FINAL REPORT | MARCH 16, 2021

MGE Connect Program Evaluation

slipstream

Project Managers: D. Leith Nye and Doug Ahl

Acknowledgements

Maddie Koolbeck, Rebecca Sadler and Melanie Lord contributed to this report.

AT A GLANCE

- We estimated that across the 12 events, participants reduced their cooling runtime by 73-79 percent translating to reduction of 691 to 955 watts.
- Our evaluated load reduction estimates are comparable to those reported by EnergyHub.
- Based on available data, we did not see evidence that thermostat brand affected load reduction outcomes among participants.
- Overall customers were satisfied with the program and the enrollment process, and most would recommend the program to others.

INTRODUCTION

The MGE Connect program allows customers with internet-connected smart thermostats to participate in demand reduction events that automatically reduce central air conditioner (AC) runtimes during peak usage hours on hot summer days. The program is an expansion of the Rush-Hour Rewards (RHR) pilot that was offered to approximately 500 customers with Nest thermostats. Nest administered eight demand response (DR) events to reduce peak cooling loads for those customers during the summers of 2017 and 2018. In evaluating the RHR program, Slipstream measured average air conditioning demand reductions that were comparable to those reported by Nest (62%) and found that customers were largely satisfied by the program.

Unlike the RHR pilot, the MGE Connect "bring your own device" (BYOD) program is open to customers with various smart thermostat brands including Nest, Ecobee and Honeywell. A new vendor, EnergyHub, administers demand response events, customer surveys and energy savings reporting. Between 200 and 400 customers participated in the three demand response events in 2019 and nine in 2020 (Table 1). To evaluate demand reduction, we compared smart thermostat cooling runtime data among these event participants and a comparable control group of non-participants. By analyzing whole-home advanced metering infrastructure (AMI) data for a subset of participants we were able to estimate how changes in cooling runtime translated into load reductions (watts) and overall electricity savings (kWh).

In this report we present the results of the demand reduction and electricity savings analysis on the BYOD program. We also compare our evaluated load reduction estimates to those reported by EnergyHub and examine if thermostat brand affects participant demand reduction. Lastly, we include a summary of customer experiences in the program based on surveys conducted by EnergyHub.

Table 1. Summary of 2019-2020 MGE Connect DR event characteristics and participation rates.

Date	Precool	Start time	Duration (hrs)	Mean Outdoor temp. (F)	Control Group (n)	Treatment Group (n)
7/18/2019	Yes	4:00PM	2	86	227	224
8/5/2019	Yes	3:00PM	2	84	224	217
9/3/2019	Yes	3:00PM	3	80	354	360
6/2/2020	Yes	4:00PM	2	89	392	390
6/4/2020	Yes	4:00PM	2	85	407	390
6/8/2020	Yes	5:00PM	2	88	403	391
6/18/2020	No	5:00PM	2	84	404	390
7/2/2020	No	5:00PM	2	88	399	393
7/6/2020	Yes	4:00PM	2	90	392	386
7/8/2020	Yes	4:00PM	2	88	402	392
8/24/2020	Yes	4:00PM	2	88	405	383
8/26/2020	Yes	4:00PM	2	89	402	386
MEAN	**83%**	**4:05PM**	**2.1**	**86**	**367**	**356**

ENERGY AND DEMAND ANALYSIS

To evaluate demand reductions and energy savings for MGE Connect we used a randomized control study design where the cooling runtime of a control group was compared to that of MGE Connect DR event participants (treatment group).[1] We used an estimate of air conditioner power to calculate load reductions and energy savings from cooling runtime. We used air conditioner power estimates from a previous 2017-2018 analysis that used linear models and simple disaggregation algorithms to estimate AC loads for fifty homes with combined whole-house AMI, weather and smart thermostat data.[2] We used 2019-2020 AMI data from a subset of

[1] EnergyHub uses an algorithm that estimates load reductions for each customer by comparing cooling loads during the event to a typical baseline load for the customer on similar non-event days. Therefore, load reductions reported by EnergyHub for each event are based on the relative reduction in cooling runtime and the estimated power draw for each customer's air conditioner. As we only had data for air conditioner runtime on event days, we were not able to use this method of estimating baseline profiles of AC operation for each customer which can be compared to profiles observed on comparable event days.

