MEMD Calibration Research – Commercial and Industrial Programmable Thermostats

Presentation to Energy Optimization Collaborative

June 16, 2015

C&I Programmable Thermostat Savings Analysis

For the programmable thermostat program, Navigant found statistically significant gas savings for Assembly, Small Office, Small Retail, and all other building types combined. In addition, Navigant found statistically significant electric savings for Small Retail and all other building types combined.

» Savings for Tier 1 programmable thermostats[1] (on a per building basis) were estimated using aggregated seasonal models for each fuel-type with indicator variables for building type.

» Statistically significant per building savings are summarized in the following table:

Table E-1. C&I Programmable Thermostat Statistically Significant Percentage Savings per Building[2]

Aggregate Building Type	Gas			Electric		
	Percentage Savings (Previous 2013 analysis)	Percentage Savings (Current 2014 analysis)	Realization Rates (Comparing billing analysis to MEMD)	Percentage Savings (Previous 2013 analysis)	Percentage Savings (Current 2014 analysis)	Realization Rates (Comparing billing analysis to MEMD)
Assembly	-	3.80%	6%	-	-	-
Small Office	10.20%	6.60%	62%	-	-	-
Small Retail	5.00%	5.60%	19%	-	3.10%	32%
All other building types[3]	5.00%	2.90%	11%	-	1.50%	14%

Source: Navigant analysis

» The term "percentage savings" refers to the percentage reduction in energy usage at the corresponding building type from being in the program. For example, Assembly buildings see a 3.8% reduction in gas usage as a result of installing a programmable thermostat.

» Statistically significant per 1000 square feet gas savings of 8.4% were found for Small Retail.

[1] Tier 1 programmable thermostats are defined as thermostats with a customer programmed set points schedule typically retailing for $25-75.
[2] Billing analysis estimates are already net savings. They implicitly account for net-to-gross, the installation rate adjustment factor, and the part use factor.
[3] All other building types includes any building types which were not statistically significant on their own. For gas, this includes Light Industrial, Full Service Restaurant, Fast Food Restaurant, Large Office, Primary School, Other School, and Other. For electric, it includes all the types just listed for gas plus Assembly and Small Office.

Navigant's Commercial and Industrial (C&I) programmable thermostat billing analysis builds on models and results presented last year to provide refined MEMD savings estimates.

» Last year, Navigant conducted billing analysis to estimate savings from C&I Tier 1 programmable thermostat installations[1] by DTE Energy's and Consumers Energy's customers, based on combined billing and tracking data from 2008 to 2013, using approximately 12,000 total electric and gas customers (including treatments and controls).

» The analysis split customers into building type bins, and estimated savings separately by building type using a Post Only (also called PPR) seasonal regression model.

» Last year's analysis found no statistically significant electric savings attributable to the program, but was able to estimate statistically significant gas savings for "small retail", "small office", and "all other" buildings:

  » Small Retail: 5.0% per building
  » Small Office:10.2% per building
  » All other buildings: 5.0% per building
  » These percentage savings are the percentage reduction in gas usage at the corresponding facility type.

» Thermostat-controlled square footage data was not collected until 2013, so the previous analysis was unable to report savings specific to thermostat-controlled square footage.

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[1] Tier 1 programmable thermostats are defined as thermostats with a customer programmed set points schedule typically retailing for $25-75.

This year's billing analysis introduced several refinements to the analysis conducted last year.

» <u>Additional Participation Data</u>: Navigant used a total of 36,989 customers this year, compared to only about 12,000 last year.

» <u>Square Footage Data</u>: Navigant made use of 2013 and 2014 square footage data to estimate savings per 1000 square feet. However, the small number of observations with square footage data made these results less precise than estimates of savings per building.

» <u>Matching Period</u>: Matching was done on 12 to 1 months before enrollment rather than 16 to 5 months before to better control for usage right up to enrollment when statistically significant differences were found in the test period.

» <u>Pooled Model</u>: Rather than estimating models for individual building types, Navigant estimated savings per building using an aggregate seasonal model for each fuel-type with indicator variables for each building type.

Figure 2-1. C&I Programmable Thermostat Statistically Significant Percentage Savings per Building
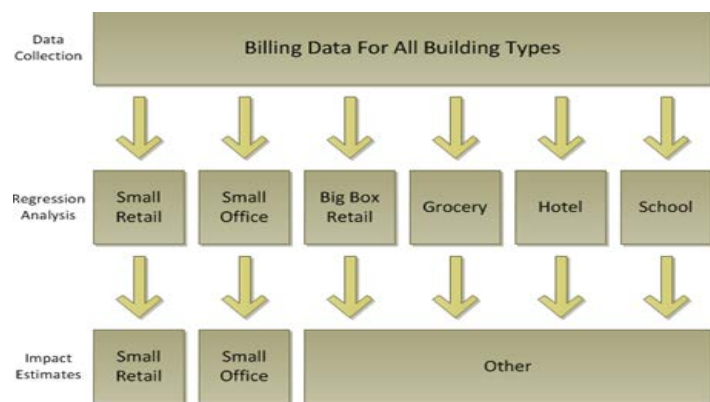
Note: All building types were segmented into their own regression model in this step. Building types listed in diagram are illustrative.
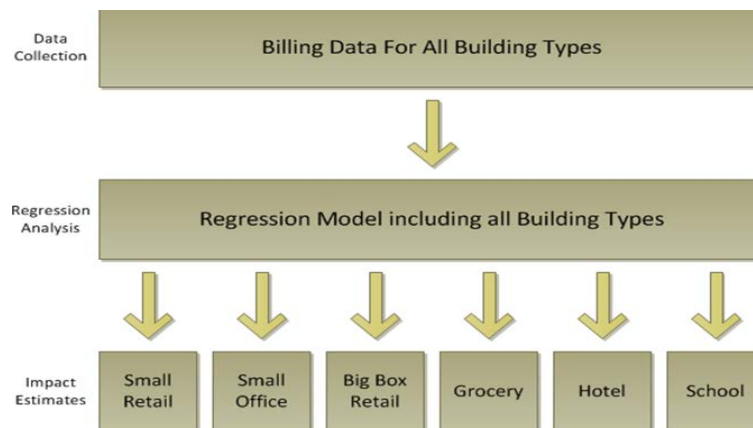
Note: All building types will be used in this analysis. Building types listed in diagram are illustrative.

» <u>Square Footage Model</u>: Navigant estimated a model include square footage data which directly outputs savings estimates per 1000 square feet rather than per building using 2013 and 2014 data.

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Navigant improved upon the previous regression methodology by using a pooled approach to estimate per building savings as opposed to running regressions on individual building types in isolation.

» Using a pooled model with indicator variables for building type is preferred to running building type specific regressions in isolation, because there is more variation available from which to estimate savings.

» Navigant estimated the following pooled model of average daily usage per building:

$$ADU_{kjt} = \sum_{j} \alpha_{1j} Participant_k \cdot Sector_j + \sum_{t} \alpha_{2t} YrMo_t + \alpha_3 DTE_k + \sum_{j,t} \alpha_{4jt} PreEnergy_{kjt} \cdot Sector_j \cdot YrMo_t + \sum_{j} \alpha_5 Sector_j + \varepsilon_{kt}$$

» Savings for each building type j are identified by the α_{1j} coefficients.

» For building types with significant estimated savings, a second model was estimated for robustness:
   » including indicators and interaction terms *only for these significant building types*
   » and all other building types in a more inclusive "Other" category

» Results for this robustness check were nearly identical to results from the main specification for the significant building types.

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Navigant estimated a similar pooled model incorporating square footage data available in the 2013 and 2014 datasets. The results are expected to be less precise than the main model, due to the greatly decreased number of square footage observations for each building type.

» Using only the 2013 and 2014 data containing square footage information, Navigant ran a pooled model of savings by building type per 1000 feet of thermostat-controlled space:

$$ADU_{kjt} = \sum_{j} \alpha_{1j} Participant_k \cdot TstatSqft_k \cdot Sector_j + \sum_{j} \alpha_{2j} Participant_k \cdot Sector_j + \sum_{t} \alpha_{3t} YrMo_t + \alpha_4 DTE_k$$
$$+ \sum_{j,t} \alpha_{5jt} PreEnergy_{kjt} \cdot Sector_j \cdot YrMo_t + \sum_{j} \alpha_{6j} Sector_j + \alpha_7 TstatSqft_k + \varepsilon_{kt}$$

» Savings for each building type j for x-thousand square feet of thermostat-controlled space is identified by $\alpha_{1j} * x + \alpha_{2j}$.

» Subsetting the dataset to only two years significantly reduced the number of observations for each building-type in the square footage regression model. As expected, this limited the number of building types where statistically significant results were identified.

