The Critical Role of Second-Order Normative Beliefs in Predicting Energy Conservation

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Sustaining large-scale public goods requires individuals to make environmentally friendly decisions today to benefit future generations[1–6]. Recent research suggests that second-order normative beliefs are more powerful predictors of behavior than first-order personal beliefs[7,8]. We explored the role second-order normative beliefs—the belief that community members believe saving energy helps the environment—play in curbing energy use. We first analyzed a dataset of 211 independent, randomized controlled trials conducted in 27 U.S. states by Opower, a company that uses comparative information about energy consumption to reduce household energy usage (pooled *N*=16,198,595). Building off the finding that the energy savings varied between 0.81% and 2.55% across states, we matched this energy use data with a survey we conducted of over 2,000 individuals in those same states on their first-order personal and second-order normative beliefs. We found that second-order normative beliefs predicted energy savings but first-order personal beliefs did not. A subsequent pre-registered experiment provides causal evidence for the role of second-order normative beliefs in predicting energy conservation above first-order personal beliefs. Our results suggest that second-order normative beliefs play a critical role in promoting energy conservation and have important implications for policy-makers concerned with curbing the detrimental consequences of climate change.

Although new technologies that may help limit the effects of climate change are becoming increasingly widespread and affordable, behavioral and interpersonal barriers continue to hinder the adoption of sustainable behavior. To design policies needed to address climate change and other environmental and social public goods, researchers need to more closely understand the factors influencing conservation behavior and how interventions can best make use of these factors. Currently, interventions often target an individual's first-order personal beliefs, i.e., one's

understanding of oneself and one's world[9]. Many people in the United States continue to believe that climate change is not a real threat or a human-induced problem[10] and one might expect that targeting these beliefs will lead to attitude and behavioral changes that may help reduce the impact of climate change.

However, such information-centered approaches are both expensive and surprisingly ineffective in influencing conservation behavior[11]. Research has found that first-order personal beliefs are often resistant to change, especially deeply held views such as environmental beliefs[9,12]. For example, one study found that providing car drivers with information about savings from reduced car usage, or information on environmental harm, or both, had virtually no effect on their driving behavior and instead lead to psychological commitment to their initial personal belief[11]. Attempting to change an individual's first-order personal beliefs and behaviors, especially if they are central to an individual's self-view, has proven to be challenging[13]. Subsidies for energy-efficient goods, as well as educational campaigns that aim to provide accurate information on climate change and recognize it as a threat to human society, are also expensive and have had fairly limited success[14,15].

Instead, recent research has found that better predictors of behavior than first-order personal beliefs are second-order normative beliefs, i.e., perceptions about what is commonly believed[7,8]. For example, decades of research in cultural psychology has assumed that cross-cultural differences in behavior are driven by differences in personal values. But recent studies have found that second-order normative beliefs are better predictors of culturally consistent behavior[16]. One study found that Chinese participants who believe that most of their fellow citizens hold collectivistic values acted in a more culturally consistent way[17]. Similarly, blame judgments by Americans and Koreans were more culturally consistent to the extent that individuals believed

that other citizens held culturally consistent beliefs[18]. Across both studies, second-order normative beliefs predicted how people behaved and judged others, over and above culturally relevant first-order personal beliefs.

Early work in prejudice reduction also theorized that interventions were effective to the extent that they changed people's first-order personal beliefs[19,20]. However, research has found that interventions designed to decrease prejudice and bullying are successful mainly due to their influence on second-order normative beliefs, rather than first-order personal beliefs. For example, a large-scale field experiment in Rwanda found that when a radio soap opera featured prejudice-reduction messages, intergroup prejudice decreased through listeners' perceptions of second-order normative beliefs; conversely, these messages had little impact on people's first-order personal beliefs. Overall, the radio program, which ran over the course of a year and repeatedly exposed groups of listeners to prejudice-reducing messages, influenced listeners' beliefs of the collective norm, which then shifted their behaviors in the direction of that norm[21,22]. Similarly, changing a peer group's public reaction towards bullying alters student's harassment behavior by altering perceptions of collective norms[23]. Several lines of research thus converge to show that second-order normative beliefs are a powerful predictor of behavior.

We explore the importance of second-order normative beliefs in predicting energy conservation behavior beyond first-order personal beliefs in the context of descriptive norm information. In recent years, a wide variety of studies have shown that people change their behavior in response to receiving information about the descriptive norm, i.e., what the majority of people in one's community are doing. From increasing honest tax reporting[24], reducing alcohol abuse[25,26], to reducing energy consumption[27,28], there is little doubt empirically that the provision

of descriptive norm information is an effective means to initiate behavior change, but various theories have been proposed to why that is the case.

One popular account[7,8] suggests that descriptive norms provide previously unknown information and by doing so shape an individual's views of what is the right thing to do: the reasoning goes that if everyone is doing it, then it must be a sensible thing to do. However, if this were the case, then the behavioral change produced by the provision of descriptive norm information should be relatively similar across different areas. A number of studies do not provide evidence for this conclusion, finding that descriptive norm interventions do not affect all individuals equally[24–30].

Take the large set of randomized controlled trials (RCTs) carried out by Opower, a firm that is contracted by utility companies to help meet energy conservation requirements. Over the last few years, Opower has systematically provided descriptive norm information across the United States and tested its effects on energy conservation behavior. We analyzed a dataset we obtained of 211 RCTs using descriptive norm interventions across the 27 states in which Opower operates and find that the effectiveness of norm information varies between 0.81% reduction in some RCTs and 2.55% in others—a relative difference of about 300% between states. While the provision of descriptive norm information has successfully reduced energy consumption overall, there is remarkable variation between RCTs. This makes it highly unlikely that descriptive norm information consistently and solely changes individuals' views of what is the right thing to do.

We therefore propose an alternative account: Instead of descriptive norms creating behavior change by altering first-order personal beliefs, as has been previously suggested[7,8], we hypothesize that descriptive norm information combines with second-order normative beliefs to influence behavior. Thus, to understand how descriptive norm information influences behavior, it

is necessary to consider an individual's second-order normative beliefs. We propose that descriptive norm information predicts energy conservation behavior when an individual holds a second-order normative belief that is consistent with the descriptive norm information. That is, we argue that people follow descriptive norm information more when they believe other people in their community support that norm. This is in part the case because, as early as childhood[31], individuals adapt to and internalize norms to avoid violating them because norm violations can be costly: offenders may be punished, avoided, ostracized, shamed, or directly attacked by their community for violating the norm[32–36]. Additionally, not sharing normative views with others hinders one's ability to form close relationships with them[37]. Conversely, those who comply with a norm are rewarded for their efforts by being valued highly by their community[33,38].

