as wind and solar energy at the utility scale, and consumer facing solutions like electric vehicles [12]. No matter how quickly we decarbonize today, we will need to also rapidly adapt to the onslaught of climate impacts, some of which are already underway. Both mitigation and adaption will require concerted, coordinated action at the local to international scale. Many of these actions are only slowly coming to bear because there is a big disconnect between any given individual in the system and system-wide changes needed to address the climate problem [3]. In some cases, individuals do not know what actions are most effective [13,14] and many do not think those effective actions apply to their own lives [15]. Other institutions are vital in the climate solution space, such as NGOs, energy companies, local-to-international governments, and so on. Sadly there is evidence that some energy companies with vested interests have actively propagated misinformation and doubt about climate change science and action [16] which has hindered public and political action.

Perceptions of energy use

When asked how many kilowatt hours (kWh) of electricity are used to run their washing machine, or even what a kWh really is, most adults are stumped [13]. With respect to reducing energy use, individuals think of curtailment actions (doing less of a particular behavior, for example turning the lights off when leaving the room), a less effective strategy, rather than switching to more energy efficient technologies (e.g. replacing incandescent bulbs with LED bulbs), a finding that has held since the 1980s [13,17]. When it comes to specific climate impacts, people tend to underestimate the carbon emissions related to air travel and overestimate behaviors like littering and using reusable grocery bags [14,18]. Although we do not need to be human calculators by accurately estimating how much energy every activity uses, we ought to know what is highly effective to do in our lives to decrease carbon emissions and how our actions, more broadly speaking, can influence system wide changes.

We also hold faulty mental models for how energy systems work. For example, in 1986, Kempton investigated mental models of how thermostats work, and found that 25–50% of Americans in his sample were 'valve theorists' (thermostat controls the amount of heat) rather than the more accurate 'feedback theorists' (thermostat sense the temperature and turns the furnace on or off to maintain an even temperature); an inaccuracy which can lead to significant increases in energy use, as valve theorists would use a higher heat setting to heat up a house faster, a practice which is inefficient [19]. Many people tend to overestimate the amount of energy low-energy use appliances use and underestimate the amount of energy high-energy use appliances use [13]. People also tend to overestimate the amount of renewables in our current energy mix in the U.S. [5••], a problematic misperception that can diminish how large the decarbonization challenge really is. These glaring gaps in our ability to understand, estimate, and effectively reduce energy use presents a significant challenge in achieving decarbonization.

Energy heuristics

To address knowledge gaps, we need better units of energy use that are more easy for novices to understand [20] and better energy heuristics to navigate complex decision landscapes of what is effective to do [21]. New research shows that there are avenues to correct misperceptions by providing more useful expert heuristics (such as 'large appliances that primarily heat or cool use a lot more energy than people think they use') [22••]. Heuristics, or simple judgment rules, are powerful ways of navigating complex decision landscapes [23]. A recent list of accurate expert heuristics (e.g. A greater temperature change requires more energy than a smaller temperature change; Insulation helps to reduce the energy use of devices that heat and cool) [21] contrasts with identified novice energy heuristics used in energy decision making tasks (e.g. Devices that have an energy label use more energy; Devices that charge other devices use more energy) [24••]. Bridging these expert-novice heuristic gaps may be useful in making the seemly invisible flows and losses of energy more visible.

Other than improving our understanding of energy use in our lives and in the system, with new technology we can reduce the number of appliances we have. Device reduction and substitution can also help decrease energy use, and provide scenarios of helping achieve decarbonization. For example, a smartphone with 5 W of power and 2.5 W of stand by power has the potential to provide a single integrated digital platform, which can potentially substitute over 15 different end-use devices (such as camera, radio, alarm clock, TV, voice recorder etc.) [25].

Policies aimed at energy behaviors

Policies can be designed to help decrease knowledge gaps. An example is providing energy disclosures for homes — for example, mandatory energy audit policies implemented in New York City showed a 2.5% reduction for multifamily residential buildings [26]. However information without motivation is usually insufficient to modify behavior [27]. Some ways to motivate effective actions uses descriptive (what is) and injunctive (what should be) social norms [28]. Applied to household energy use (by Opower, acquired by Oracle in 2016), using social comparisons lead to a sustained ~2% energy reduction over the long run [29] and are relatively cheap to implement compared to other interventions [30]. A more recent innovation in norm interventions has been using dynamic social norms (the rate of change of norms) on food choice and other sustainability behaviors [31]. That said, the amount of sustained energy conservation from these kinds of interventions (usually <5%) while large on a national level, are still quite small on an individual level. Thus, when it comes to these kinds of interventions, we also need to understand what the ceiling may be for energy saved, and if and how far that ceiling can be pushed.