» The value of this separate square-footage-based model is that it produces savings estimates more directly comparable with MEMD savings values, which are reported in terms of 1000's of square feet of thermostat-controlled space.

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Navigant separately cleaned DTE and Consumers' data by removing outliers, accounting for missing data, and making adjustments for other data issues such as multiple installations.

» Billing data and tracking data files from DTE and Consumers, from 2008 to 2014, were combined to form the final dataset for analysis.

» Major cleaning steps included[1]:

   » Removing customers missing an installation date or with an installation date outside of 2008-2014

   » Using the earliest installation date for customers who installed multiple thermostats at the same site

   » Removing customers who had average annual usage more than two standard deviations away from the mean usage for their building type

» After data cleaning processes, we had the following number of treatment and control customers:

   » Electric – 7,976 participants and 7,517 controls

   » Gas – 11,365 participants and 10,131 controls

   » **Total – 19,341 participants and 17,648 controls**

» The 36,989 customers included in this year's analysis is a significant improvement over the 12,000 customers used last year.

[1] A complete list of all data cleaning steps and observation counts at each step is included in Appendix A.

Navigant combined building types into 10 aggregated building types according to building energy use profiles. Several building types show potential for estimating statistically significant savings given an additional year of data.
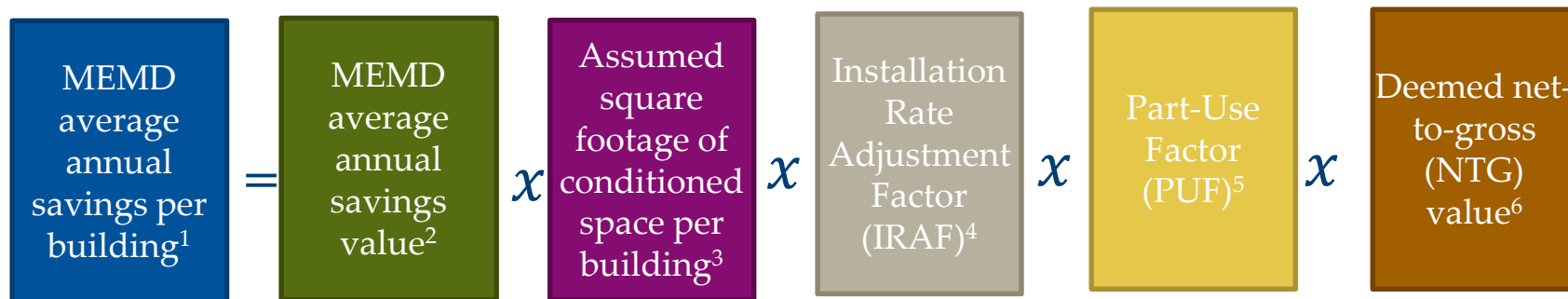
Table 2-1. C&I Programmable Thermostat Building Types

Aggregate Building Type	Tracking Data Building Type ID	Number of Gas Customers	Number of Electric Customers	Statistically Significant Gas Savings[1]	Statistically Significant Electric Savings[1]
Small Retail	Small Retail	2,228	1,916	✓	✓
Small Office	Small Office	1,491	1,524	✓	●
Light Industrial	Light Industrial	611	436	●	
	Light Industry	177	247		
Full Service Restaurant	Full Service Restaurant	401	405	●	
Fast Food Restaurant	Fast Food Restaurant	154	164		
Assembly	Assembly	481	340	✓	
Large Office	Large Office	380	262		
Other School	School	18	16		
	School (K-12)	3	5		
	Schools (K-12)	0	3		
	College/University	6	24		
Primary School	Primary School	43	20		
Other	Retail/Service	279	244		
	Office	131	101		
	NA	3,858	1,213		
	N/A	678	505		
	Other	335	534		
	Miscellaneous	359	421		
	Hospital	0	6	✓	✓
	Medical	15	14		
	Warehouse	79	103		
	Hotel	7	20		
	Hotel/Motel	8	8		
	Restaurant	32	31		
	Grocery	125	123		
	Heavy Industry	35	53		
All non-significant building types and Other combined		7,734	6,833	✓	✓
Total		11,955	8,758	4	2

Source: Navigant analysis

[1] Checks (✓) indicate building type/fuel combinations that produced statistically significant savings results at the 90% confidence level. Solid dots (●) indicate combinations that suggest potential to produce statistically significant results given one additional year of data.

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In order to make the results from our building type model comparable to MEMD values, which are reported in 1000 square feet of condition space, we used the conversion below. Billing analysis results are implicitly net estimates. To compare the MEMD to the results from our square footage model we need only adjust the MEMD for the IRAF, PUF, and NTG.

MEMD average annual savings per building[1] = MEMD average annual savings value[2] x Assumed square footage of conditioned space per building[3] x Installation Rate Adjustment Factor (IRAF)[4] x Part-Use Factor (PUF)[5] x Deemed net-to-gross (NTG) value[6]

$$\frac{kwh\ (or\ ccf)}{building} = \frac{kwh\ (or\ ccf)}{1,000\ sq\ ft}\ x\ \frac{1,000\ sq\ ft}{building}\ x\ IRAF\ x\ 0.89\ PUF\ x\ 0.90\ NTG$$

[1] A table showing the original and adjusted MEMD values is included in Appendix A.

[2] Based on the average savings in the Detroit City Airport weather zone for each building type from the 2014 Weather Sensitive MEMD. All system types were equally weighted.

[3] Average square footage for statistically significant building types are 7,282 for Assembly, 2,266 for Small Office, 2,239 for Small Retail, 4,516 for all other gas building types, and 3,404 for all other electric building types based on PY2013-PY2014 DTE and Consumers program tracking data.

[4] The fuel specific stratum-level (Direct Install Thermostat) Installation Rate Adjustment Factor of 0.93 and 0.99 for electric and gas respectively, developed in PY2013 DTE C&I Prescriptive evaluation, was applied to accordingly to the electric and gas MEMD average annual savings value.

[5] Part-use factor 0.89 developed in PY2013 evaluation for the DTE C&I Prescriptive program applied to account for programmable thermostats installed but operating in manual mode.

[6] Net-to-gross value deemed 0.90 by Michigan Public Service Commission.

Matches were based on usage during each participant's 12-month pre-period, because our gas savings regression is a heating season model, this graph shows match performance in the heating season.

Figure 3-1. C&I Programmable Thermostat Gas Match Comparison
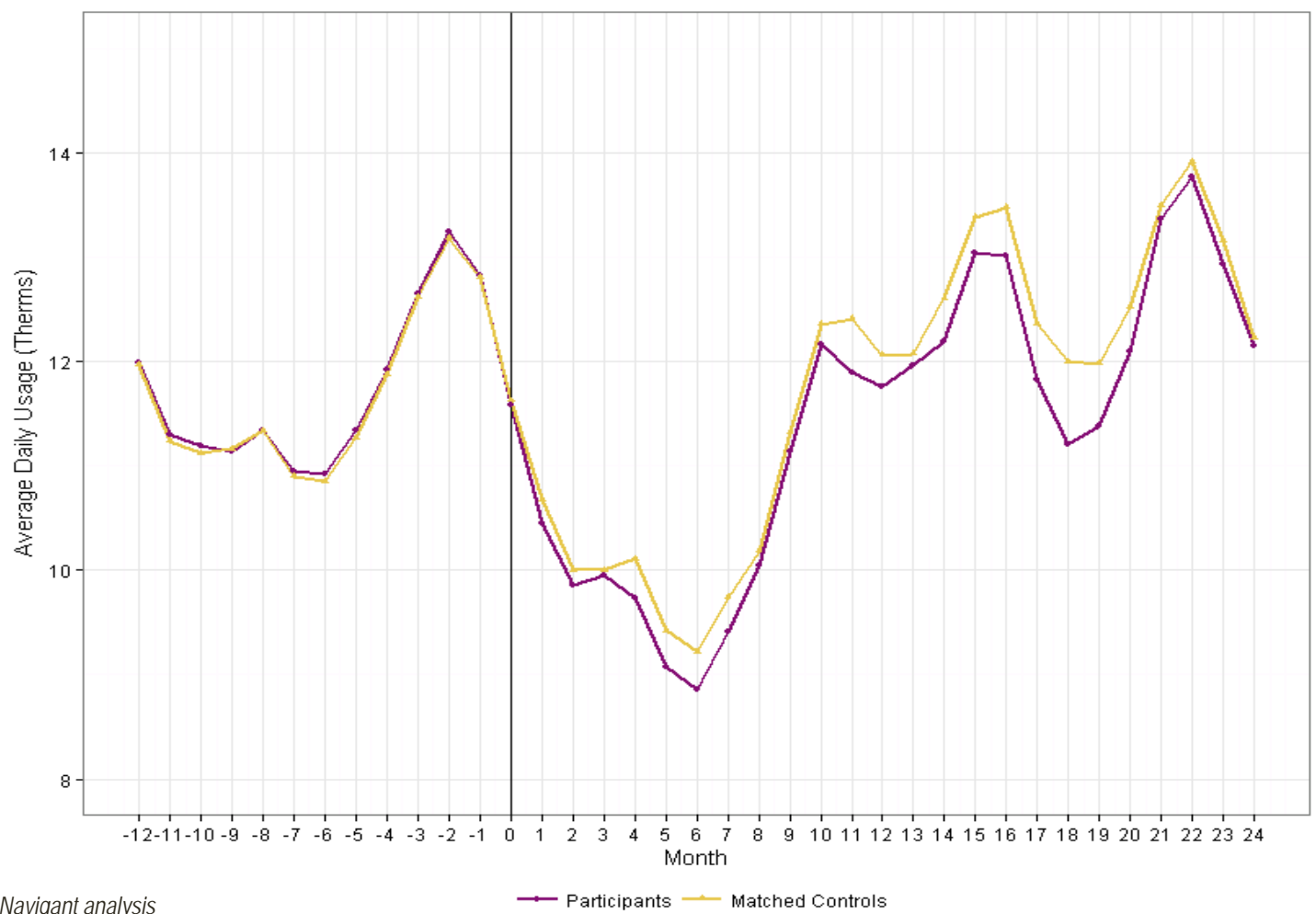
Source: Navigant analysis

