MICHIGAN TIER 3 THERMOSTAT CALIBRATION STUDY

PRESENTATION TO THE MICHIGAN ENERGY WASTE REDUCTION COLLABORATIVE

MOLLY PODOLEFSKY, NAVIGANT CONSULTING, INC.

MAY 15, 2018

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BACKGROUND
MEASURE DESCRIPTION

Tier 3 thermostats are enhanced by data gathering and analytics functionalities, which enables them to use a variety of methods to optimize HVAC settings for efficient and automated energy consumption. Specifically, a Tier 3 thermostat is defined as a thermostat that is compatible with the participant's HVAC system, and has

- Two-way communication,
- Occupancy detection (through the use of occupancy sensors, geo-fencing, etc.), and
- At least two of the following features: scheduled learning, heat pump auxiliary heat optimization, up-staging/down-staging optimization, humidity control, weather-enabled optimization, and free-cooling/economizer capability.

Nest

Honeywell

ecobee

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BACKGROUND
MEASURE HISTORY

Tier 3 thermostats were first included in the 2016 Michigan Energy Measures Database (MEMD).

- Measure savings was based on 12 studies from across the United States, with the expectation that savings would be calibrated once a sufficient number of thermostats were installed through Michigan utility programs.

- At the end of 2016, DTE Energy and Consumers Energy had installed approximately 19,000 Tier 3 thermostats. By the start of 2018, with 12 months of post-installation data for these thermostats, Navigant had sufficient data to directly estimate savings.

MEASURE PROGRAM SUMMARY

Our analysis is based on customers that installed Tier 3 thermostats through DTE and CMS programs during calendar year 2016.

DTE Programs

Audit & Weatherization
Energy Efficiency Assistance
Home Energy Consultation
HVAC
Multi-Family Residential
Residential Energy Star & Lighting

CMS Programs

Energy Star Appliances
Home Performance with Energy Star
Residential HVAC & Water Heating
Residential Home Energy Audit

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STUDY OBJECTIVES

The objective of this study is to calibrate Tier 3 thermostats for inclusion in the 2019 MEMD.

- Specific study objectives include conducting:
  - (1) primary research to calibrate the electric energy savings factor for space cooling and heating, and the gas energy savings factor for space heating, and
  - (2) secondary research to update measure characterization.

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SAVINGS ANALYSIS OVERVIEW

- **Slides in this section provide a high-level overview of the methodologies employed in this study.**

- **The Appendix contains detailed descriptions of all methodological components, including:**

  - Full regression specifications
  - Definitions of all variables included in regression models
  - Explanations of how cooling and heating savings are calculated based on regression outputs
  - Description of the uplift calculation methodology
  - Comparisons of different zip cluster matching results relative to matching on single zip codes
  - Full regression outputs for preferred gas and electric specifications
  - Full regression outputs for a series of alternate model variants, both for gas and electric savings, to show robustness of the model and provide additional detail on savings by subpopulations of interest

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METHODOLOGY
STUDY PERIOD

The evaluation period for this study is 2014 through 2017.

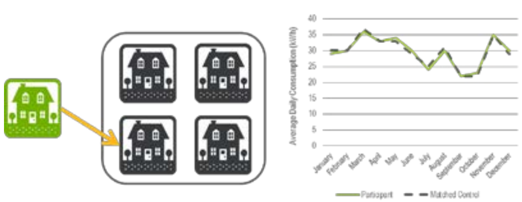
$$ADU_{k,t}$$
$$= \alpha_k + \beta_1 HDD_{65,k,t} + \beta_2 CDD_{65,k,t} + \beta_3 post_t + \beta_4 post_t * HDD_{65,k,t} + \beta_5 post_t * CDD_{65,k,t} +$$
$$\beta_6 treat_k * HDD_{65,k,t} + \beta_7 treat_k * CDD_{65,k,t} +$$
$$\beta_8 post_t * treat_k + \beta_9 post_t * treat_k * HDD_{65,k,t} + \beta_{10} post_t * treat_k * CDD_{65,k,t} + \varepsilon_{k,t}$$

2015
Pre-Program Period

2017
Post-Program Period

2014
Matching Period

2016
Installation Period



Refer to Appendix A for the linear fixed effects regression analysis and calculation for determining uplift.

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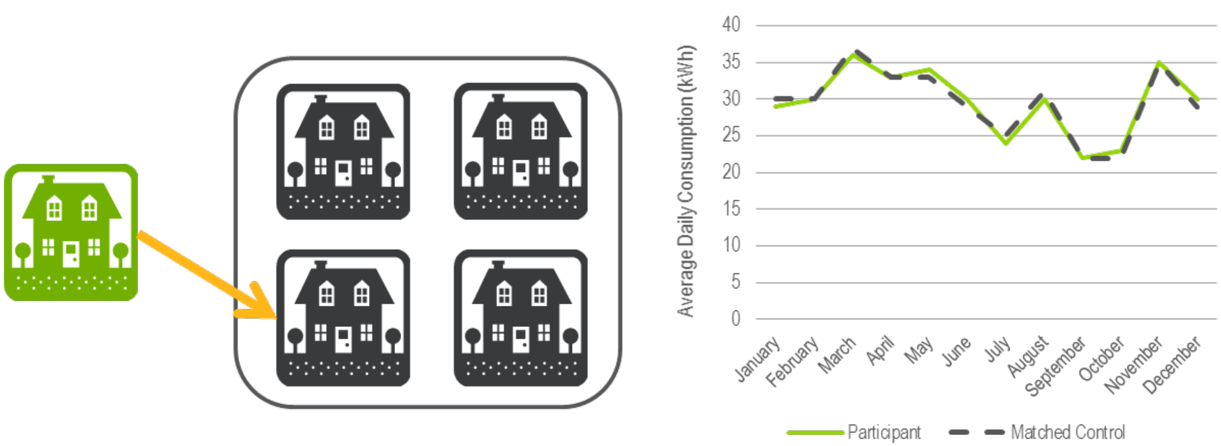
SAVINGS ANALYSIS OVERVIEW

Energy impacts were estimated using regression with pre-program matching (RPPM).[1]

- RPPM is a quasi-experimental approach whereby a comparison group is constructed consisting of non-participants with the most similar pre-program period consumption patterns to program participants, by using Euclidean distance ("nearest neighbor") matching.

Figure 1. Hypothetical Illustration of Choosing Matched Control Households with Similar Pre-Program Energy Usage



[1] The evaluation team employed the same methodology to update the residential advanced thermostat measure in the Illinois Technical Reference Manual Version 7.

METHODOLOGY

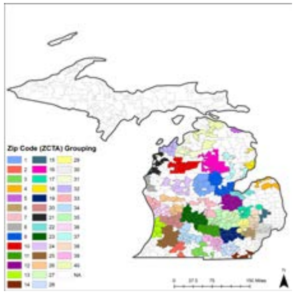
MATCHING METHODOLOGY

Matching was performed within utility, within zip code cluster, and either within HER wave for HER participants, or within HER non-participants.

- There were a large number of cases in which a single thermostat was installed within a zip code
- Due to a limited matching pool for CMS, and because we had to find matches also within HER wave, this would have dropped many zip codes
- Accordingly, we created clusters small zip clusters using Geographic Information Systems (GIS) software to match within

DTE Energy

Consumers Energy



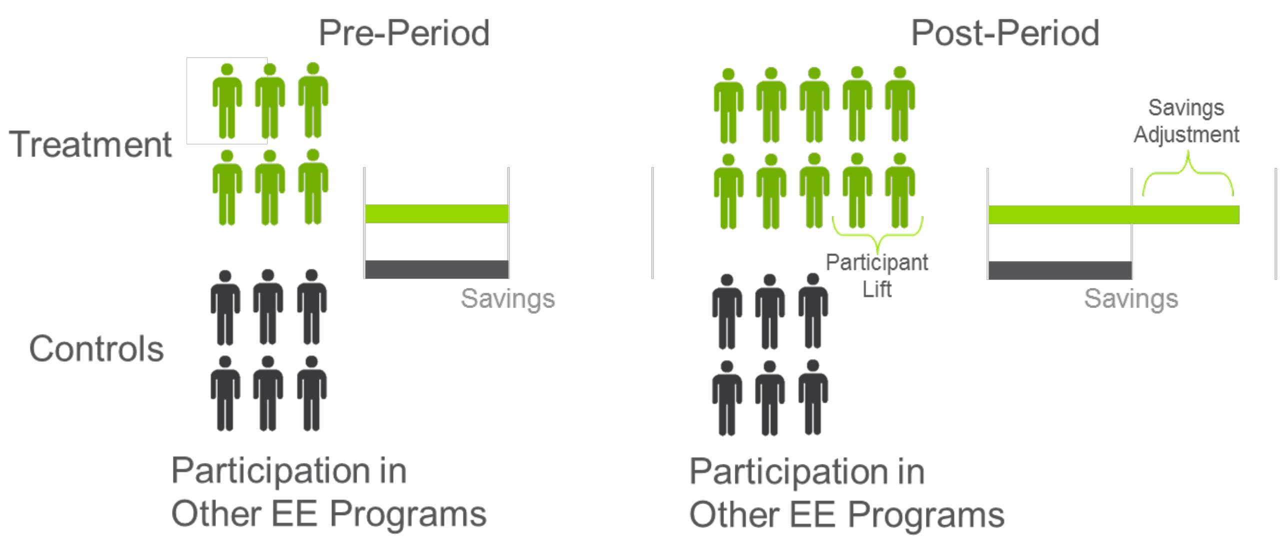
Note: For robustness we created two levels of zip clusters—large and small--and compared results of both versus single zip-based matches. Refer to Appendix B for these results. Large zip code clusters utilized latitude and longitude to create clusters of the nearest neighbor zip codes limiting the total number of clusters to 20; Small zip code clusters utilized the same approach to create clusters limiting the total number of clusters to 40. The graphics above show small zip clusters.

