

Applications of Behavioral Economics to Climate Change

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




Kent D. Messer, Diya Ganguly, and Lusi Xie

University of Delaware

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1. Introduction

As with most environmental challenges, problems associated with climate change are largely the result of human behavior that is intricately embedded in our daily actions and lifestyles and part of societal and cultural norms. Thus, mitigating and adapting to climate change require changing human behavior and practices. And, as we adjust our behavior, we must continue those new behaviors to sustain our efforts. However, making these fundamental changes will not be easy, and, so far, large numbers of people have not made the large-scale behavioral changes needed to avoid the most serious problems related to climate change. Thus, there is a call now for development of government policies and programs that promote and facilitate sustainable behaviors.

As recently noted by the Intergovernmental Panel on Climate Change (IPCC 2022), with appropriate policy support behavioral change could help reduce greenhouse gas (GHG) emissions by “at least 5% rapidly” with most of the change occurring in developed countries. It further estimates that “comprehensive demand-side strategies” could reduce GHG emissions by 40-70% globally by 2050. Moreover, changing individual behavior can reduce GHG emissions at low cost and buy time to develop long-term and more costly solutions such as inducing new, low-carbon energy technologies, as well as cap-and-trade regimes (Dietz et al. 2009). However, to date, most research funding has mostly been directed to studies of the natural science of climate change and its consequences and trying to predict those consequences. As noted by Overland and Sovacool (2020), “Between 1990 and 2018, the natural and technical sciences received 770% more funding than the social sciences for research on issues related to climate change. Only 0.12% of all research funding was spent on the social science of climate mitigation”. Thus, relatively little funding has gone to developing and testing behavioral

approaches and thus little is known about the kinds of interventions that are most likely to be truly effective in mitigating releases of greenhouse gases and to understanding how best to adapt, now and in the future, to climate change. As highlighted throughout this report, changing habitual behavior tends to be difficult and there tends to be a big gap between well-meaning intention and actual behavioral change.

A wide range of human behaviors can become “climate friendly” and can be considered demand-side strategies. For instance, households and businesses can reduce their energy consumption. Households can consume products and foods that have smaller carbon footprints, purchase energy directly from renewable sources or even purchase carbon offset credits. Likewise, government regulators might require changes in how the pricing of products and services are structured and how this pricing information is communicated to customers. In the context of consumer behavior, McFadden et al. (2022) argue that interventions that have “plasticity” should be prioritized for policy interventions. Plasticity is a measure that defines the willingness of non-adopters to change a behavior. Therefore, effective behavioral interventions in the consumption domain are those target behaviors that have high abatement potential and high plasticity.

The domain of environmental economics is characterized by missing markets and undocumented economic behaviors. Economic theory about market failures addresses environmental concerns through collective bargaining theorems, Pigouvian taxes/subsidies and through standards and permit markets. However, the key foundational assumption is that of rational behavior which may not spillover to account for the missing markets and undocumented behaviors found in this field. Behavioral economic evidence makes space for behavioral anomalies in the environmental domain such as choice under risk and mechanism design to

control market failure. Shogren & Taylor (2008) link these anomalies to market failures and call them *behavioral failures*. Some examples include status quo bias and endowment effect, loss aversion, framing effects, anchoring, preference reversals, self control, time inconsistency and coherent arbitrariness. These authors advocate for the need for incorporating insights about behavioral failures to design efficient policies. For example, a Pigouvian tax or subsidy on a climate change externality would be ineffective if people's tendency to overestimate the upfront costs than future benefits is ignored.

Insights from behavioral economics studies, often from individual decision making in contexts other than climate change, have identified several behavioral “anomalies” (systematic deviations from the predictions of economic theory) that make these types of changes particularly difficult. Among the challenges is the nature of behavior related to climate change, which frequently involves significant temporal and spatial spans and difficulty visualizing actual consequences of behavior. These time lags and ambiguities make it difficult for people to develop a strong sense of cause and effect that can motivate them to change their behavior. These factors combine to create fertile ground for individuals and organizations to sow doubts about the accuracy of the science and/or the effectiveness of various policy interventions. Likewise, though greenhouse gases released anywhere on the planet contribute roughly equally to climate change, the negative impacts of climate change tend to be disproportionately experienced in some locations and by some groups of people. For instance, people living along coasts, in drought prone areas, and those that generally lack financial resources or who have been historically disadvantaged are generally most vulnerable to the risks associated with climate change. As a result of these issues, societies have a difficult time achieving consensus – on whether to act and on the best types and scales of action.

Because, in general, the costs of changing behavior to reduce the risks of climate change are borne in the short term and the benefits are accrued in the medium and long terms, it is particularly difficult to change behavior and to sustain these actions over time. Humans tend to be myopic in their thinking and behavior, and painstaking policymaking processes are caught up in frequent changes in leadership because of relatively short periods between elections. Furthermore, many of the benefits from preventing and mitigating climate change do not flow to the people making the changes. As noted by the IPCC report (2022) significant mitigation can be achieved by affluent people who reduce their relatively large carbon footprints; thus, the affluent people will be bearing significant costs in the short-term. Yet the reality is that the benefits of those changes are likely to have a greater impact in the long-term on low-income and disadvantaged communities, who suffer disproportionately from the effects of climate change. Thus, costs and benefits do not closely match needs and resources.

A burgeoning literature has addressed ways in which policymakers can tap into insights derived from behavioral economics and other behavioral sciences to overcome these challenges. In this report, we identify policy-relevant interventions that have been analyzed in the peer-reviewed literature. The studies have addressed everything from one-time changes in behavior to larger-scale societal changes sustained over time. A key distinction we examine is the relative effects of small behaviors that must be frequently repeated to become long-lasting habits (such as consumption of foods that have small carbon footprints) versus larger one-time changes that, once made, would have long term impacts (such as installing solar panels).

To facilitate this discussion, we summarize the key findings in a series of tables in which we report on the studies in terms of five core principles of behavioral economics that are especially relevant to public policy:



- (1) *limited attention and cognition,*
- (2) *present bias,*
- (3) *reference dependence,*
- (4) *social preferences and social norms, and*
- (5) *incorrect beliefs.*

For an in-depth description of these principals, see the broader report by the National Academy of Sciences.

These core principals are then applied to four key policy areas related to climate change:

- (1) *energy use and efficiency,*
- (2) *transportation,*
- (3) *consumption, reduction, recycling, and reuse, and*
- (4) *land use decisions.*

These sectors all emit large amounts of greenhouse gases. For instance, commercial and residential energy use accounted for 13% of total US greenhouse gas emissions in 2020, while transportation accounted for 27% (EPA, 2020). Consumption and a lack of reduction, recycling, and reuse not only produces waste that needs to be transported and shortens the lifespan of these products, but also requires more production as consumers replace the various goods, leading to more emissions throughout the lifecycle of these products. Finally, agriculture accounted for 11% of total US greenhouse gas emissions in 2020 (EPA, 2020), and development of previously undeveloped land and forests can release the carbon once stored in the now disturbed ecosystem and also destroy a carbon sink.

This report evaluates existing evidence in the peer-reviewed literature to identify gaps in knowledge. Then, we evaluate those gaps using **CREDIBLE**, an acronym we developed to represent eight important factors to consider when determining whether scientific evidence is adequate to use to recommend policies and programs. We provide a summary table for each of the five core principals and four policy areas to identify where there are significant gaps in the literature and where sufficient CREDIBLE evidence already exists. Furthermore, when CREDIBLE evidence exists, we provide the following symbol  and provide a rating on the quality of evidence as being one, two, or three stars, where a three-star rating signifies particularly very strong evidence. We also identify areas in which conflicting evidence exists, indicated by the caution symbol, (.

1.1 CREDIBLE Criteria



Cost-effective: Is there evidence that the behavioral intervention’s ratio of benefits to costs is high?



Replicable: Has the evidence supporting the behavioral intervention been replicated in similar and different contexts?



Evidence-based: Has the behavioral intervention been peer-reviewed or comes from a high-quality source? Is the intervention internally valid, such as being backed by an appropriate statistical analysis with a large sample size, based on revealed preference methods, and other best research practices?



Durable: Will the impact of the behavioral intervention lead to long-lasting, behavioral change after the intervention ends?



Identity-respecting: Does the behavioral intervention respect affected groups’ identities and ethnic/cultural traditions? Is the intervention generally non-partisan and thus likely to survive changes in the political environment?



Boomerang minimizing: Will the behavioral intervention minimize unintended consequences that are contradictory to its original intentions?



Logistically feasible: Can the behavioral intervention be implemented by relevant institutions or organizations?



Ethical: Are the impacts of this behavioral intervention on historically marginalized and disadvantaged individuals and communities ethical?



Cost-effective

Achieving societal improvements by reducing greenhouse gas emissions and improving our adaptation strategies is a key challenge for climate change policymakers. Consequently, many are interested in applying insights from behavioral economics to improve the design and cost-effectiveness of their efforts (Higgins et al., 2017). One of the most valuable contributions of behavioral economic research is the connection to the design of economic experiments that can test multiple interventions and evaluate the relative cost-effectiveness of these interventions at achieving their objectives. Following the book by Sunstein and Thaler (2008), behavioral inventions are often referred to as “nudges” or changes in “choice architecture” and often require little or no cost to implement. When these behavioral interventions lead to positive behavioral change, even if these changes are relatively modest, given their low cost, they can be highly cost-effective means for inducing behavior change that leads to reductions in carbon footprints.



Replicable

In the social sciences, scholars have identified a “replication crisis” because much of the evidence that gets attention is derived from single published studies that are not and, in some cases, cannot be replicated. Replication is the cornerstone of good science, yet economic experiments are rarely replicated (Duvendack et al., 2017). Several reviews of experimental

economic (Camerer et al., 2016) and environmental and resource economics (Ferraro and Shukla, 2020) studies have found that the results could not be replicated, leading researchers to question the validity of published findings (Open Science Collaboration, 2015; Camerer et al., 2018). Unfortunately, however, the structure of academic institutions and incentives discourage replicative studies (Moonesinghe et al., 2007). Furthermore, Hamermesh (2007) has noted that peer reviewers in economics rarely try to replicate a study’s regressions because of the arduousness of the process and thus frequently fail to catch mistakes. Replicative studies are particularly useful when informing policymaking. Ideally, climate change policymakers would compare the results from initial experiments with results from replication studies involving different samples, thus obtaining robust estimates of treatment effects in a variety of contexts before choosing policy changes in actual programs. In this report, we place extra value in findings that have been reproduced in multiple settings and with multiple sample populations.

Evidence-based

Credible scientific knowledge is the foundation of evidence-based policies and programs. In the U.S., the push for a strong evidence base behind policies was bolstered with the Foundations of Evidence-based Policymaking Act in 2018 (often referred to as the Evidence Act). The Evidence Act calls for all federal agencies in the U.S. to take evidence-based approaches when analyzing and developing programs and policies. The goal is to ensure the effectiveness of those efforts in delivering the desired objectives and cost-effective use of taxpayer funds. As federal programs come into compliance with the Evidence Act, behavioral and experimental economics will be essential tools for producing such credible scientific information. In particular, the Evidence Act requires federal agencies to develop agency “learning agendas” to assist their staffs in identifying


key questions related to programs and evidence-based approaches to answer those questions (Abraham et al., 2017). Embedding behavioral insights and experimental designs into these learning agendas of agencies dealing with climate change may be an effective way of improving policy in this area (Palm-Forster and Messer, 2021).



Durable

Given the complexity of developing new policies and programs and the cost of implementing them, policymakers typically want those efforts to have long-lasting impacts. Long-term effects are particularly crucial when addressing climate change since rapid one-time solutions are rarely possible. Actions must become habitual. For policies to be durable, the actions they promote must be sustainable. Despite these critical characteristics, most studies so far have only examined adoption of policies and programs.