Note: Navigant also considered using matches drawn on the period 16 to 5 months before a participant's enrollment date, however usage was found to deviate during the test period from months 4 to 0 before enrollment. Therefore, Navigant chose to use the 12-1 matches to best control for usage right up until enrollment. A complete explanation of the 16-5 matches is included in Appendix A.

Matches were based on usage during the participant's 12-month pre-period, because our electric savings regression is a cooling season model, this graph shows match performance in the cooling season.

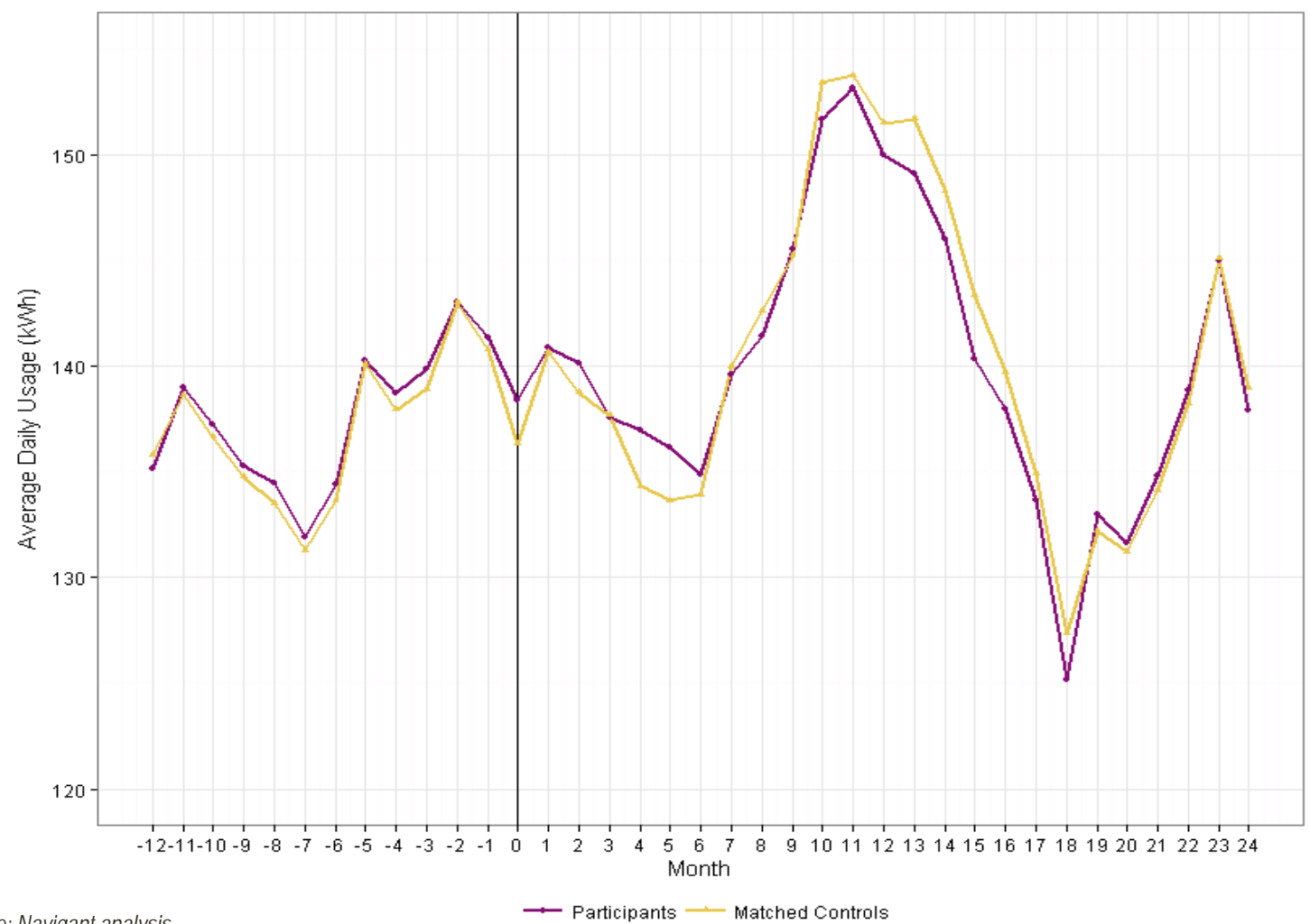Figure 3-2. C&I Programmable Thermostat Electric Match Comparison

Source: Navigant analysis

Note: Navigant also considered using matches drawn on the period 16 to 5 months before a participant's enrollment date, however usage was found to deviate during the test period from month 4 to 0 before enrollment. Therefore, Navigant chose to use the 12-1 matches to best control for usage right up until enrollment. A complete explanation of the 16-5 matches is included in Appendix A.

Navigant found statistically significant savings for more building type/fuel combinations than in last year's analysis. For those building types where results were found last year, the estimates were not statistically different this year.

» Statistically significant per building savings are summarized in the following table:

Table 4-1. C&I Programmable Thermostat Statistically Significant per Building Savings Summary[1]

Aggregate Building Type	Gas					Electric				
	Percentage Savings (Previous 2013 analysis)	90% Confidence Interval (Previous 2013 analysis)	Total Heating Season Savings (Therms per building)	Percentage Savings	90% Confidence Interval	Percentage Savings (Previous 2013 analysis)	90% Confidence Interval (Previous 2013 analysis)	Electric Total Cooling Season Savings (kWh per building)	Percentage Savings	90% Confidence Interval
Assembly	-	-	151.6	3.8%	[1.3%, 6.3%]	-	-	-	-	-
Small Office	10.2%	[7.9%, 12.5%]	80.8	6.6%	[4.5%, 8.8%]	-	-	-	-	-
Small Retail	5.0%	[2.7%, 7.3%]	81.4	5.6%	[3.8%, 7.4%]	-	-	590	3.1%	[1.1%, 5.1%]
All other building types[2]	5.0%	[3.7%, 6.3%]	66.7	2.9%	[1.8%, 4.0%]	-	-	234	1.5%	[0.2%, 2.8%]

Source: Navigant analysis

» The term "percentage savings" refers to the percentage reduction in energy usage at the corresponding building type from being in the program. For example, Assembly buildings see a 3.8% reduction in gas usage as a result of installing a programmable thermostat.

» The confidence bounds for all of our gas estimates this year overlap with last year's confidence bounds except for all other building types. Note that all other building types contains a different set of customers since Assembly is now broken out on its own.

» Light Industrial and Full Service Restaurant for gas and Small Office for electric showed the potential to produce positive and significant savings with another year of data.

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[1] Billing analysis estimates are implicitly net savings, and as such the part-use factor, net-to-gross, and the installation rate adjustment factor do not apply.
[2] All other building types includes any building types which were not statistically significant on their own. For gas, this includes Light Industrial, Full Service Restaurant, Fast Food Restaurant, Large Office, Primary School, Other School, and Other. For electric, it includes all the types listed for gas plus Assembly and Small Office.

Realization rate for all building and fuel types are quite low, ranging from 6% to 62%.

