Maximizing Home Energy Report Savings: Who Saves the Most, the Least and Why?

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ABSTRACT

Home energy reports (HER) are by far the most common type of behavioral energy efficiency program used by utilities. These programs achieve savings by encouraging large numbers of customers (typically in the tens or even hundreds of thousands) to make small changes to reduce their energy consumption. As these programs mature and low-hanging energy savings grow scarcer, it is important to understand not just whether programs are achieving any savings at the aggregate level, but which customers are achieving the highest and lowest savings because of participation, and why. Such knowledge could enable utilities to target program expansion at customers likely to save the most, and develop different opportunities for customers who seem unlikely to benefit.[1]

In this paper, we build on previous evaluations of an established HER program by conducting a survey (n = 2,898) to learn more about why, despite the program's overall success in achieving goals, some 40% of participants experience negative savings, and other customers experience much higher savings than average. Understanding what causes these differences in savings is critical to developing actionable recommendations to improve the HER program. Our paper will focus on how we combined data from a wide range of methods (multilevel modeling, traditional survey analysis, and machine learning) to delve into what makes participants tick and create actionable recommendations for deepening HER program savings. Our findings are useful both to HER program implementers interested in our substantive results, as well as to evaluators eager to expand their analytic toolkit.

Introduction

Home Energy Reports (HERs) are the most common type of a wider class of energy efficiency interventions known as behavioral modification programs.[2] Such programs achieve savings by changing customer usage habits, as well as equipment installation practices. HER programs typically rest on two key drivers of behavioral change: historical usage and social norming. The program logic argues that giving customers information about their own past usage and about that of their peers will change their beliefs about "normal" energy consumption and create social pressure to use less. HERs leverage both billing data and publicly available data to provide energy efficiency information, usage history, and benchmarking to participants. The reports are typically provided by a third party (e.g. Aclara, Tendril Energy, C3 Energy, Oracle).

There is strong evidence to suggest that these programs produce energy savings. Most HER programs are evaluated via statistical analysis of billing records of participants that are compared to those of control or comparison group customers. Some HER reports are distributed within a randomized control trial framework, while other programs must be evaluated in a quasi-experimental manner. Regardless of the evaluation method, most HER program evaluations find evidence of small, but consistent household-level savings while the treatment continues. When these small savings are applied to a large number of customers, overall program savings can be substantial.

However, these evaluations rarely probe more deeply into whether and to what degree individual households respond differently to reports. The typical statistical methodology for calculating program savings is designed to produce an overall average savings value across all participating households, not to estimate

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[1] Any changes to program design, particularly excluding customers, requires maintaining fidelity of the Randomized Controlled Trail (RCT) design.

[2] Patterson, O. 2014. "The Adolescent Years of Behavioral Programs: Optimizing Behavioral Program Design through Energy Savings Persistence." Presentation at the 2014 Behavior, Energy, & Climate Change Conference. http://beccconference.org/2014-presentations/

individual savings. As a result, Opinion Dynamics used a multilevel approach to calculating individual savings estimates for a multi-year home energy savings report program. Multi-level models allow us to generate individual-level savings estimates that take household and demographic characteristics, as well as traditional controls like weather into account. These individual-level estimates allow us to identify groups of high, low, and negative savers, and to investigate whether participants tend to stay in the same group or move into a higher or lower savings group over time. In addition, we conducted a survey with treatment and control customers in the program to better understand these groups and optimize future messaging and delivery efforts.

Methodology

The following sub-sections outline our approach to the multilevel modeling and customer survey efforts.

Multilevel Modeling

We used a multilevel billing analysis to estimate individual savings for each participating customer. We then used those individual savings estimates to group customers into five categories (high, medium, neutral, negative, and very negative savers) and analyze the correlation of these categories with demographics and household characteristics. The multilevel modeling approach provides several advantages over individual regression to establish individual household savings levels. These include:

- Multilevel modeling statistically controls for weather differences between pre- and post-periods for an individual household as well as across households. In contrast, individual models solely control for weather differences between pre- and post-periods for an individual household.
- Multilevel modeling allows for modeling the influence of variables that do not change over time that apply to customers and for generating appropriate standard errors and statistical tests.
- Results from multilevel regression models adjust individual savings estimates based on control group usage during the treatment period, so the savings estimates are much closer to net savings than results from individual regressions.
- Information is shared across customers in multilevel models, so the unexplained variance in individual savings across participants is much lower when we make estimates using a multilevel model.