For instance, in the context of agricultural conservation, the durability of adoption of climate-friendly practices and factors that influence their durability are poorly understood, as noted in a recent review of 35 years of research on adoption of conservation practices: “[T]here is . . . little to no focus on adoption over time, a phenomenon that is referred to as maintenance and persistence” (Prokopy et al., 2019, p. 531). In contrast to numerous empirical studies of adoption of agricultural conservation practices, only twelve empirical studies have assessed the persistence of such practices and six of those (Hayes, 2012; Johnson et al., 1997; Kuhfuss et al., 2016; Race and Curtis, 2013; Ramsdell et al., 2016; Skaggs et al., 1994) analyzed behavioral intentions rather than actual behaviors. Potential bias in reports on intentions can make such studies poor proxies for actual behaviors. The six studies that reported on actual persistence

(Jackson-Smith et al., 2010; Roberts and Lubowski, 2007; Sawadgo and Plastina, 2022; Smart et al., 2015; Tran and Kurkalova, 2019; Wallander et al., 2018) arrived at conflicting conclusions about the degree to which agricultural conservation practices persist after adoption. We anticipate this sparsity of research on persistence is true for many other behaviors related to climate change. ()



Identity-respecting

When behavioral interventions perform well in field experiments and randomized controlled trials with targeted participants, they are likely to be well suited for implementation in policies. Given the disproportionate impact of climate change on historically underserved communities, behavioral studies can generate valuable insights when participants of the study are representative of the population being studied (Banerjee, 2022). For effective and ethical outcomes, behavioral interventions must address and respect many different self-identities and cultural identities. Furthermore, behavioral interventions should accommodate socio-cultural identity of the population being studied – for example, messages using injunctive norms should not make some population subgroups feel excluded. For example, messages around the importance of carpooling to reduce emissions from private transportation should acknowledge the safety concerns of some women. Likewise, messages that seek to dissuade certain behaviors through stigmatization need to be careful to not use approaches that may be objectionable from various cultural or religious perspectives. For instance, while electing to not have children is a behavior that has one of the largest reductions in a person’s carbon footprint, messages that aim to dissuade people to having children could be quite objectional to many people, especially if

these messages are coming from the government and are perceived as being directed to some groups of people more than others.



Boomerang Minimizing

The “boomerang effect” occurs when people learn that others’ behaviors are worse than theirs and change their own decisions in response, generally for the worse. This is called the boomerang effect (it can also be called the rebound effect or slippage) as it means that the results of the policy go in the opposite direction of the original intent. This phenomenon is critically important in behavioral studies because good initial intentions do not necessarily result in beneficial actions and well-intended interventions do not necessarily lead to desired behaviors in either the short or long terms. Whenever a strong boomerang effect is present, interventions will not be nearly as effective as originally expected. For example, if drivers of plug-in hybrid cars decide to drive more miles with these cars than they otherwise would given the per mile cost of fuel, then the true reduction in the emissions of greenhouse gases from plug-in hybrid cars would be less than would be estimated by sampling replacing a high-emission vehicle with a plug-in hybrid vehicle. Similarly, if efforts to preserve carbon in soil through conservation measures ending up lowering the agricultural yield per acre, then this behavioral change could lead to price increases in commodities that incentivize the conversion of forested lands – an outcome that would likely be more detrimental from a climate perspective.



Logistically Feasible

Many interesting ideas that can be explored via academic research cannot feasibly be implemented in actual settings. Numerous complications can arise, including hidden information possessed by one of the parties and difficulty observing, quantifying, and enforcing behavior. Likewise, some interventions might promote certain behaviors that may not be feasible in all situations. For instance, adoption of solar power may not be beneficial in places that are cloudy or have high levels of forest cover. Similarly, land use choices that benefit the climate will be highly dependent on the local soil and weather conditions. In this report, we have tried to focus on actions that are generally logistically possible when dealing with climate change and have not tried to address all of the potential solutions that have been proposed that generally fall outside of most people's decision set, such as geoengineering solutions like cloud seeding.



Ethical

As noted by Prokopy (2008, p. 261), researchers must be aware that their studies “deal either directly or indirectly with people's livelihoods and well-being” and must not “take this responsibility lightly.” Behavioral economic studies often ask policy-oriented questions that have important and potentially negative implications for the livelihoods of the people involved. Palm-Forster and Messer (2021) note that researchers have a responsibility to think carefully about their conduct and to ensure that they are ethical when choosing research ideas and designs and when implementing, analyzing, and disseminating the results of their research. Policies likewise should be ethical and seek to avoid disproportionate impacts, especially on historically disadvantaged people and communities.

1.2 *Methods Used to Develop the Literature Review*

In this report, we aim to identify how behavioral economic interventions can be employed as climate change interventions. Therefore, we examine four broad areas of climate mitigation: *energy use and efficiency, transportation, consumption, and land use*. Studies of behavioral interventions fall mainly into one of two categories: (1) measuring target behaviors in laboratory, online, and field environments and (2) quasi-experiments and natural experiments that affect evaluations of empirical strategies. We reviewed current empirical evidence on the effects of behavioral interventions and results of behavioral experiments and evaluated the evidence using the CREDIBLE criteria. Our systematic review of experimental and behavioral economic applications to climate change problems consisted of the following steps.

Step 1: Literature search. We first examined results published in prominent review journals, such as the *Review of Environmental Economics and Policy* and the *Journal of Economic Literature*. We then expanded the search to individual articles published on both general economics journals (e.g., *American Economic Review* and *American Economic Journal: Economic Policy*) and more-specific field journals (e.g., *Journal of the Association Environmental and Resource Economists*, *American Journal of Agricultural Economics*, *Journal of Environmental Economics and Management*, *Journal of Economic Psychology*, *Journal of Economic Behavior and Organization*, and *Food Policy*) and inter-disciplinary and general interest journals (such as the *Proceedings of the National Academies of Science*, *Nature*, and *Science*). In addition to including seminal research, we focused on research published within the past decade: 2012 through 2022. After assessing abstracts, we selected potential studies of interest, downloaded the papers,

and examined the cited literature in those papers to identify other papers of interest, resulting in approximately 400 published studies, of which over 200 of the most relevant studies are included in this report.

Step 2: Review of papers using a set of inclusion criteria. We selected studies that met three criteria for inclusion:

- (1) Must link directly to issues associated with greenhouse gas emissions and climate change.
- (2) Must address development and climate change in developed countries, though a few studies from developing countries were included.
- (3) A strong preference for the use of a revealed-preference methodology rather than a stated-preference methodology (i.e., hypothetical surveys or focus groups). In situations where there was only evidence from stated-preference studies, we provided these areas with a lower rating on the strength and quality of the evidence.

Step 3: Identify and tabulate the methods and elements on which the evidence was based in multiple rounds of evaluation. We ascertained the key behaviors targeted and tabulated characteristics of the sample population, the research methods employed, and the interventions tested. In the various tables, we then distilled the key behavioral findings in terms of four sectors – energy use and efficiency, transportation, consumption, and land use decisions. These tables also show where there is a gap in the existing literature.

Step 4: Evaluate the behavioral interventions examined in the studies using CREDIBLE. We used the CREDIBLE criteria to evaluate the synthesized findings and highlight the strengths, weaknesses, and potential opportunities presented by the interventions in addressing climate change. We also provide an overall score (one to three stars) on how credible the evidence is, where three stars indicates that the evidence is most credible.

1.3 Areas in Need of Additional Research

As noted by Ferraro et al. (2022), in principle, behavioral economic theories regarding systematic and predictable deviations from traditional economic theory should apply equally to consumers and producers. However, the results of many empirical studies do not support that assertion. For consumers, who are viewed as utility-maximizing decision-makers, extensive evidence supports the behavioral economic theories. For producers, however, variances have been noted, associated with three characteristics of producer samples. First, producers typically compete in markets, and market experience can mitigate or even eliminate myopic thinking and behavior (Alevy et al., 2015; List, 2003, 2011). In highly competitive markets, producers' cognitive biases lead to sub-optimal decisions, thus motivating them to change their behaviors or forcing them to exit the market due to unsustainable financial losses. Second, the stakes associated with producer decisions are generally much greater than the stakes associated with consumer decisions in laboratory and field studies. Third, most producers are experts in their domains. They complete multiple transactions within a single choice context, which gives them comprehensive experience that consumers typically cannot acquire. Scholars have also posited that behavioral economic theories make the most accurate predictions in unfamiliar and

exceptional scenarios as they are likely to rely upon heuristics and gut instincts (Aumann, 2019; Koszegi and Rabin, 2008). Thus, producers' familiarity and expertise likely allow them to avoid behavioral biases.

Whether such factors influence the power of behavioral economic theories to explain producer behavior is an empirical question. Virtually none of the evidence supporting the power of behavioral economic theories for producers (e.g., Beggs and Graddy, 2009; Camerer et al., 1997; Coval and Shumway, 2005; Gao et al., 2018; McAlvanah and Moul, 2013) is based on experiments. And this is particularly true for commercial producers in relatively developed countries, an important source of profit-maximizing, cost-minimizing producers that operate in competitive environments. This is a critical gap in the literature on behavioral interventions designed to address climate change that must be kept in mind when reviewing the results highlighted in this report.

Likewise, the behavioral economic literature provides little insight into decisions made in groups. We do not know, for example, whether responses to behavioral interventions depend on whether individuals or groups make the decisions. Much of the evidence of the efficacy of behavioral interventions comes from studies of individual decisions while many such decisions are made by groups, such as users of shared resources. A large body of evidence from laboratory studies indicates that groups and individuals make decisions differently (see Brown (1986) and Forsyth (2013) for reviews). For example, in laboratory studies groups have tended to behave more selfishly (Schopler and Insko, 1992), take on greater risks (Stoner 1961), adhere more closely to "rational" behavior (Bornstein et al., 2004), and display less myopic loss aversion (Sutter, 2007) and anchoring (Meub and Proeger, 2018) than individuals.

Finally, we note that there likewise is a lack of evidence regarding how interventions based on behavioral economics affect the behavior of policymakers and government bodies. This represents another critical gap in the literature that needs to be addressed by future research.

2. Energy Use and Efficiency

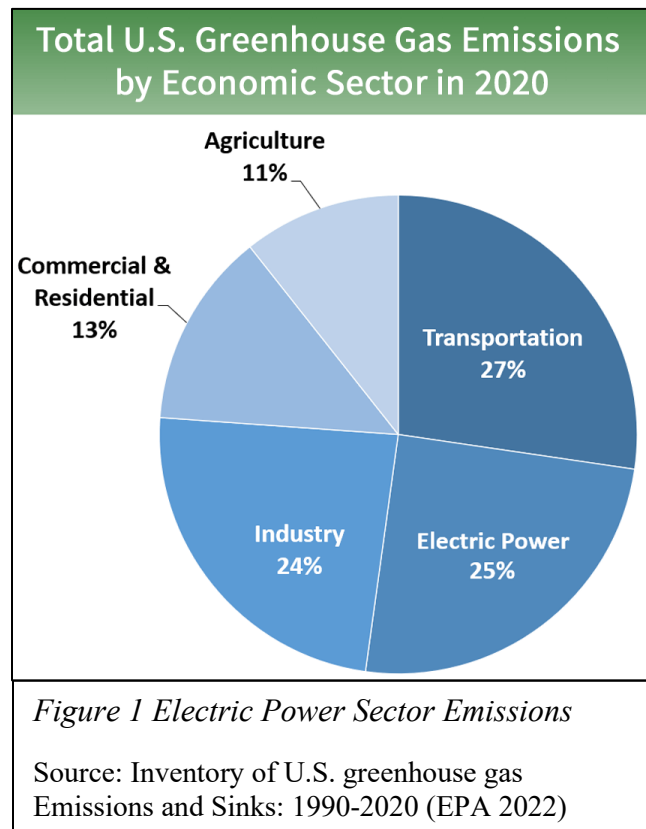
In 2021, U.S. energy-related carbon dioxide emissions amounted to 4.9 billion metric tons, an increase of 6% over 2020 levels (U.S. Energy Information Administration, 2021). Most of these emissions came from the transportation and electric power sectors. Residential energy use contributes about 20% of overall carbon emissions in the U.S. (Goldstein et al., 2020).

Significant attention has been paid to long-term responses to the effects of climate change, such as energy-efficient technologies and cap-and-trade regimes. However, changing individual behavior is a potentially faster and less expensive approach presenting opportunities to harvest low-hanging fruit (Dietz et al., 2009; Vandenbergh et al., 2007). Such individual behaviors fall generally into reductions in emissions at the intensive or the extensive margins. At the extensive margin, energy efficiency is increased via relatively costly, but longer-lasting, one-shot decisions such as replacing old appliances and other durable goods with new energy-efficient ones and purchasing renewable energy. At the intensive margin, individuals do not change their appliances, but instead reduce their consumption of energy by choosing to use less electricity at home. Decisions such as turning off lights or setting the house temperature are made frequently. Behavioral change on both the extensive and intensive margins can be incentivized via policies that incorporate market-based solutions such as subsidies and price increases/reductions and by behavioral interventions such as nudges.