To test these predictions, we first analyzed a large set of RCT results carried out by Opower. After establishing the predictive effect of second-order normative beliefs on energy conservation, we subsequently conducted an experimental study that manipulated second-order normative beliefs to provide causal evidence.

As previously mentioned, the provision of descriptive norm information showed wide variation in effectiveness across the RCTs within the 27 states in which Opower operates. We applied our theoretical framework to clarify the roles of first-order personal and second-order normative beliefs in explaining the impact of descriptive norm interventions. We predicted that an individual's likelihood to change their behavior—and thus, save energy—depends on both exposure to descriptive norm information (i.e., the Opower treatment assignment) and an individual's second-order normative beliefs (i.e., whether an individual believes their neighbors or community care about energy conservation). More precisely, we predicted that second-order

normative beliefs would predict energy conservation behavior over and above first-order personal beliefs.

In our first study, we tested the relationship between first-order personal and second-order normative beliefs on behavior change following descriptive norm interventions by combining two large datasets. The first dataset is comprised of 211 large-scale RCTs from Opower. This dataset includes energy consumption rates at the RCT-level from 16,198,595 households over 7 years across 27 states. Households in these energy savings trials were randomly assigned to either a control or treatment condition. In the treatment condition, households received regular descriptive norm information about their neighbors' energy consumption. In addition to the descriptive norm information, participants in the Opower trials also received prescriptive norm information regarding their current energy conservation (e.g., "GOOD" and a smiley face in Figure 1 below). This additional information was introduced to ensure that participants who were already conserving more energy than their neighbors would not change their behavior to consume more energy, as earlier studies have found[28]. In contrast, households in the control condition received no additional communications and were treated no differently than they would have been otherwise (for a more detailed explanation, see [27,30,39]). The dataset that is the focus of the current investigation represents an expanded version of a prior set of Opower data which contained 111 RCTs involving 8.6 million households[39].

All Opower RCTs include a core program element, a so-called "Home Energy Report" (see Figure 1) that graphically illustrates the focal household's energy usage and the average energy usage of similar, nearby households over the same time period. While small variations in the layout of the energy reports exist, the fundamental aspects of these trials are identical (i.e., a series of

comparable "procedural field experiments" [40]). It is therefore highly unlikely that the variability of the outcome across RCTs can be explained by small differences in experimental design.

Figure 1 about here

Figure 1. An example of an Opower Home Energy Report. Customers in the treatment condition receive a bi-monthly (or less frequent) mailing that compares their energy usage with that of similar, nearby households. These descriptive norm messages have been shown to be effective in influencing people to conserve energy, but the effectiveness of descriptive norm varies across U.S. states.

The most likely source for the variation is where in the United States the trial was conducted. Indeed, we find that the effectiveness of the provision of descriptive norm information in achieving energy savings varies on a state-by-state basis (M=1.59%, SD=.50%, min=.81%, max=2.55%), which we take as a starting point for our investigation.

The dependent variable in our research is the standardized average monthly rate of energy conservation by RCT trial in each state during Opower's trial period. The energy savings rate is defined as the percentage of energy saved in the treatment group relative to the control group usage by RCT trial. The energy savings data arises from real behavioral changes in household behavior as measured by utility companies.

The second dataset comes from a sample of survey respondents (N=2,001) from the same 27 states. The questionnaire answered by these respondents measured both first-order personal and second-order normative beliefs. Participants were asked whether they themselves believe that energy conservation helps save the environment (first-order personal beliefs) and whether they believe the majority of their neighbors believe saving energy helps save the environment (second-order normative beliefs). Both questions were scored on a 7-point scale ranging from 1 (not at all) to 7 (very much). We aggregated individual level responses from the survey to the state level, as

this was the level at which we could match to the Opower RCT data, which (in line with ref. 39) were aggregated on the RCT-level within a state and used as the unit of analysis. Unless otherwise noted, we cluster robust standard errors at the state level (for methodological details, see the Supplementary Information, SI).

In the regressions presented below, we control for several variables previously associated with the Opower treatment effect. For example, treatment effects vary considerably by how long the trial has been running[39]. We therefore followed the regression strategy outlined in ref. 39, controlling for program duration. Consistent with past work, we weighted observations by the inverse variance of the cohort size. We also controlled for the average household energy usage in the state, population density, and survey respondents' demographics. Finally, we use standardized z-scores of both the independent and dependent variables for the analysis because our variables have different magnitudes and units; however, not standardizing these variables does not alter the significance or interpretation of our results[41] (for more details on the analytical strategy, see SI).

We hypothesized that second-order normative beliefs would predict the effectiveness of descriptive norm information on the energy savings rate over and above first-order personal beliefs. This is exactly what we found: second-order normative beliefs predicted energy savings rates (*coeff*=.755, *SE*=.323, *p*=.030; Model 1 in Table 1). In contrast, first-order personal beliefs did not predict energy savings rates (*coeff*=.209, *SE*=.324, *p*=.527; Model 2 in Table 1). These results hold when entering both predictors simultaneously: second-order normative beliefs predicted energy savings rates (*coeff*=1.138, *SE*=.446, *p*=.020), while first-order personal beliefs did not (*coeff*=-.696, *SE*=.478, *p*=.162; see Model 3 in Table 1). In addition, because first-order personal beliefs and second-order normative beliefs are moderately correlated ($r_{Pearson}$=.58, $r_{Spearman}$=.62, *p*<.001), we tested for multicollinearity, and the variance inflation factor remained

within acceptable standards[42] (i.e. below 10). Furthermore, the results were robust to the inclusion of control variables (Model 5 in Table 1) and were similar when analyzing RCTs from states with at least 50 survey respondents (N=195) as well as when we included every RCT (Model 6 in Table 1). Figure 2 provides a graphical illustration of Models 3 (main sample without covariates), 5 (main sample with covariates), and 6 (full sample with covariates).

Figure 2 about here

Figure 2. Second-order normative beliefs predict energy savings in 211 large-scale energy savings RCTs (pooled N = 16,198,595. The effect of second-order normative beliefs is plotted for a regression model with standardized coefficients based on the main sample (i.e., states that had at least 50 survey respondents) without and with covariates, as well as for a regression model with all states. Regardless of survey response rate, and covariates, second-order normative beliefs significantly predicted savings rate in all model specifications, while first-order personal beliefs did not. For each estimate, the outer (thin) error bar represents the 99% confidence interval, the middle error bar the 95%, and the inner (thick) error bar the 90% confidence intervals.