Model description

We used Equation 1 to estimate household-specific changes in energy consumption for the treatment group in the post-period using utility billing data. The calculations and modeling used R statistical software, with multilevel models using the lme4 package.

$$ADC_{it} \sim N(\alpha_i + \theta_i Treatment_t + \beta_1 HDD_t + \beta_2 CDD_t + \beta_3 PreADC_i + \beta_4 PreADC * Treatment_{it}, \sigma_{ADC}^2),$$

$$for\ t = 1, \dots, t, i = 1, \dots, n;$$

$$\begin{pmatrix} \alpha_i \\ \theta_i \end{pmatrix} \sim N\left(\begin{pmatrix} \mu_\alpha \\ \mu_\theta \end{pmatrix}, \begin{pmatrix} \sigma_\alpha^2 & \rho\sigma_\alpha\sigma_\theta \\ \rho\sigma_\alpha\sigma_\theta & \sigma_\theta^2 \end{pmatrix} \right), for\ i = 1, \dots, n$$

Equation 1: Multilevel Model

Where:

ADC_{it} = Average daily consumption (kWh or therms) for household i at time t

α_i = Household-specific intercept for household i

θ_i = Household-specific change in consumption for the treatment group in the post period

β_1 = Coefficient for HDD (Heating Degree Days)

β_2 = Coefficient for CDD (Cooling Degree Days)

β_3 = Coefficient for PreADC (Pre-Period average daily consumption)

β_4 = Coefficient for PreADC by Treatment interaction

σ^2_{ADC} = Variance of ADC (average daily consumption)

μ_α = Mean of household-specific intercept

μ_θ = Mean of household-specific change in consumption due to treatment

σ^2_α = Variance of household-specific intercept

σ^2_θ = Variance of household-specific change in consumption due to treatment

$\rho\sigma_\alpha\sigma_\theta$ = Covariance of household-specific intercept and change in consumption

We drew data for this analysis from several sources, including program-tracking data, customer billing data, and demographic and household data purchased from Experian. The billing data includes monthly records for over 250,000 electric, gas, and dual-fuel customers. The duration of exposure to the program varies: the program we analyzed is entering its seventh year, and new cohorts are added to the program each year.

Savings groups

We used the individual savings results from the multilevel model to identify "High," "Medium," "Neutral," "Negative," and "Very Negative" savers within the treatment population of a utility HER program and to identify characteristics to support future targeting efforts. We examined the savings groups for gas and electricity consumption and looked at three years of participation for select cohorts to help understand the evolution of the savings groups over time. We present our findings consolidating the five modeled groups into three groups: "Very Positive", which are "High" Savers, "Typical", which are "Medium", "Neutral" and "Negative", and "Very Negative" which are "Very Negative" savers. We did this separately for the gas savings results and the electric savings results, so a participant might be a medium gas saver and a neutral electric saver. We define the groups as follows.

Table 1. Multilevel Modeling Savings Groups

Consolidated Group	Original Group	Percent of Population in PY7	kWh Savings per Day	Therm Savings per Day
Very Positive	High Savers	Top 10%	>7 kWh	>0.33 therms
Typical	Medium Savers	Next 30%	>1 and <=7 kWh	>0.08 and <= 0.33 therms
	Neutral Savers	Middle 20%	>-0.5 and <=1 kWh	>-0.02 and <= 0.08 therms
	Negative Savers	Next 30%	>-6 and <=-0.5 kWh	>-0.25 and <=-0.02 therms
Very Negative	Very Negative Savers	Bottom 10%	<-6 kWh	<-0.25 therms

Customer Surveys

Opinion Dynamics implemented a computer-assisted web interviewing (CAWI) survey with 48,374 treatment and 17,946 control group customers across all program cohorts. The treatment group was inclusive of multilevel model savings groups (as described above). Broadly, the survey was designed to compare differences between treatment and control groups related to self-reported energy efficiency actions and behaviors, structural retrofits, and household changes; determine whether energy-saving measures were in response to the HER program; and measure differences in satisfaction and customer engagement between the savings groups.

We fielded the survey to a third of customers for whom we had email addresses. The survey sample was proportionally stratified to represent the true distribution of customers across the prior evaluation's gas and electric savings groups. From these groups, we drew a proportionally stratified sample for "High" savers, "Medium" savers, "Neutral" savers, "Negative" savers, and "Very Negative" savings groups. This approach yielded an outgoing sample of 66,320 people, including the control group.