In terms of the intensive margin, reductions in household electricity use have been widely studied, testing dynamic pricing structures, rewards, and information-based behavioral interventions. Regarding the extensive margin, studies have addressed a few types of interventions, such as promotion of adopting solar panels and participating in energy efficiency programs. The interventions have included subsidies, tax credits, retrofit programs, and information nudges. These studies used a variety of empirical methods, including field experiments, quasi-experiments, and natural experiments. In this section, we synthesize evidence related to modifying energy consumption from behavioral studies.

2.1 Electricity Use


As shown in Figure 1, in the U.S., the electricity sector was the second largest source of greenhouse gas emissions, accounting for one quarter of all emissions, a significant increase from 12% in 1990 (EPA, 2020). Electricity is predominantly generated by burning fossil fuels and demand has been growing over the past 30 years. Because residential uses account for a large share of the emissions, we summarize studies of policy tools designed to encourage household electricity conservation.



2.1.1 *Limited Attention and Cognition*

The wholesale cost of electricity is in constant flux in response to peak and off-peak hours and days of use. In most cases, though, consumers pay flat or tiered rates that do not reflect wholesale prices at the time of consumption, resulting in inefficient allocations. Policymakers have long discussed adopting dynamic pricing (also called peak load pricing and real-time pricing) to address this problem (Allcott, 2011b), leading to theoretical and simulation analyses. Compared to simple unit and static pricing schemes, dynamic pricing schemes are relatively more variable and complicated to understand, resulting in a larger cognitive cost to consumers. Given consumers' limited attention span, they may not perfectly respond to dynamic pricing schemes as expected by the theory. In recent years, with development of large-scale field experiments and availability of high-frequency data, studies have provided abundant empirical evidence of consumers' responses to various pricing schemes (e.g. Burkhardt et al., 2019; Ito, 2014; Jessoe and Rapson, 2015; Shawhan et al. 2011), information on electricity consumption and prices (e.g., Jessoe et al., 2021; Jessoe and Rapson, 2014; Martin and Rivers, 2018).

In this section, we selected and reviewed nine key studies that addressed the effects of pricing schemes and information provision on reductions in residential electricity use. These studies employed large-scale field experiments, quasi-experiments, and natural experiments to identify causal effects. The sample sizes in the studies were quite large; most exceeded 10,000 households while a few involved less than 1,000 households, mostly in the U.S. (e.g., California, Chicago, Texas, Connecticut) and a few in Canada (e.g., Martin and Rivers, 2018).

The studies provide mixed results regarding the effectiveness of dynamic pricing schemes () . For example, Allcott (2011) and Burkhardt et al. (2019) found that real-time pricing and peak load pricing encouraged energy conservation during peak periods. Allcott

(2011) also found that consumers did not increase their average consumption during off-peak periods, and Burkhardt et al. (2019) found that reductions in electricity use persisted for two hours after peak hours ended. Jessoe et al. (2014), on the other hand, found that consumers reduced their use of electricity only when offered decreased prices, indicating that consumers' responses were affected by behavioral factors, including paying infrequent attention to dynamic pricing changes. Ito (2014) examined the effects of nonlinear pricing schemes and found that consumers responded to average prices rather than to marginal or expected marginal prices even though standard economic theory predicts that consumers will respond to marginal and expected marginal prices. This study found that consumers used average prices as approximations of marginal prices because the cognitive cost of understanding complex nonlinear pricing structures based on monthly utility bills was substantial. This finding of sub-optimal behavior raises questions about the efficacy of policies designed to charge higher marginal prices for excess consumption to encourage conservation. It also points to the potential of providing consumers with additional information to reduce the cognitive burden.



Both Ito (2014) and Jessoe et al. (2014) note that providing information and real-time feedback regarding electricity prices and consumption to increase salience of prices can potentially resolve consumers' anomalous responses and act as a nudge (Carlsson et al., 2021). Electricity bills generally are not designed to draw consumers' attention to their patterns of usage, but Gilbert and Graff Zivin (2014) found that households reduced their overall electricity consumption the week after receiving routine electricity bills, especially during summer months, and during peak hours.

Consumers can obtain real-time information via technologies such as smart meters, smart thermostats, in-home displays of usage, and apps that could report usage on smart phones. Jessoe

and Rapson (2014) found that households using in-home displays were more responsive to temporary price increases than households not using them. Harding and Lamarche (2016) found that households using smart thermostats reduced consumption during peak hours, shifting their use to off-peak hours. The households' responses to time-of-use pricing depended on their demographic characteristics, weather patterns, and their usage in July. In contrast, Martin and Rivers (2018) found that in-home displays reduced electricity consumption largely because in-home displays helped household members to form habits of reducing electricity and improving energy efficiency through appliance updates rather than encouraging them to better respond to real-time prices. Brandon et al. (2022) likewise found little evidence that use of smart thermostats reduced energy consumption.

Dynamic and nonlinear pricing schemes have been studied in parts of the U.S. and other countries as part of efforts to reduce electricity use, especially during the peak times. Although the sampled studies have found the lack of effectiveness of dynamic pricing due to consumers' limited attention or by the large cognitive cost required of them, the studies have found that providing consumers with information about their electricity use and real-time pricing has led to various degrees of reduced consumption and that some of those effects arose from consumers adjusting their electricity use habits and not from their having a better understanding of the relationship between their usage and prices. Therefore, additional research is needed to understand behavioral factors that limit the effectiveness of providing information and to better target information provided.



<i>Cost-effective:</i>	Uncertain – The evidence of cost-effectiveness is mixed () Implementation costs associated with dynamic electricity pricing scheme are not thoroughly discussed. The cost of providing information via routine bills and smart technologies should be relatively small compared to changing pricing schemes.
<i>Replicable:</i>	High. Evidence of the effects of combining information with dynamic pricing schemes is provided within different areas in North America and is replicable to other areas and demographic groups
<i>Evidence-based:</i>	Yes. The studies on this topic are generally peer-reviewed and published in reputable journals with robust empirical analyses
<i>Durable:</i>	Uncertain. Examination of persistent treatment effects is limited.
<i>Identity-respecting:</i>	Yes.
<i>Boomerang minimizing:</i>	Uncertain. Provisions of information have been shown to reduce the boomerang effect in some of the studies but not in all. ()
<i>Logistically possible:</i>	Yes. Given the generalizability of the dynamic pricing schemes and information provision, it is logistically possible.
<i>Ethical:</i>	Yes. Real-time information provided together with dynamic pricing schemes is ethical because it is true information and provides real-time feedback to residents.

Note that industry uses large quantities of electricity but policies and programs to reduce that consumption have rarely been studied. An exception is Jessoe and Rapson (2015), which found only negligible positive effects from mandatory time-of-use pricing on overall use, peak use, and peak loads. And though agricultural uses of groundwater require electricity for pumping, recent studies have only addressed their groundwater use in response to electricity prices. Thus, we do not know how dynamic pricing combined with provision of information would affect agricultural electricity use.


2.1.2 Social Preferences and Social Norms

Moral suasion, social norms, and social comparisons are among the most used and studied moral nudges to encourage energy conservation (Carlsson et al., 2021). Moral suasion informs people about desirable moral behaviors, social norms present others' behaviors, and social comparisons appeal to humans' desire for greater success than others. Currently, these kinds of comparisons are used to encourage conservation via home energy reports. Given the abundance of studies of such behavioral interventions, we selected 11 key studies that examined treatment and persistent effects of moral green nudges on reductions in residential energy use that used field experiments. Sample sizes in most of these studies exceeded 100,000 households and the studies were conducted in the U.S. (e.g., Allcott, 2011b; Allcott and Kessler, 2019; Allcott and Rogers, 2014; Brandon et al., 2017), in Japan (Ito et al., 2018), in Colombia (Carlsson et al., 2021), in Italy (Bonan et al., 2021), and in India (Sudarshan, 2017).

Allcott (2011b), Allcott and Rogers (2014), and Allcott and Kessler (2019) examined the effects of social comparisons provided in home energy report letters from OPOWER, a data analytic firm that works with utilities to address climate change. The seminal study, Allcott (2011b), found that consumers who viewed comparisons of their electricity use to use by a neighbor reduced their consumption of electricity. This paper also showed that this social-comparison nudge was cost-effective because its effect was equivalent to a temporary electricity price increase of between 11% and 20%. Allcott and Rogers (2014) subsequently examined the persistence of effects of social-comparison behavioral interventions used by OPOWER. They found that the effects persisted, decaying between 10% and 20% annually. Likewise, Allcott and Kessler (2019) also showed that the effects persisted and further found that “renudging” encouraged household energy savings. Notably, by eliciting households' willingness to pay for

receiving home energy reports, they further found that prior estimates of welfare gains from the nudges had been overstated because they ignored significant financial, time, and psychological costs incurred by the recipients.

Several other studies produced interesting findings regarding social-comparison behavioral interventions. Myers and Souza (2020) found that their social comparisons had no effect on participants' energy use for heat in a university residence hall in which the tenants did not pay the utility bills. Sudarshan (2017) found that social comparisons reduced consumption of electricity in the summer months in India but also found that the effect disappeared when the nudge was combined with monetary rewards for saving electricity. Evidence of the persistence of effects of moral green nudges is limited. Brandon et al. (2017) generally found persistent effects in response to social comparisons in the form of home energy reports in 38 field experiments.

Social norms and moral suasion have also been used to encourage energy conservation, revealing mixed results and heterogeneity among types of energy users (). Allcott (2011b) used an injunctive norm that present “smiley faces” and “frownie faces” according to participants' electricity use in neighbor comparison groups. The results showed that the injunctive norm could lead to decreased energy use and that the magnitude of the change varied with each household's consumption relative to consumption by the group. In particular, households that used relatively little energy were less responsive to the injunctive norm than high-use households. Similarly, Delmas and Lessem (2014) tested the effect of providing real-time feedback on energy used by appliances and a social-norm nudge regarding use privately and conservation ratings of the appliances publicly. They found that private information alone was not effective while a combination of private and public information was effective, particularly in reducing use of energy for heating and cooling. They also found that the median energy user was

most responsive to the public information. In a study conducted in Japan, Ito et al. (2018) found that a moral suasion reduced electricity use in the short term and that the effect rapidly diminished despite repeated moral-suasion messages. Bonan et al. (2021), in a study conducted in Italy, found no average effect of a message equating a positive social identity with environmental concern but suggested that this type of priming could be effective when applied to high-use households.

Two of the studies examined spillover effects of information about water use on electricity use. In Jessoe et al. (2021), home water reports compared participants' water use to that of their neighbors and provided water conservation tips. This combination of a social comparison and provision of information led to temporary reductions in electricity use in summer months even though the water reports did not mention or target electricity use. Similarly, Carlsson et al. (2021b) found that personalized reports on water consumption led to reductions in electricity use in Colombia, potentially because household members inferred information about their electricity use from the water use reports.

In summary, the studies indicate that moral and social green behavioral interventions generally and social comparisons are effective in convincing households to reduce their energy use and that the effects can persist. The findings from the studies of the effects of social norms, pro-social information, priming, and moral suasion are less consistent but point to such behavioral interventions being effective for high-use households. These results indicate that the behavioral interventions must be designed specifically to target low-use and high-use households.



<i>Cost-effective:</i>	High. Though none of the studies quantified the implementation costs of the behavioral interventions tested, we can presume that they would be significantly less costly than formal policy instruments Most of the social-comparison nudges were found to be effective and cost-effective
<i>Replicable:</i>	High. Because the studies used large samples and were conducted in multiple nations, their evidence regarding social nudges is replicable to other areas and demographic groups.
<i>Evidence-based:</i>	Yes. The sampled studies were peer-reviewed and published in reputable journals with robust empirical analyses.
<i>Durable:</i>	Yes. Persistent effects have been found in field experiments.
<i>Identity-respecting:</i>	Yes.
<i>Boomerang minimizing:</i>	Yes. Behavioral interventions have not been found to increase electricity use unexpectedly.
<i>Logistically possible:</i>	Yes. Provisions of social norm information are logistically possible given.
<i>Ethical:</i>	Yes. Behavioral interventions associated with social preference and norms are ethical as they provide truthful information to residents.