UPLIFT ANALYSIS

After conducting matching, we estimate a linear fixed effects regression model to determine energy savings, accounting for uplift.

- The installation of a Tier 3 thermostat may increase participation in certain other energy efficiency programs. To avoid double-counting, the savings associated with program uplift are subtracted from the Tier 3 thermostat savings.

Illustration of Uplift Analysis



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SUMMARY

- **The following slides provide a detailed review of data cleaning, including starting and final populations by utility and program, and the percent of participants lost at each cleaning stage**
  - It also provides summary statistics describing key characteristics of the final population used in our analysis

- **This section also provides detailed plots demonstrating the closeness of treatment and matched control customer energy usage in the matching period (2014) and throughout the pre-period (2015) prior to thermostat installation**
  - Percentage difference plots are provided and demonstrate that our matches are extremely close

DATA COLLECTION

We collected, combined and cleaned program tracking data, monthly energy consumption data, and weather data from both DTE Energy and Consumers Energy between Jan 1, 2014 and Dec 31, 2017.

- 2014-2017 Program Tracking Data from DTE and CMS
- 2014-2017 Residential Monthly Energy Consumption Data (Electric and Gas) from DTE and CMS
- 2014-2017 Michigan Weather Data from National Oceanic and Atmospheric Administration

DATA MANAGEMENT

The savings analysis included 6,479 unique Tier 3 thermostat customers.

Data Cleaning	DTE	CMS
Commercial Customers	2%	<1%
Outliers	0%	0%
<10 months pre or post data	44%	44%
Duplicates	0%	0%
Miscellaneous	2%	2%
Multiple Measures	19%	6%
Total Remaining (%)	33%	41%
Total Remaining (Count)	4,108	2,371

DATA MANAGEMENT

The electric savings analysis included 4,466 Tier 3 thermostat customers and the gas savings analysis included 3,697.

	DTE	CMS
Electric		
Raw Participant Count	9,198	3,332
Final Participant Count	3,151	1,315
Matching Pool	1,130,930	63,733
Gas		
Raw Participant Count	7,881	4,673
Final Participant Count	1,985	1,712
Matching Pool	621,325	92,756

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DATA MANAGEMENT & MATCHING

COUNTS BY PROGRAM

Customers were removed from the analysis if they installed measures in addition to thermostats through the same program during the study period.

CMS programs	Raw	Final
Energy Star Appliances	5,774	2,384
Home Performance w/ Energy Star	99	0
Residential HVAC & Water Heating	576	36
DTE programs	**Raw**	**Final**
Audit & Weatherization	4	0
Energy Star Appliances	29	0
Home Energy Consultation	3,897	312
HVAC	1,142	41
Multi-Family Residential	33	0
Residential Energy Star and Lighting	7,953	3,700

Note: Raw values are the total participants in our dataset before any data cleaning; Final are the total counts by program, post-cleaning.

DESCRIPTIVE STATISTICS

The following summary tables describes the final sample of Tier 3 thermostat participants used in our analysis.

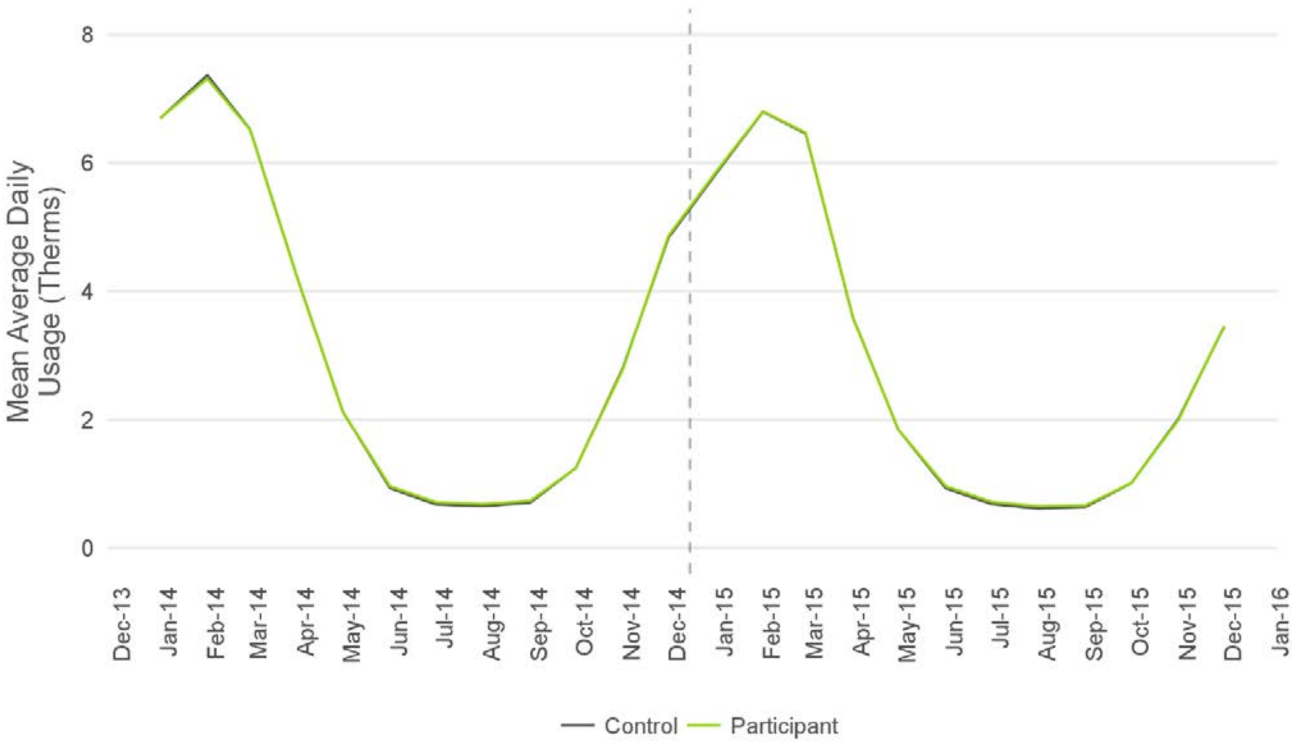
Characteristics	Percentage
DTE	63%
CMS	37%
Electric Only	43%
Gas Only	31%
Dual Fuel	26%
Nest Thermostat	53%
ecobee Thermostat	11%
Other/Unknown Thermostat	36%
Multiple Thermostats	3%

Note: Multi-family versus single family status was not captured in DTE's Energy Star program tracking data. As a result, we cannot comment on the overall proportion of multi-family to single family homes represented in the study.

GAS MATCHING RESULTS

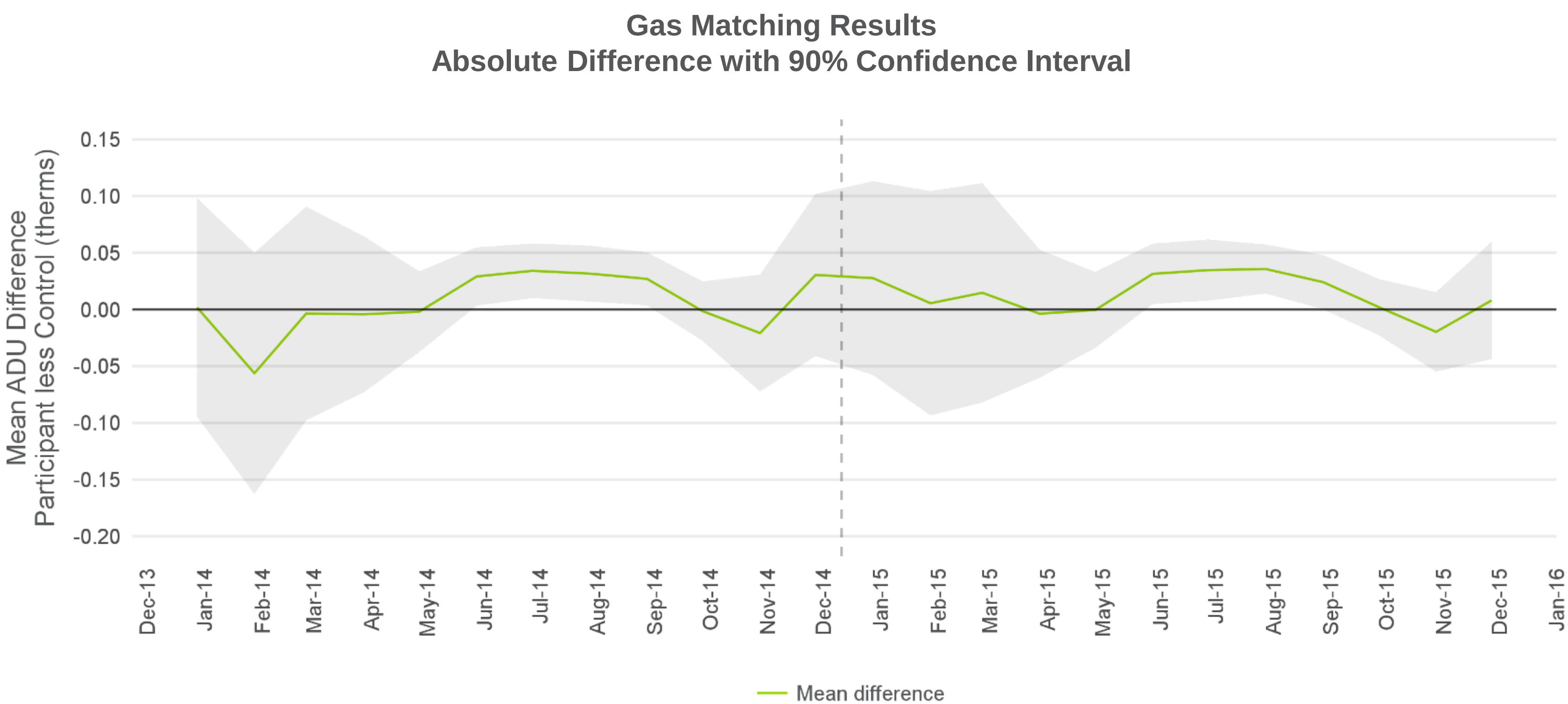
The matched comparison group had very similar usage patterns throughout the pre-program period (2015).