[2] We decided to use these previous estimates because no key was available to merge smart thermostat and AMI data for the same customer. We did have some success matching the two datasets based on correlations between air conditioner runtime and power readings. AC power estimates from this data were similar to those estimated previously. Even so, only the previous estimates of AC power were used here so as to avoid introducing additional uncertainty in the analysis arising from possible matching errors. The following formula was used to estimate AC power: AC_power (watts) = AC_runtime x (1313 + 15.6 x Outdoor_temp.). Therefore, for this pilot the expected AC load for a participant would be 2,560 watts at 80 °F and 2,795 watts at 95 °F.

approximately 100 customers to provide an additional external validation of the load reduction trends estimated from the smart thermostat data provided by EnergyHub.

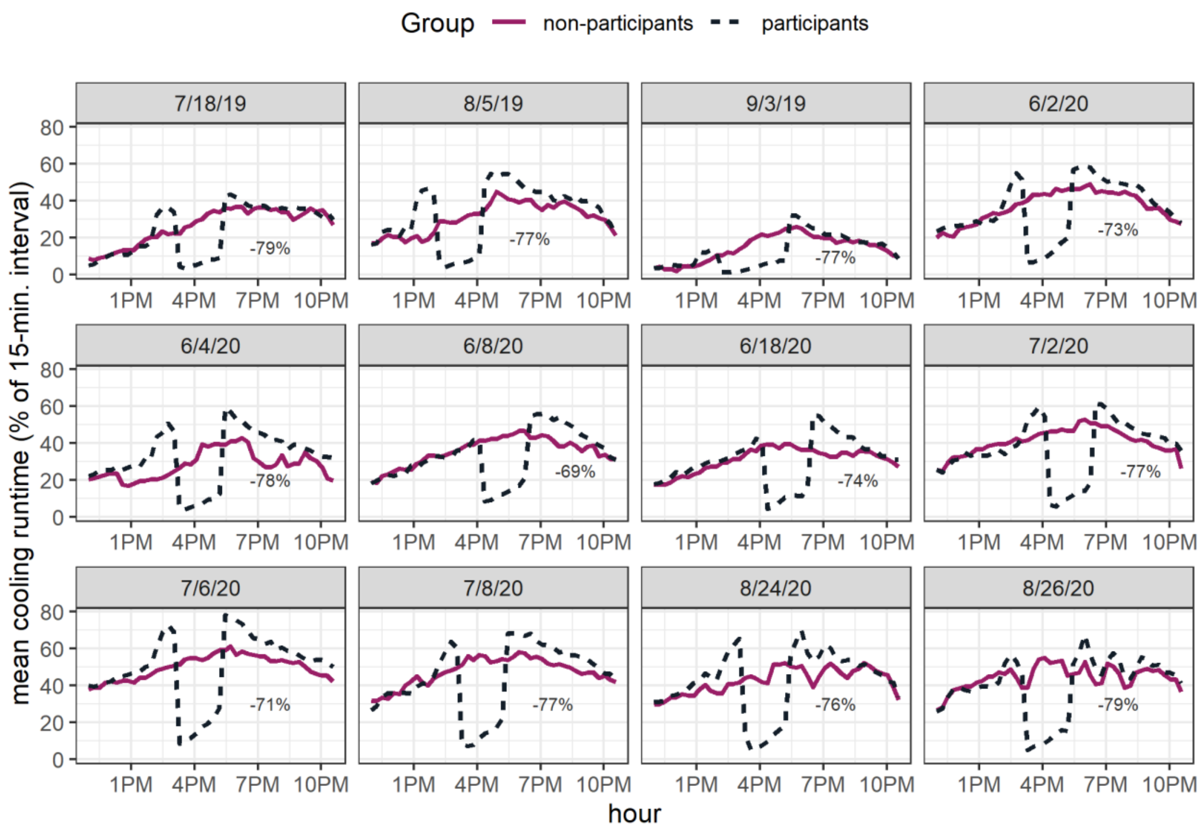
The difference in the mean cooling runtime, load, and energy consumption between the participants (treatment group) and non-participants (control group) provides an estimate of the demand reduction during the two- to three-hour event windows. When calculating the reduction in cooling runtime, we calculated the mean fraction of an event phase during which the air conditioner was running across participants and non-participants. For example, if a customer's air conditioner was running for a total of 30 minutes of a two-hour event they would have a cooling runtime fraction of 0.25. Similarly, to estimate the mean per-participant load reduction (watts), we estimated the mean power for each participant during event periods as a function of the rate of AC operation and outdoor temperature and then calculated the difference between the participant and non-participant groups. To estimate energy savings (kWh) we compared the mean total energy consumption during the event period plus one hour prior and one hour after the event window. This one hour buffer allowed us to account for the increase in energy use observed in precooling (one hour prior to the event) and in the rebound phase after the event where participant air conditioners run more to cool the home back down to the set point temperature. We then compared these demand reduction and energy savings estimates to those reported by EnergyHub.