2.1.3 Present Bias and Reference Dependence

Several of the studies of electricity use addressed present bias and/or reference dependence. Energy is not consumed and paid for at the same time, resulting in inter-temporal tradeoffs between immediate energy consumption and delayed payments. Compared to consumers with time-consistent discounting (i.e., assigning equal discounting weights to benefits and costs across time periods), present-bias consumers devalue the future electricity costs and increase energy consumption. Using a survey and an incentivized experiment, Werthschulte and Lösschel (2021) measured the effects of present bias and found that biased consumers used more electricity than

consumers who relied on time-consistent discounting. Harding and Hsiaw (2014) examined the behavior of present-biased consumers who possessed reference-dependent preferences in a goal-setting program that aimed to reduce household electricity consumption in northern Illinois. They found that present bias led to sign-ups from consumers who were aware of predicted overconsumption in the future and reference-dependence would counteract overconsumption because the goal established a reference point. Fraser (2022), analyzing data from successive annual conservation challenges in British Columbia, Canada, found that consumers responded to their successes and failures in achieving their ongoing energy conservation goals rather than to the financial incentives.


Fowlie et al. (2021) studied the effects of default opt-in and opt-out options in a program involving time-based dynamic electricity pricing. They found that the opt-in default had a large effect on program participation and electricity consumption. When the default for participation was to opt in, most consumers did not opt out and did reduce their electricity use in response to higher prices during peak times. Similarly in Wang et al. (2020), when the default for participating in a critical peak pricing program was to opt in, most consumers agreed to participate and reduced their consumption. They also found a persistent effect from the opt-in default as a reduction in electricity usage was observed during off-peak hours.

In summary, relatively few studies have examined other behavioral economic principles such as present bias and reference dependent. The few that have suggest that electricity use is affected by these behavioral biases, which can be inexpensively addressed using behavioral interventions.

2.2 *Solar Panel Adoption*

So far, we have addressed interventions that can be applied “inside the grid.” However, with the emergence of rooftop solar technology, households need not confine their conservation efforts to consumption of electricity from the grid. They can opt to produce their own electricity while simultaneously reducing carbon emissions associated with their consumption. Despite energy independence and long-term reductions in energy costs from solar photovoltaic (PV) systems, many households have been unwilling or unable to adopt these systems, primarily because of large upfront installation costs. Thus, we examine studies that have tested interventions designed to ease this barrier.

2.2.1 *Limited Attention and Cognition*

Because solar panels are costly initial investments that have long-term financial impacts, various financial incentives (e.g., rebates, tax credits, and loans) have been tested to encourage adoption of solar power. The results from studies that relied on observational data are mixed (). We selected several studies that discussed the effects of rebates. Note that these studies rarely address potential behavioral factors that could contribute to a lack of effectiveness of rebates. We suspect that consumers do not necessarily formally compare the costs and benefits of solar panels and, therefore, that providing information on costs and benefits could improve the effectiveness of rebates.

Hughes and Podolefsky (2015) examined the effects of an upfront rebate on residential solar installation in California and found that the rebate motivated 53% of the consumers who adopted solar. Crago and Chernyakhovskiy (2017) investigated the impacts of rebates (direct subsidies), tax-based incentives, and loan financing on solar photovoltaic capacity in 13

northeastern U.S. states. Only rebates were found to have a significant effect on increasing additions of annual capacity across all empirical model specifications.

Gillingham and Bollinger (2021), on the other hand, used a field experiment and found that lower group pricing had no effect on solar panel adoption in Connecticut. Boccard and Gautier (2021) in a study in Belgium found that subsidies combined with net metering had a rebound effect on adoption of solar panels in that households installed oversized solar panels that exceeded their needs, resulting in overconsumption of electricity, in order to cover the upfront investment costs.



CREDIBLE Assessment: Solar Panel Adoption - Rebates ★★☆☆

<i>Cost-effective:</i>	Medium. Provision of rebates incurs direct financial costs and does not always increase adoption or reduce consumption.
<i>Replicable:</i>	Medium. The number of studies is small, a problem that is not entirely mitigated by large samples and broad geographic reaches.
<i>Evidence-based:</i>	Yes. These studies were peer-reviewed and published in reputable journals with robust empirical analyses.
<i>Durable:</i>	Yes. Adoption of solar panels is essentially a one-time decision. As long as rebates encourage the one-time decision of adopting solar panels, the effect is persistent.
<i>Identity-respecting:</i>	Yes.
<i>Boomerang minimizing:</i>	Uncertain. As rebates for solar panel adoption have a potential rebound effect of increasing electricity consumption.
<i>Logistically possible:</i>	Yes. Rebates generally are logistically possible; solar panel installation is less so because of financial and climate constraints.
<i>Ethical:</i>	Yes.

2.2.2 Social Preferences and Social Norms

Peer effects and provision of information on social norms have been found to affect households' adoption of solar panels in field experiments and quasi-experiments that were conducted mainly in Connecticut and California (Bollinger & Gillingham, 2012; Kraft-Todd et al., 2018).


According to Bollinger et al. (2022), potential channels by which peer influence affects adoption are visibility of peer choices and word of mouth, which increase social comparisons and social learning.

The studies of peer effects relied primarily on observational data. Bollinger and Gillingham (2012) in a study conducted in California were the first to identify peer influence on adoption of solar panels. They found that previous nearby installations of solar panels led to increased adoption and that the effect was strongest when the existing panels were installed by neighbors at the street level. Similarly, Graziano and Gillingham (2015) showed that adoption was influenced by the number of previous nearby adoptions, indicating considerable clustering of adoptions that did not follow income and population distributions. However, they also found that this peer effect diminished with time and distance, suggesting that visibility and social interactions produced the effects. Moreover, Bollinger et al. (2022) examined whether the visibility of solar panels (from the road) affected adoption in Connecticut. They found that the effect of visibility was significant up to least 500 meters whereas the effect of non-visibility extended up to 100 meters, confirming that the effect was related to social learning achieved by visually identifying neighbors' adoption of solar panels.

Impacts of information behavioral interventions on social norms have been identified using field experiments. Bollinger et al. (2020), Gillingham and Bollinger (2021), and Kraft-Todd et al. (2018) examined the effects of information campaigns in Connecticut. Kraft-Todd et

al. (2018) investigated the effect of encouragements from volunteer solar ambassadors who were also community organizers. They found that community organizers who installed solar panels through a program increased adoption by residents in the community. Gillingham and Bollinger (2021) also found a positive effect from information campaigns by volunteer solar ambassadors, but the effect did not persist. Bollinger et al. (2020) compared the effects of self-interest and pro-social community-oriented messages in an information campaign using net present value. They found that the self-interest message outperformed the pro-social message and that high-income communities were more responsive to the self-interest message than low-income and medium-income communities. Interestingly, the pro-social message led to a greater number of peer recommendations and greater satisfaction with solar panel adoptions, evidence that pro-social information can reinforce peer influence.

Since adoption of solar panels is affected by peer influence and social norms and the peer effect occurs within visible distances, policymakers may want to consider adding a specific number of solar panels in a neighborhood when employing social-norm behavioral interventions and information campaigns.

<i>CREDIBLE Assessment:</i>	 <i>Solar Panel Adoption - Information campaigns</i> ★★ ★
<i>Cost-effective:</i>	High. The information campaigns had a strong effect on solar panel adoption.
<i>Replicable:</i>	Medium. Most of the studies were conducted in California and Connecticut, and the peer effects were limited in terms of spatial distance, though that could be partly due to the popularity of solar panels and to ideal weather conditions.
<i>Evidence-based:</i>	Yes. The studies were peer-reviewed and published in reputable journals with robust empirical analyses.

<i>Durable:</i>	Yes. Adoption of solar panels is essentially a one-time decision. As long as information campaigns encourage the one-time decision of adopting solar panels, the effect is persistent.
<i>Identity-respecting:</i>	Yes.
<i>Boomerang minimizing:</i>	Yes. Information campaigns have not been found to discourage the adoption of solar panels.
<i>Logistically possible:</i>	Yes. The information campaigns are logistically possible; solar panel installation is less so because of financial and climate constraints.
<i>Ethical:</i>	Yes. Information campaigns are ethical as they provide truthful information to residents.

2.2.3 *Present Bias, Projection Bias, and Ambiguity Aversion*

Contrary to energy consumption with immediate benefits and delayed costs, adoption of solar panels has immediate large investments and delayed benefits. Individuals respond to this inter-temporal trade-offs differently, due to present bias, projection bias, and ambiguity aversion. De Groote and Verboven (2019) found that households in northern Belgium discounted the future benefits of solar panels when considering subsidies for future electricity production. Those results indicate that future subsidies would increase the cost of promoting solar panels relative to upfront subsidies (as noted under limited attention and cognition) for present-biased consumers. Similarly, Liao (2020) found that households that had signed solar panel contracts were more likely to cancel the contracts after enduring particularly bad weather despite the long term of their investments, which would not be affected by short-term fluctuations in weather. This response could arise from projection bias in that solar adopters tended to estimate their returns based on recent weather conditions.

Salience effects also could be a factor with adopters responding strongly to weather patterns related to solar productivity. Tsvetanov (2019) examined the effect of uncertainty about

continuation of financial incentives (potential discontinuation of a program in the future) and about the magnitude of future incentives. The results showed that a temporary exhaustion of funds would reduce participation in the California rebate program by an average of 67% and that the reduction depended on households' income levels and the size of their PV systems. These findings could be associated with individuals' aversion to uncertainty and, thus, that any uncertainty about a rebate program would reduce its effectiveness.

2.3 Energy Efficiency Program Participation

Investments in energy efficient equipment and appliances have been shown to reduce carbon emissions (Gillingham & Palmer, 2014). Consequently, market-based programs and behavioral interventions have been used to encourage those investments. Energy efficiency retrofit programs that include facilitated and subsidized energy audits and energy efficiency investments (e.g., improved insulation and heating and cooling systems) are commonly used for appliances in residential and commercial buildings. These types of programs are conducted by steps in two stages – energy audits and appliance installations – and both have been studied. Several other studies have examined energy use after retrofits and upgrades (Liang et al., 2018; Novan & Smith, 2018). The evaluations of these programs and products mostly addressed program participation and upfront costs relative to energy savings (Giandomenico et al., 2022), particularly the energy-efficiency gaps where adoption of energy efficient appliances is low despite the significant cost savings associated with the products. The studies examined behavioral factors that could explain these energy efficiency gaps (see Gillingham and Palmer 2014 for a review), but little empirical testing using field experiments was conducted. Giandomenico et al. (2022) provided a systematic review of 39 studies that evaluate the energy

savings and cost-effectiveness of residential energy efficiency retrofit programs. We selected studies that provide experimental evidence and focused on addressing behavioral outcomes associated with limited attention and cognition, as well as social preferences and norms.

2.3.1 Limited Attention and Cognition


The studies of participation in energy efficiency programs examined the impacts of subsidies (see Giandomenico et al., 2022 and Gillingham et al., 2018 for more discussions) and provision of information about the benefits and costs of the programs. They found that the subsidies had a strong impact while the information provisions did not. Moreover, they determined that the actual energy savings were mostly smaller than the engineering projection and investment costs. This may partly due to that individuals could fail to pay full attention to information about the costs and benefits of energy efficiency programs (Palmer & Walls, 2015).

Holladay et al. (2019) examined the effects of subsidies provided by a sponsored in-home energy audit program in a field experiment in southeastern U.S.. They found that the subsidies increased participation in the audit program but did not increase installation of energy efficient products. Boogen et al. (2022) examined customized information about potential monetary savings from adopting energy efficient lightbulbs and home appliances in Switzerland and found that the information increased the energy efficiency of newly purchased durable good.

Two studies examined both subsidies and information provision. Allcott and Taubinsky (2015) examined the effects of information provision, a subsidy of compact fluorescent lightbulbs, and a ban on standard incandescent bulbs on lightbulb choices and values in two field experiments. They found that moderate subsidies were optimal and increased welfare whereas

the ban decreased welfare. They also showed that provision of information increased the compact fluorescent lightbulb’s market share and consumers’ willingness to pay, though willingness to pay was less than the corresponding cost savings. Allcott and Greenstone (2017) investigated the effects of subsidies and information on residential energy efficiency programs in a field experiment. They found that only the subsidies had a significant impact on participation in audits and investments under the programs. The effect of information on the private and public benefits of the programs, availability of low-interest financing had an insignificant effect. These studies suggest that information and behavioral biases did not affect participation and that realized energy savings were less than predicted savings because of unobserved costs missed in traditional evaluations.