Gas Matching Results
Average Daily Usage Comparison between Participants and Matched Controls



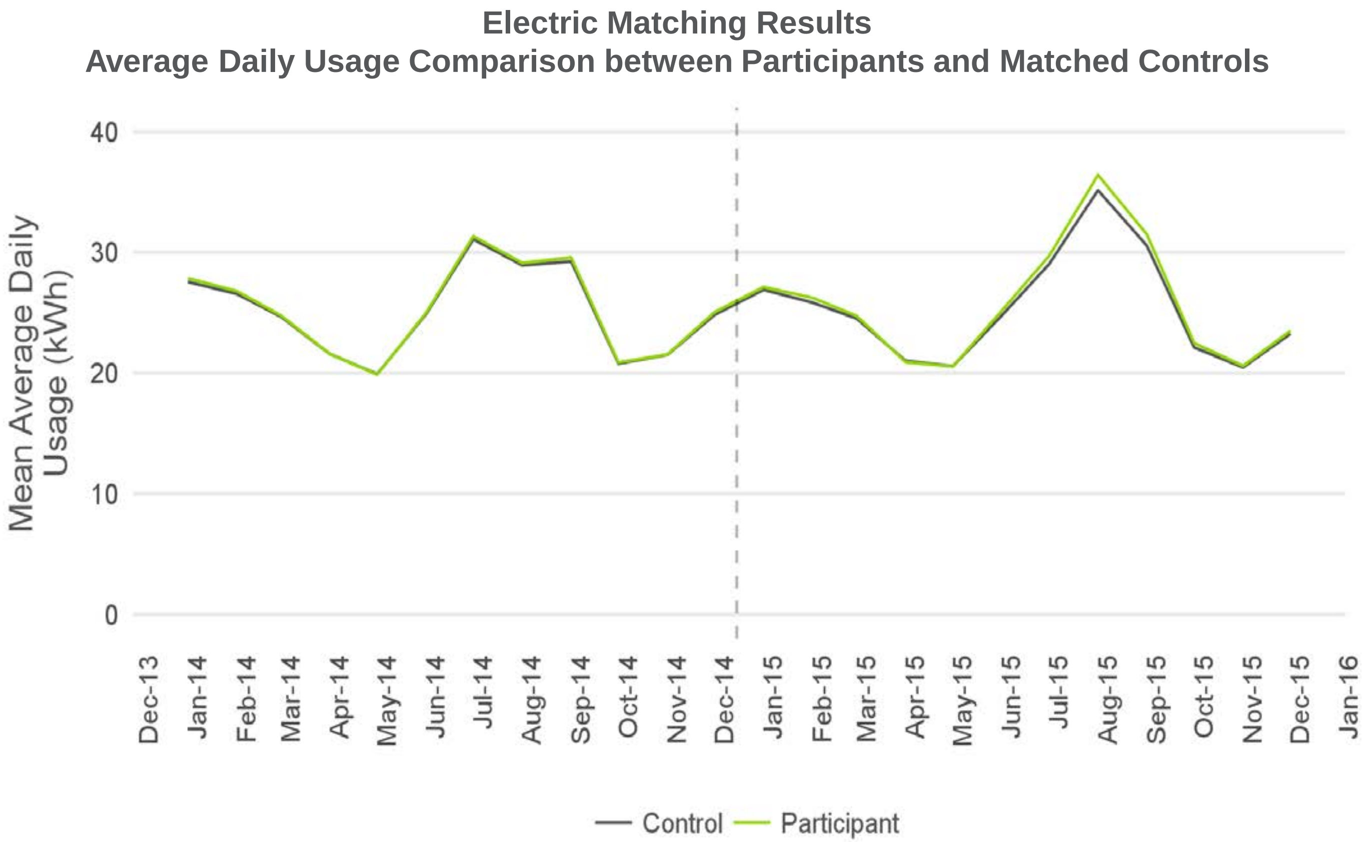
GAS MATCHING RESULTS

Any remaining differences between the matched comparison group and participants are accounted for in the linear fixed effects regression model.



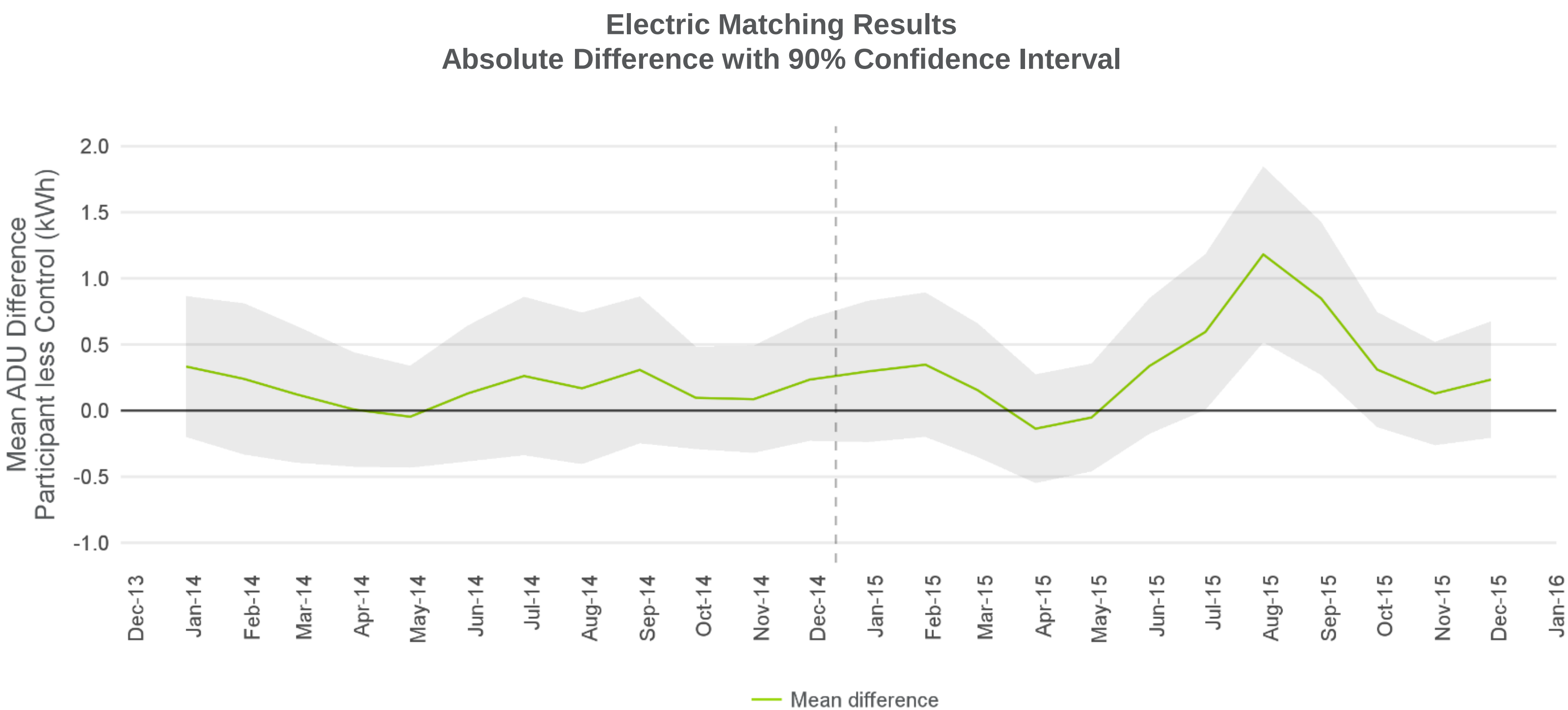
ELECTRIC MATCHING RESULTS

The matched comparison group had very similar usage patterns throughout the pre-program period (2015).



ELECTRIC MATCHING RESULTS

Any remaining differences between the matched comparison group and participants are accounted for in the linear fixed effects regression model.



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SUMMARY

- **The slides in this section provide detailed results from our preferred model specification**
  - This specification uses small zip code cluster-based matches, and removes all participants that installed additional measures beyond thermostats through the same program during the study period
  - Because Nest gas savings (excluding other thermostat models) were found to be statistically significant, we report those savings in this section as well
    - Other models such as Honeywell and ecobee did not have large enough sample sizes to generate statistically significant regression results in isolation

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ELECTRIC SAVINGS

We find annual electric savings are not statistically different from zero. Gas savings are positive and statistically significant, while Nest-only gas savings are modestly higher and also statistically significant.