» Comparisons of the per building billing analysis savings to the MEMD savings are summarized in the following table:

Table 4-2. C&I Programmable Thermostat Statistically Significant per Building Savings Comparison to MEMD values[1]

Aggregate Building Type	MEMD Total Heating Season Savings (Therms per building)	MEMD Percentage Savings[2]	Gas Billing Analysis Total Heating Season Savings (Therms per building)	Billing Analysis Percentage Savings[2]	Realization Rate	MEMD Total Cooling Season Savings (kWh per building)	MEMD Percentage Savings[2]	Electric Billing Analysis Total Cooling Season Savings (kWh per building)	Billing Analysis Percentage Savings[2]	Realization Rate
Assembly	2,629	40.9%	151.6	3.8%	6%	-	-	-	-	-
Small Office	130	10.3%	80.8	6.6%	62%	-	-	-	-	-
Small Retail	418	23.2%	81.4	5.6%	19%	1,839	9.1%	590	3.1%	32%
All other building types[3]	598	21.3%	66.7	2.9%	11%	1,622	9.5%	234	1.5%	14%

Source: Navigant analysis

Assembly, Small Office, Small Retail, and all other building types combined had statistically significant gas savings per building at the 90% confidence level using a two tailed t-test.

Figure 4-1. C&I Programmable Thermostat Statistically Significant Gas Savings per Building by Building Type

Source: Navigant analysis

Note: Model coefficients are included in Appendix A.

Gas realization rates for per building savings range from 6% for Assembly to 62% for Small Office.

Figure 4-2. C&I Programmable Thermostat Gas Realization Rates for per Building Savings

Source: Navigant analysis

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For electric, Small Retail and all other building types combined had statistically significant savings per building at the 90% confidence level using a two-tailed t-test.

Figure 4-3. C&I Programmable Thermostat Statistically Significant Electric Savings per Building by Building Type

Source: Navigant analysis

Note: Model coefficients are included in Appendix A.

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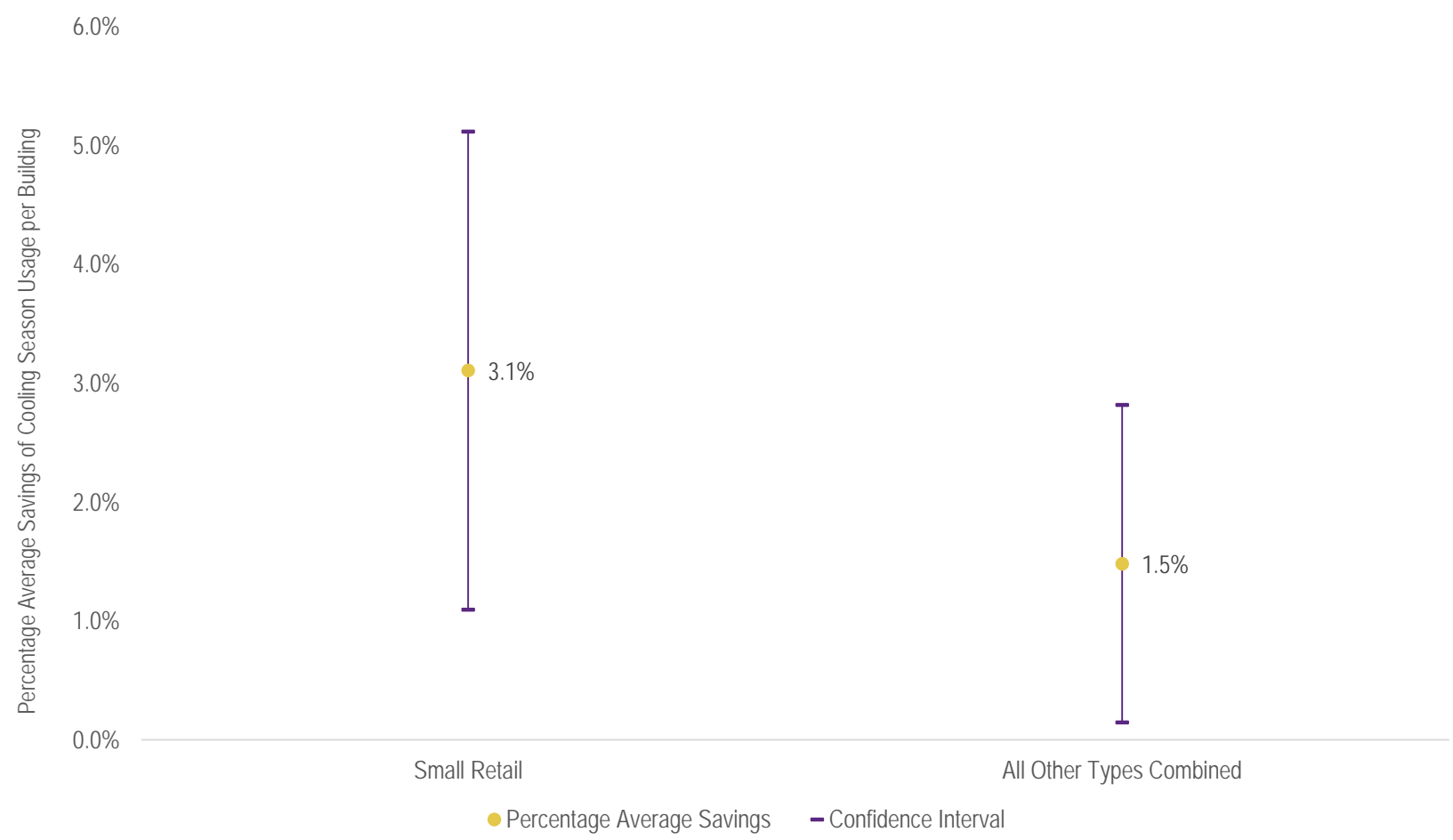
Electric realization rates for per building savings are 32% for Small Retail and 14% for all other building types combined.

Figure 4-4. C&I Programmable Thermostat Electric Realization Rates for per Building Savings
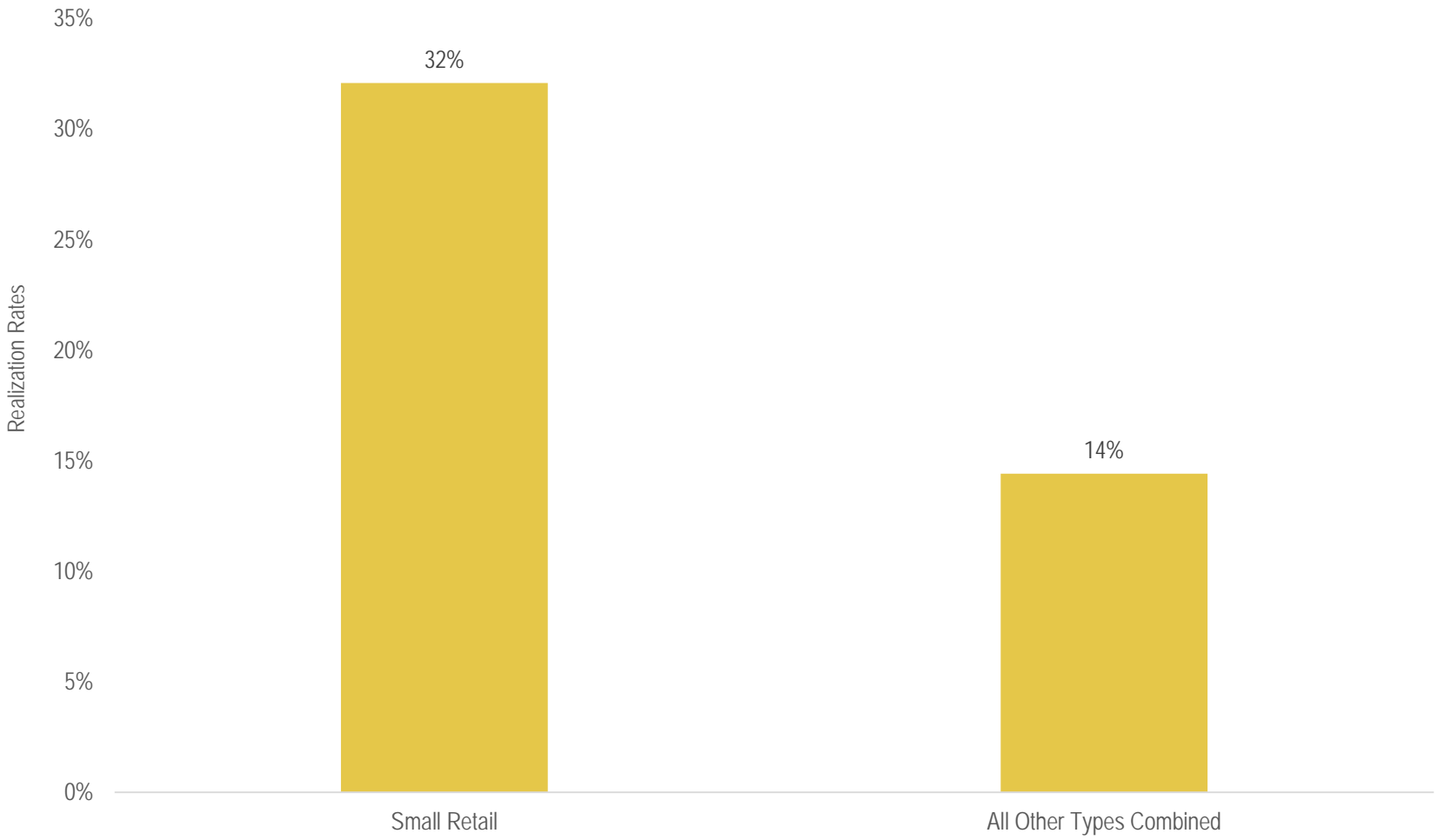
Source: Navigant analysis

Given another year of data, Light Industrial and Full Service Restaurant both showed the potential for positive and statistically significant gas savings per building. Similarly for electric, Small Office showed savings potential given additional data.