Standard statistical bootstrapping procedures using 10,000 sampling iterations were used to generate 95 percent confidence intervals for estimates of both demand and energy savings for each event and across all 12 events. These bootstrapped confidence intervals were designed to account for the variation in response both between participants and between event dates.

ENERGY AND DEMAND REDUCTIONS

A comparison of the profiles of cooling runtime between the participants and non-participants shows that the planned DR events are consistently producing the intended effect across the 12 event days. For participants, we see an increase in air conditioning operation in the one-hour precooling phase followed by a 70-80 percent reduction in runtime during the event window followed by a slight increase in cooling runtime in the hour after the event. As expected, during the events on June 8 and June 18, 2020, where no precooling phase was called, we see no difference in the cooling runtime between the event participants and non-participants in the hour leading up to the event (Figure 1).

Figure 1. Comparison of mean cooling runtime as a percent of each 15-minute interval on the twelve event days for the treatment and control groups. Plot labels indicate the percent change in cooling runtime during the event window between the control and treatment groups.



Across all events, the mean reduction in cooling runtime during the event window was 76 percent (95 percent CI: 73 to 79 percent) with a range of 69 (±6) to 79 (±5) percent (Table 2). Based on our air conditioner power estimates, this translates to a mean load reduction of 832 watts (95 percent CI: 691 to 955 watts) and a mean energy savings of 0.94 kWh (95 percent CI: 0.61 1.27 kWh). Across the events, estimated per participant load reductions ranged from 355 (±76) to 1,076 (±112) watts and estimated energy savings ranged from 0.02 (±0.64) to 1.73 (±0.55) kWh.

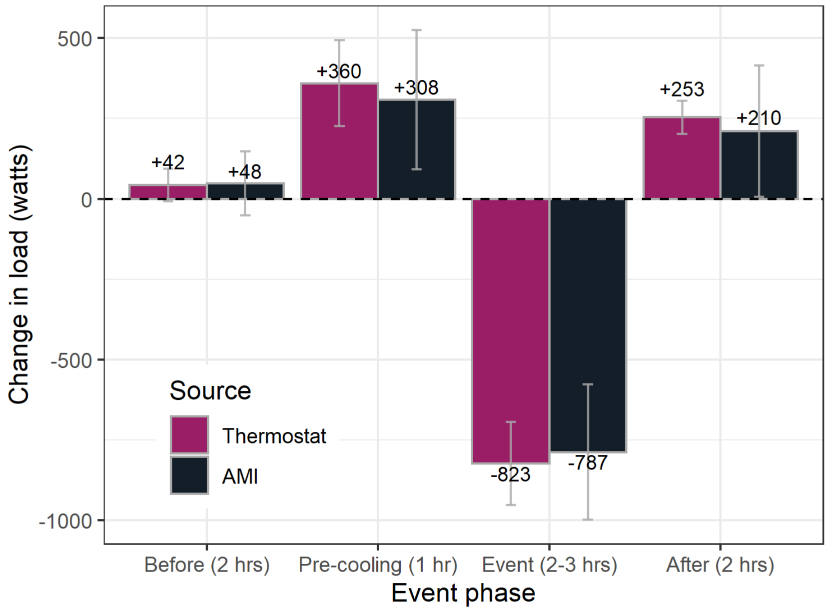
It is worth noting that the event with the smallest estimated per-participant load reductions (355 watts on 9/3/19) had the lowest mean outdoor temperatures (80 ºF). This unusually low outdoor temperature likely reduced the amount of cooling required and reduced the average load. It is also worth noting that compared to load reductions, we see more uncertainty in the estimated per-participant energy savings across each event with some events showing no significant energy savings and others showing savings exceeding 1.5 kWh. In part, this reflects the wide variation in how much precooling happens for each participant. This is discussed more in the next section.