Results

We used the participant survey to study several sets of potential savings drivers to characterize what could be causing the observed differences in customer savings as determined through multilevel modeling. We divided these potential barriers or drivers into two broad categories: addressable and structural. Addressable drivers or barriers are those that are likely to respond to adjustments to the HER program. For example, knowing whether different savings groups are concerned about the environment could inform differences in marketing strategy to each of those groups. Understanding which energy savings actions "Very Positive" savers take and do not take could help the utility create suggestions to deepen HER savings. By contrast, it is unlikely that the utility could influence structural drivers or barriers. If a customer is a "Negative" saver because he or she lives in a very old house or because he or she needs energy-hungry medical equipment, adjustments to that customer's HER likely will not improve their savings.

Figure 1 summarizes the different drivers and barriers we investigated by type. Understanding the relative importance of these potential drivers and barriers is important for understanding not only which customer characteristics to target to deepen savings, but whether savings can be deepened at all. If fixed drivers or barriers primarily define a savings group, that group will likely be better served with different program offerings. These drivers and barriers are based on survey results, so they are not necessarily causing the savings differences because the reports themselves could have caused the differences, or those differences could have been preexisting.
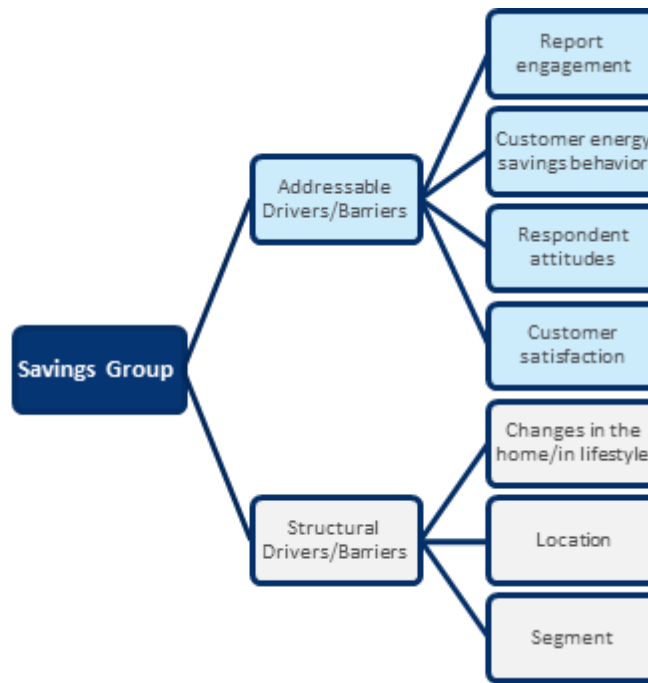
Figure 1: Potential Drivers/Barriers for Savings Groups

Within the following sections, we present key results from the customer surveys.

Addressable Drivers or Barriers for Energy Savings

Report readership and engagement

Report recall was the same across both gas and electric savings groups. However, "Very Negative" electric savers were significantly less likely to read every report than other electric saver groups, with readership being 38% for "Very Negative" savers versus 47% and 45% for "Very Positive" and "Typical" savers, respectively.

"Very Negative" electric savers also gave significantly lower scores on all aspects of the report, including their practicality, helpfulness, and motivational value (Table 2). Additionally, "Very Negative" electric savers had significantly higher agreement with the statement," I do not like being told to use less energy". There were no differences between gas savings groups.

Table 2. Electric Energy Savings Groups Engagement with Home Energy Reports

Customer-Reported Engagement with Home Energy Reports	Mean Agreement Scores		
	Very Positive Savers, A (n=365)	Typical Savers, B (n=2,045)	Very Negative Savers, C (n=313)
The reports provide enough information to take energy savings actions.	5.6 (0.16)	5.8 (0.06)	5.0 [AB] (0.17)
The report tips are not practical.	4.4 (0.16)	4.2 (0.07)	4.8 [B] (0.18)
The reports motivate me to take energy savings actions.	5.6 (0.16)	5.8 (0.07)	5.2 [AB] (0.17)
The reports remind me to take energy savings actions.	6.1 (0.16)	6.3 (0.06)	5.7 [AB] (0.17)