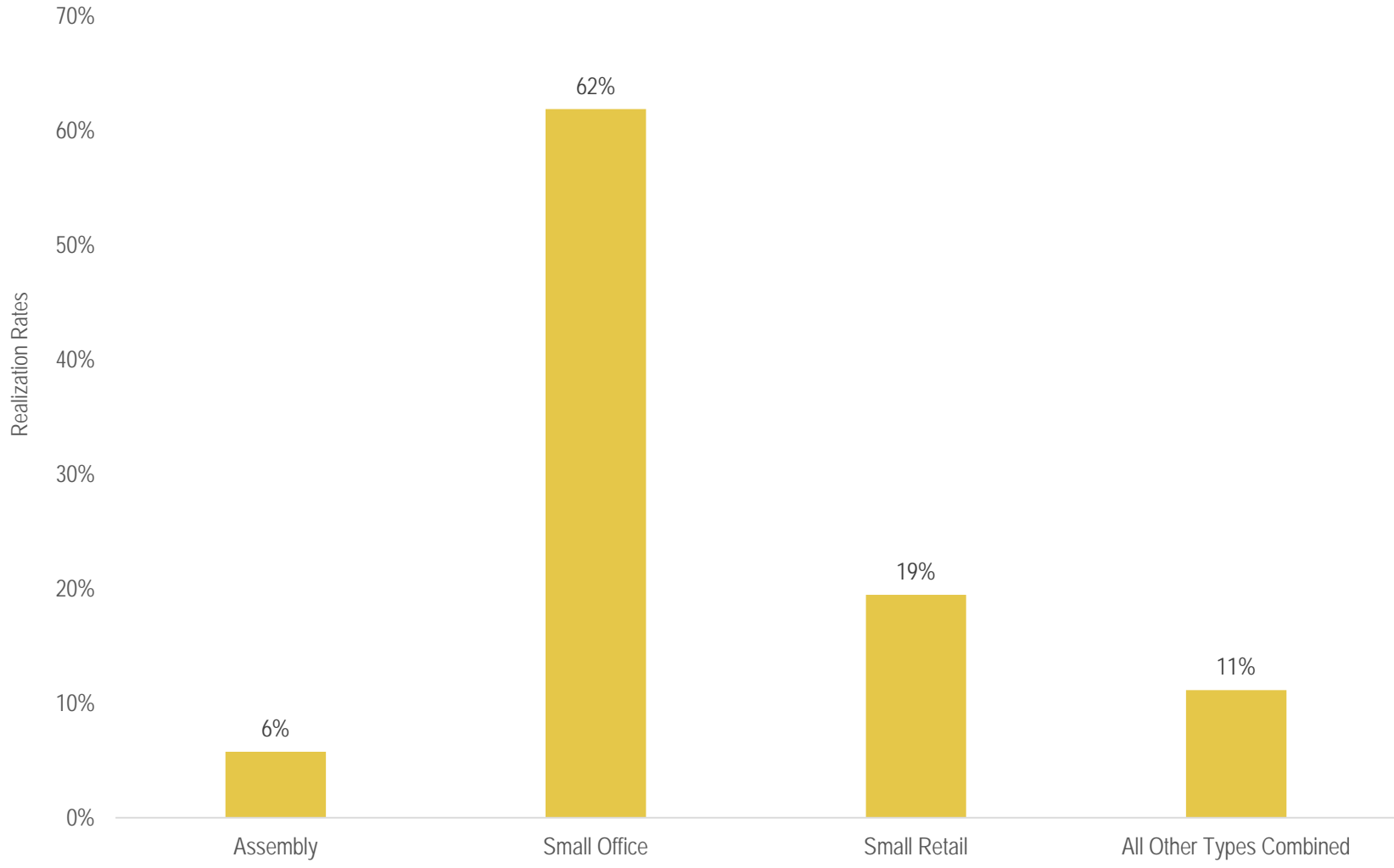Figure 4-5. C&I Programmable Thermostat Building Types with the Potential for Statistically Significant Savings per Building in the Future
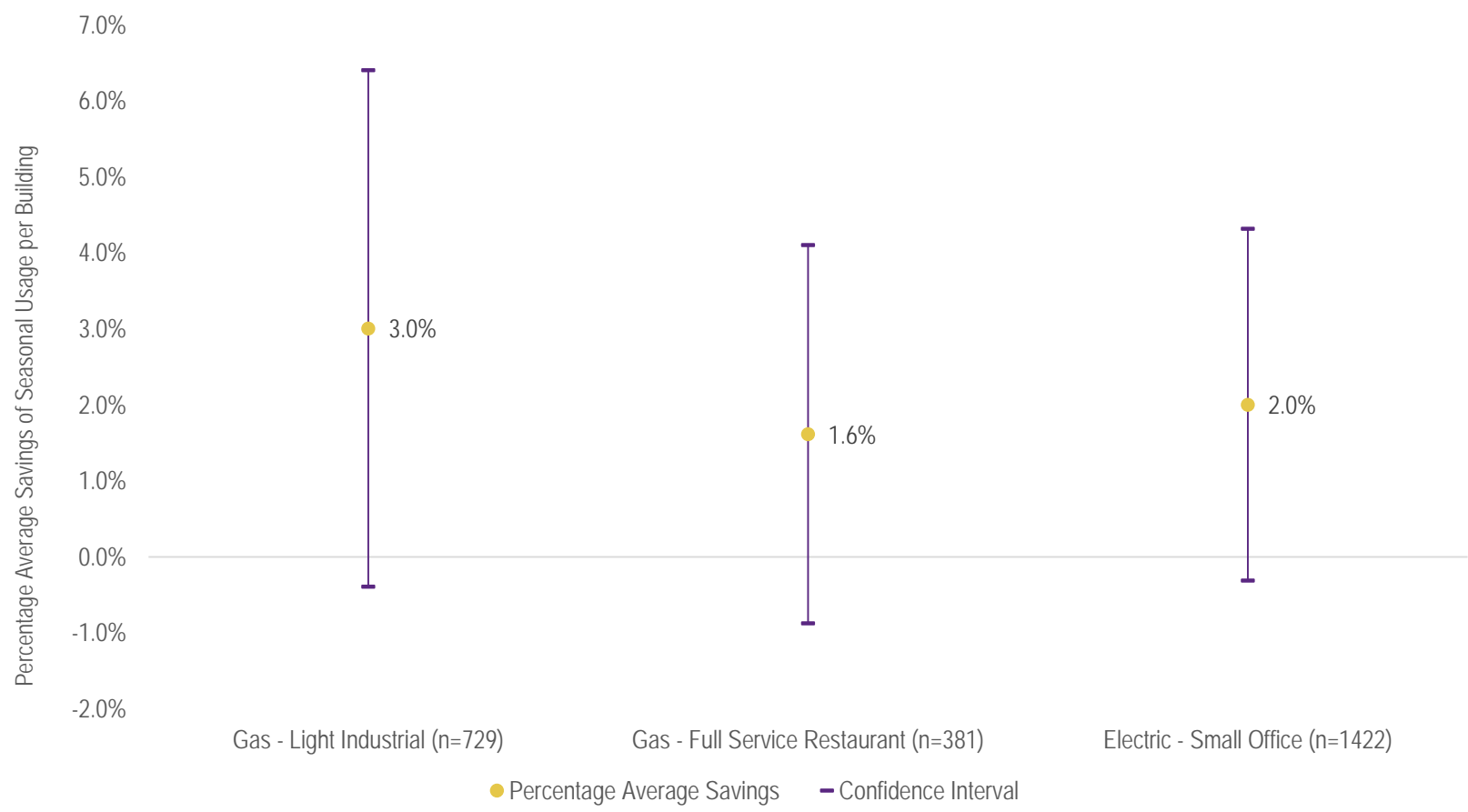
Source: Navigant analysis

Note: Model coefficients are included in Appendix A.