Table 1. Second-order normative beliefs predicted energy savings in 211 large-scale energy savings RCTs (pooled *N* = 16,198,595), whereas first-order personal beliefs did not. Model 1 shows that second-order normative beliefs predicted energy savings rates, while Model 2 shows that first-order personal beliefs did not predict energy savings rates. Model 3 lists the control variables derived from past research on Opower trials. When control variables are added to the main model in Model 4, the effect of second-order normative beliefs remains statistically significant. The main sample of states with at least 50 respondents is used in Models 1–5. All states regardless of sample size are included in Model 6. All variables are standardized (z-scores). Observations are weighted using cohort size by inverse variance. Robust standard errors are clustered at the state-level.

VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Second-Order Normative Beliefs	.755*		1.138*		1.030*	1.082***
	(.323)		(.446)		(.385)	(.281)
First-Order Personal Beliefs		.209	-.696		.006	-.341
		(.324)	(.478)		(.629)	(.499)
Control group daily energy usage				.030	.072	.080
				(.071)	(.066)	(.069)
Program start date				-.370***	-.341***	-.339***
				(.050)	(.052)	(.051)
State population density				-.075	-.154*	-.124*
				(.071)	(.074)	(.061)
Average age of respondents in state				-.084	.298	.232
				(.277)	(.272)	(.256)
% female respondents in state				-.702	-.588	-.595
				(.462)	(.531)	(.433)
Constant	-.240**	-.214*	-.237**	-.147*	-.173**	-.165**
	(.072)	(.081)	(.072)	(.063)	(.056)	(.057)
Observations	195	195	195	195	195	211
R-squared	.031	.002	.041	.250	.283	.264

Note. *** $p < .001$, ** $p < .01$, * $p < .05$, $^{+}$ $p < .1$

In the SI, we report further robustness checks using alternative sampling weights to control for survey uptake in each state, restricting our analysis only to trials without imputed averages for missing variables, including survey respondents who did not pass the attention quiz, and using the amount of energy saved as the outcome variable; results are qualitatively similar across all specifications. In our supplemental analyses, we rule out, for example, that our effects are driven

by differential sample select biases across states. To do so, we use inverse-variance weights based on representative gender and age demographics in each state from the 2010 U.S. Census, and replicate our findings (see Tables S1–S5, and SI for more information).

In sum, the results from our analysis of the Opower data show that second-order normative beliefs, but not first-order personal beliefs, are associated with an increased energy savings rate following the provision of the energy comparison information. This data provides correlational support into the relationship between second-order normative beliefs and energy conservation behavior. Next, we conducted an experimental study to provide causal evidence for the role of second-order normative beliefs.

To provide causal evidence for the role of second-order normative beliefs in predicting energy conservation behavior, we conducted a pre-registered experimental study (see http://aspredicted.org/blind.php?x=xy3a4f). Both the sample size and the exclusion criteria we describe below were pre-registered in advance of data collection. We recruited 561 participants (M_{age} = 36.96, SD_{age} = 11.84, 52.23% female) from AMT, who were first asked to indicate what state and county they lived in (see SI for additional information). Next, all participants were asked to imagine that their energy provider recently sent them a bill including information about their energy consumption. This information was presented in text and graphically and showed that participants used 28% more energy than their neighbors, and was closely modeled to resemble the neighborhood comparison information that Opower sends to its customers (see Figure 3).

Figure 3 about here

Figure 3. Information given to all participants about their energy consumption in the experimental study. The design was closely modeled after the information Opower sends to its customers. The x-axis represents the amount of energy consumed.

All participants were then told that we would access information about the energy conservation beliefs of individuals living in their home county. A loading screen appeared on the page, which took four seconds to retrieve information about participants' home county. The information subsequently provided to participants represents our random assignment to the *low second-order beliefs* and *high second-order beliefs* condition (for a similar methodology, see ref. 43).

In the *low second-order beliefs* condition, participants were told that their county was in the 11th percentile of energy conservation beliefs in the United States. We further elaborated, "[t]hat means that there exists very low awareness that households in your home county can help save the environment: most of your neighbors do not believe that saving energy is important to help the environment." In the *high second-order beliefs* condition, participants were told that their county was in the 89th percentile of energy conservation beliefs in the United States. We further elaborated, "[t]hat means that there exists very high awareness that households in your home county can help save the environment: most of your neighbors believe that saving energy is important to help the environment."

As our dependent variable, we assessed participants' likelihood of reducing their energy consumption with the following question: "how willing would you be to decrease your energy consumption in the next month?". Responses were given on a 7-point scale ranging from 1 (not at all willing) to 7 (extremely willing).

As a manipulation check, we asked participants to report their second-order beliefs with the question: "To what extent do you believe your neighbors (or community) think that reducing household energy contributes to saving the environment?". To control for participants' first-order beliefs in our analyses, we also assessed participants first-order beliefs with the question: "To what extent do you believe that reducing household energy contributes to saving the environment?'. Both questions were presented in counter-balanced order, and responses to both questions were given on a 7-point scale ranging from 1 (not at all) to 7 (very much). Because the order of questions had no significant effect on responses to these questions, we collapsed across order in our subsequent analyses. At the end of the study, participants were asked whether they believed the information provided about energy conservation beliefs in their home county. Consistent with our pre-registration plan, we excluded suspicious participants; importantly, all results hold with and without any data exclusions (see SI), and there was no statistically significant difference in suspicion across conditions ($t(559) = .83$, $p = .41$).

To summarize the experimental set-up: we manipulated second-order beliefs, held constant the descriptive norms information, and measured and controlled for first-order personal beliefs. As a result, our design allows us to test whether second-order normative beliefs have a causal effect on energy conservation behavior over and above first-order personal beliefs.

We first examined whether the manipulation of second-order beliefs was successful. We find that participants in the *high second-order beliefs* condition had significantly higher levels of second-order normative beliefs (M=5.66, SD=1.22) than participants in the *low second-order beliefs* condition (M=4.01, SD=1.45; $t(346)$=11.45, p<.001). We thus conclude that our manipulation was successful.

We subsequently tested whether the manipulation of second-order beliefs influenced participants' willingness to reduce their energy consumption in the next month. We find that participants in the *high second-order beliefs* condition were significantly more willing to reduce their energy consumption (M=5.83, SD=1.17) than participants in the *low second-order beliefs condition* (M =5.33, SD=1.30; t(346)=3.65, p<.001). The effect of condition holds even when controlling for measured first-order personal beliefs (B=.332, SE=.115, p=.004). We note that, unlike the first study based on Opower field data, higher first-order personal beliefs were significantly related to an increased willingness to reduce energy consumption (B=.557, SE =.044, p<.001). The 95% confidence intervals around the experimental manipulation of second-order normative beliefs condition and the measurement of first-order personal beliefs overlapped, indicating that they are both of similar size..