Customer-Reported Engagement with Home Energy Reports	Mean Agreement Scores		
	Very Positive Savers, A (n=365)	Typical Savers, B (n=2,045)	Very Negative Savers, C (n=313)
I am glad to have help in reducing my energy consumption.	6.8 *(0.15)*	6.9 *(0.06)*	6.6 [B] *(0.16)*
I do not like being told to use less energy.	3.6 *(0.17)*	3.7 *(0.07)*	4.0 [AB] *(0.19)*

Note: Letters indicate statistically significant differences at the 90% confidence level between savings groups represented by the letter.
Note: Respondents were asked about agreement with the statements in the table, where 0 is "strongly disagree," 5 is "neutral," and 10 is "strongly agree." The table summarizes mean scores on this 11-point scale.
Note: Values in parentheses represent standard errors.

Engagement with energy use

When looking at the results by savings groups, a significantly lower proportion of "Very Negative" electric savers read their utility bills to understand their energy use than "Typical" electric savers (Figure 2). However, "Very Negative" electric savers reported significantly higher rates of discussion about their home energy use and enrolling in online services with the utility. There were no differences between gas savings groups for energy use engagement.
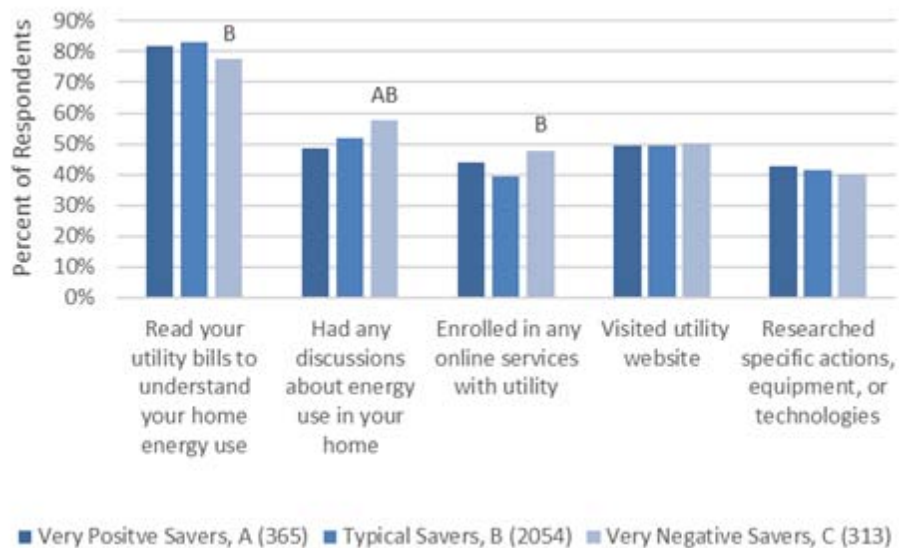

Figure 2: Energy Use Engagement by Electric Savings Group

Note: Letters indicate statistical significance between savings groups at the 90% level.

In terms of utilizing the utility website as a resource, "Very Positive" electric savers reported significantly higher regular use of the utility website to manage their energy use (Table 3). Conversely, "Very Negative" electric savers had a significantly lower frequency of website use and reported the highest rate of non-use. It is important to note that, while there was no difference between savings groups in terms of the number of customers who visited the utility website, the use of the website to manage energy use was significantly lower for "Very Negative" savers. This suggests that the number of short visits to the website does not vary between groups, but more in-depth use of the website does differ between different types of savings groups.

Table 3. Percent of Electric Savings Groups That Use the Utility Website to Manage Their Energy Use

Do you use the utility website to manage your energy use?	Very Positive Savers, A (n=365)	Typical Savers, B (n=2,045)	Very Negative Savers, C (n=313)
Yes, regularly	9.9% BC	5.3%	6.4%
Yes, occasionally	7.5%	7.6%	4.8% B
I have looked at the tools but do not use them regularly	16.4%	20.4% A	21.0%
I do not use this	66.3%	67.1%	67.7%

Note: Letters indicate statistically significant differences at the 90% confidence level between that savings group and the one represented by the letter.

Energy savings behavior

There were few significant differences in the frequency with which each electric or gas savings group took habitual energy-saving actions. However, within the electric groups, "Very Negative" savers were much less likely than members of other groups to attribute this behavior to their HERs. There were no clear patterns among the gas savings groups.