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Realization rates for per building savings that showed the potential for positive and statistically significant savings per building were for 25% for gas Light Industrial, 6% for gas Full Service Restaurant, and 12% for electric Small Office.

Figure 4-6. C&I Programmable Thermostat Realization Rates for per Building Savings for Building Types with the Potential for Statistically Significant Savings
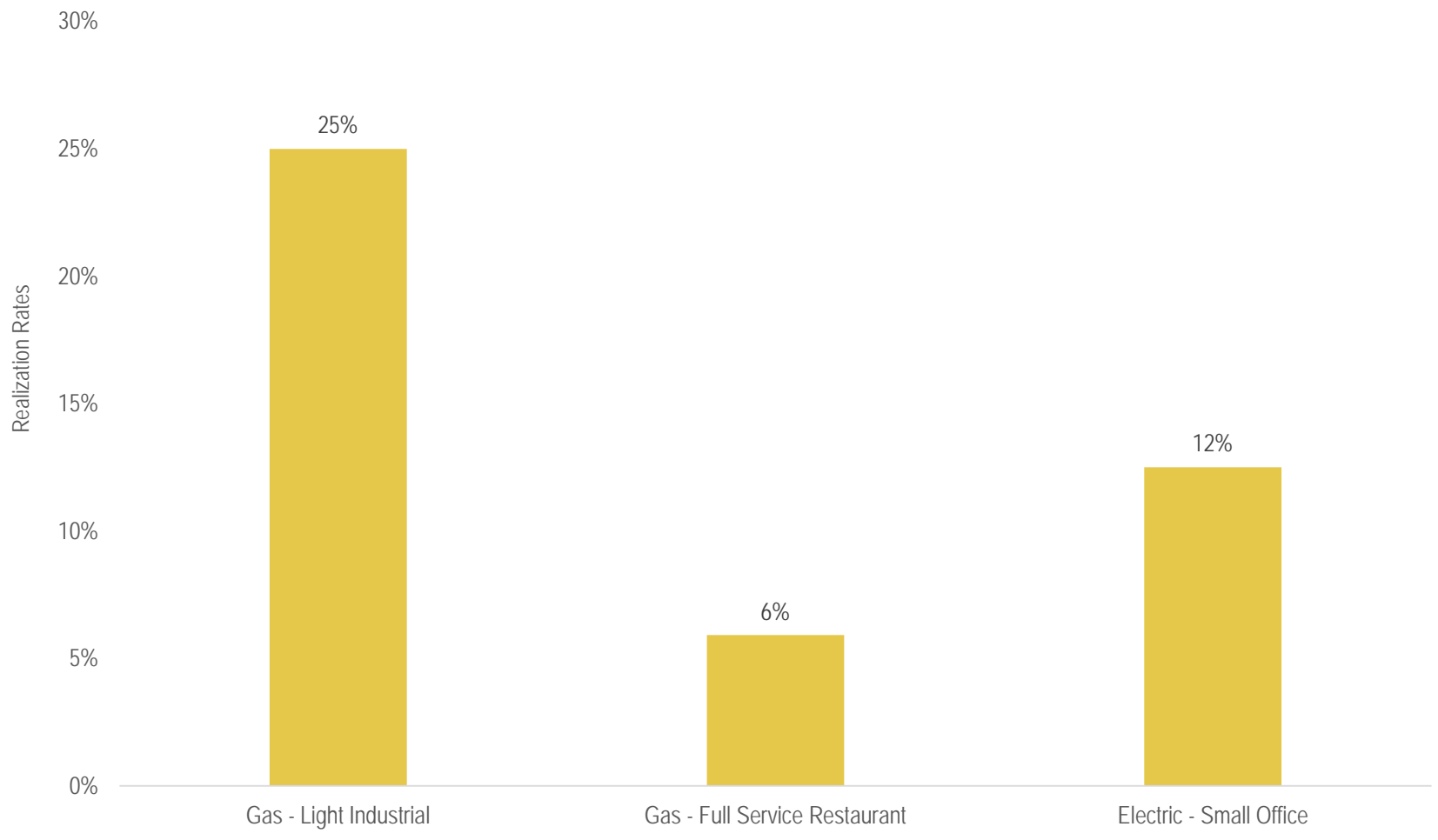
Source: Navigant analysis

Navigant used the subset of the data covering 2013 and 2014 to estimate separate pooled models for gas and electric savings per 1000 square feet of thermostat controlled space for direct comparison to MEMD values. Navigant also estimated per building savings on the 2013-2014 dataset to allow for a direct comparison of the two methods.

» Analysis of savings by 1000 square feet of thermostat-controlled space was conducted on the subset of the data covering 2013 and 2014, because square footage data was not available until 2013.

» Navigant also estimated a pooled model of per building savings using only the 2013-2014 data to allow a direct comparison of the two approaches.

» One building type, Small Retail, yielded statistically significant gas savings results using 2013-2014 data.
   » 9.2% per building
   » 8.4% per 1000 square feet
   » These percentage savings are the percentage reduction in gas usage at the corresponding facility type

» No building types resulted in statistically significant electric savings per building or 1000 square feet using 2013-2014 data.

» Comparisons of the per 1000 square feet billing analysis savings to the MEMD savings are summarized in the following table:

Table 5-1. C&I Programmable Thermostat Statistically Significant per 1000 Square Feet Savings Comparison to MEMD values[1]

| Aggregate Building Type | Gas | | | | |
	MEMD Total Heating Season Savings (Therms per 1000 square feet)	MEMD Percentage Savings[2]	Billing Analysis Total Heating Season Savings (Therms per 1000 square feet)	Billing Analysis Percentage Savings[2]	Realization Rate
Small Retail	186.6	13.3%	103.8	8.4%	60%

Source: Navigant analysis

[1] MEMD savings are adjusted for part-use factor, net-to-gross, and the installation rate adjustment factor as described on slide 11. Billing analysis estimates are implicitly net savings, and as such these adjustments do not apply.
[2] All percentage savings are calculated based on average counterfactual usage for each building type by participants in the post program period. Counterfactual usage is actual usage in the post program period plus estimated program savings. The MEMD percentages use MEMD savings for estimated savings while the billing analysis percentages use the billing analysis estimated savings.

Using only the 2013 and 2014 data, we find statistically significant per building savings at the 90% confidence level only for Small Retail for gas using a two-tailed t-test. This is many fewer statistically significant results than we found with the whole dataset.

Figure 5-1. C&I Programmable Thermostat per Building Savings with 2013-2014 Data
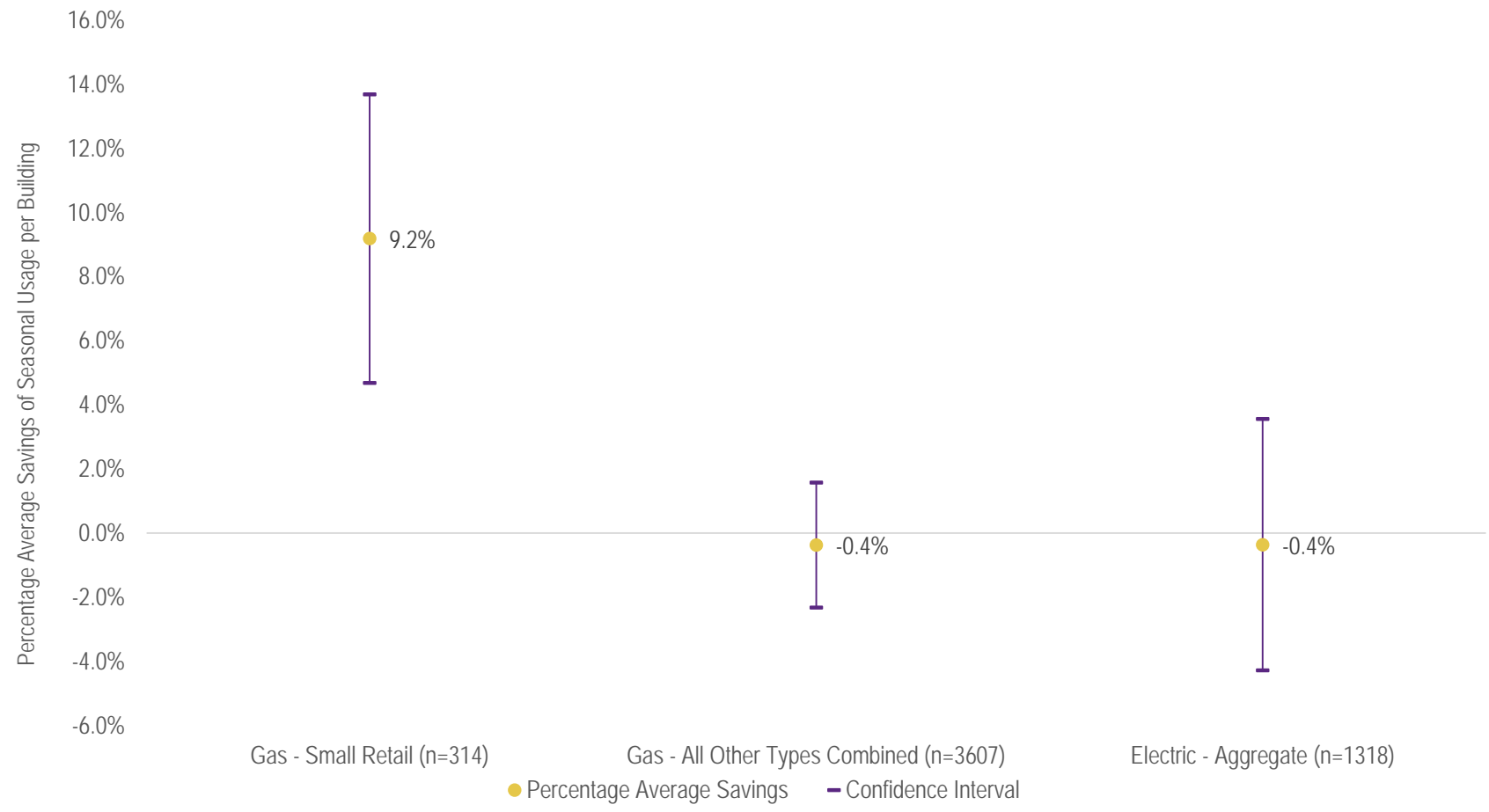
Source: Navigant analysis