Electric and Gas Savings Summary

	Savings/yr	Savings/yr Net Uplift	Recommended MEMD Savings
Electric Total	0 kWh	0 kWh	0 kWh/yr
Gas Total	27.8 Therms (22, 33)	27.6 Therms	28 Therms/yr
Nest Gas Total	35.4 Therms (29, 41)	35.2 Therms	35 Therms/yr

Note: 90% confidence interval reported in parentheses. Electric savings were not statistically significantly different from zero, and so we do not present confidence intervals.

1. Uplift for CMS & DTE both yield approx. -0.2 kWh/yr (0.7% current savings levels) and approx. -0.1 Therms/yr (0.4% current savings levels). Refer to Appendix C for regression results.
2. Note that annual total electric savings in the MEMD will be broken out by climate zone, single or multi-family structure, heating and cooling system configurations, and other considerations that will ultimately determine what values appear in the MEMD

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SUMMARY AND METHODS

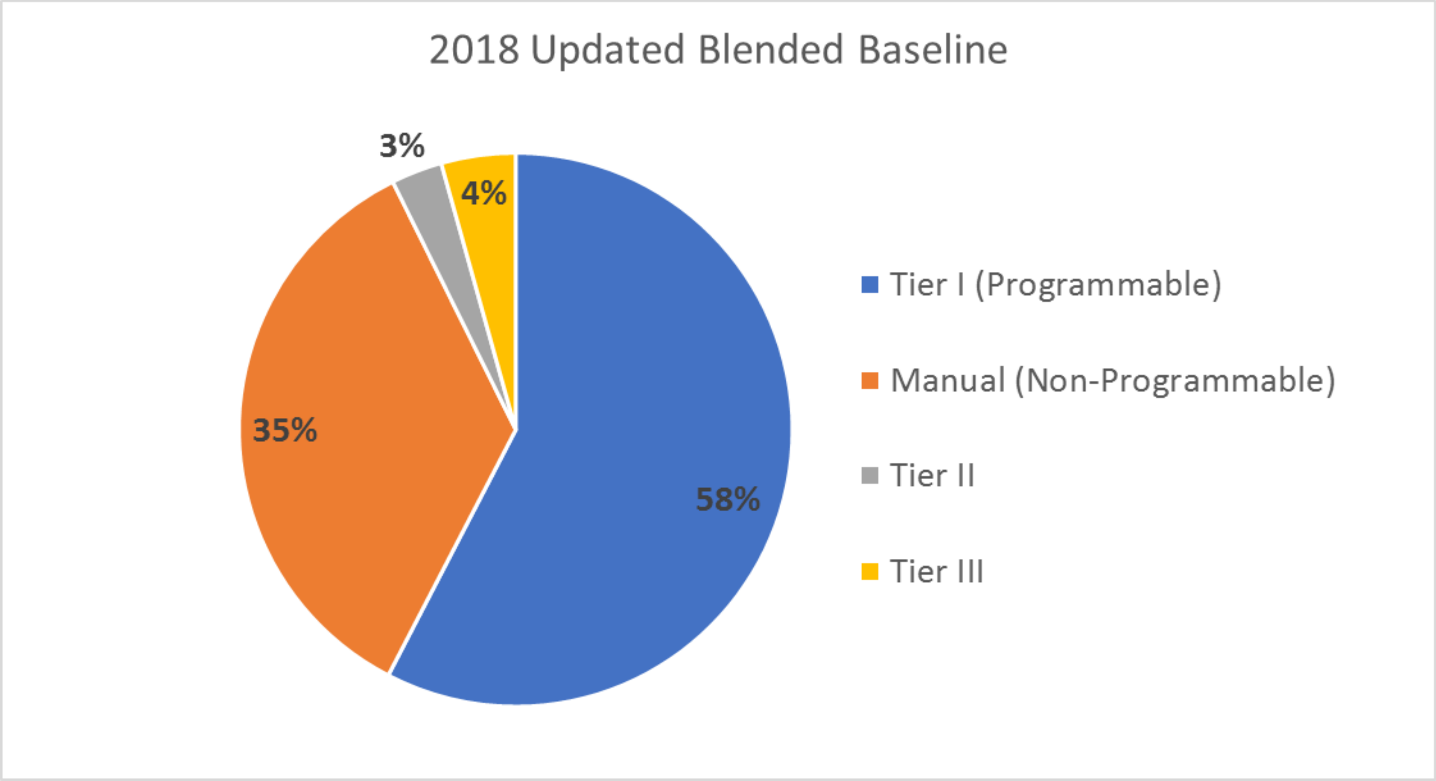
We reviewed secondary literature, conducted online research, and referenced recent utility program survey results and baseline studies to update these values.

Table 1. Approach for Review of Baseline, Incremental Cost and Measure Life

Category	2016 MEMD	Calibration Plan
Baseline	Manual Thermostat	DTE and CMS studies and thermostat-specific survey results will be referenced
Incremental Cost	$221, if actual costs are not available	Online cost collection for costs of prominent software integrated Tier 3 thermostats and baseline equipment
Measure Life	9 years	Review of state Technical Resource Manuals and manufacturer specifications

BASELINE

The market baseline represents a mix of manual, programmable and advanced thermostats.



Note: Values represent a weighted average based on data collected through various utility studies.

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INCREMENTAL COST

The incremental cost for a Tier 3 thermostat relative to the baseline is $207, a $14 decrease from the $221 value currently in the MEMD.

- The weighted average cost of Tier 3 thermostats was $254.10.
- The weighted average cost of the baseline technology was $46.76.

MEASURE CHARACTERIZATION

MEASURE LIFE

Most Technical Reference Manuals suggest a 10-year measure life.

- Navigant reviewed six current state TRMs for Tier 3 Thermostat measure life. The average value was 10 years.

MEMD	Measure Life
Existing Value [2]	9 Years
Proposed Value	10 Years

1. The existing MEMD value was established in 2016. At that time, due to the limited number of studies and lack of consensus, our research identified 9 years, the measure life for non-Tier 3 thermostats in the MEMD, as a value for Tier 3 thermostat measure life.

APPENDICES

APPENDICES

The Appendices contain the following information:

- Appendix A—Matching Detail
  - Comparison of large zip code clusters, small zip code clusters and single zip code matching results, for gas and electric separately
- Appendix B—Detailed Methodology
  - Detailed description of the LFER gas savings model
  - Detailed description of the LFER electric savings model
  - Description of uplift analysis approach
- Appendix C—Heating and Cooling Savings Methodology
  - Methodology for calculating heating and cooling savings from electric model outputs
- Appendix D—Alternate Model Results
  - This section contains regression outputs for various alternate specifications, illustrating similarities and differences of results by different subsections of the data

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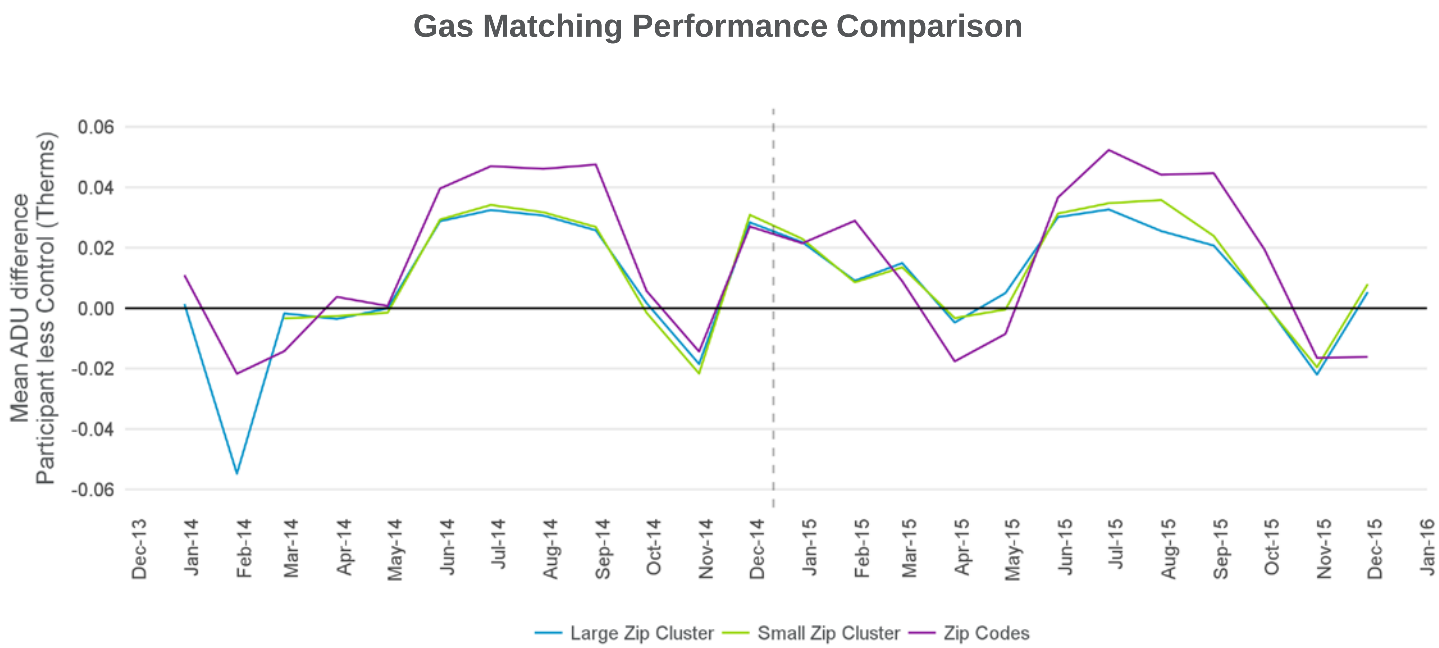
PERFORMANCE OF MATCHING WITHIN ZIP CODES

Both zip cluster levels outperformed matching within a single zip code. Because the 4- and 8-clusters performed similarly, we relied on the smaller zip cluster to be conservative.