The same pattern holds for one-time energy-saving actions, such as getting a home energy audit, upgrading insulation or lighting, or replacing or recycling major appliances. While there were generally no differences in the overall rates of different activities for the electric savings groups, more "Very Positive" savers and "Typical" savers attribute their actions to their HERs than do "Very Negative" savers. There were again no clear patterns in the gas savings groups.

Energy-saving attitudes

We also explored three general dimensions of customer attitudes that could help explain different savings levels from the program: the benefits customers expect from participating in a program, customers' general attitudes about the environment and climate changes, and customers' preferences about competition and comparison. The primary goal of this analysis was to understand what types of messaging might be most effective for each savings group.

We found that, compared to other groups, "Very Negative" electric savers were felt significantly less responsibility to protect the environment, were less concerned about climate change and were significantly less convinced that climate change is the result of human activities than "Typical" savers. As a result of these findings, the utility could consider working with their implementation partners to test messaging with these customers who do not draw on these potential motivators to save energy.
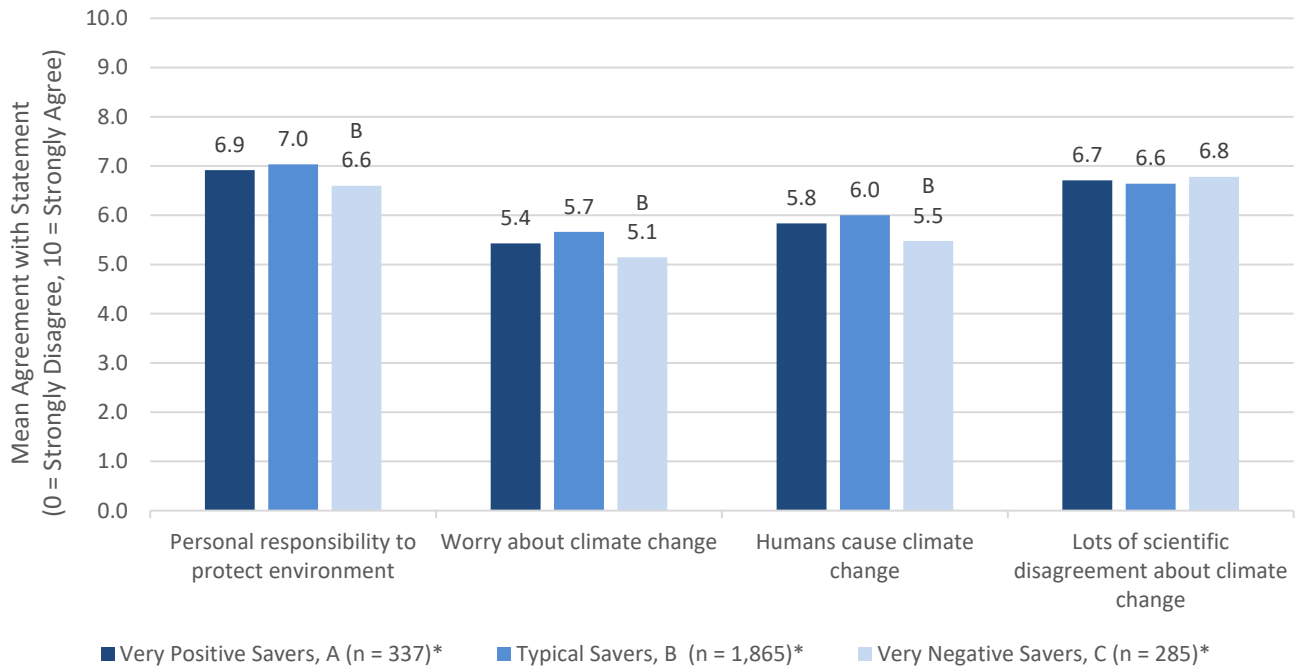
Figure 3. Environmental Attitudes by Electric Savings Group

Note: Letters indicate statistical significance between savings groups at the 90% confidence level.

* Reported N's are the average across all questions in chart for each savings group.

Customer Satisfaction

When comparing electric savings groups, we see that "Very Negative" electric savers have significantly lower satisfaction rates with the utility overall; the HER program; and the utility's website, energy efficiency program offerings, and energy management tools (Table 4). In most cases, "Very Negative" electric savers reported having significantly lower satisfaction than both control customers and other electric savings groups. There were fewer significant differences between gas savings groups, with satisfaction of the "Very Negative" savings group being significantly lower only for the HER program and energy efficiency program offerings.