Table 2. Summary of energy savings outcomes for demand reduction events. All savings estimates were calculated on a per-participant basis. Uncertainty estimates in parenthesis represent symmetrical 95% bootstrapped confidence intervals.

Date	Cooling Runtime Reduction (%)	Est. Load Reduction (watts)	Est. Energy Savings (kWh)
7/18/2019	79 (±8)	617 (±132)	0.79 (±0.63)
8/5/2019	77 (±9)	610 (±130)	0.02 (±0.64)
9/3/2019	77 (±8)	355 (±76)	0.75 (±0.39)
6/2/2020	73 (±6)	872 (±122)	1.15 (±0.6)
6/4/2020	78 (±6)	698 (±104)	0.05 (±0.51)
6/8/2020	69 (±6)	818 (±121)	1.28 (±0.58)
6/18/2020	74 (±6)	742 (±111)	0.83 (±0.45)
7/2/2020	77 (±5)	998 (±114)	1.42 (±0.47)
7/6/2020	71 (±5)	1052 (±125)	0.91 (±0.59)
7/8/2020	77 (±5)	1111 (±117)	1.58 (±0.58)
8/24/2020	76 (±5.)	946 (±109)	0.74 (±0.55)
8/26/2020	79 (±5)	1067 (±112)	1.73 (±0.55)
MEAN	**76 (±3)**	**823 (±132)**	**0.94 (±0.33)**

The mean difference in whole-home loads between participants and non-participants from the AMI meter data shows similar results to what we estimated using the thermostat data (Figure 2). For all event phases (before, pre-cooling, event and after) the 95 percent confidence intervals for the estimated change in load (watts) overlap suggesting that there is no significant difference between these estimation methods. Unlike the thermostat data which reflects a direct measurement of cooling runtime, the AMI load data is for the whole-home and therefore changes in non-cooling loads during events can mask the effect of the DR event on air conditioner loads. For this reason and because the AMI sample is smaller, the estimated load changes from the AMI data may be less reliable than those estimated from the thermostat data. Even so, the close correspondence between these two estimates provides some external validation that the thermostat data provides an accurate reflection of how the DR events are affecting cooling loads.

Figure 2. Comparison of estimated average load reduction per participant between the smart thermostat data and AMI data for each event phase. Error bars represent standard 95% confidence intervals.