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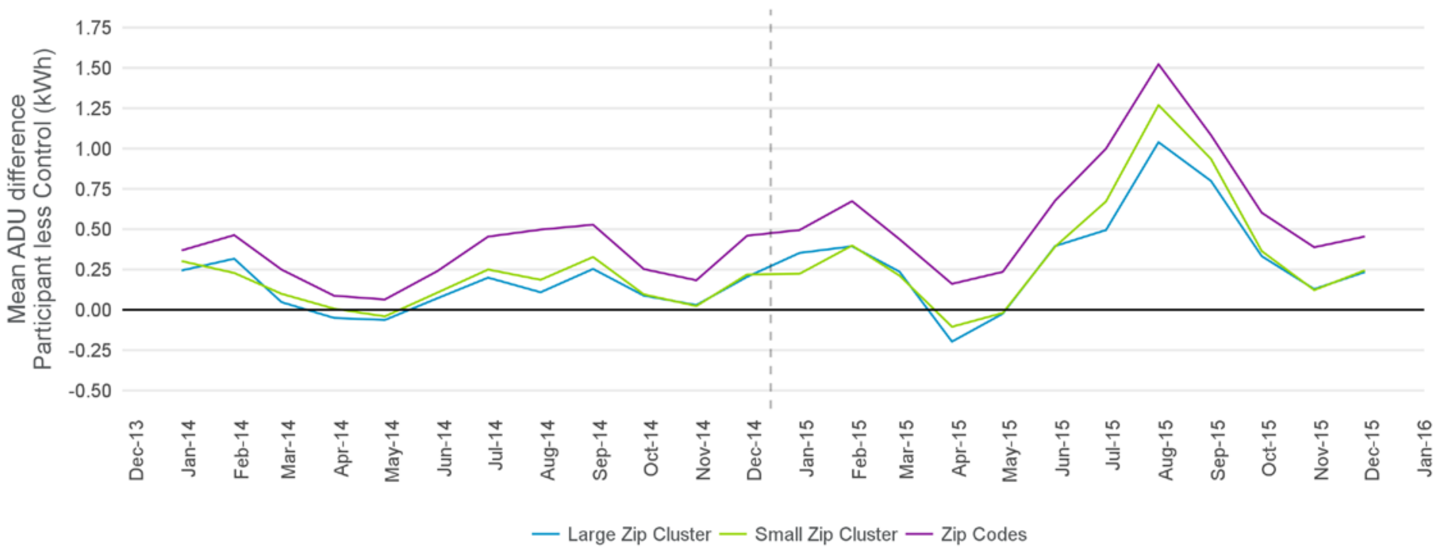
PERFORMANCE OF MATCHING WITHIN ZIP CODES

Both zip cluster levels outperformed matching within a single zip code. Because the 4- and 8-clusters performed similarly, we relied on the smaller zip cluster to be conservative.

Electric Matching Performance Comparison



APPENDIX A

MATCHING DIFFERENCES ROBUSTNESS CHECK

Though nearly identical in the matching period, we observed slight differences between the treatment and control groups the summer after matching. To ensure our model properly accounted for any remaining differences, we compared and tested regression residuals for these groups.

- Regression residuals are the difference between fitted and actual values
- We compared regression residuals between the treatment and comparison group from our main model, to see if persistent differences remained
- We performed a t-test on the treatment versus the control residuals and found that they were not statistically significantly different at the 90% confidence level
- We fail to reject the null hypothesis that there is a difference between the mean residuals between treatment and control after fixed effects regression modeling
- As a result, we confirm that any small difference in matching did not persist to affect savings estimates from our regression model

MATCHING DIFFERENCES ROBUSTNESS CHECK

The results below show no statistically significant difference between treatment and control residuals. This suggests the fixed effects and variables in our model have effectively accounted for any small differences remainng between the treatment and control groups after matching.

	Treatment Sample Size	Treatment Mean	Treatment Variance	Control Sample Size	Control Mean	Control Variance	Difference in Means	SE of Difference in Means	T Statistic	P Value
Electric Residuals	52,953	-8.50E-16	62.72	52,406	6.64E-15	57.31	-7.50E-15	0.05	-1.60E-13	1
Gas residuals	43,951	3.37E-17	2.12	43,247	-3.70E-17	2.03	7.12E-17	0.01	7.30E-15	1

APPENDIX B
LINEAR FIXED EFFECTS GAS REGRESSION MODEL

$$ADU_{k,t} = \alpha_k + \beta_1 HDD_{65,k,t} + \beta_2 post_t + \beta_3 post_t * HDD_{65,k,t} + \beta_6 treat_k * HDD_{65,k,t} + \beta_8 post_t * treat_k + \beta_9 post_t * treat_k * HDD_{65,k,t} + \varepsilon_{k,t}$$

Where

- $ADU_{k,t}$= average daily usage for customer k during time (i.e., bill) t
- α_k = Site fixed effects, which are binary variables (one for each site) that take on the value of 1 for a given site and 0 otherwise. This variable accounts for site specific conditions, such as the number of occupants.
- $HDD_{65,k,t}$ = Heating degree days for customer k during time (i.e., bill) t at a 65ºF balance temperature.
- $post_t$ = A binary variable indicating whether time period t is after the installation (taking a value of 1) or before (taking a value of 0). This variable will take values of 1 and 0 for both customers who receive a new thermostat and comparison group sites.
- $treat_k$ = A binary variable indicating whether customer k is in the treated participant group (taking a value of 1) or in the comparison group (taking a value of 0). This variable will not change over time for any customers.
- $\varepsilon_{k,t}$ = The cluster-robust error term for customer k during date t. Cluster-robust errors account for heteroscedasticity and autocorrelation at the customer level.

In this model, β_8 and β_9 are combined to estimate average daily energy savings for space heating associated with Tier 3 thermostats.

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APPENDIX B
LINEAR FIXED EFFECTS ELECTRIC REGRESSION MODEL

$$ADU_{k,t}$$

$$= \alpha_k + \beta_1 HDD_{65,k,t} + \beta_2 CDD_{65,k,t} + \beta_3 post_t + \beta_4 post_t * HDD_{65,k,t} + \beta_5 post_t * CDD_{65,k,t} +$$

$$\beta_6 treat_k * HDD_{65,k,t} + \beta_7 treat_k * CDD_{65,k,t} +$$

$$\beta_8 post_t * treat_k + \beta_9 post_t * treat_k * HDD_{65,k,t} + \beta_{10} post_t * treat_k * CDD_{65,k,t} + \varepsilon_{k,t}$$

Where

- $ADU_{k,t}$= average daily usage for customer k during time (i.e., bill) t
- α_k = Site fixed effects, which are binary variables (one for each site) that take on the value of 1 for a given site and 0 otherwise. This variable accounts for site specific conditions, such as the number of occupants.
- $HDD_{65,k,t}$ = Heating degree days for customer k during time (i.e., bill) t at a 65ºF balance temperature.
- $CDD_{65,k,t}$ = Cooling degree days for customer k during time (i.e., bill) t at a 65ºF balance temperature.
- $post_t$ = A binary variable indicating whether time period t is after the installation (taking a value of 1) or before (taking a value of 0). This variable will take values of 1 and 0 for both customers who receive a new thermostat and comparison group sites.
- $treat_k$ = A binary variable indicating whether customer k is in the treated participant group (taking a value of 1) or in the comparison group (taking a value of 0). This variable will not change over time for any customers.
- $\varepsilon_{k,t}$ = The cluster-robust error term for customer k during date t. Cluster-robust errors account for heteroscedasticity and autocorrelation at the customer level.

In this model, β_9 and a portion of β_8 in combination yield the estimate of average daily energy savings for space heating associated with Tier 3 thermostats, while β_{10} and a portion of β_8 are combined to estimate average daily energy savings for space cooling associated with Tier 3 thermostats.

APPENDIX B
UPLIFT ANALYSIS

We use a difference-in-difference (DID) statistic to estimate channeling in other energy efficiency programs, i.e., the change in participation rate in another energy efficiency program during the same months of the pre-program year and participation months during the program year are subtracted. Formally, the calculation is:

$$DID\,Statistic = \left(Program\ year\ treatment\ group\ participation - pre\ year\ treatment\ group\ participation\right)$$
$$-\left(program\ year\ control\ group\ participation - pre\ year\ control\ group\ participation\right)$$

Multiplying the DID statistic by the number of program households produces the participant lift in the energy efficiency program generated by the Tier 3 thermostat program. Multiplying this participant lift by deemed net savings for the energy efficiency program generates the savings adjustment, which must be subtracted from either the Tier 3 thermostat program or the energy efficiency program to avoid double-counting savings.