In summary, the evidence indicates that subsidies can increase adoption of energy efficiency products and programs and that information provision has little or no effect on average, perhaps because of consumers’ limited attention and cognition. However, the studies also show that the upfront costs usually exceeded energy savings, suggesting that these types of programs are not cost-effective.

<i>CREDIBLE Assessment:</i>	<i>Energy Efficiency Program Participation - Subsidies and information provision</i>	 ★☆☆
<i>Cost-effective:</i>	Low. Regardless of any effects of the subsidies and information, the upfront costs of these programs usually exceed the corresponding energy savings.	
<i>Replicable:</i>	High. Subsidies and the role of information provision have been tested in multiple studies in the U.S. and Europe with various demographic groups (see Giandomenico et al. (2022) for a review.	
<i>Evidence-based:</i>	Yes. The studies were peer-reviewed and published in reputable journals with robust empirical analyses.	

<i>Durable:</i>	Yes. As with solar panels, these programs are one-time investments. As long as subsidies and provided information encourage the energy efficiency upgrades, the effect is persistent.
<i>Identity-respecting:</i>	Yes.
<i>Boomerang minimizing:</i>	Yes. Subsidies and information provision that encourage participation in energy efficiency programs have not been shown to increase energy use as a result of these programs.
<i>Logistically possible:</i>	Yes. Provisions of subsidies and information are logistically possible. While upgrading light bulbs is less costly, retrofits could be too costly to be feasible.
<i>Ethical:</i>	Yes.

2.3.2 *Social Preferences and Social Norms*

Though information behavioral interventions employing social comparisons and social norms have been shown to reduce electricity consumption, these types of behavioral interventions have not proven effective for programs promoting adoption of energy efficiency products in most cases. The exception is Toledo (2016), which examined the effects of persuasive environmental communication on adoption of energy efficient light-emitting diode (LED) bulbs in Brazil. They found that the persuasive communication increased adoption, mostly from purchases at the medium price. Wealthier participants and women were most responsive to the information.

Three of the studies found that social norm and preference behavioral interventions changed behavior but did not actually increase consumers' energy savings. Holladay et al.'s (2019) study of an in-home energy audit program showed that social-comparison information about energy use increased participation in the audit program but not actual installation of large energy-efficient durable goods and thus did not increase energy savings. Fowlie et al. (2018, 2015) examined impacts of provision of encouraging information and assistance with applications on enrollment in energy efficiency programs by households in Michigan eligible for

weatherization assistance. Though aggressive encouragement led to a moderate increase in participation, the upfront investment costs were about twice as much as the realized energy savings, which were only 30% of projections. In these cases, the gaps between costs and savings did not seem to be related to rebound effects.

CREDIBLE Assessment: Energy Efficiency Program Participation - Social norms and comparisons















<i>Cost-effective:</i>	High. Although the nudges did not have large impacts, they did not involve upfront costs. It is more cost-effective for products with less upfront investments (e.g., light bulbs) than energy efficiency programs.
<i>Replicable:</i>	Low. The selected studies covered only covered Michigan households and Brazil.
<i>Evidence-based:</i>	Yes. The studies were peer-reviewed and published in reputable journals with robust empirical analyses.
<i>Durable:</i>	Yes. These programs involve one-time enrollment. As long as interventions encourage the energy efficiency upgrades, the effect is persistent.
<i>Identity-respecting:</i>	Yes.
<i>Boomerang minimizing:</i>	Yes. Interventions using social norms to encourage participation in energy efficiency programs have not been shown to increase energy use as a result of these programs.
<i>Logistically possible:</i>	Yes. Provision of the information behavioral interventions is logistically possible; retrofits could be infeasible because of costs.
<i>Ethical:</i>	Yes.

2.4. CREDIBLE Assessment for Energy Use and Efficiency

The CREDIBLE assessment (Table 1) compares evidence from the studies of household electricity conservation, solar panel installation, and participation in energy efficiency programs, which reduce greenhouse gas emissions by decreasing energy use. These interventions used

market-based approaches and information behavioral interventions to change individual consumer behavior. The results of the studies show that limited attention and cognition and social norms are the primary behavioral features that explain consumers’ behavioral responses to the interventions. Furthermore, we find that the evidence supporting social-norm behavioral interventions as effective in changing behavior is the most credible and that the evidence supporting subsidies and information behavioral interventions as increasing participation in energy efficiency programs is the least credible. Importantly, this table also shows area where the literature is currently missing evidence.

Table 1. CREDIBLE Assessment for Energy Use and Efficiency

Core Principles of Behavioral Economics	Behavioral Interventions	Electricity use	Solar panel installation	Participation in energy efficiency programs
Limited Attention and Cognition	Dynamic pricing and information	 		
	Rebates		 	
	Subsidies and Information			 
Social Preferences and Social Norms	Information Nudges and Campaigns	 	 	 

Notes: Symbols are provided when the evidence is high or medium in abundance. The absence of a symbol suggests that there is little evidence, or that the existing evidence is generally inclusive.


3 **Transportation**

Greenhouse gases associated with consumption have been established as the primary driver of global warming (IPCC, 2014). The IPCC (2022) has further noted that global emissions could be reduced by 40% to 70% by people in developed countries reducing air travel, making green lifestyle choices, and choosing to walk, cycle, and use electric transportation. We thus examine evidence from studies of behavioral interventions designed to reduce carbon footprints, both by reducing emissions and by increasing sequestration. Our literature search highlights studies that target behavioral interventions and pricing policies that can address decision-making due to limited attention and cognition; social preferences and social norms; and present bias and reference dependence. We examine interventions at the extensive margin that identify effective interventions that impact big purchases, such as buying hybrid and electric vehicles. At the intensive margin the interventions are designed to influence reduction of carbon footprint of consumers' current habits, such as opting for public transportation, replacing individual car trips with carpooling and planning trips more efficiently. In this section, we synthesize evidence from behavioral interventions that influenced transportation choices made both at the extensive and intensive margins.

3.1 Private Vehicle Choices

3.1.1 Limited Attention and Cognition

The standard economic models assume that consumers correctly value future operating costs when making the trade-offs between vehicle product prices and future costs at the point of purchase (Huse & Koptyug, 2022). However, limited attention and cognition while making large vehicle purchase decisions can lead consumers to underestimate their future fuel savings from a

more energy efficient car purchases and buy low-fuel economy vehicles (Gillingham & Palmer, 2014). There is an alternative argument for poorly targeted taxes and subsidies and if they are effective interventions in reducing inattention and raising salience. O'Donoghue & Rabin (2006) postulate that taxes and subsidies can generate first order welfare gains for inattentive consumers and only second order distortions for attentive consumers. Public policies can also play a role in lowering the cost of attention and this area is a promising area for future research, () Researchers can test models of inattention with testable predictions (Sallee, 2014).

Hybrid vehicles have been well studied empirically and market penetration rates of hybrid vehicles have been found to affect future purchases. Moreover, the learning spillovers spans across the original producer of these spillovers. Larger market presence of Toyota Prius resulted in hybrids of all makes (Heutel & Muehlegger, 2015). Studying the effect of spillovers of more energy efficient cars that are introduced in the market offers up a promising area of future research.

Turrentine and Kurani (2007) find that car buyers usually have simple ways of calculating fuel savings that do not involve present discounted value of future fuel costs. Additionally, Gillingham et al. (2021) find that consumers are myopic with regards to future fuel costs. Several studies discussed whether the salience of future operating costs to draw consumers' attention would affect their valuation and decisions. Consumers exhibit present bias and Pigouvian pricing can be suboptimal in internalizing externalities. Heutel (2015) finds that the optimal policy is one that corrects the externality and the present bias. These authors state that in the US automobile industry, the optimal price policy would include a gasoline tax equal to the marginal external damages and a fuel economy tax that would increase the price of non-

hybrid cars by \$550-\$2,200 compared to a hybrid car. Huse and Koptyug (2022) examined whether salience changed consumers' valuation of lifetime fuel costs and vehicle taxes, two components of operating costs. In a structural model with revealed preference data from Swedish used car markets, they found that under-valuation of both costs and taxes was common. However, consumers will correct their valuation once fuel costs and vehicle taxes became salient. Their findings support the use of salience to address inattention and recommend targeting inattentive consumers to enhance the cost-effectiveness of policies.

Allcott and Knittel (2019) provided the experimental evidence on whether providing fuel economy information would cause consumers to buy higher fuel economy vehicles. In two field experiments with new car sales, they did not find significant effects of individually tailored fuel cost information in consumers' consideration sets. While their findings suggested that information provision did not draw consumers' attention, they also discussed the null effects may be related to how interventions were provided (e.g., timing). DellaValle et al. (2019) conducted an online survey-based experiment to determine whether an incentive combined with behavioral nudges led to adoption of electric vehicles by residents. They found that making future cost savings salient for consumers significantly increased adoption only for those who strongly valued future benefits, preferred large vehicles, and self-identified as pro-environmental. The reviewed studies also show that point-of-purchase interventions are important when promoting sales of electric vehicles.

Matthews et al. (2017) in a study conducted in Canada employed "mystery shoppers" to visit auto dealers and observe their sales approaches for electric vehicles. They identified several common barriers to purchasing, including a lack of electric vehicles at dealerships to test drive and waiting periods of three to four months to receive vehicles after ordering them. Their

findings indicate that purchases could be improved by automakers providing consistent supplies, dealerships maintaining adequate stocks, and salespersons projecting positive attitudes about electric vehicles. The authors point to the importance of government agencies to work with dealerships and salespeople to improve adoption of electric vehicles.


CREDIBLE Assessment: *Private Vehicle Choices - Salience*  ★★★

- Cost-effective:* **High.** From the standpoint of behavior change, salience is relatively cost effective since it strictly involves providing information about the cost-saving potential of electric and hybrid vehicles or about the value of choosing fuel-efficient vehicles.
- Replicable:* **High.** Studies on salience have been replicated in multiple settings.
- Evidence-based:* **Yes.** The studies were peer-reviewed and published in reputable journals with robust empirical analyses.
- Durable:* **Yes.** These decisions are generally durable as they are one-time purchases that the consumer uses over a longer time horizon than other consumer products.
- Identity-respecting:* **Yes.**
- Boomerang minimizing:* **Uncertain** There is not enough evidence to know whether salience behavioral interventions have unintended consequences for consumer behavior. The type of information provided would be critical. If information is intended to nudge people toward pro-environmental choices, the risk of overpowering negative unintended consequences should be low.
- Logistically possible:* **Yes.** Information interventions are relatively easy to implement and typically are applied at purchase points.
- Ethical:* **Yes.** Salience behavioral interventions are ethical because they do not present false information; they merely highlight points consumers could miss when making purchase decisions.

3.1.2 Social Preferences and Social Norms

The literature on elective vehicle adoption is growing but is still relatively sparse. We find that descriptive norms are not effective, in large part because the norms at the current time is that relatively few people are driving electric vehicles. Barth et al. (2016) also found that cost of the vehicle was more important to consumers in Germany than their social identities.

Encouraging consumers to buy electric vehicles directly reduces greenhouse gas emissions. Evidence from the studies indicates that virtue signaling is an effective intervention because consumers want to see their choices in cars as “green” rather than as economic (Schubert, 2017). In Griskevicius et al. (2010), nudges related to status led a greater number of consumers to choose green products over more-luxurious traditional products. Sexton and Sexton (2014) similarly uncovered a conspicuous conservation effect they described as the “Prius halo,” estimating mean willingness to pay a premium of as much as \$430 to \$4,200 for a Toyota Prius to signal their greenness. Thaler and Sunstein (2008) showed the persistence of virtue and status effects depends on sufficient visibility to others, such as stickers identifying cars as fuel efficient.