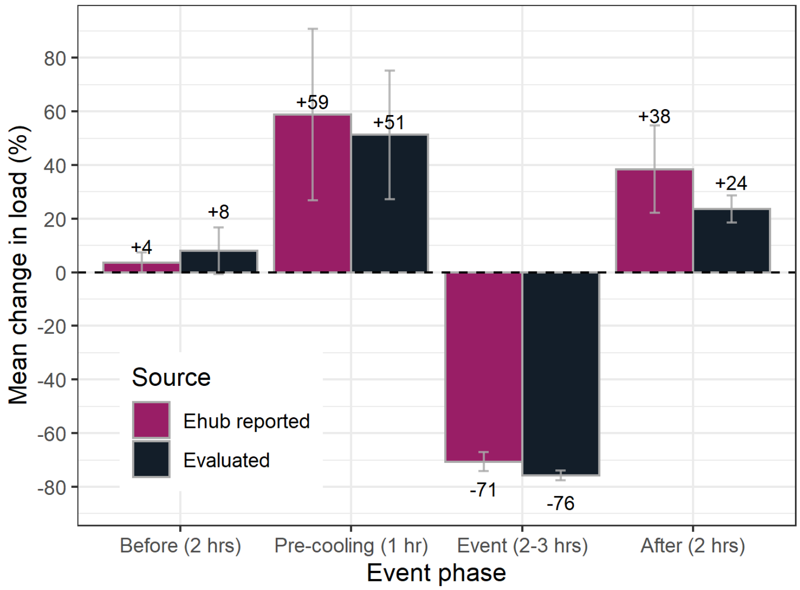
COMPARISON TO ENERGYHUB REPORTED DEMAND REDUCTION

To compare our demand reduction estimates to those reported by EnergyHub, we first compared the mean percent change in load for each "event phase": prior to the event, precooling, the event window and the period after the event. EnergyHub reports total estimated load reduction (kW) across all participants. To reduce some uncertainty around how EnergyHub estimates the participant total for each event, we did not convert our per-participant load reduction estimates to a total population or convert EnergyHub's estimates to a per-participant basis. Rather we compared the relative percent change between the baseline and demand reduction groups.

As shown in Figure 3, the overall expected effect of event participation on loads is similar between our evaluated estimates and those reported by EnergyHub. As expected, we see no significant change in load prior to the event (error bars overlap zero), followed by a significant 50-60 percent increase in air conditioner loads during precooling. The event phase typically produces a 70-75 percent reduction in loads and the hour after the event produces a significant increase (15 to 25 percent) in loads. Although we see some differences in the EnergyHub versus evaluated differences in loads by event phase, in all cases the 95 percent confidence intervals overlap suggesting that the estimates are comparable.

As noted earlier, the relatively wide fluctuation in load during precooling likely contributes to the variation in energy savings (kWh) between events and participants. Events with more precooling will have lower overall energy savings per participant, all else being equal.

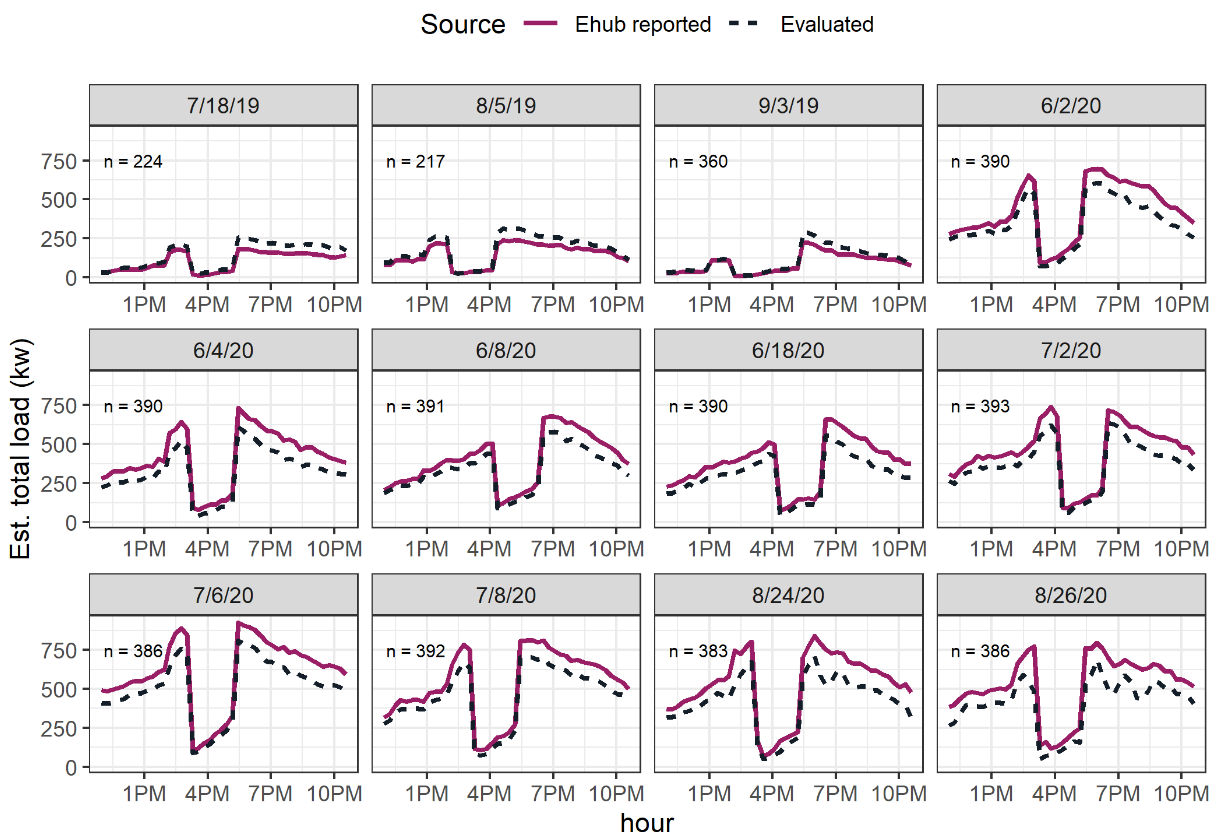
Figure 3. Comparison of percent changes in load compared to expected baseline for each event phase between EnergyHub and evaluated estimates.