The results of the experimental study provide support for the causal role of second-order beliefs in the formation of energy-saving intentions. Consider that all participants in this study received the same descriptive norm information that they used more energy than their neighbors, similar to what participants in the Opower treatment received. However, when additionally told that their neighbors believe saving energy is important to them, participants were more willing to subsequently reduce their energy consumption, in comparison to participants who were told that their neighbors do not believe that saving energy is important to them. These results provide further evidence of the important role of second-order normative beliefs in predicting energy savings behavior, over and above first-order personal beliefs.

Current approaches to reduce energy consumption typically focus on interventions that attempt to motivate individuals to change their first-order personal beliefs[9–11,14,15]. These interventions make intuitive sense: by educating and informing citizens about the importance and

dangers of global warming, policy-makers may intend to change the first-order personal beliefs of its citizens. But this information-centered approach is expensive and often inefficient in altering behavior[11]. We believe that a better policy approach for changing behavior requires policy-makers and researchers to more closely understand what factors drive behavior change and how these factors can best be implemented at all levels of policy-making.

To this end, sustainable energy-use behavior—one important element in curbing climate change—has been encouraged in recent years through the application of descriptive norms[17,18]. But these norm interventions vary in their effectiveness, with some prior research unable to find any effect of these norm-based manipulations on behavior altogether[24–30]. Indeed, in the large-scale Opower dataset we present here, the effectiveness of descriptive norm information in producing reductions in energy usage varied by 300% across different states. Because interventions need to be maximally successful to limit the effects of global warming, we set out to understand why descriptive norms worked better in some states than others. To do so, we leveraged recent research on the importance of second-order normative in predicting behavior change. Stated simply, we proposed that second-order normative beliefs towards energy conservation would predict energy-saving behavior, over and above first-order personal beliefs.

Our findings provide insight into why descriptive norm messaging produces a change in behavioral outcomes in some cases, but not in others. In a dataset of 211 RCTs, we found that the provision of descriptive norm information was associated with greater energy conservation in those states where individuals believed that energy conservation was valued by members of their community, i.e., higher second-order normative beliefs. In a subsequent experimental study, we provide causal evidence for our proposition that receiving descriptive norm information about a household's energy usage relative to similar neighbors is more effective when household members

believe their neighbors value energy conservation. Because this experiment manipulated second-order beliefs, while holding constant normative information, and measuring and controlling for the first-order beliefs, it demonstrates that second-order beliefs have a causal effect over and above first-order beliefs.

These results mirror earlier findings that both cross-cultural differences and prejudice reduction are driven by second-order normative beliefs[16–18,21–23]. When we think our community cares about a behavior, we worry more about the costs of norm violation[33,38,44]. Indeed, second-order normative beliefs may have implications for our understanding of sustainable and cooperative behaviors more generally. For example, recent work finds that beliefs about others' intention to cooperate shape one's intuitive cooperativeness in social dilemmas [45]. Under what circumstances cooperation is intuitive (i.e., the default behavior) has recently received considerable attention [46–48]. In the context of sustaining large-scale public goods, such as combating climate change, saving energy or recycling, future work needs to be conducted to further our understanding of the conditions—including the role of second-order normative beliefs—which lead to intuitive, habitual, sustainable behaviors [49,50].

These findings have important implications for policy-makers. Based on our findings that the combination of descriptive norms and second-order normative beliefs is associated with greater energy conservation behavior, utility companies could consider implementing descriptive norm information programs in areas where second-order normative beliefs are higher, as they are likely to be more effective there. In addition, because prior research has shown that second-order normative beliefs are more amenable to change than first-order personal beliefs[21,23,51], our results also suggest that a communication strategy focused on changing second-order normative beliefs, in combination with providing descriptive norms, may be more effective than current approaches

that focus only on impacting individuals' first-order personal beliefs. For example, communities could engage in public demonstrations of desirable behaviors, especially those that may help limit the effects of climate change.

We chose to rely on Amazon Mechanical Turk (AMT) for the study population because AMT workers tend to be younger, less wealthy, and less educated but more racially diverse than the general U.S. population and comparable survey samples[52,53]. This is important because prior research found that wealthier, well-educated households were more likely to be in neighborhoods that were early adopters of the Opower trials, and those early trials tended to have higher savings rates[39]. However, if anything, this implies that our findings are a conservative test of our hypothesis: we find that second-order normative beliefs predict conservation rates, even among a less wealthy, less educated population. In addition, in the SI we report analyses where we created weights for gender and age bins for each state based on U.S. Census data, and all results remain qualitatively similar. This provides additional evidence that differential sample selection biases (i.e., non-randomness) are unlikely drivers of our effects. That said, we encourage further research into different population segments to better understand the heterogeneous effects of wealth, education, and other demographics on sustainable energy behaviors.

In addition, future research would benefit from investigating other levels of analysis of first-order personal and second-order normative beliefs. For example, it is feasible that first-order personal and second-order normative beliefs also vary within a state, such that communities with high second-order normative beliefs exist in states with low first-order personal beliefs (e.g., Austin in Texas) and vice versa[54,55]. Moreover, while the Opower intervention focuses specifically on energy use in households, curbing individual-level energy use is only one of the many factors to limit the devastating effects of climate change. Indeed, other important approaches include

urging individuals to change their equipment, such as installing solar panels or insulating their house. It is possible that second-order normative beliefs may also influence individuals to adopt a wider range of energy-efficient household equipment and a sustainable lifestyle, beyond the individual-level energy use measured by the Opower trials. A more detailed mapping of first-order personal and second-order normative beliefs to other sustainable behaviors may not only deepen our understanding of the underlying psychology of descriptive norms but could also help refine climate change communication strategies.

Finally, subsequent research could investigate additional mechanisms for why second-order normative believes combine with descriptive norm information to predict energy savings. Our theorizing built off prior literature in cross-cultural psychology and prejudice reduction, which proposes that individuals worry more about the costs of norm violation when they have higher second-order normative beliefs[33,38,44]. However, we believe there are likely additional pathways. One such possibility concerns the role of attributions[56–58]. Consider that a neighbors' reduced energy use could be attributed to the punishment of norm violation ("their neighbors scolded them for leaving their lights on"), volition ("they saved energy because they took conscious steps to do so"), or happenstance ("they saved energy because they weren't home much in the last few months"). One possibility is that higher second-order normative beliefs increase one's tendency to conclude that one's neighbors purposefully reduced their energy consumption. As a result of these second-order normative beliefs, the descriptive norm information becomes a more relevant standard and more likely to guide individuals' behavior. We encourage future research to further uncover the mechanisms involved in the role of second-order normative beliefs.