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CALCULATION OF ELECTRIC HEATING AND COOLING SAVINGS

In Appendix C we present electric results with heating and cooling savings broken out separately. This slide and the following explain the process through which we derive those separate estimates

- Estimation of our electric savings model yields two coefficients, β_8 and β_9, seen on the previous slide; β_8 must be partitioned and summed to β_9 or β_{10} derive heating or cooling savings
  - The coefficient estimated for *post x treat,* β_8, includes electric savings from both cooling and heating
  - The coefficients estimated for *post x treat x CDD (β_{10})* and *post x treat x HDD (β_9),* separately identify electric savings from cooling and heating

- The following steps are used to calculate electric cooling savings (kWh):
  1. Sum annual electric cooling usage
     - *Annual Electric Cooling Use: CDD (β_2) + CDD x treat (β_5) + CDD x post (β_7)*
  2. Sum annual electric heating usage
     - *Annual Electric Heating Use: HDD (β_1) + HDD x treat (β_4) + HDD x post (β_6)*
  3. Sum total annual electric heating and cooling usage
     - *Total Annual Heating and Cooling Use = Annual Cooling Use + Annual Heating Use*
  4. Calculate *Annual Cooling Use* and *Annual Heating Use* as proportions of *Total Annual Heating and Cooling Use*
  5. Apply these proportions to estimated savings from the *post x treat (β_8)* variable to separate cooling from heating savings
  6. Add these to the separately estimated cooling and heating savings from *post x treat x CDD (β_{10})* and *post x treat x HDD (β_9)* to calculate *Total Annual Electric Heating Savings* and *Total Annual Electric Cooling Savings*

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CALCULATION OF HEATING AND COOLING SAVINGS

After completing the steps from the previous slide, final percent cooling and heating savings are calculated as follows:

- Percent cooling savings is calculated as:
  - *Total Annual Electric Cooling Savings/Annual Electric Cooling Use*

- Percent heating savings is calculated as:
  - *Total Annual Electric Heating Savings/Annual Electric Heating Use*

APPENDIX D

REGRESSION OUTPUTS

The following slides contain detailed preferred specification results with electric savings broken into heating and cooling savings, and reporting savings in percent form. They also contain regression results for alternative specifications run as robustness checks, and to provide additional information on savings by sub-populations. These variant models include:

- Without removing any customers with additional measures installed through the same program
- Removing customers with additional measures installed through the same program, but allowing Direct Install (DI) participants with multiple measures
- Large zip code cluster matching as opposed to small cluster
- Single zip code cluster matching as opposed to small cluster
- Nest only specification
- HER-participant only specification
- Non-HER participant only specification
- Detroit MEMD climate zone only specification
- Lansing MEMD climate zone only specification

REGRESSION OUTPUTS

We find an increase in electric cooling of nearly five percent and a decrease in electric heating of approximately five percent. Both results are statistically significant at the 90% confidence level. Annual electric savings are not statistically different from zero.

Electric Savings

	Savings (kWh/yr)	Savings (%)
Cooling	-67.5 (-120, -15)	-4.7% (-8.4%, -1.0%)
Heating	39.6 (5, 74)	4.7% (0.6%, 8.8%)
Annual[1]	-27.8 (-99, 44)	-1.2% (-4.3%, 1.9%)

Note: 90% confidence interval reported in parentheses. Results are net of uplift.[2]

1. Note that annual total electric savings in the MEMD will be broken out by climate zone, single or multi-family structure, heating and cooling system configurations, and other considerations that will ultimately determine what values appear in the MEMD.
2. Uplift for CMS & DTE both yield approx. -0.2 kWh/yr (0.7% current savings levels).

APPENDIX D
REGRESSION OUTPUTS

As our main finding, for our whole final sample, we find a decrease in gas heating of over four percent, significant at the 90% confidence level.

Gas Savings

	Savings (Therms/yr)	Savings (%)
Heating / Annual[1]	27.6 (22, 33)	4.2% (3.4%, 5.0%)

Note: 90% confidence interval reported in parentheses. Results are net of uplift.[2]

1. Note that annual total gas savings in the MEMD will be broken out by climate zone, single or multi-family structure, heating and cooling system configurations, and other considerations that will ultimately determine what values appear in the MEMD.
2. Uplift for CMS & DTE both yield approx. -0.1 Therms/yr (0.4% current savings levels).

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As an additional finding, for Nest only, we find a decrease in gas heating of over five percent, significant at the 90% confidence level.

Nest Only Gas Savings

	Savings (Therms/yr)	Savings (%)
Heating / Annual[1]	35.2 (29, 41)	5.4% (4.5%, 6.3%)

Note: 90% confidence interval reported in parentheses. Results are net of uplift.[2]

1. Note that annual total gas savings in the MEMD will be broken out by climate zone, single or multi-family structure, heating and cooling system configurations, and other considerations that will ultimately determine what values appear in the MEMD.
2. Uplift for CMS & DTE both yield approx. -0.1 Therms/yr (0.4% current savings levels).

APPENDIX D

GAS REGRESSION OUTPUTS

Preferred specification results—small zip code clusters, removal of all customers with multiple measure participation through program.

Variable	Definition	Estimate	Standard Error	P-Value	Therms/yr/Site
HDD	Heating Degree Days (HDD) for Customer	0.1348	0.0009	<0.01	702.30
Post	Post Period Indicator	0.0316	0.0056	<0.01	11.52
*HDD*Post*	Post Period Heating Degree Days	-0.0092	0.0004	<0.01	-47.85
*HDD*Treat*	Treatment Group Heating Degree Days	0.0003	0.0013	0.84	1.42
*Post*Treat*	Treatment Group in Post Period	-0.0002	0.0088	0.99	-0.06
*HDD*Post*Treat*	Treatment Group Post Period HDDs	-0.0053	0.0006	<0.01	-27.69

Note: Please see slide 35 for a complete listing and definition of variables. In the above table, “X*Y” refers to two variables interacted, while “X*Y*Z” refers to three variables interacted.

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APPENDIX D
GAS REGRESSION OUTPUTS

Preferred specification—without removing any multiple participation.

Variable	Definition	Estimate	Standard Error	P-Value	Therms/yr/Site
HDD	Heating Degree Days (HDD) for Customer	0.1336	0.0007	<0.01	696.06
Post	Post Period Indicator	0.0435	0.0042	<0.01	15.89
*HDD*Post*	Post Period Heating Degree Days	-0.0084	0.0003	<0.01	-44.01
*HDD*Treat*	Treatment Group Heating Degree Days	-0.0002	0.0010	0.83	-1.11
*Post*Treat*	Treatment Group in Post Period	-0.0079	0.0066	0.23	-2.87
*HDD*Post*Treat*	Treatment Group Post Period HDDs	-0.0049	0.0005	<0.01	-25.39

Note: Please see slide 35 for a complete listing and definition of variables. In the above table, “X*Y” refers to two variables interacted, while “X*Y*Z” refers to three variables interacted.

APPENDIX D

GAS REGRESSION OUTPUTS

Preferred specification—removing multiple measures, but without removing DI.

Variable	Definition	Estimate	Standard Error	P-Value	Therms/yr/Site
HDD	Heating Degree Days (HDD) for Customer	0.1313	0.0007	<0.01	684.20
Post	Post Period Indicator	0.0450	0.0045	<0.01	16.44
*HDD*Post*	Post Period Heating Degree Days	-0.0083	0.0003	<0.01	-43.18
*HDD*Treat*	Treatment Group Heating Degree Days	-0.0002	0.0011	0.84	-1.10
*Post*Treat*	Treatment Group in Post Period	-0.0099	0.0071	0.16	-3.61
*HDD*Post*Treat*	Treatment Group Post Period HDDs	-0.0037	0.0005	<0.01	-19.48

Note: Please see slide 35 for a complete listing and definition of variables. In the above table, “X*Y” refers to two variables interacted, while “X*Y*Z” refers to three variables interacted.

APPENDIX D
GAS REGRESSION OUTPUTS

Preferred specification—with large zip code clusters matching.

Variable	Definition	Estimate	Standard Error	P-Value	Therms/yr/Site
HDD	Heating Degree Days (HDD) for Customer	0.1349	0.0009	<0.01	702.61
Post	Post Period Indicator	0.0323	0.0060	<0.01	11.77
*HDD*Post*	Post Period Heating Degree Days	-0.0087	0.0004	<0.01	-45.32
*HDD*Treat*	Treatment Group Heating Degree Days	0.0002	0.0013	0.87	1.11
*Post*Treat*	Treatment Group in Post Period	-0.0009	0.0091	0.93	-0.31
*HDD*Post*Treat*	Treatment Group Post Period HDDs	-0.0058	0.0006	<0.01	-30.22

Note: Please see slide 35 for a complete listing and definition of variables. In the above table, “X*Y” refers to two variables interacted, while “X*Y*Z” refers to three variables interacted.

APPENDIX D
GAS REGRESSION OUTPUTS

Preferred specification—with single zip code matching.

Variable	Definition	Estimate	Standard Error	P-Value	Therms/yr/Site
HDD	Heating Degree Days (HDD) for Customer	0.1353	0.0009	<0.01	704.85
Post	Post Period Indicator	0.0242	0.0054	<0.01	8.82
*HDD*Post*	Post Period Heating Degree Days	-0.0087	0.0004	<0.01	-45.28
*HDD*Treat*	Treatment Group Heating Degree Days	-0.0002	0.0013	0.85	-1.26
*Post*Treat*	Treatment Group in Post Period	0.0077	0.0087	0.38	2.81
*HDD*Post*Treat*	Treatment Group Post Period HDDs	-0.0058	0.0006	<0.01	-30.36

Note: Please see slide 35 for a complete listing and definition of variables. In the above table, “X*Y” refers to two variables interacted, while “X*Y*Z” refers to three variables interacted.

GAS REGRESSION OUTPUTS

Preferred specification—Nest only.