Note: Model coefficients are included in Appendix A.

Navigant estimated savings per 1000 square feet for 3 building type/fuel combinations. Only gas savings for Small Retail were statistically significant at the 90% confidence level with savings of 8.4% or 112 therms per 1000 square feet using a two-tailed t-test.

Figure 5-2. C&I Programmable Thermostat per 1000 Square Feet Savings with 2013-2014 Data
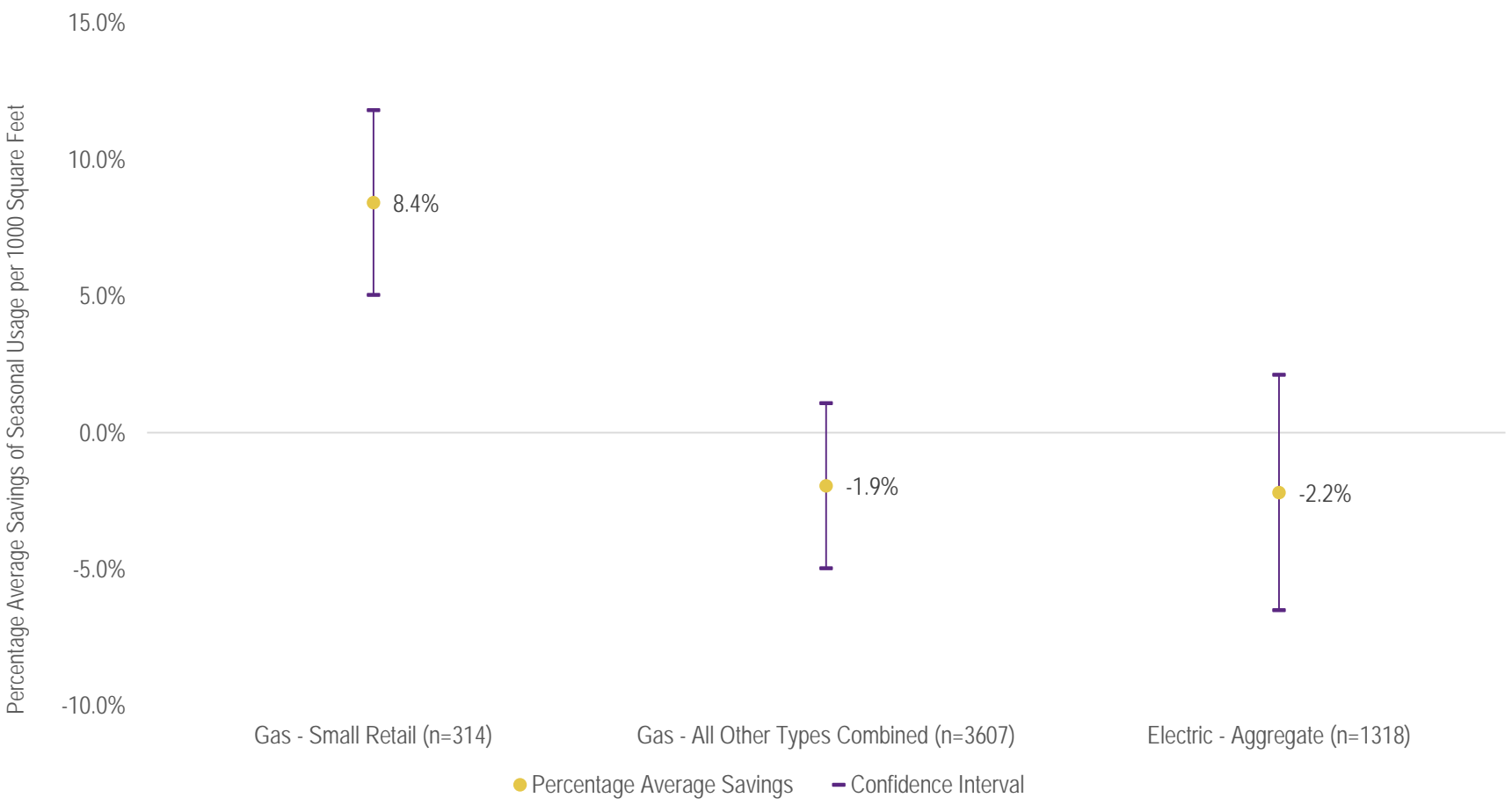
Source: Navigant analysis

Note: Model coefficients are included in Appendix A.

The gas savings realization rate per building is 30% and per 1000 square feet it is 60%. The 90% confidence bounds for these two estimates overlap suggesting that the two realization rates are not statistically different.

Figure 5-3. C&I Programmable Thermostat Gas Realization Rate and 90% Confidence Interval per Building and per 1000 Square Feet with 2013-2014 Data

Source: Navigant analysis

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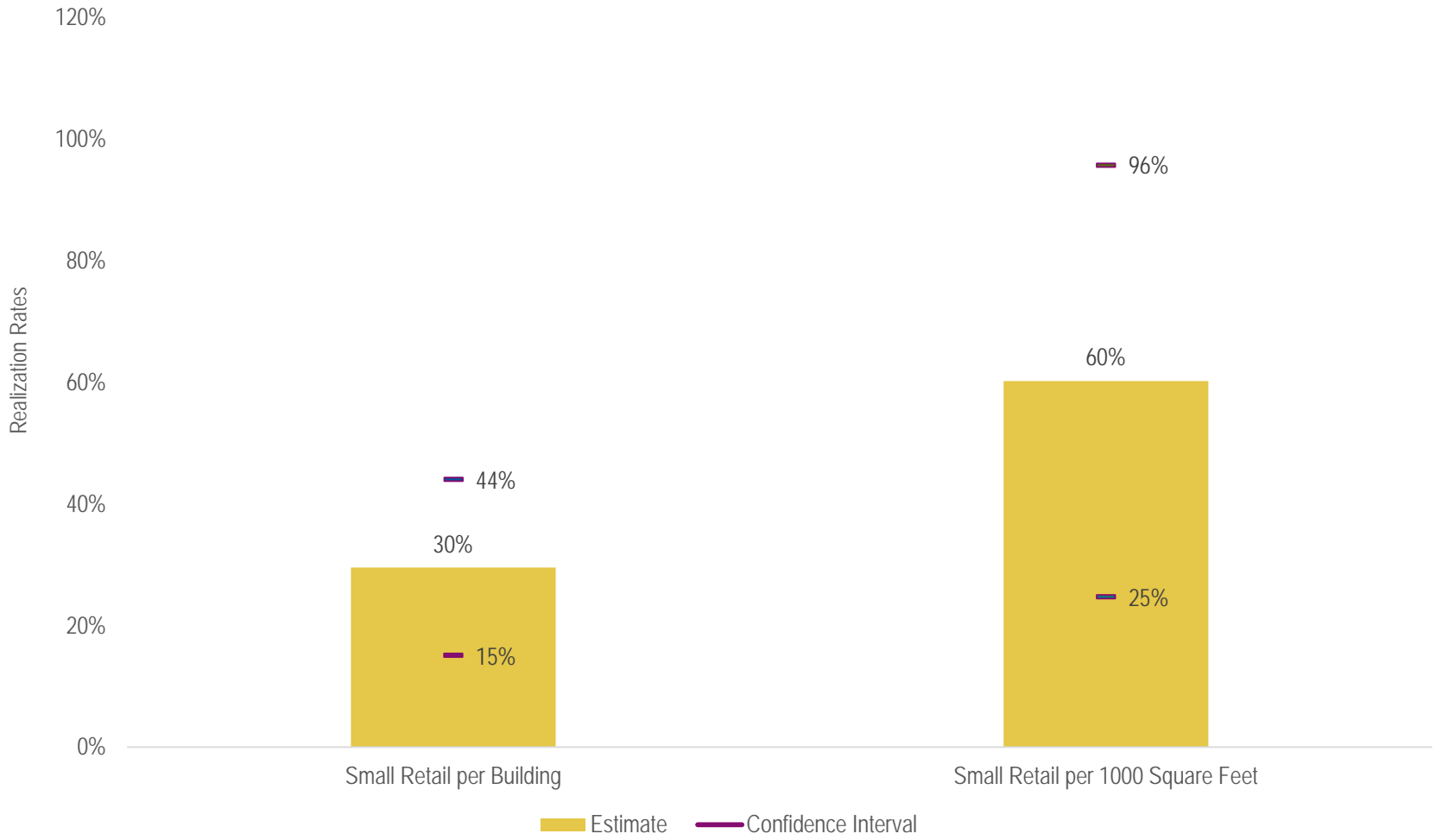
Navigant's analysis produced statistically significant estimates of gas savings for four building types, and of electric savings for two building types. It also yielded a single significant estimate of savings by square footage for direct comparison to the MEMD value.