Although there is some uncertainty in how EnergyHub estimates total load for event participants, we compared the expected total loads for all participants using our evaluation method to those reported by EnergyHub. The results shown in Figure 4 indicate that our analysis estimates similar total load reductions across participants to the values reported by EnergyHub.

Some of the differences seen in the estimates may come from using slightly different numbers of event participants and differences in assumptions in air conditioner power. For example, an examination of the EnergyHub load estimates suggests that they mostly apply a fixed estimate of 2,600 watts for air conditioner power that does not vary with outdoor temperature while our air conditioner load estimation includes an upward adjustment for increasing outdoor temperature. Overall, it appears that the EnergyHub reported load reductions for events are reasonably accurate.

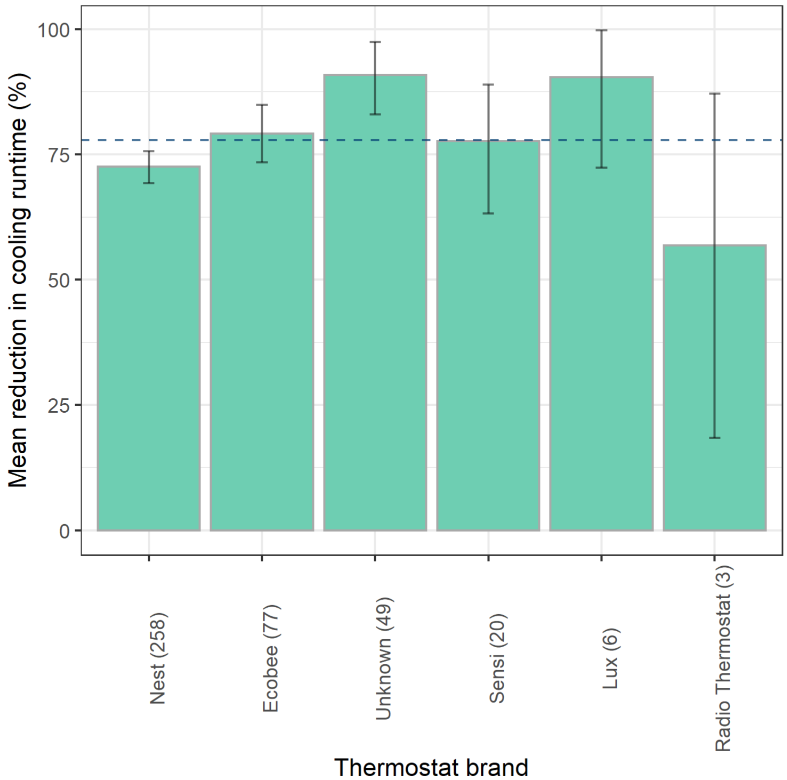
Figure 4. Comparison of total loads for event participants by data source.



COMPARISON OF THERMOSTAT BRANDS

Unlike the previous “Rush Hour Rewards” residential DR pilot program, which was delivered only to customers with thermostats provided by Nest, the MGE Connect program included a variety of smart thermostat brands. Using the available data, we looked for evidence that the thermostat model effected the observed demand reduction. Based upon the available data, we do not see evidence of significant differences in the mean reduction in cooling runtimes during events for different thermostat brands (Figure 5). However, thermostat brand is missing for a significant fraction of the participants and Nest is by far the most common brand. This missing data arose from incompatible thermostat identification keys between program years and different EnergyHub data export files. In the future, as a larger sample of thermostat brands show up in the program and the ability to track demand response outcomes by thermostat model improves, it would be useful to confirm that no differences exist.