Variable	Definition	Estimate	Standard Error	P-Value	Therms/yr/Site
HDD	Heating Degree Days (HDD) for Customer	0.1340	0.0011	<0.01	698.04
Post	Post Period Indicator	0.0295	0.0061	<0.01	10.75
*HDD*Post*	Post Period Heating Degree Days	-0.0091	0.0005	<0.01	-47.46
*HDD*Treat*	Treatment Group Heating Degree Days	0.0004	0.0016	0.80	2.04
*Post*Treat*	Treatment Group in Post Period	0.0023	0.0101	0.82	0.85
*HDD*Post*Treat*	Treatment Group Post Period HDDs	-0.0069	0.0007	<0.01	-36.18

Note: Please see slide 35 for a complete listing and definition of variables. In the above table, “X*Y” refers to two variables interacted, while “X*Y*Z” refers to three variables interacted.

APPENDIX D
GAS REGRESSION OUTPUTS

Preferred specification—HER participants only.

Variable	Definition	Estimate	Standard Error	P-Value	Therms/yr/Site
HDD	Heating Degree Days (HDD) for Customer	0.1455	0.0014	<0.01	757.78
Post	Post Period Indicator	0.0373	0.0092	<0.01	13.62
*HDD*Post*	Post Period Heating Degree Days	-0.0097	0.0006	<0.01	-50.64
*HDD*Treat*	Treatment Group Heating Degree Days	-0.0003	0.0020	0.90	-1.31
*Post*Treat*	Treatment Group in Post Period	-0.0035	0.0140	0.80	-1.29
*HDD*Post*Treat*	Treatment Group Post Period HDDs	-0.0056	0.0009	<0.01	-29.25

Note: Please see slide 35 for a complete listing and definition of variables. In the above table, “X*Y” refers to two variables interacted, while “X*Y*Z” refers to three variables interacted.

NAVIGANT

APPENDIX D
GAS REGRESSION OUTPUTS

Preferred specification—Non-HER participants only.

Variable	Definition	Estimate	Standard Error	P-Value	Therms/yr/Site
HDD	Heating Degree Days (HDD) for Customer	0.1245	0.0012	<0.01	648.34
Post	Post Period Indicator	0.0254	0.0065	<0.01	9.28
*HDD*Post*	Post Period Heating Degree Days	-0.0087	0.0005	<0.01	-45.08
*HDD*Treat*	Treatment Group Heating Degree Days	0.0007	0.0017	0.69	3.62
*Post*Treat*	Treatment Group in Post Period	0.0030	0.0109	0.78	1.11
*HDD*Post*Treat*	Treatment Group Post Period HDDs	-0.0050	0.0008	<0.01	-26.13

Note: Please see slide 35 for a complete listing and definition of variables. In the above table, “X*Y” refers to two variables interacted, while “X*Y*Z” refers to three variables interacted.

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APPENDIX D
GAS REGRESSION OUTPUTS

Preferred specification—Detroit MEMD climate zone only.

Variable	Definition	Estimate	Standard Error	P-Value	Therms/yr/Site
HDD	Heating Degree Days (HDD) for Customer	0.1466	0.0012	<0.01	763.72
Post	Post Period Indicator	0.0327	0.0066	<0.01	11.92
*HDD*Post*	Post Period Heating Degree Days	-0.0117	0.0005	<0.01	-60.82
*HDD*Treat*	Treatment Group Heating Degree Days	0.0002	0.0017	0.91	1.04
*Post*Treat*	Treatment Group in Post Period	0.0068	0.0105	0.52	2.49
*HDD*Post*Treat*	Treatment Group Post Period HDDs	-0.0061	0.0008	<0.01	-31.74

Note: Please see slide 35 for a complete listing and definition of variables. In the above table, “X*Y” refers to two variables interacted, while “X*Y*Z” refers to three variables interacted.

GAS REGRESSION OUTPUTS

Preferred specification—Lansing MEMD climate zone only.

Variable	Definition	Estimate	Standard Error	P-Value	Therms/yr/Site
HDD	Heating Degree Days (HDD) for Customer	0.1220	0.0024	<0.01	635.44
Post	Post Period Indicator	0.0094	0.0240	0.69	3.44
*HDD*Post*	Post Period Heating Degree Days	-0.0075	0.0012	<0.01	-38.89
*HDD*Treat*	Treatment Group Heating Degree Days	0.0002	0.0036	0.96	0.88
*Post*Treat*	Treatment Group in Post Period	0.0133	0.0402	0.74	4.87
*HDD*Post*Treat*	Treatment Group Post Period HDDs	-0.0071	0.0020	<0.01	-37.15

Note: Please see slide 35 for a complete listing and definition of variables. In the above table, “X*Y” refers to two variables interacted, while “X*Y*Z” refers to three variables interacted.

APPENDIX D

ELECTRIC REGRESSION OUTPUTS

Preferred specification results—small zip code clusters, removal of all customers with multiple measure participation through program.

Variable	Definition	Estimate	Standard Error	P-Value	kWh/yr/Site
HDD	Heating Degree Days (HDD) for Customer	0.1876	0.0038	<0.01	977.12
CDD	Cooling Degree Days (HDD) for Customer	1.7953	0.0229	<0.01	1434.76
Post	Post Period Indicator	0.2958	0.1151	0.01	107.96
*HDD*Post*	Post Period Heating Degree Days	-0.0337	0.0039	<0.01	-175.61
*CDD*Post*	Post Period Cooling Degree Days	-0.1228	0.0189	<0.01	-98.17
*HDD*Treat*	Treatment Group Heating Degree Days	0.0080	0.0055	0.15	41.48
*CDD*Treat*	Treatment Group Cooling Degree Days	0.1198	0.0330	<0.01	95.73
*Post*Treat*	Treatment Group in Post Period	0.3608	0.1651	0.03	131.68
*HDD*Post*Treat*	Treatment Group Post Period HDDs	-0.0170	0.0056	<0.01	-88.59
*CDD*Post*Treat*	Treatment Group Post Period CDDs	-0.0196	0.0270	0.47	-15.68

Note: Please see slide 35 for a complete listing and definition of variables. In the above table, “X*Y” refers to two variables interacted, while “X*Y*Z” refers to three variables interacted.

NAVIGANT

ELECTRIC REGRESSION OUTPUTS

Preferred specification—without removing any multiple participation.

Variable	Definition	Estimate	Standard Error	P-Value	kWh/yr/Site
HDD	Heating Degree Days (HDD) for Customer	0.1917	0.0031	<0.01	998.52
CDD	Cooling Degree Days (HDD) for Customer	1.8039	0.0198	<0.01	1441.60
Post	Post Period Indicator	0.3574	0.0948	<0.01	130.47
*HDD*Post*	Post Period Heating Degree Days	-0.0351	0.0033	<0.01	-182.87
*CDD*Post*	Post Period Cooling Degree Days	-0.1234	0.0158	<0.01	-98.60
*HDD*Treat*	Treatment Group Heating Degree Days	0.0064	0.0046	0.17	33.17
*CDD*Treat*	Treatment Group Cooling Degree Days	0.1219	0.0283	<0.01	97.44
*Post*Treat*	Treatment Group in Post Period	0.3370	0.1375	0.01	122.99
*HDD*Post*Treat*	Treatment Group Post Period HDDs	-0.0186	0.0048	<0.01	-96.71
*CDD*Post*Treat*	Treatment Group Post Period CDDs	-0.0893	0.0231	<0.01	-71.36

Note: Please see slide 35 for a complete listing and definition of variables. In the above table, “X*Y” refers to two variables interacted, while “X*Y*Z” refers to three variables interacted.

APPENDIX D
ELECTRIC REGRESSION OUTPUTS

Preferred specification—removing multiple measures, but without removing DI.

Variable	Definition	Estimate	Standard Error	P-Value	kWh/yr/Site
HDD	Heating Degree Days (HDD) for Customer	0.1873	0.0034	<0.01	975.71
CDD	Cooling Degree Days (HDD) for Customer	1.7592	0.0213	<0.01	1405.90
Post	Post Period Indicator	0.3398	0.1050	<0.01	124.03
*HDD*Post*	Post Period Heating Degree Days	-0.0328	0.0036	<0.01	-170.87
*CDD*Post*	Post Period Cooling Degree Days	-0.1083	0.0172	<0.01	-86.55
*HDD*Treat*	Treatment Group Heating Degree Days	0.0074	0.0050	0.14	38.37
*CDD*Treat*	Treatment Group Cooling Degree Days	0.1058	0.0304	<0.01	84.54
*Post*Treat*	Treatment Group in Post Period	0.2665	0.1517	0.08	97.27
*HDD*Post*Treat*	Treatment Group Post Period HDDs	-0.0152	0.0052	<0.01	-79.30
*CDD*Post*Treat*	Treatment Group Post Period CDDs	-0.0068	0.0247	0.78	-5.40

Note: Please see slide 35 for a complete listing and definition of variables. In the above table, “X*Y” refers to two variables interacted, while “X*Y*Z” refers to three variables interacted.

APPENDIX D
ELECTRIC REGRESSION OUTPUTS

Preferred specification—with large zip code clusters matching.