Ultimately, combating environmentally damaging behaviors requires individual-level cooperation[1–6], which is difficult to achieve because self-interest can quickly lead to free-

riding[32,33,38]. Past research has found that how we view our community and how likely we think they will choose to cooperate rather than free-ride exerts a strong influence over our own decision to cooperate[59]. But our results suggest an additional component: what we think our community thinks about an issue affects our likelihood to act. In other words, people might generally agree that reducing energy consumption is needed to help the environment and save our planet—but to make it happen, they need to believe that others care about it too.

Methods

Ethical Approval

All participants in the online survey and the online experiment consented to participating in this study, and ethical approval for both the survey and the experiment, as well as the use of the Opower data, was obtained from Columbia University's Institutional Review Board.

Opower Context

The company Opower (acquired by Oracle in 2016; subsequently referred to as Opower) built a commercial platform to promote household energy conservation. As of the time of data collection, Opower operated in 27 states across the United States in collaboration with energy providers. Opower runs randomized controlled trials (RCT) with most energy providers they work with to measure program effectiveness. Over the past decade, Opower has conducted over 200 RCTs testing the effectiveness of descriptive norm adherence on energy consumption across 27 states. Opower programs employ RCTs where program households are selected, matched to similar households based on their energy usage, and randomly assigned to a treatment or control group. Treatment group households receive information on how their energy consumption compares to the energy consumption of similar households. The treatment effect—energy savings rate—is defined as the percentage of energy saved in the treatment group relative to the control group usage by RCT trial.

Survey Sample

We surveyed individuals in the same 27 states to assess the effects of normative and first-order personal beliefs on this treatment effect. We recruited 2,001 participants (51% female; age: M=37.05, SD=54.88) on Amazon Mechanical Turk, an online labor market[60,61], across the 27 states in which Opower operates. In advance of data collection, we aimed for equal representation of all

states in our dataset and specified to have at least 50 participants per state; we stopped recruitment when the sample size per state reached 100 participants or after three weeks of continuous data collection, whichever occurred first. For 7 (of 27) states, the smallest states in the Opower trials, we were unable to collect our target sample size. Unsurprisingly, the number of survey respondents in our sample was proportional to a state's population (linear regression of state population predicting number of survey respondents, with robust standard errors: *coeff*=2.73 X 10^{-6}, *p*=.020). Thus, smaller states were less likely to meet our minimum sample size criteria (linear regression of state population predicting the minimum threshold of at least 50 survey participants, with robust standard errors: *coeff*=2.8 X 10^{-8}, *p*=.043). Our main analysis focuses on states where we have at least 50 participants; however, when we include participants from all 27 states, the results are qualitatively similar.

To ensure survey responders were paying attention throughout the survey, we included an attention check, as commonly done on Mechanical Turk [62]. Ninety-one percent out of 2,001 participants passed the attention check; our final sample thus consists of 1,819 participants. Although our main analysis focuses on participants who passed the attention check, the results are qualitatively similar when we include participants who failed it.

Predictor Variables: First-Order Personal and Second-Order Normative Beliefs

Our main predictor variables were individuals' first-order personal and second-order normative beliefs. Our survey participants were asked two questions about their beliefs toward energy conservation. One question elicited their *first-order personal beliefs*, asking to what extent participants thought, "reducing household energy contributes to saving the environment." The other question elicited *second-order normative beliefs*, asking to what extent the survey respondent thought, "the majority of [his or her] neighbors (or community) thinks that reducing household

energy contributes to saving the environment." Both questions were scored on a 7-point scale ranging from 1 (not at all) to 7 (very much). First-order personal and second-order normative beliefs were elicited in randomized order. Because results are qualitatively similar regardless of question order, our analysis collapses across order.

Dependent Variable: Energy Savings

The outcome variable in our investigation is the standardized average monthly rate of energy conservation. The commonly used measure of energy conservation in the Opower trials is the energy savings rate, the percentage of energy saved in the treatment group relative to the control group usage by RCT trial.

Control Variables

In Table 1 of the main text, we first report our results without any control variables (see Models 1-3). However, to check for robustness, we repeated the analysis including a number of control variables (see Models 5 and 6). First, we control for the duration of the RCT, as this has been implicated previously in Opower effectiveness [39]. Second, we control for the amount of energy used in the control group of each particular state. This takes into account that some states might have higher levels of energy usage than others. Third, to ensure the effectiveness of descriptive norm interventions does not depend on people living together closer (e.g. densely-populated cities), we control for population density at the state-level. Finally, we also control for age and gender of survey respondents, for which we compute the state-level average in our regressions.

Analytic Strategy

We use *t*-tests based on individual-level data when analyzing survey responses alone. Following ref. 39, when studying correlations between survey responses and energy savings, we

use linear regressions predicting average energy savings rates with inverse variance weighted by cohort size. For observations where the cohort size was missing ($N = 12$ trials; or 5.6% of all trials), we imputed the average cohort size in the sample; we followed a similar strategy with missing control group energy usage. Results are qualitatively similar when the observations with missing cohort size and control energy usage are excluded from the analysis.

While we follow ref. 39 in most respects of the analysis, we cannot cluster standard errors on the household level because this data is not available to us. Instead, as a more conservative strategy, we cluster robust standard errors at the state level, which is the common unit of analysis between our datasets and accounts for potential correlation between first- and second-order beliefs within a state.

Finally, we use standardized z-scores of both the independent and dependent variables for the analysis because our variables have different magnitudes and units; however, not standardizing these variables does not alter the significance or interpretation of our results.

DATA AVAILABILITY

The dataset containing household energy savings from 211 large-scale RCTs is Opower's propriety data and may not currently be shared publicly. To inquire about access to the proprietary Opower data, please get in touch with Julie O'Brien (jdpobrien@gmail.com). The survey response data collected on Amazon Mechanical Turk is available on the Open Science Framework (OSF): https://osf.io/jaz4w.

CODE AVAILABILITY

The corresponding Stata code is also available on the OSF: https://osf.io/6yug2/.

COMPETING INTERESTS STATEMENT

J.O. and E.S. previously worked at Opower. The remaining authors declare no competing interests.

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Author Contributions

J.D.O. and E.S. oversaw the Opower data collection, and J.M.J and O.P.H. analyzed the data. J.M.J. and O.P.H. designed the online experiment. J.M.J. and O.P.H. wrote the manuscript, and J.O., E.S., and A.D.G. provided critical revisions. All authors approve the final version of this manuscript.