Figure 5. Mean reduction in cooling runtime during events by smart thermostat brands. The horizontal line represents the overall mean reduction across all brands. Error bars represent bootstrapped 95% confidence intervals. The numbers in parentheses next to each thermostat brand are the mean number of participants with that brand across the 12 events.



Note: The "Unknown" category arose from some of the device keys changing between years and different data exports provided by EnergyHub. Alarm.com was excluded from this summary because none of the participants with that model had any air conditioner operation during events. The Vivint GoControl model was excluded because only one participant had that brand.

CUSTOMER PERSPECTIVE

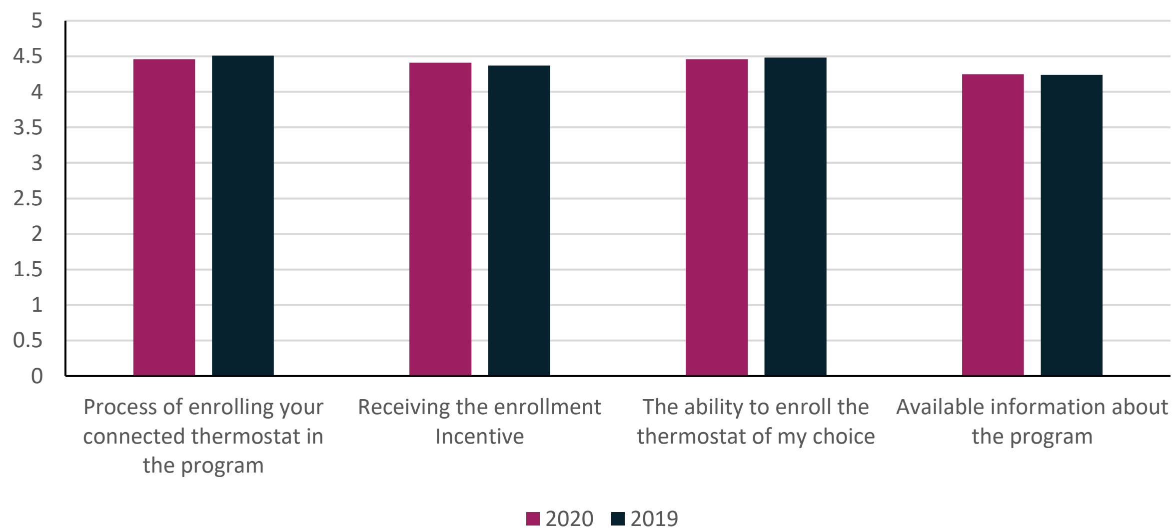
The customer survey conducted by EnergyHub had 262 customer responses in 2020 and 430 in 2019. The participants were roughly 90 percent single-family homes, and close to 60 percent of participants had a Nest thermostat. Ninety percent of 2019 respondents had a smart thermostat prior to enrolling in the program while only 73 percent of 2020 respondents did. Close to 65 percent of all respondents found out about the program either through an email or bill insert from MGE.

The survey asked several questions about why participants both purchased a smart thermostat and why they enrolled in the program. The three top reasons for purchasing a thermostat in both 2019 and 2020 were to be more energy efficient, to be able to access the thermostat remotely, and to save money. However, the top reasons for enrolling in the MGE Connect program differed between 2019 and 2020. In 2019, the top reason was the enrollment incentive while in

2020, it was to reduce the adverse impact on the environment. In both years, the second most popular reason for enrolling in the program was to save money.

The survey also asked how satisfied customers were with the enrollment process overall. Figure 6 shows a weighted rating (from one to five) for how satisfied all participants were with each aspect of the enrollment process. As it shows, customers were generally satisfied with all aspects of the enrollment process, with ratings above four for all aspects and across both years.

Figure 6. Mean satisfaction ratings with the enrollment process by program year.