Table 4. Reported Satisfaction with Key Program Components by Electric Savings Group

Using a scale of 0 to 10, where 0 means you are "extremely dissatisfied" and 10 means you are "extremely satisfied" how satisfied were you with…	Very Positive Savers, A (n=365)	Typical Savers, B (n=2,045)	Very Negative Savers, C (n=313)	Control, D (n=1,479)
Utility overall	7.1 (0.13)	7.4 [A] (0.05)	6.6 [ABD] (0.15)	7.2 (0.04)
Utility website	7 [D] (0.17)	7.1 [D] (0.06)	6.7 [BD] (0.17)	7.3 (0.07)
Home Energy Report Program	6.3 (0.16)	6.6 [A] (0.06)	5.7 [AB] (0.17)	N/A
Energy efficiency programs offered by the utility	6.3 [D] (0.17)	6.6 (0.07)	5.8 [ABD] (0.20)	6.8 (0.09)
Energy management tools on the utility website	6.24 (0.19)	6.24 (0.07)	5.6 [ABD] (0.19)	6.1 (0.07)

Note: Letters indicate statistically significant differences at the 90% level between savings groups.

Note: Values in parentheses represent standard errors.

As part of our survey effort, we sought to better understand whether customers would be responsive to, or satisfied with, different types of messaging strategies (e.g., social norming and goal setting), and whether receiving a positive or negative report result was motivational for different savings groups. If differences were found, then the utility could deliver reports that are more motivational or more satisfying to specific groups of customers.

The utility included in this study has employed two types of messaging strategies in their reports: social norming and goal-setting (i.e., target rank) comparisons for a cohort of customers. As a result, we embedded an experiment within our survey to see whether reactions to different types of reports varied by savings group. Within the survey, respondents were randomly shown an image of one of four reports: a traditional report showing that they compared favorably to other customers ("Social Norming – Positive"), a traditional report showing that they compared unfavorably to other customers ("Social Norming– Negative"), a target rank report showing that they compared favorably ("Goal-Setting – Positive"), and a target rank report showing that they compared unfavorably ("Goal-Setting – Negative").

Survey results from two questions about general reactions to the report images suggest that "Very Negative" electric savers responded more negatively than other groups to the positive goal-setting report (Figure 7). The first question asked customers whether they would be motivated to reduce their energy consumption by such a report. The second asked whether they would be more careful about how they used energy in their home after receiving the report. We found no statistically significant differences among the gas savings groups.