The solution space to decarbonize our energy system is very siloed and needs innovative policies that are feasible and have public support. For example, a new report aimed at accelerating decarbonization of the U.S. energy system states: '*The committee was not confident in its ability to design policy that would both attract public support and achieve the behavioral changes required for a significant reduction in the demand for energy services.*' [32] This statement highlights the enormous need for more integrative work across the sciences and engineering when it comes to decarbonization research and policy implementation [33]. Below are a few themes we could keep in mind as we think about how to design policies. They are by no means exhaustive, but they are ones I have been thinking about of late.

Adapting solutions to their context

Context and location matter for policy design, recommendations, and uptake. Solutions that make a lot of sense in the global north, are not as applicable in the global south. For example, food and services are relatively more important for decarbonization at low income than higher income communities [1]. It may be easier to phase out coal in Germany than in India, and it may be easier to build a nuclear power plant in China with its established industry than in Kenya [34]. Technological solutions will need to be adaptable and context specific, and will need cooperation from all levels [12].

Implementation challenges and political feasibility are important to consider when designing policies. Harmonized carbon prices (or a carbon tax), which have been hailed as being efficient economic instruments to address climate change [35], have been set too low in reality to make significant decreases in carbon emissions, as was shown in an ex-post evaluation of carbon tax performance [36••]. Given this work shows that carbon prices are incremental at best at motivating changes to carbon emissions, we need to implement them with other more effective policies.

Political ideology matters in interesting and puzzling ways. When asked to indicate the amount of each energy source they hoped the U.S. would use in 2050, there is surprising broad consensus across conservatives, moderates and liberals [5••]. All groups wanted to use far more renewable energy and much less fossil fuel, however there is less agreement on how to get there [5••]. Across the political spectrum, there is strong and temporally stable support for policies that promote renewable energy technologies and that prioritize environmental protection over energy extraction [37••]. However, in the U.S. research shows that partisanship is the most important determinant of Americans' energy policy preferences and that there is an increasing divide between conservatives and liberals on energy policy [37••].

We also need to include social and environmental justice in policy design. During the Covid-19 pandemic, multiple crises exacerbated existing inequities. Energy insecurity is a growing public health threat among low-income groups [38] and Black and Hispanic households. Additionally, there are many disparities in access to energy-efficient technologies and programs. For instance, access to LED light bulbs (which only use a fraction of the energy as CFLs or incandescent bulbs [17]) are less available and more expensive in high-poverty areas and smaller stores, leading to less uptake by poorer communities [39].

Decision architecture and more specifically defaults can be leveraged for climate solutions. When faced with a choice between options where one option is the default, majority of individuals follow the default. This finding has held in areas from organ donations [40], retirement savings [41], and electricity choices [42]. More work is needed in the decarbonization space on when and why defaults are followed and how they can de designed to maximize welfare.

Although mitigation and adaptation are complementary strategies for reducing and managing climate risks, they will require very different kinds of policies and potential tradeoffs. Adapting to climate change is defined as adjusting to the actual or expected future climate to reduce vulnerability to the effects of climate change [43]. For example, adapting to hotter temperatures will require more air conditioning, increasing energy demand in the summer [44]. Some behavioral features including descriptive norms and perceived self-efficacy are more strongly associated with adaptation actions [45].

Future directions

There are a variety of ways behavioral science can help transform energy use [46,47]. One big question in the field is how to more effectively harness the power of individuals to help facilitate solutions for large *N*-common pool resource dilemmas like climate change [48]. Individual can do many things to help the problem: from talking about climate change, to changing one's own life, to changing social norms, to political action. How can we more effectively bridge the growing partisan divide on climate policy support? How do we find ways to eliminate the 'drop in the bucket' phenomena, where any given individual feels like their actions are futile? How do we move people from thinking only about their 'carbon footprint', which we know is a start but nowhere enough, and harness greater means of effective action?

Another question is how can we leverage stories to help people grasp the problem and solution space better? Stories allow us to mentally time traveling to the future, to connect more deeply with people who are different from us, and can even change our behaviors in the present [49]. Climate fiction (fiction about climate change) can challenge their audiences to reimagine how systems of governance and responsibility ought to work [50]. Stories about what the world can look and feel like under different climate change scenarios could serve as valuable intervention tools to help people create a future that is more sustainable [51]. Stories provide emotional scaffolding, which identify ways to deal with the grief associated with where we are, and also provide hope for a better world. Feelings and emotions are necessary precursors to action because information alone is rarely sufficient for sustaining behavior change or increasing policy support [27]. Emotion can be invoked through various means, such as aesthetics, morality, and kinship [52]. How can motivating feelings about energy conservation and related policies be induced, given that attention is a limited resource? What feelings are potent and transmittable across individuals? Research that fuses facts and feelings can help motivate action on climate change, and possibly help individuals see how they are connected to and part of the larger system.

Conflict of interest statement

Nothing declared

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