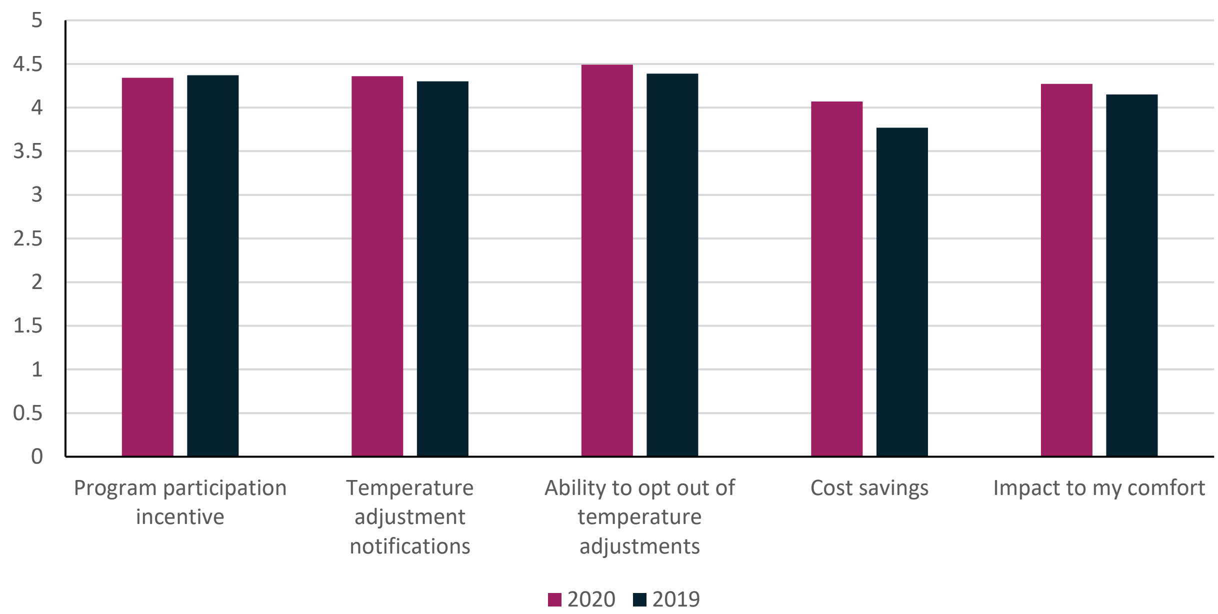


Another set of survey questions focused on behavior during the events. In both years, more than 70 percent of customers never opted out of a temperature adjustment. Most people who had opted out of an event had only done so one or two times. There were three primary reasons in both years why participants opted out of an adjustment. The primary reason was that someone in their family was home during the adjustment, the second reason was that it was at an inconvenient time, and the third was that it negatively affected their comfort.

Participants were asked to indicate their preference for different ways they might receive incentives for participating in future demand response events through the program. Around 45 to 50 percent of customers indicated that they would prefer receiving the incentive through a bill credit while about 20 percent indicated a preference for an electronic or physical gift card.

The last set of questions focused on customers' overall satisfaction with the program. The survey asked participants to rank their satisfaction (rating scale of one to five) for five different aspects of the program. Figure 7 below provides a weighted average of the ranking provided by participants in both 2020 and 2019 for each of the five aspects. The results indicate that participants were largely satisfied with the program with an overall satisfaction rating of 4.5 and 4.4 in 2020 and 2019 respectively. The lowest ranking was related to cost savings. Some 2019 respondents commented that they did not notice any cost savings from being involved with the program. In 2020, a similar open-ended question was not asked.

Figure 7. Mean overall program satisfaction ratings by program year.



Lastly, between 58 and 66 percent of respondents stated that they would recommend the program to others. When asked what would make people more willing to recommend the program, most comments from both 2019 and 2020 suggested a larger incentive would make them more likely to recommend the program.

CONCLUSIONS

The MGE Connect smart thermostat program effectively sheds residential cooling loads on hot summer days. We estimated that across the 12 events participants reduced their cooling runtime by 73-79 percent compared to a similar group of non-participants. We estimate that this reduction in cooling runtime translates to a mean load reduction of 691 to 955 watts per participant during the two-to-three-hour event windows. Our evaluated load reduction estimates are comparable to those reported by EnergyHub. Based on available data, we did not see evidence that thermostat brand affected load reduction outcomes among participants. Overall customers were satisfied with the program and the enrollment process and most would recommend the program to others. Most would be more likely to recommend the program with larger incentives for participation.