These findings illustrate that different types of customers do in fact respond differently to the current messaging strategies employed by HER programs. Furthermore, the research suggests that goal-setting is not a promising strategy for customers who tend to be less satisfied and save less energy while participating in the program. Based on this, program implementers and sponsoring utilities may want to conduct additional customer research to understand the responses of "Very Negative" electric savers to both different types of social norming and alternative messaging strategies outside of social norming and goal-setting.
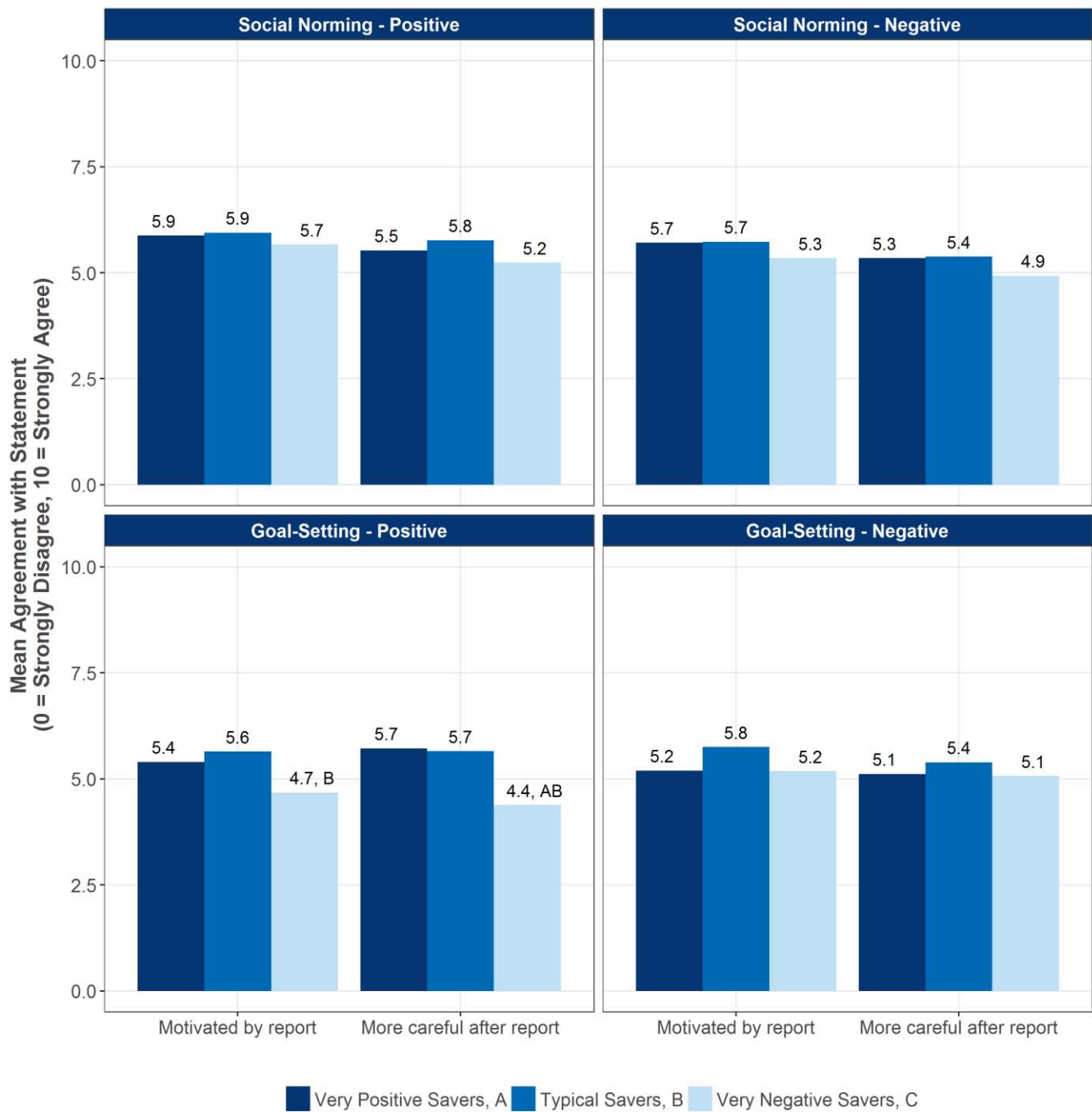
Figure 4. Electric Savings Group Report Reactions

Note: Letters indicate statistical significance between savings groups at the 90% confidence level.

For the "Motivated by report" question, n = 697 for Social Norming – Positive; n = 624 for Social Norming – Negative; n = 617 for Goal-Setting – Positive; n = 628 for Goal-Setting – Negative.

For the "More careful after report" question, n = 680 for Social Norming – Positive; n = 619 for Social Norming – Negative; n = 589 for Goal-Setting – Positive; n = 619 for Goal-Setting – Negative.

Structural Drivers or Barriers for Energy Savings

Changes in occupancy and circumstances

We also examined "unintentional" changes in energy-related behaviors. By this we mean changes in lifestyle, housing, or personal circumstances that could lead to a change in energy usage independent of the customer following or ignoring HER suggestions. For example, spending more time at home during the day, developing a medical condition that required specialized equipment or strict temperature control, or adding a pool would likely increase energy use. In contrast, spending more time out of the house or having a child leave for college could reduce usage.