Variable	Definition	Estimate	Standard Error	P-Value	kWh/yr/Site
HDD	Heating Degree Days (HDD) for Customer	0.1872	0.0036	<0.01	975.13
CDD	Cooling Degree Days (HDD) for Customer	1.8029	0.0232	<0.01	1440.83
Post	Post Period Indicator	0.3642	0.1177	<0.01	132.92
*HDD*Post*	Post Period Heating Degree Days	-0.0344	0.0038	<0.01	-179.13
*CDD*Post*	Post Period Cooling Degree Days	-0.1383	0.0187	<0.01	-110.53
*HDD*Treat*	Treatment Group Heating Degree Days	0.0083	0.0054	0.12	43.47
*CDD*Treat*	Treatment Group Cooling Degree Days	0.1122	0.0332	<0.01	89.65
*Post*Treat*	Treatment Group in Post Period	0.2924	0.1669	0.08	106.72
*HDD*Post*Treat*	Treatment Group Post Period HDDs	-0.0163	0.0055	<0.01	-85.06
*CDD*Post*Treat*	Treatment Group Post Period CDDs	-0.0042	0.0268	0.88	-3.32

Note: Please see slide 35 for a complete listing and definition of variables. In the above table, “X*Y” refers to two variables interacted, while “X*Y*Z” refers to three variables interacted.

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ELECTRIC REGRESSION OUTPUTS

Preferred specification—with single zip code matching.

Variable	Definition	Estimate	Standard Error	P-Value	kWh/yr/Site
HDD	Heating Degree Days (HDD) for Customer	0.1891	0.0038	<0.01	985.16
CDD	Cooling Degree Days (HDD) for Customer	1.8094	0.0232	<0.01	1446.06
Post	Post Period Indicator	0.2257	0.1181	0.06	82.38
*HDD*Post*	Post Period Heating Degree Days	-0.0293	0.0041	<0.01	-152.67
*CDD*Post*	Post Period Cooling Degree Days	-0.1297	0.0194	<0.01	-103.69
*HDD*Treat*	Treatment Group Heating Degree Days	0.0065	0.0055	0.24	33.76
*CDD*Treat*	Treatment Group Cooling Degree Days	0.1057	0.0332	<0.01	84.47
*Post*Treat*	Treatment Group in Post Period	0.4246	0.1671	0.01	154.97
*HDD*Post*Treat*	Treatment Group Post Period HDDs	-0.0215	0.0057	<0.01	-111.77
*CDD*Post*Treat*	Treatment Group Post Period CDDs	-0.0133	0.0273	0.63	-10.61

Note: Please see slide 35 for a complete listing and definition of variables. In the above table, “X*Y” refers to two variables interacted, while “X*Y*Z” refers to three variables interacted.

ELECTRIC REGRESSION OUTPUTS

Preferred specification—Nest only.

Variable	Definition	Estimate	Standard Error	P-Value	kWh/yr/Site
HDD	Heating Degree Days (HDD) for Customer	0.1831	0.0041	<0.01	953.73
CDD	Cooling Degree Days (HDD) for Customer	1.7864	0.0256	<0.01	1427.66
Post	Post Period Indicator	0.3719	0.1287	<0.01	135.75
*HDD*Post*	Post Period Heating Degree Days	-0.0343	0.0044	<0.01	-178.49
*CDD*Post*	Post Period Cooling Degree Days	-0.1268	0.0216	<0.01	-101.35
*HDD*Treat*	Treatment Group Heating Degree Days	0.0071	0.0060	0.24	36.78
*CDD*Treat*	Treatment Group Cooling Degree Days	0.1253	0.0371	<0.01	100.13
*Post*Treat*	Treatment Group in Post Period	0.1642	0.1831	0.37	59.95
*HDD*Post*Treat*	Treatment Group Post Period HDDs	-0.0136	0.0063	0.03	-70.81
*CDD*Post*Treat*	Treatment Group Post Period CDDs	-0.0269	0.0304	0.37	-21.54

Note: Please see slide 35 for a complete listing and definition of variables. In the above table, “X*Y” refers to two variables interacted, while “X*Y*Z” refers to three variables interacted.

APPENDIX D
ELECTRIC REGRESSION OUTPUTS

Preferred specification—HER participants only.

Variable	Definition	Estimate	Standard Error	P-Value	kWh/yr/Site
HDD	Heating Degree Days (HDD) for Customer	0.2093	0.0059	<0.01	1090.21
CDD	Cooling Degree Days (HDD) for Customer	2.0876	0.0355	<0.01	1668.35
Post	Post Period Indicator	0.2493	0.1709	0.14	91.01
*HDD*Post*	Post Period Heating Degree Days	-0.0432	0.0061	<0.01	-224.94
*CDD*Post*	Post Period Cooling Degree Days	-0.2033	0.0304	<0.01	-162.47
*HDD*Treat*	Treatment Group Heating Degree Days	0.0041	0.0086	0.63	21.40
*CDD*Treat*	Treatment Group Cooling Degree Days	0.1055	0.0500	0.04	84.32
*Post*Treat*	Treatment Group in Post Period	-0.0032	0.2514	0.99	-1.17
*HDD*Post*Treat*	Treatment Group Post Period HDDs	-0.0119	0.0086	0.17	-62.17
*CDD*Post*Treat*	Treatment Group Post Period CDDs	0.0229	0.0427	0.59	18.32

Note: Please see slide 35 for a complete listing and definition of variables. In the above table, “X*Y” refers to two variables interacted, while “X*Y*Z” refers to three variables interacted.

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ELECTRIC REGRESSION OUTPUTS

Preferred specification—Non-HER participants only.

Variable	Definition	Estimate	Standard Error	P-Value	kWh/yr/Site
HDD	Heating Degree Days (HDD) for Customer	0.1662	0.0046	<0.01	865.81
CDD	Cooling Degree Days (HDD) for Customer	1.5047	0.0277	<0.01	1202.51
Post	Post Period Indicator	0.3381	0.1544	0.03	123.42
*HDD*Post*	Post Period Heating Degree Days	-0.0234	0.0048	<0.01	-121.90
*CDD*Post*	Post Period Cooling Degree Days	-0.0431	0.0226	0.06	-34.42
*HDD*Treat*	Treatment Group Heating Degree Days	0.0119	0.0069	0.08	62.15
*CDD*Treat*	Treatment Group Cooling Degree Days	0.1345	0.0411	<0.01	107.523
*Post*Treat*	Treatment Group in Post Period	0.7246	0.2137	<0.01	264.47
*HDD*Post*Treat*	Treatment Group Post Period HDDs	-0.0219	0.0070	<0.01	-114.12
*CDD*Post*Treat*	Treatment Group Post Period CDDs	-0.0612	0.0330	0.06	-48.90

Note: Please see slide 35 for a complete listing and definition of variables. In the above table, “X*Y” refers to two variables interacted, while “X*Y*Z” refers to three variables interacted.

ELECTRIC REGRESSION OUTPUTS

Preferred specification—Detroit MEMD climate zone only.

Variable	Definition	Estimate	Standard Error	P-Value	kWh/yr/Site
HDD	Heating Degree Days (HDD) for Customer	0.1870	0.0038	<0.01	974.07
CDD	Cooling Degree Days (HDD) for Customer	1.8396	0.0254	<0.01	1470.13
Post	Post Period Indicator	0.3765	0.1277	<0.01	137.43
*HDD*Post*	Post Period Heating Degree Days	-0.0271	0.0042	<0.01	-141.23
*CDD*Post*	Post Period Cooling Degree Days	-0.0749	0.0201	<0.01	-59.84
*HDD*Treat*	Treatment Group Heating Degree Days	0.0131	0.0056	0.02	68.40
*CDD*Treat*	Treatment Group Cooling Degree Days	0.1280	0.0366	<0.01	102.31
*Post*Treat*	Treatment Group in Post Period	0.5488	0.1814	<0.01	200.33
*HDD*Post*Treat*	Treatment Group Post Period HDDs	-0.0288	0.0060	<0.01	-150.10
*CDD*Post*Treat*	Treatment Group Post Period CDDs	-0.0535	0.0283	0.06	-42.73

Note: Please see slide 35 for a complete listing and definition of variables. In the above table, “X*Y” refers to two variables interacted, while “X*Y*Z” refers to three variables interacted.

ELECTRIC REGRESSION OUTPUTS

Preferred specification—Lansing MEMD climate zone only.

Variable	Definition	Estimate	Standard Error	P-Value	kWh/yr/Site
HDD	Heating Degree Days (HDD) for Customer	0.2166	0.0153	<0.01	1128.10
CDD	Cooling Degree Days (HDD) for Customer	1.9801	0.0948	<0.01	1582.40
Post	Post Period Indicator	2.1451	0.4198	<0.01	782.97
*HDD*Post*	Post Period Heating Degree Days	-0.1181	0.0160	<0.01	-615.31
*CDD*Post*	Post Period Cooling Degree Days	-0.8295	0.0772	<0.01	-662.88
*HDD*Treat*	Treatment Group Heating Degree Days	-0.0085	0.0217	0.69	-44.36
*CDD*Treat*	Treatment Group Cooling Degree Days	0.1115	0.1280	0.38	89.09
*Post*Treat*	Treatment Group in Post Period	0.0102	0.5998	0.99	3.72
*HDD*Post*Treat*	Treatment Group Post Period HDDs	0.0183	0.0216	0.40	95.42
*CDD*Post*Treat*	Treatment Group Post Period CDDs	0.0470	0.1077	0.66	37.58

Note: Please see slide 35 for a complete listing and definition of variables. In the above table, “X*Y” refers to two variables interacted, while “X*Y*Z” refers to three variables interacted.

CONTACTS

MOLLY PODOLEFSKY
Associate Director
303.728.2494
Molly.Podolefsky@Navigant.com

TRACE O'RORKE
Consultant
608.497.2339
Trace.Ororke@Navigant.com

DEBBIE BRANNAN
Director
303.728.2493
Debbie.Brannan@Navigant.com