<i>CREDIBLE Assessment:</i>		 ★★★
<hr/>		
<i>Cost-effective:</i>	High. From the standpoint of behavior change, this virtue signaling is costless because it is driven by the consumers’ need to self-identify and promote themselves as pro-environmental.	
<i>Replicable:</i>	High. Encouraging competition in terms of social status has been effective in nudging people to choose green alternatives in various domains.	
<i>Evidence-based:</i>	Yes. The studies were peer-reviewed and published in reputable journals with robust empirical analyses.	
<i>Durable:</i>	Uncertain.	
<i>Identity-respecting:</i>	Yes. Virtue signally generally allows individuals to highlight their own pro-environmental identities without having large impacts on other parts of their identities or identities of others.	

- Boomerang minimizing:* **Yes.** There is not enough evidence to know whether virtue signaling has unintended consequences for consumer behavior. A potential source of boomerang effects is consumers engaging in other polluting behaviors because they chose an environmentally friendly automobile, such as a Prius, and believe that their car choice offsets carbon emissions from their other activities (Schubert, 2017).
- Logistically possible:* **Yes.** Virtue signaling is easy and inexpensive to implement so long as resources are available to make the environmentally friendly choice conspicuous to participants in the studies.
- Ethical:* **Yes.** Virtue signaling does not adversely affect consumers who cannot afford the pro-environmental option yet promotes the green choice to consumers who can afford it.

3.1.3 *Other: Ease of Access and Incorrect Beliefs about Fuel Prices*

The reviewed studies show that the main barriers to purchasing electric vehicles are the high cost to acquire them and their short travel ranges. Also, the electricity needed to power these vehicles must come from renewable sources to present a truly green alternative. Consequently, the environmental performance of electric vehicles is a primary criterion (Degirmenci & Breitner 2017). These results indicate that the feasibility of any new form of transportation will depend on creating incentives and programs that invoke s-framing as described by Loewenstein & Chater (2017) – analyzing choices through a system lens rather than through an individualistic lens.

Hardman (2019) pointed out that adoption of electric vehicles would require incentives beyond financial purchase-points. Non-financial incentives could include access to special lanes for plug-in electric vehicles similar to carpool and bus lanes, parking incentives, increased charging stations, toll waivers, and licensing fee reductions. Purchases of gasoline-fueled vehicles could be discouraged by implementing gasoline and vehicle taxes. However, literature that examines behavioral anomalies about fuel prices find that consumers' downward-biased

beliefs about fuel prices contributes to underinvestment in energy efficient technologies. In the context of automobile purchases consumers are likely to mis-estimate future fuel usage, but there is a need for more research on consumers' predictions of future usage (Gerarden et al., 2017).

Studies on the vehicle fuel economy indicate evidence of bounded rationality. Experiments conducted in this domain show that consumers misperceive fuel economy ratings due to the inverse relationship between gas consumption and miles per gallon aka “the MPG illusion” (Allcott, 2013; Larrick & Soll, 2008). Consumption of fuel efficient vehicles is highest when cost effectiveness of fuel is expressed in terms of cost of gas per 100,000 miles. (Camilleri & Larrick, 2014) and findings have suggested that tailoring the scale of energy labels based on the expected lifetime of the car or energy efficiency metrics could help with decision-making (Ungemach et al., 2018). There is a need for more research on revealed preferences in this domain. The main research challenge here is distinguishing bounded rationality from heuristics in decision-making (Gerarden et al., 2017).

3.2 Use of Public Transportation, Carpooling, and Trip Planning

Consumers can directly reduce their carbon footprints by opting to use public transportation for daily commutes and other long-distance trips. We examine the interventions to encourage desirable behaviors of choosing public transportation, carpool and plan trips more efficiency through discussing behavioral barriers below.

3.2.1 Reference Dependence

A behavioral barrier that prevents individuals from switching to public transportation is habitual behavior around car use (Chen & Chao, 2011). Behavioral change can be facilitated by asking

people to make visible personal commitments and making personalized trip plans. Matthies et al. (2006) found that asking consumers for personal commitments when providing monetary incentives such as free try-out periods motivated them to choose public transportation. Fuji & Taniguchi (2006) in a study conducted in Japan, found that asking consumers to make personalized behavioral plans was an effective nudge. Verplanken et al. (2016) found that respondents in the United Kingdom who were in the midst of transitions to a different home or town were more likely than the other respondents to opt for public transportation. Providing information on the new town’s bus system, personalized travel plans for shopping, and free one-day bus tickets was effective in reducing car usage (Bamberg 2006).

CREDIBLE Assessment: Use of public transportation, carpooling and trip planning - planning and commitments



<i>Cost-effective:</i>	Uncertain. The evidence shows that behavioral interventions eliciting trip plans and commitments to use public transportation were somewhat cost-effective for reducing trips and increasing bus use, factors at the intensive margin. However, creating personalized trip plans is a time intensive activity. The evidence indicates that these prompts are most cost-effective for people who are transitioning from one home or town to another.
<i>Replicable:</i>	Yes. Studies conducted in Europe and Japan have shown that personal commitments are effective, providing evidence that these results are replicable.
<i>Evidence-based:</i>	Yes. The studies were peer-reviewed and published in reputable journals with robust empirical analyses.
<i>Durable:</i>	Unknown. The studies do not provide evidence of the durability of planning and commitment behavioral interventions.
<i>Identity-respecting:</i>	Yes. Generally, these commitments are not coercive and respect an individuals’ constraints regarding accessibility to public transportation infrastructure.
<i>Boomerang minimizing:</i>	Yes. There is little evidence of unintended consequences from interventions promoting personal commitments and planning.

Logistically possible: **Yes.** Few logistical difficulties are associated with promoting trip planning and seeking commitments other than the time required to make plans and reaching people who new to a community.

Ethical: **Yes** In most cases, policies developed on this approach would assume that the commitments are being made voluntarily and therefore ethical.

3.2.2 *Social Preferences and Social Norms*

An important consideration when nudging the use of public transportation and carpools is consumer heterogeneity and linked social identities. For example, a desired behavior could conflict with individual self-interests (Bujold et al., 2022). In the U.S., driving is associated with autonomy, an issue that carpooling fails to address. Kristal et al. (2020) find nudges towards carpooling, which included letters, emails, non-cash incentives and personalized travel plans, yielded null results. These results point to the difficulty of changing commuter behavior. Moreover, both personal identities and cultures are associated with car trips (Seiler, 2012) and age and gender affect willingness to use carpools. Wilkowska (2014) found that older people who preferred the convenience of being picked up by a private car were relatively risk-averse and prioritized the condition of carpool vehicles. Many women avoided carpools because of safety concerns.

Kormos et al. (2014) found that a combination of descriptive norms and requests for personal commitments reduced vehicle use significantly for commutes but not for other kinds of travel. Those results suggest that norms could have stronger impacts on habitual choices. However, Eriksson et al. (2008) and Matthies et al. (2006) found that emphasizing social norms was effective for consumers already intending to reduce their car use. In a study conducted in

Sweden, Horlen et al. (2008) studied a campaign by municipal officials that used the slogan “No ridiculous car trips” and asked residents to submit written accounts of times they had driven unnecessarily and gave small gifts to people who used bicycles for trips.

In a field experiment designed to identify behavioral interventions that could motivate people to use the bus system, Beale and Bonsall (2017) found that descriptive messaging that removed misconceptions about the bus system was effective for women and for people who already used the bus at times. However, it had a rebound effect on men and infrequent bus users. Therefore, they launched another information campaign – this message nudge conceded that cars were convenient for some trips while buses should be preferred alternative for other trips. They found that the men and infrequent bus users increased their use of the bus system with this alternative message.

Several studies addressed the effect of behavioral interventions on trip planning that allows for shorter and/or fewer trips. Root and Schintler (2003) found that gender mattered. Men tended to take direct relatively short trips related to work. Women tended to take trips required for caretaking and used “trip chains” involving several stops. Several studies addressed other fuel-efficiency actions associated with driving, such as ensuring that car tires are properly inflated. Bolderdijk et al. (2013) found that a coupon for a free tire check was more often accepted when it provided a pro-environmental message rather than an economic message. Yeomans and Hereberich (2014) found that combining a social-norm message with an attendant’s offer to check the tires increased the likelihood that drivers would do the checks relative to the message combined with waiving the pump fee.

CREDIBLE Assessment: Use of public transportation, carpooling and trip planning - Social norms and preferences



<i>Cost-effective:</i>	High. The evidence shows that providing social-norm messages is cost-effective.
<i>Replicable:</i>	High. Studies of the effects of social-norm messaging to promote use of public transportation and carpooling have been used conducted in numerous countries.
<i>Evidence-based:</i>	Yes. The studies were peer-reviewed and published in reputable journals with robust empirical analyses.
<i>Durable:</i>	Uncertain. There is some evidence that these interventions are durable, especially when the campaigns are catchy such as “no ridiculous car trips.” However, additional research is needed to see how long this type of behavioral change lasts.
<i>Identity-respecting:</i>	No. The evidence indicates that some interventions to promote carpooling do not recognize cultural identities and autonomy associated with driving personal vehicles in the U.S. and conflict with the personal interests of older individuals and women. Therefore, such interventions to promote carpooling must be designed with respect for these differences.
<i>Boomerang minimizing:</i>	No. Some evidence exists that social-norm messages regarding use of public transportation had the unintended consequence of motivating men to opt out under some framings.
<i>Logistically possible:</i>	Yes. Interventions employing social-norm messaging are logistically possible and feasible.
<i>Ethical:</i>	Yes.

3.3 CREDIBLE Assessment for Transportation

The CREDIBLE assessment (Table 2) compares evidence from the studies related to transportations. Again, this table shows both the areas that are promising for policy development and the areas where the literature is currently missing evidence.

Table 2. CREDIBLE Assessment for Transportation

Core Principles of Behavioral Economics	Behavioral Interventions	Private Vehicle choices	Use of public transportation, carpooling and trip planning
Limited Attention and Cognition	Saliency	 ★★★	
	Planning and Commitments		 ★★★
Social Preferences and Social Norms	Virtue Signaling	 ★★★	
	Social Norm Messaging		 ★★★

Notes: Symbols are provided when the evidence is high or medium in abundance. The absence of a symbol suggests that there is little evidence, or that the existing evidence is generally inclusive.

4 Lower Carbon Footprint Consumption

4.1 Consumption Behavior

Consumer behavior is a key driver of climate change. Around two-thirds of global emissions are linked to private household activities (UN Emissions Gap Report, 2020). Some consumption activities we have already examined in this report include mobility and residential energy consumption. We will now turn to food choices. Shifting consumption to low carbon diets could reduce emissions – for example, moving to a vegetarian diet could reduce emissions by an average of 0.5 tCO₂e per capita per year (UN Emissions Gap Report, 2020). As discussed previously, McFadden et al. (2022) argue that behavioral interventions that have plasticity should be prioritized for policy interventions. Food choice, reducing food waste and recycling behavior

are target behaviors that can have high plasticity. In the following sections, we examine each of these target behaviors of changing food consumption through the behavioral lens of Limited Attention and Cognition, Social Preferences and Social Norms and Present Bias and Reference Dependence.

4.2 Climate Friendly Food Choices

Production of meat generally and beef, in particular, emits large quantities of greenhouse gases because of the energy-intensive nature of raising livestock. Studies of potential behavioral interventions to address this problem from the demand side have mainly explored ways to encourage consumers to eat less meat and more vegetable-based foods. For example, the EAT-Lancet diet commission that was brought together to examine if the future population could be fed a healthy diet given climate change, recommends a diet with little or no red meat while at the same time acknowledging that this diet costs a small fraction of average incomes in high income countries but is not affordable to the world's poor (Willett et al., 2019).

4.2.1 Limited Attention and Cognition

Changing Food Consumption through Choice Architecture

As well established in behavioral economics, consumers tend to exhibit status quo bias in their consumer behavior. They are attached to their habits and routines besides experiencing limited attention while in a shopping environment. Moreover, due to present bias, consumers may not pay sufficient attention to the long-term consequences of their choices. Additionally, another important barrier that people face when it comes to food choices is it involves one's socio-cultural and personal values and is a vital part of social events. There is growing literature on

menu options and the best way to promote vegetarian food choices in a restaurant setting. Some choice architectural aspects that have been examined include changing the order in which vegetarian items appear (Garnett et al., 2019), having more vegetarian options in the menu (Kurz, 2018) and making the meatless option the default (Campbell-Arvai et al., 2014; Campbell-Arvai and Arvai, 2015). Bacon and Krpan (2018) also examined how vegetarian options appeared on the menu. They find that vegetarian dishes when recommended by the chef or tastefully describing them increased their consumption for non-vegetarian eaters. However, these approaches had a boomerang effect on those who were frequent vegetarian eaters. Moreover, Vennard et al. (2018) found that describing vegetarian dishes with associated cuisines and/or good qualities of its ingredients were more favorable than calling them “meat free” or “low fat.” Friis et al. (2017) tested and compared three nudges in promoting vegetarian consumption in a food lab-based experiment. Although the study uses a small sample size, they find that creating intentional designs of food options in buffet-setting impacts the choice of meat.