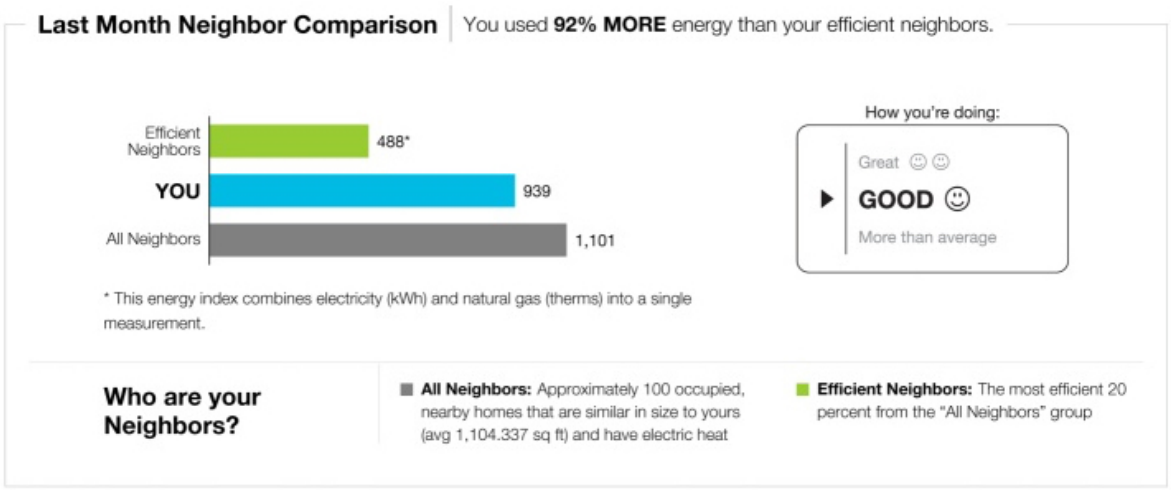

Figure 1. An example of an Opower Home Energy Report. Customers in the treatment condition receive a bi-monthly (or less frequent) mailing that compares their energy usage with that of similar, nearby households. These descriptive norm messages have been shown to be effective in influencing people to conserve energy, but the effectiveness of descriptive norm varies across U.S. states.

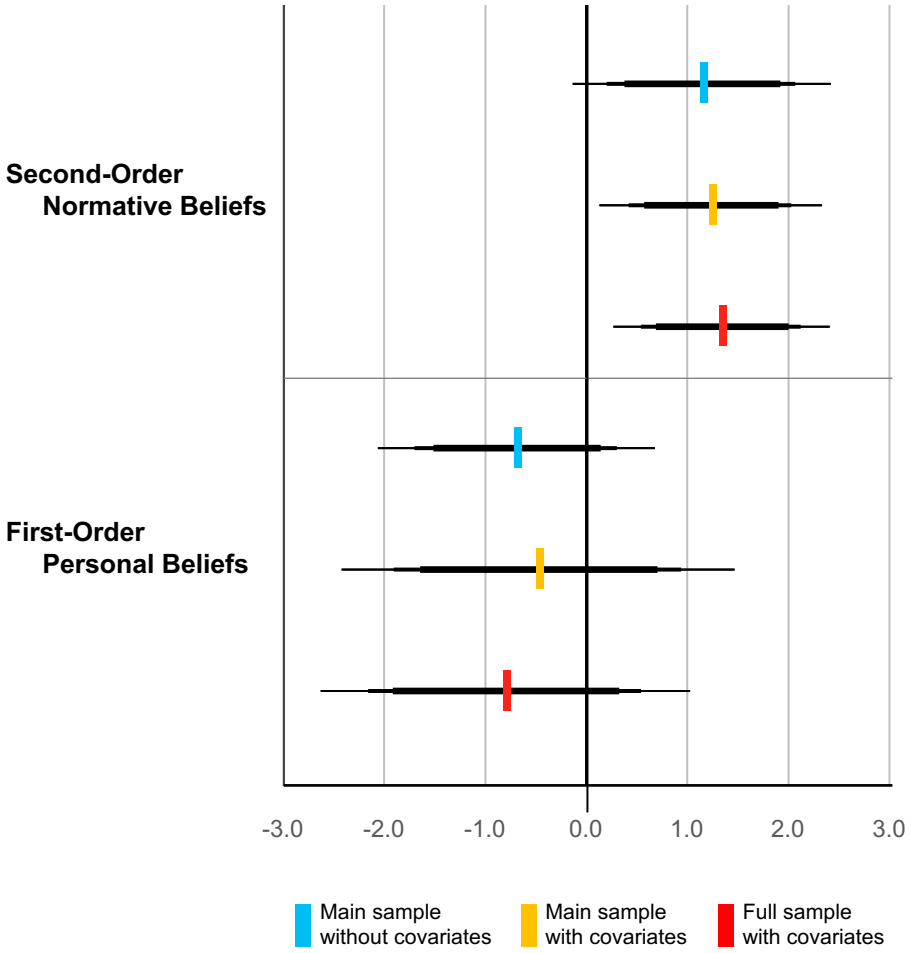

Figure 2. Second-order normative beliefs predict energy savings in 211 large-scale energy savings RCTs (pooled *N* = 16,198,595). The effect of second-order normative beliefs is plotted for a regression model with standardized coefficients based on the main sample (i.e., states that had at least 50 survey respondents) without and with covariates, as well as for a regression model with all states. Regardless of survey response rate, and covariates, second-order normative beliefs significantly predicted savings rate in all model specifications, while first-order personal beliefs did not. For each estimate, the outer (thin) error bar represents the 99% confidence interval, the middle error bar the 95%, and the inner (thick) error bar the 90% confidence intervals.

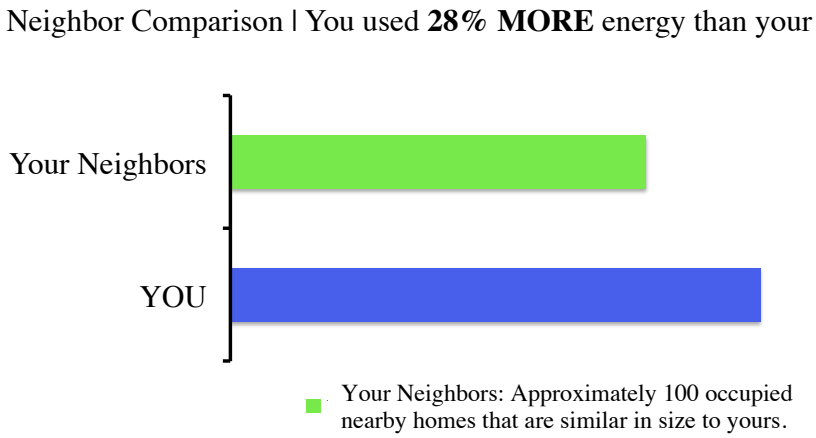

Figure 3. Information given to all participants about their energy consumption in the experimental study. The design was closely modeled after the information Opower sends to its customers.