These types of changes may be major drivers of the differences between electric savings groups. For instance, "Very Negative" savers were significantly more likely to report usage-increasing changes, while "Very Positive" savers were significantly more likely to report usage-decreasing changes (Figure 5). While these findings are purely directional in nature, they provide some indication of the importance of structural barriers in the response of targeted customers to HER programs.
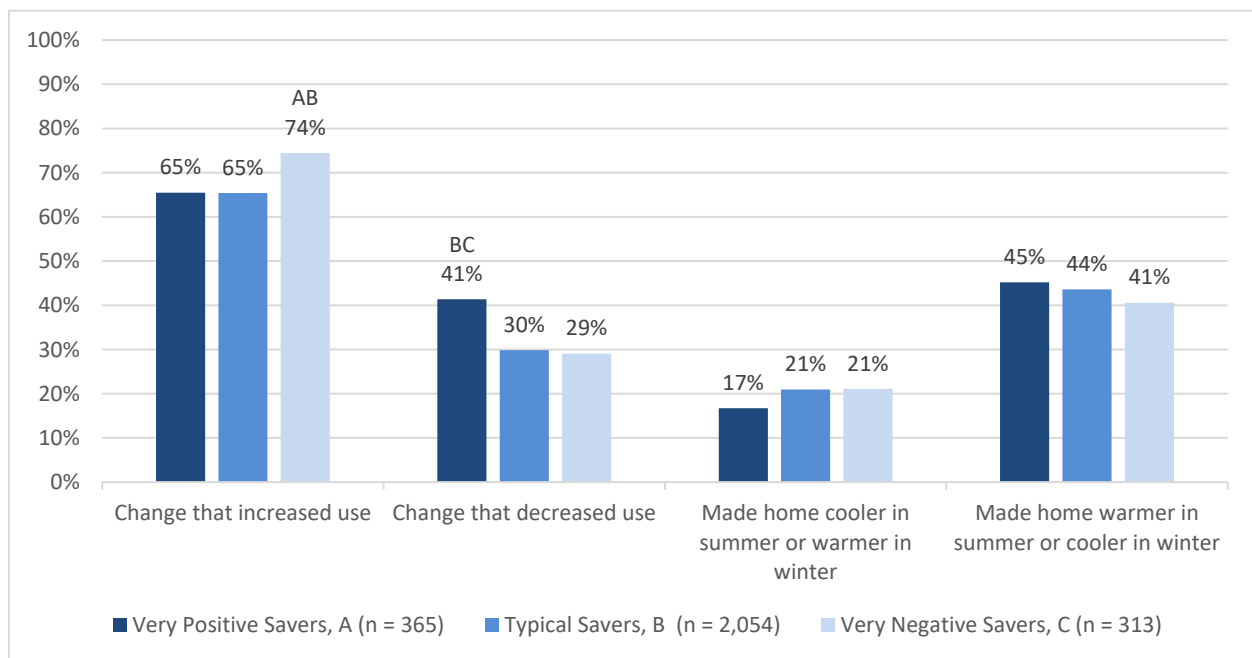

Figure 5. Change in Energy Usage by Electric Savings Group

Note: Letters indicate statistical significance between savings groups at the 90% confidence level.

Conclusion

Persistent "Very Negative" savers tended to have different characteristics than other program participants. Through follow-up customer surveys, we found that electric "Very Negative" savers tended to be distinct from other electric savings groups. First, their engagement with and satisfaction with the HERs were significantly lower, on average, than other savings groups. In addition, despite having a similar frequency of reported energy saving actions, electric "Very Negative" savers were much less likely than members of other groups to attribute this behavior to the reports. There also appear to be intrinsic features that are correlated with this energy savings group. For example, electric "Very Negative" savers reported a much higher rate of making changes to increase energy usage in their home, while "Very Positive" (e.g., "High") savers reported a

higher rate of making changes to decrease energy usage.[3] In addition, these customers were much less interested or concerned about climate change than other groups.

These findings illustrate the need to consider what types of constraints or barriers customers in different savings groups may be facing, and what types of messaging may be relevant to them. Additionally, the findings indicate the potential benefit of targeting specific-types of savers for new interventions. Based on these findings, recommendations for improved targeting and program performance include:

- **Implement tailored messaging strategies designed to resonate with different types of customers**. As shown through this research, "Very Negative" electric savers differ from the other electric savings groups in their response to positive goal-setting strategies. As such, moving from a social norming to goal-setting approach will not necessarily lead to the increases in satisfaction sought through this approach.
- **Conduct qualitative research to understand the perceptions and motivations of each electric savings group**. Exploring the experiences of customers in each energy savings group will enable implementers to assess the viability of and test different messaging and intervention strategies. As the results from this study indicate, since customers are different, they may benefit from different treatments. For example, there may be room to focus reports for "Typical" electric savers on increasing customer engagement with utility programs and platforms, such as online bill-pay or other web-based services and features.
- **Consider whether "Very Negative" electric savers can effectively generate savings for the program**. If this group cannot be effectively reached through social norming or alternative messaging strategies as outlined above, utilities should consider stopping or modifying reports for this group of customers.

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[3] By this we mean changes in lifestyle, housing, or personal circumstances that could lead to a change in energy usage independent of the customer following HER suggestions. For example, spending more time at home during the day, developing a medical condition that required specialized equipment or strict temperature control, or adding a pool would likely increase energy use. Spending more time out of the house or having a child leave for college could reduce usage.