Eco-labels on consumer products are effective behavioral interventions in making pertinent product information salient without reducing consumers’ choice set. Green defaults that automatically select the pro-environmental choice nudge people towards the green choice but still retain the ability to choose the less environment friendly option. Similarly, making the green choice “salient” through eco-labels allows the individual to make a decision without expending cognitive resources about the decision. Therefore, salient labels work as good informational interventions without cutting down on the choice set.

There is evidence that reframing meat dishes with their carbon dioxide emissions may nudge the consumers to a more plant-based diet. Camilleri et al. (2019) find adding food labels that describe its GHG emissions in “light bulb minutes” purchased 50% fewer high emission

products. For example, by stating that the energy used in the production of a food item is equivalent to 2.127 light bulbs made it easier for consumers to visualize the emissions generated from their food. Adding dietary information about the food choice at the point of purchase has a significant effect on purchasing behavior (Sogari et al., 2019). However, Nisa et al. (2019) find that most of the behavioral interventions in the household sphere are not persistent and may need bundling with financial incentives for the interventions to be effective.

A recent study by McFadden et al. (2022) conducted an incentivized auction involving U.S. consumers to assess the cost of interventions to reduce meat consumption and vehicle use. They found that the median abatement costs exceeded \$600 per ton of carbon dioxide emissions for beef consumption and \$1,300 per ton for vehicle use and thus concluded that promotion of meat alternatives and emission-free vehicles would be a more cost-effective approach than restricting beef consumption and vehicle use.

CREDIBLE Assessment: Climate friendly food choices - Salience, labels, and framing



<i>Cost-effective:</i>	High. The evidence shows that making environmental aspects salient for consumers through labeling and adding informational nudges in labels are cost-effective interventions.
<i>Replicable:</i>	High. Most of the studies were generally replicated and extend the findings of prior studies.
<i>Evidence-based:</i>	Yes. To date the studies so far are narrow in scope and address a small number of consumption behaviors
<i>Durable:</i>	No. Evidence suggests that the behavioral interventions are not likely durable.
<i>Identity-respecting:</i>	Yes. Salience, framing and labels do not directly dispute socio-cultural identities; however, there is not enough evidence to indicate if the behavioral interventions were perceived as identity respecting.
<i>Boomerang minimizing:</i>	No. Evidence exists that some unintended consequences. For instance, consumers who had already chosen to eat more


vegetarian foods and opted to stop when vegetarian items were promoted to meat eaters via salience and labels.

Logistically possible: **Yes.**

Ethical: **Yes.**

4.2.2 *Social Preferences and Social Norms*

Many food choices involve events, traditions, and social activity and what people eat is often determined by social context. Therefore, using social norm messaging in restaurant settings have increased selection of vegetables among participants who were infrequent consumers of vegetables (Higgs et al., 2019). For instance, the use of dynamic norms that highlight the trend towards less meat consumption and feeling more connected to those who change the norm has been effective in getting more people to adopt meatless choices (Sparkman & Walton, 2017; Sparkman et al., 2020).

<i>CREDBLE Assessment:</i>	<i>Climate friendly food choices - Social norm messaging</i>	 ★☆☆
<i>Cost-effective:</i>	High. Highlighting existing social norms are cost effective interventions and can be implemented with relative ease through restaurant menus and online ordering portals.	
<i>Replicable:</i>	High. Interventions have been tested and replicated through several experiments.	
<i>Evidence-based:</i>	Uncertain. The small number of studies were peer-reviewed and published in reputable journals with robust empirical analyses. However, there is a need for more evidence in this field.	
<i>Durable:</i>	Uncertain. The studies provide no clear measures of durability.	
<i>Identity -respecting:</i>	Uncertain. The studies show that identity-respect depends on the types of social-norm messages used. People who lack access to nourishing protein and/or consider meat consumption as part of their socio-cultural identities could view these kinds of messages as alienating.	

Boomerang minimizing: **No.** In fact, the static descriptive norms used in these studies regarding eating less meat can lead to a boomerang effect.

Logistically possible: **Yes.**

Ethical: **Yes.**

4.3 Recycling and Waste Management

Waste prevention and recycling jointly contribute to reducing solid waste. Reducing waste and using recycled items is instrumental in reduction of GHG emissions through various channels. Using recycle materials in the production process means overall less energy use as products made from recycled materials take up less energy. Waste prevention also limits GHG emissions by sending less items to the incinerator. Additionally, composting items and recycling them prevents them from going to the landfill and reduces methane emissions. The EPA found more than 40% of GHG emissions result from production, transportation, and disposal of material goods (EPA, 2022). In our analysis below, we will focus waste management interventions from the household and consumption perspective and examine the behavioral implications of limited attention and cognition, social preferences, and social norms.

4.3.1 Limited Attention and Cognition

Choice architecture plays an important role in targeting desirable waste management practices and moving people away from less desirable behavior that they do out of habit. Qi and Roe (2017) studied the effect of message framing on reducing food waste in an experiment conducted in a dining hall. The study showed that individuals who received information about food waste and composting discarded far less food than individuals who received neutral information on financial. Interestingly, individuals who got information on food waste and were told that their waste would be composted wasted more than individuals who knew their waste would go to a


landfill. These results indicate that composting was not as effective as providing information about food waste and information that waste was going to a landfill.

Growing concerns about the high revenue spent on clean up, recycling and landfilling of disposable carry-out bags lawmakers across the U.S. are changing how consumers get their food. Policies to reduce single use plastic products are multiple. One such policy intervention is adding strictly banning the use of single use products. The effect of bans has several unintended consequences. There is ample critique in the literature that indicate that narrow bans, such as Starbucks banning distribution of plastic straws at its stores (Rochman, 2018), results in unintended consequences, especially when undesirable substitutes of the banned product remain unregulated. Starbucks introduced a straw-less “cold cup” lid that added more plastic to the environment than the original lid and straw combined. Taylor (2019) found that outright bans on plastic in California resulted in an increase trash bag purchase offsetting the resulting 40-million-pound reduction in the use of plastic carry out bags by a 12-million-pound increase in the purchase of plastic trash bags.

An alternative policy instrument to the outright ban is the use of a symbolic price charge for using plastic bags. Such prices are small and meant to be implemented as a nudge to make people think about their decision in a non-coercive manner. However, the internal validity of such behavioral interventions has been debated in the academic literature (⚠️). Rivers et al. (2017) find that Toronto’s plastic bag tax in fact has heterogeneous implications for different population subgroups. The tax was successful among those who already used reusable bags and households with high socio-economic status. The tax has no impact on infrequent users of reusable bags and people with lower socio-economic status. Another area of emerging concern is the how this policy induced behavioral intervention impacts consumers’ time and effort

allocation in a shopping environment. Local government regulation around disposable carry-out bags impact the wait and processing time of checkout services provided by the supermarkets. This seemingly low-cost behavioral intervention may have large non-monetary costs in terms of time and convenience (Taylor, 2020). Annoyance cost of a nudge intervention shows that not accounting for time costs overstates the welfare effects by a factor of ten (Damgaard and Gravert, 2018).

A common pro-environmental intervention for climate change is adoption of reusable grocery bags and reusing plastic bottles. These single-use plastics end up in landfills, which are the third largest source of methane emissions after transportation and electric power sectors (Environmental Protection Agency EPA, 2021). Therefore, considerable effort has also gone into making recycling convenient. For instance, Ando and Gosselin (2005) identified a strong connection between convenience and recycling in multi-family dwellings, and Jenkins et al. (2003) found that access to curbside recycling improved rates. Making recycling mandatory, however, has not had a significant effect. Berck et al. (2020) investigated deposit refunds in California and found that consumers preferred recycling centers that were nearby and had flexible hours and short wait times. The refund of deposits induced recycling but increasing the refund value did not increase the amount of waste recycled.

<i>CREDIBLE Assessment:</i>	<i>Recycling and Waste Management - Choice Architecture</i>	 ★★★☆☆
<i>Cost-effective:</i>	Medium. As mentioned in our discussion above, time costs are a significant factor in recycling and waste management efforts.	
<i>Replicable:</i>	Medium. Most of the studies are have been replicated and extend the findings of prior studies.	
<i>Evidence-based:</i>	Yes. There is a broad evidence base on waste management interventions that have been successful.	

<i>Durable:</i>	Uncertain. there is no clear evidence that behavioral interventions are make long lasting changes on waste management behavior.
<i>Identity-respecting:</i>	Yes. The behavioral economics interventions do not impinge on anybody's identity and only provide easy access waste management options.
<i>Boomerang minimizing:</i>	No. The studies provide evidence of some unintended consequences of specific message framing.
<i>Logistically possible:</i>	Yes.
<i>Ethical:</i>	Yes.

4.3.2 *Social Preferences and Social Norms*

Recycling and waste management are socially visible behaviors and thus can potentially be influenced by pro-social behavioral interventions. Literature on food waste provides evidence that social-norm interventions can reduce food waste. Kallbekken et al. (2013) conducted a field experiment in a hotel in California and found that reducing portion sizes and adding a social cue asking guests to visit the buffet again for second helpings reduced food waste significantly. Descriptive norms that inform consumers what their peers are doing have been used widely as a behavioral intervention. These norms have been studied extensively in the context of littering and recycling (Cialdini et al., 1990; Schultz 1999). Towel reuse by hotel guests is another much cited case study where descriptive norms have been successful. Goldstein et al. (2008) showed that placing a note in the bathroom of a hotel indicating that 75% of the fellow guests reuse their towels led to more hotel guests choosing to reuse their towels during their stay. However, this study involved some deception, and, moreover, results from this study were not replicable when Bohner and Schlüter (2014) repeated it in two German hotels. Descriptive norms especially when used to prompt individuals to consume less water reported a boomerang effect as people now know that it is the norm to behave non-environmentally and therefore continue maintaining the

status quo (Schubert, 2017). The authors find no evidence of boomerang effect. However, they do find that the impact of the intervention did not persist over time. They suggest that norm-based messages should be targeted to the most responsive groups of the population to make the intervention cost effective.

Social context matters when it comes to visible waste management behaviors. Videras et al. (2012) studied behavior regarding household carbon footprint management in networks in which the ego is connected to a heterogeneous group of alters – co-workers, neighbors, and family members. The networks vary in terms of number of ties and intensity of relationships. The findings of the study identified education, high incomes, and household size as important factors driving pro-environmental behavior. Moreover, self-image relative to one’s network peers is an important consideration. The results of a study by Kurz et al. (2007) indicated that social context significantly impacts recycling rates and attitudes.

Using household longitudinal panel data, Binder and Blanckenberg (2016) investigated how strong self-image was as a motivator for actual pro-environmental actions and found that a “green self-image” increased pro-environmental behaviors but did not eliminate environmentally damaging behaviors. Some studies also find behavioral spillovers resulting from waste management behavioral interventions. Alacevich et al. (2021) identified a behavioral spillover effect where sorting household’s organic waste led to waste reduction overall but found that the effect did not persist.



CREDIBLE Assessment: Recycling and Waste Management - Social Norms Messaging

Cost-effective: High. Social norm messages usually are low-cost interventions.

Replicable: **Medium.** Several studies have failed to arrive at the same results when replicated.

Evidence-based: **Yes.** There is a large body of peer-reviewed evidence on behavioral interventions in this domain.

Durable: **No.** Based on the studies that have reported durability the consensus is that these behavioral interventions are not generally durable.

Identity-respecting: **Yes.**

Boomerang minimizing: **No.** There is evidence that points to boomerang effects present in the studies reviewed



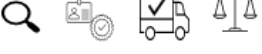





Logistically possible: **Yes.**

Ethical: **Yes.**

4.4 CREDIBLE Evidence for Lower Carbon Footprint Consumption

The CREDIBLE table (Table 3) compares evidence from the studies related to the reduction of consumption and consumer selection of climate-smart alternatives.