Table 1. Second-order normative beliefs predicted energy savings in 211 large-scale energy savings RCTs (pooled *N* = 16,198,595), whereas first-order personal beliefs did not. Model 1 shows that second-order normative beliefs predicted energy savings rates, while Model 2 shows that first-order personal beliefs did not predict energy savings rates. Model 3 lists the control variables derived from past research on Opower trials. When control variables are added to the main model in Model 4, the effect of second-order normative beliefs remains statistically significant. The main sample of states with at least 50 respondents is used in Models 1–5. All states regardless of sample size are included in Model 6. All variables are standardized (z-scores). Observations are weighted using cohort size by inverse variance. Robust standard errors are clustered at the state-level.

VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Second-Order Normative Beliefs	.755*		1.138*		1.030*	1.082***
	(.323)		(.446)		(.385)	(.281)
First-Order Personal Beliefs		.209	-.696		.006	-.341
		(.324)	(.478)		(.629)	(.499)
Control group daily energy usage				.030	.072	.080
				(.071)	(.066)	(.069)
Program start date				-.370***	-.341***	-.339***
				(.050)	(.052)	(.051)
State population density				-.075	-.154*	-.124*
				(.071)	(.074)	(.061)
Average age of respondents in state				-.084	.298	.232
				(.277)	(.272)	(.256)
% female respondents in state				-.702	-.588	-.595
				(.462)	(.531)	(.433)
Constant	-.240**	-.214*	-.237**	-.147*	-.173**	-.165**
	(.072)	(.081)	(.072)	(.063)	(.056)	(.057)
Observations	195	195	195	195	195	211
R-squared	.031	.002	.041	.250	.283	.264

Note. *** $p < .001$, ** $p < .01$, * $p < .05$, $^{+}$ $p < .1$

Supplementary Materials for

The Critical Role of Second-Order Normative Beliefs in Predicting Energy Conservation

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Adam D. Galinsky

This PDF file includes:

Methods
Results
Figure S1
Table S1-S5

Supplementary Notes

Additional Analyses in Opower Data

Overall, survey respondents in every state indicated higher first-order personal than second-order normative beliefs (Figure S1). That is, across all states, participants indicated that they had stronger first-order personal beliefs about the extent to which energy conservation helps save the environment (M=4.95, SD=1.53) than they believed their neighbors did (M=4.14, SD=1.37), $t(1,675)=19.51$, $p<0.001$). This suggests that regardless of one's state, people have stronger first-order personal beliefs about energy savings than they have second-order normative beliefs (see Figure S1).

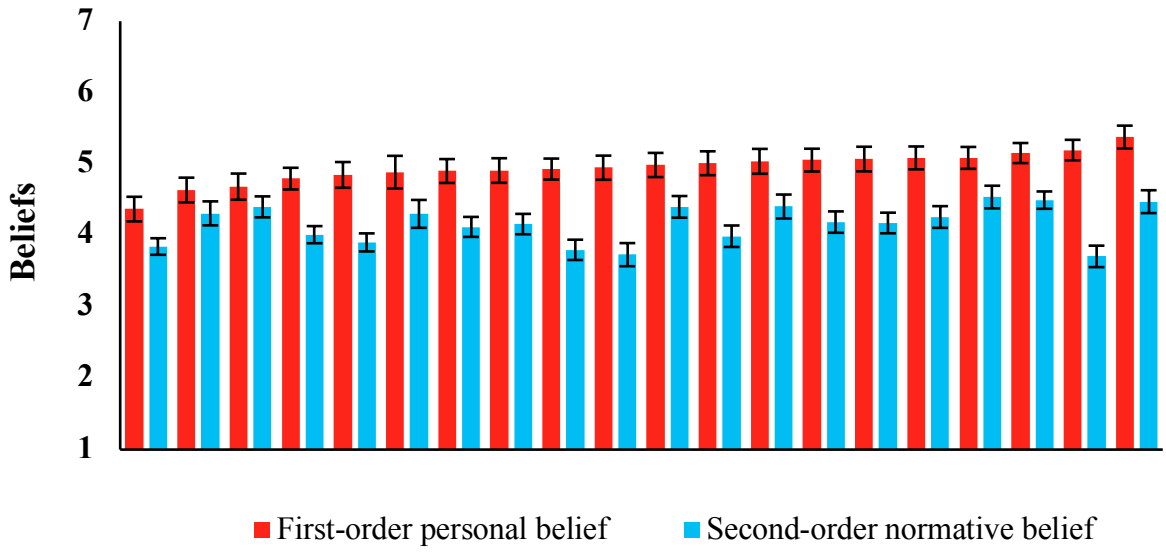

Figure S1. First-order personal beliefs are higher than second-order normative beliefs in all states. Respondents in our survey report that they believe that conserving energy helps the environment. In all states, these reported first-order personal beliefs are higher than respondents' second-order normative beliefs about the relevance of energy savings. The y-axis represents the first-order personal beliefs (red) and second-order normative beliefs (blue) measured on a 7-point scale (with higher values indicating more agreement with the corresponding belief). Error bars represent the 95% Confidence Interval.

Robustness Checks

In addition to our main result presented in the main text (see Table 1 and Figure 2), we include robustness checks of our main regression results in this section. The robustness checks take into account alternative sampling weights to control for survey uptake in each state, focus only on trials without imputed averages for missing variables, and including survey respondents who did not pass the attention quiz, and show the relationship to an additional dependent variable (absolute amount of energy saved, rather than relative energy savings).

For our first robustness test, we repeat the main analysis using the number of survey respondents in weighting observations to account for survey uptake, instead of cohort size (which we include as a control variable in the regression equation). A common approach to deal with independent and dependent variables that have been averaged from other datasets is to weigh observations in the regression by the inverse variance of the source file's number of observations[5]. This approach was followed by ref. 4 using cohort size to weigh observations; we closely follow this analytical strategy in our main analysis. We find that the results are robust to this variation: second-order normative beliefs predict the savings rate (*coeff*=2.407, $p<.001$), but first-order personal beliefs do not ($p=.155$). When control variables and smaller states outside the main sample are included, second-order normative beliefs continue to be significant predictors (both ps<.001; see Table S1).

Second, we repeat the main analysis with only Opower trials where there was no missing data in any variables (N=182 trials). While there is no effect of first-order personal beliefs ($p=.352$) on energy savings, second-order normative beliefs are a marginally significant predictor (*coeff*=.962, $p=.076$). The precision of the estimator increases when control variables (*coeff*=1.397, $p=.003$) and smaller states (*coeff*=1.503, $p=.001$, see Table S2) are included.

Third, we include all survey respondents in the main analysis, regardless of whether they did or did not pass the attention test during the survey (total N=2,001). As before, the savings rate is predicted by second-order normative beliefs (*coeff*=1.170, p=.003), but not by first-order personal beliefs (p=.135). The results are robust to including control variables and smaller states in the analysis (both ps<.01, see Table S3).