Table 3. CREDIBLE Assessment for Lower Carbon Footprint Consumption

Core Principles of Behavioral Economics	Behavioral Interventions	Climate Friendly Food Choices	Recycling and Waste Management
Limited Attention and Cognition	Saliency, Labels and Framing	  ★★★	  ★★★☆
Social Preferences and Social Norms	Social Norm Messaging	  ★☆☆	  ★★★

Notes: Symbols are provided when the evidence is high or medium in abundance. The absence of a symbol suggests that there is little evidence, or that the existing evidence is generally inclusive.

5. Land Use

Climate change poses a severe threat to agriculture. Agricultural productivity is affected by variability in weather, rising temperatures, flooding and other natural disasters, and invasive pests. At the same time, agriculture is a major contributor of greenhouse gas emissions – 19-20% of total emissions worldwide (World Bank, 2021). In 2021, the U.S. Department of Agriculture issued a Climate Adaptation Resilience Plan that prioritized: (1) implementing climate-smart production practices, (2) measuring and monitoring associated greenhouse gas benefits, and (3) developing markets that promote climate-smart commodities. Thus, there is a need to mitigate emissions from both production (supply) and consumption (demand) side. The U.S. Department of Agriculture currently spends \$6 billion annually on conservation programs that offer voluntary payments for ecosystem services to offset costs of adopting best practices (Palm-Forster & Messer, 2021). We selected studies of behavioral interventions designed to promote climate-smart practices in agricultural production.

5.1 Adoption of Climate-smart Agricultural Practices

Given limits on funding for agri-environmental programs (Duke et al., 2013; Messer and Allen, 2018), numerous studies have applied behavioral interventions in economic experiments in efforts to improve program designs and cost-effectiveness (Higgins et al., 2017). Dessart et al. (2019) examined voluntary adoption of conservation practices and developed a framework that affected producer decision-making and found an individual's disposition (personality, values, beliefs, and preferences), views of social norms, signaling motives, and perceptions of benefits, costs, and risks all affected their behavior. Streletskaia et al. (2020) identified three areas that could benefit from behavioral economic insights: responses to risk, deviations from expected

utility, and modeling of learning, social, and time preferences. Palm-Forster et al. (2019) examined studies of land use using Dolan et al.'s (2012) MINDSPACE framework, analyzing how each behavioral intervention used in the studies could be applied in the agri-environmental domain and areas in need of additional research.

Incorporation of non-expected utility models into the environmental economics literature has been relatively slow (see Shaw and Woodward 2007). One example is Ranjan and Shogren (2006), who construct a behavioral model to explain the sluggish development of water markets. Farmers have been reluctant to participate in water markets because they fear that their participation today will lead to a loss of water rights to urban users tomorrow. A farmer assigns greater weight to low probabilities of future water rights loss and lower weights to high probabilities. Their results suggest that subjective weighting of probabilities leads to discounting of resources when farmers overestimate probabilities of loss. When farmers have idiosyncratic time preferences, total water supply in the market depends on the level of heterogeneity in the population.

5.1.1 Limited Attention and Cognition

Agri-environmental programs have been plagued by low adoption rates because of complexity associated with completing paperwork and navigating the enrollment requirements of federal programs. Making programs salient and simple is key. Ferraro et al. (2022) found that changing default enrollment increased farmers' investments in the programs. Higgins et al. (2017) found that even simple behavioral interventions that sent reminders to farmers to enroll were effective. Wallander et al. (2017) conducted a large-scale field experiment testing behavioral nudges in the U.S. Department of Agriculture's Conservation Reserve Program in the form of three types of

reminder letters on producer offers. They found that reminder letters were effective only for well-informed groups and for farmers whose contracts were expiring, highlighting the potential value of nudges to reduce inattention.

Producers also fail to adopt sustainable practices because they perceive them as novel and potentially high risk. Dessart et al. (2019), McCann & Classen (2016), and Palm-Forster et al. (2016) found that risk aversion could be addressed by extension agents launching campaigns to provide information that is simple, readily understandable, and relatable. Dessart et al. (2019) also found that outreach efforts should highlight program benefits rather than costs.

Banerjee (2022) studied the effects of framing of climate change and found a lack of consensus on the existence, definition, and effects of climate change. Davidson et al. (2019) conducted a survey of beliefs about climate change and the adoption of mitigation practices of beef and grain producers in Canada, and found that producers rarely adopted mitigation practices because they were perceived as minimally beneficial and costly. Their main motivations for adoption were economic benefits and improvements in soil quality and biodiversity. The strongest predictor of adoption was having learning orientations that valued improvement, research, learning, and innovation.

CREDIBLE Assessment: Adoption of climate-smart agricultural practices - Defaults, framing, and salience



<i>Cost-effective:</i>	High. These behavioral interventions are low cost and could have a high impact when successful.
<i>Replicable:</i>	Low. Generally, the existing studies in this domain do not have published studies that sought to replicate the results.
<i>Evidence-based:</i>	Yes. The studies were peer-reviewed and published in reputable journals with robust empirical analyses.
<i>Durable:</i>	Unknown. None of the studies clearly measured durability.

<i>Identity -respecting:</i>	Yes. These behavioral interventions were tailored using evidence gathered in the field.
<i>Boomerang minimizing:</i>	Yes.
<i>Logistically possible:</i>	Uncertain. Changing a default requires changes in the system at the policy level and requires a lot of paperwork for the changes to be approved.
<i>Ethical:</i>	Yes.

5.1.2 Social Preferences and Norms

Numerous studies have found that messaging related to social norms and preferences has been instrumental in encouraging producers to adopt climate-smart practices (Butler et al., 2020; Banerjee, 2018; Wallander et al., 2017; Wu et al., 2021). Palm-Forster et al. (2022) showed through ego behavioral interventions contained in road signs identifying participation in conservation programs were effective in motivating producers to follow through with practices they agreed to adopt because producers viewed their decisions as consistent with their self-images and identities. Czap et al. (2019), Czap et al. (2015), and Lynne et al. (2016) found evidence that empathy nudges are effective in promoting pro-environmental decisions.

Several studies examined the effects of social-norm behavioral interventions. Kuhfuss et al. (2016) and Wu et al. (2021) found that, in programs in which participation was already high, producers responded to nudges informing them about other farmers who had already adopted climate-smart practices. However, Le Coent et al. (2021) showed that social-norm strategies could backfire when only a small number of farmers have already adopted desired practices. Their study further showed that combining injunctive norms with descriptive norms increased retention in the climate-smart program through the contract terms. Wu et al. (2021) found that the messenger who delivers an injunctive norm matters. Producers were more likely to act when

they received positive information from individuals they viewed as similar to themselves. Bujold et al. (2021), Kwayu et al. (2014), and Wossen et al. (2013) studied the effects of social “proof” that adopters’ new practices had been successful and found such proof to be particularly effective when it came from a producer’s social network. Dessart et al. (2019) and Palm-Forster et al. (2022) found that social networks could be used to send credible signals about pro-environmental stewardship actions producers were taking (e.g., certification and verification programs). Rommel et al. (2022), using linear public-good games involving producers in Germany, examined their willingness to cooperate in response to four behavioral interventions: (1) heterogeneous endowments, (2) leading by example, (3) social norms, and (4) promoting socially optimal solutions. They found that the behavioral intervention promoting the socially optimal solutions was the most effective.



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CREDIBLE Assessment: Adoption of climate-smart agricultural practices - Social norms

<i>Cost-effective:</i>	High. Behavioral interventions based on social norms are relatively inexpensive.
<i>Replicable:</i>	Low. The existing published studies were conducted with students and small samples of farmers. Studies with larger sample sizes in the field are needed.
<i>Evidence-based:</i>	Yes. The studies were peer-reviewed and published in reputable journals with robust empirical analyses.
<i>Durable:</i>	Uncertain. Evidence of the persistence of these interventions is lacking.
<i>Identity-respecting:</i>	Uncertain Social norms are formed from the majority of opinions and therefore may not include minorities and their opinions.
<i>Boomerang minimizing:</i>	No. Some studies have shown that social-norm messages can highlight that a small group of people are following the desirable behavior thereby, leading people to choose the non-desirable behavior because norm message highlighted the lack of adoption of a practice.

Logistically possible: **Yes.** These types of interventions are logistically possible, but it can be difficult to recruit agricultural producers for behavioral studies.

Ethical: **Yes.**

5.1.3 Present Bias and Reference Dependence

Studies have found that farmers are strongly loss-averse (Bockqueho et al., 2014) and tend, therefore, to be risk-averse, which can limit their willingness to adopt new climate-smart practices. Palm-Forster and Messer (2021) conjecture that reducing potential risk and income volatility could motivate producers to try new practices and thereby increase adoption of new conservation practices through trial and error. Duquette et al. (2012) examined how producers weigh short-term and long-term costs when adopting conservation technologies and found distinct differences in weighting of discount rates for early and late adopters. Early adopters put much less weight on the discount rate than late adopters, suggesting the timing of payments and payments made upfront influence adoption. Pannell et al. (2006) showed that providing insurance options and cost-free trial periods were effective.



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CREDIBLE Assessment: ***Adoption of climate-smart agricultural practices - Interventions accounting for discounting behavior***

Cost-effective: **Low.** The evidence shows that studies that elicit farmer’s temporal preferences require large stakes and payments, which can make studies of these interventions a costly endeavor particularly for field experiments.

Replicable: **Low.** There are few studies in this area and they generally have not been replicated.

Evidence-based: **Yes.** The studies were peer-reviewed and published in reputable journals with robust empirical analyses.

Durable: **Uncertain.** There is not enough evidence to evaluate the persistence interventions that employ discounting behavioral interventions.

Identity-respecting: **Yes.** Behavioral interventions associated with discounting take different types of farmers and adoption behaviors into account.

Boomerang minimizing: **Yes.**




Logistically possible: **Yes.**

Ethical: **Yes.**

5.2 CREDIBLE Evidence for Land Use

The CREDIBLE table (Table 4) compares evidence from the studies related to land use.

Table 4. CREDIBLE Assessment for Land Use

Core Principles of Behavioral Economics	Behavioral Interventions	Adoption of climate-smart agricultural practices
Limited Attention and Cognition	Defaults, Framing and Salience	
Social Preferences and Social Norms	Social Norm Messaging	
Present Bias and Reference Dependence	Eliciting Discounting Preferences	

Notes: Symbols are provided when the evidence is high or medium in abundance. The absence of a symbol suggests that there is little evidence, or that the existing evidence is generally inclusive.

6 Conclusion

Climate change is fundamentally a human behavior problem. Mitigating and adapting to climate change requires adjustment to human behavior, where the impacts are long-lasting. Well-designed, evidence-based policies can facilitate this transition to more sustainable behaviors. A burgeoning literature has addressed ways in which policymakers can tap into insights derived from behavioral economics and other behavioral sciences to overcome these challenges. This report summarizes the insights from behavioral economics studies related to climate change behavior and evaluates the evidence according to the CREDIBLE criteria (*Cost-effective, Replicable, Evidence-based, Durable, Identity-respecting, Boomerang Minimizing, Logistically Feasible, and Ethical*), an acronym we developed to represent eight important factors to consider when determining whether scientific evidence is adequate to use to recommend policies and programs.

This report summarizes the key findings in a series of write-ups and corresponding tables in which we report on the studies in terms of five core principles of behavioral economics: (1) *limited attention and cognition*, (2) *present bias*, (3) *reference dependence*, (4) *social preferences and social norms*, and (5) *incorrect beliefs*. These core principals are then applied to four key policy areas related to climate change: (1) *energy use and efficiency*; (2) *transportation*; (3) *consumption, reduction, recycling, and reuse*; and (4) *land use decisions*.

The bad news is that significantly more research is needed in many dimensions. The good news is that CREDIBLE areas exist that would be good places to develop policies and programs. In particular, policies should be designed to overcome limited attention and cognition as that seems to be a common challenge across acres. Information provision can generally be used to increase salience to address limited attention. Additionally, social norms and comparisons can be

cost-effectively used to encourage pro-environmental behavior. The effects are not always large, but they tend to be cost-effective. Finally, policy makers are encouraged to consider ethical implications and whether these policies are identity-respecting for various groups of the population, especially those that have been historically disadvantaged or are disproportionately impacted by climate change.

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