Fourth, we repeat the main analysis with inverse-variance weights based on representative gender and age demographics in each state, based on the 2010 U.S. Census. For each gender and four age groups (based on the U.S. Census: 18-24, 25-44, 45-64, and 65+ years of age), weights were generated on a state-level to adjust the online survey sample to be more representative of the general U.S. population. The results are similar as prior model specifications (see Table S4).

Finally, we repeat the main analysis using the amount of energy saved as the outcome vaiable, and find similar results to prior model specifications (see Table S5).

In sum, we find that the distinct effect of second-order normative believs on energy savings is robust to a number of additional model specification, thus providing additional confidence in the results of our analysis.

Table S1. We repeat the main analysis with inverse-variance weights based on the number of survey respondents. Cohort size is added as an additional control variable for this analysis. Following SI ref. 4, in this and all other regression tables (unless specified otherwise), the program start date is the date ("td" format in Stata) when Opower started the RCT, divided by 365 (days). Additionally, all variables have been standardized (z-scores). Robust standard errors are clustered on the state-level.

VARIABLES	Model 1	Model 2
Second-Order Normative Beliefs	2.260***	1.908***
	(.433)	(.342)
First-Order Personal Beliefs	-.955	-.527
	(.667)	(.612)
Control group daily energy usage		.047
		(.094)
Program start date		-.262***
		(0.051)
Program cohort size		-.092
		(.084)
State population density		-.140*
		(.064)
Average age of respondents in state		-.327
		(.292)
% female respondents in state		-.586
		(.538)
Constant	-.075	-.081
	(.089)	(.060)
Observations	211	211
R-squared	.131	.251

*** p<0.001, ** p<0.01, * p<0.05, $^{+}$ p<0.1

Table S2. We repeated the main analysis restricting the sample to RCT programs without any missing data. All variables are standardized. Observations are weighed using cohort size by inverse variance. Robust standard errors are clustered at the state-level.

VARIABLES	Model 1	Model 2
Second-Order Normative Beliefs	.802*	1.186***
	(.313)	(.310)
First-Order Personal Beliefs	-.610	-.269
	(.361)	(.510)
Control group daily energy usage		.089
		(.073)
Program start date		-.341***
		(.056)
State population density		-.145*
		(.062)
Average age of respondents in state		.283
		(.287)
% female respondents in state		-.629
		(.461)
Constant	-.259***	-.165***
	(.070)	(.056)
Observations	199	199
R-squared	.028	.245

*** p<0.001, ** p<0.01, * p<0.05, $^{+}$ p<0.1

Table S3. We repeated the main analysis with all survey respondents regardless of whether or not they passed the attention test. Observations are weighed using cohort size by inverse variance. Robust standard errors are clustered at the state-level.

VARIABLES	Model 1	Model 2
Second-Order Normative Beliefs	1.075***	1.202**
	(.284)	(.358)
First-Order Personal Beliefs	-1.010*	-.647
	(.446)	(.633)
Control group daily energy usage		.070
		(.065)
Program start date		-.343***
		(.050)
State population density		-.114^{+}
		(.059)
Average age of respondents in state		.176
		(.249)
% female respondents in state		-.497
		(.518)
Constant	-.252**	-.191**
	(.068)	(.062)
Observations	211	211
R-squared	.042	.263

*** p<0.001, ** p<0.01, * p<0.05, $^{+}$ p<0.1

Table S4. We repeat the main analysis with inverse-variance weights based on representative gender and age demographics in each state, based on the 2010 U.S. Census. For each gender and four age groups (based on the U.S. Census: 18-24, 25-44, 45-64, and 65+ years of age), weights were generated on a state-level to adjust the online survey sample to be more representative of the general U.S. population. Cohort size is added as an additional control variable for this analysis; all variables have been standardized (z-scores). Robust standard errors are clustered on the state-level.

VARIABLES	Model 1	Model 2
Second-Order Normative Beliefs	.153*	.102*
	(.058)	(.040)
First-Order Personal Beliefs	.080	.067
	(.073)	(.065)
Control group daily energy usage		-.056
		(.156)
Program start date		-.772*
		(.342)
Program cohort size		-.097^{+}
		(.054)
State population density		.371
		(.513)
Constant	.617	1.370^{+}
	(.605)	(.746)
Observations	2,001	2,001
R-squared	.008	.085

*** p<0.001, ** p<0.01, * p<0.05, $^{+}$ p<0.1

Table S5. We repeat the main analysis using the amount of energy saved as outcome variable; all variables have been standardized (z-scores). Because the outcome variable in this regression is not normalized by the control group usage, the latter is a highly significant predictor of energy savings, consistent with findings in SI ref. 4. Robust standard errors are clustered on the state-level.

VARIABLES	Model 1	Model 2
Second-Order Normative Beliefs	.854*	.884*
	(0.311)	(.352)
First-Order Personal Beliefs	-.661	-.373
	(.399)	(.577)
Control group daily energy usage	.747***	.681***
	(.089)	(.082)
Program start date		-.223***
		(.039)
State population density		-.092^{+}
		(.046)
Average age of respondents in state		.309
		(.220)
% female respondents in state		-.317
		(.482)
Constant	-.219**	-.166**
	(.063)	(.054)
Observations	211	211
R-squared	.467	.543

*** p<0.001, ** p<0.01, * p<0.05, $^{+}$ p<0.1

Additional Analyses in the Experimental Study

In our pre-analysis plan (http://aspredicted.org/blind.php?x=xy3a4f), we pre-registered both the sample size as well as an exclusion criterion. At the end of the study, participants were asked whether they believed the information provided about energy conservation beliefs in their home county. Responses were binary (yes/no), and 213 participants (37.97%) indicated they were suspicious about the manipulation. There was no statistically significant difference in suspicion levels across conditions ($t(559) = .83$, $p = .41$). In the main text, we present the analysis excluding suspicious participants, concordant with the pre-analysis plan. Here, we report the results when including participants that were suspicious; all results remain qualitatively similar.

When including all participants, participants in the *high second-order beliefs* condition had significantly higher levels of second-order beliefs (M=5.28, SD = 1.49) than participants in the *low second-order beliefs* condition (M=4.10, SD=1.55; $t(559)$=9.21, p<.001). We thus conclude that the manipulation check was successful. In addition, in the full sample, participants in the *high second-order beliefs* condition were also significantly more willing to reduce their energy consumption (M=5.65, SD=1.37) than participants in the *low second-order beliefs* condition (M =5.35, SD=1.46; $t(559)$=2.52, p=.012). These results hold when controlling for measured first-order personal beliefs (B=.213, SE=.096, p=.027). In sum, the results of our experimental study thus provide causal support for the role of second-order normative beliefs in predicting energy conservation behavior.