» Realization rates for both gas and electric per building savings are quite low (ranging from 6% to 62%).
   » This is based on statistically significant savings for the building types Assembly, Small Office, Small Retail, and all other combined for gas and for Small Retail and all other combined for electric.

» Realization rates for gas savings per 1000 square feet are larger than, but not statistically different from, realization rates using gas savings per building.
   » This is based on statistically significant per building and per 1000 square feet gas savings for Small Retail using only 2013-2014 data.

» Navigant recommends the following six savings values for MEMD revision:

Table 6-1. C&I Programmable Thermostat MEMD Revision Proposal[1]

Measure	Gas				Electric			
	Percentage Savings	Absolute Savings per Building (Therms / MCF)[2]	Average Square Footage per Building	Absolute Savings per 1000 Square Feet (Therms/MCF)[2,3]	Percentage Savings	Absolute Savings per Building (kWh)	Average Square Footage per Building	Absolute Savings per 1000 Square Feet (kWh)[3]
Assembly	3.8%	151.6 / 1558	7,282	20.8 / 214	-	-	-	-
Small Office	6.6%	80.8 / 830	2,266	35.6 / 366	-	-	-	-
Small Retail	5.6%	81.4 / 837	2,239	36.4 / 374	3.1%	590	2,239	263
All Other	2.9%	66.7 / 686	4,516	14.8 / 152	1.5%	234	3,404	69

» The term "percentage savings" refers to the percentage reduction in energy usage at the corresponding building type from being in the program.
   » For example, Assembly buildings see a 3.8% reduction in gas usage as a result of installing a programmable thermostat.

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[1] Current MEMD values are gross savings, however these billing analysis estimates are net savings. Therefore, if these estimates were adopted into the MEMD the part-use factor, net-to-gross, and the installation rate adjustment factor would no longer apply.
[2] MCF is equal to therms times 10.28.
[3] Percent reductions of these values compared to the 2014 and 2015 MEMD values are included in Appendix A.

Navigant's analysis produced results for a larger number of building types than previously found, and estimated savings per 1000 square feet for direct comparison to MEMD values. Our findings suggest several extensions and future research paths.

» Estimate per building savings again in the future using more data.
  » Light Industrial and Full Service Restaurant for gas and Small Office for electric showed the potential to produce positive and significant savings with another year of data.

» Continue to collect square footage data and estimate per 1000 square feet savings again in the future.
  » Having square footage data only in 2013-2014 significantly limited our ability to estimate savings per 1000 square feet.

» With more per 1000 square feet savings results, compare estimates of per building and per 1000 square feet realization rates to ensure that the per building adjustment is accurate.
  » With just one statistically significant estimate of per 1000 square feet savings, Navigant found that the two realization rates were not statistically different. More results to compare would allow for more accurate conclusions.

» The savings estimates from this analysis apply only to Tier 1 programmable thermostats and do not necessarily apply to Tier 2 or Tier 3 thermostats[1]. If Tier 2 or Tier 3 thermostats are adopted, Navigant recommends that a separate billing analysis be conducted for each of these thermostat types[2].

[1] Tier 1 programmable thermostats are defined as thermostats with a customer programmed set points schedule typically retailing for $25-75. Tier 2 thermostats are defined as communicating thermostats where a customer can access set points and schedule from anywhere using a smart device. Tier 3 thermostats are defined as analytics capable thermostats with additional energy savings features such as coaching, HVAC diagnostics, and geofencing.
[2] Research has shown that in residential settings Tier 2 and 3 thermostats save more than Tier 1 thermostats, but little research has been done in the commercial and industrial sector.
Navigant Consulting, Inc. "DTE Residential Thermostats: Market Assessment of Advanced Residential Programmable Thermostats." December 15, 2014.

A total of 11,261 DTE participants and 8,907 Consumers participants were identified in the tracking data.

Table A-1. C&I Programmable Thermostat Tracking Data Cleaning

Source	Cleaning Step	DTE Participants	Consumers Participants
	2009-2014 Tracking Databases	102,908	145,803
	Keep only programmable thermostat measures[1]	13,939	20,061
	Drop participants where both gas and electric savings are equal to zero	13,099	20,061
	Drop participants with a missing installation date	12,255	19,825
	Drop participants with an installation date outside 2009-2014	12,254	19,820
Tracking Data	Keep one unique observations for each IC project number and installation date combination	11,535	16,867
	Drop participants where status is cancelled, closed, or duplicate	11,535	16,776
	Keep the earliest installation for participants who installed more than one thermostat at the same site	11,261	8,907
	Final Data for Analysis	**11,261**	**8,907**

Source: Navigant analysis

[1] Measures used for DTE were 'Programmable Thermostat' for 2009 and 'Setback/Setup' for 2010-2014. Measures used for Consumers were all measure containing 'Thermostat' which had at least 75 observations in a given year.

A total of 7,976 electric participants were used in the building type model analysis. Of these, 1,318 has square footage data and were used in the square footage analysis.

Table A-2. C&I Programmable Thermostat Electric Tracking Data Cleaning

Source	Cleaning Step	DTE Participants	Consumers Participants
Electric Billing Data	Identify participants by merging billing data with clean tracking data	4,710	5,287
	Drop duplicate observations of billing data		
	Sum usage for observations for the same customer and product name that begin and end on the same date	Observations rather than participants are removed in these steps	
	Drop observation where the previously aggregation results in usage of zero		
	Drop observations that occur before June 2008 or after December 2014		
	Drop observations that are more than 40 or less than 20 days		
	Drop outliers, defined as bills that have usage more than 3 standard deviations from median usage		
	Calendarize data	4,689	5,262
	Match participants who have at least 8 out of 12 months in the matching period	3,899	4,859
	Drop participants who have average annual usage more than 2 standard deviations from median usage for their building type	8,250	
	Drop observations where usage is outside the cooling season and where usage or pre-usage are missing	7,976	
	Final Data for Building Type Analysis	**7,976**	
	Drop observations before 2013 because these do not have square footage	1,318	
	Final Data for Square Footage Analysis	**1,318**	

Source: Navigant analysis

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A total of 11,365 gas participants were used in the building type model analysis. Of these, 3,921 has square footage data and were used in the square footage analysis.

Table A-3. C&I Programmable Thermostat Gas Tracking Data Cleaning

Source	Cleaning Step	DTE Participants	Consumers Participants
Gas Billing Data	Identify participants by merging billing data with clean tracking data	7,111	7,201
	Drop duplicate observations of billing data		
	Sum usage for observations for the same customer and product name that begin and end on the same date		
	Drop observation where the previously aggregation results in usage of zero	Observations rather than participants are removed in these steps	
	Drop observations that occur before June 2008 or after December 2014		
	Drop observations that are more than 40 or less than 20 days		
	Drop outliers, defined as bills that have usage more than 3 standard deviations from median usage		
	Calendarize data	7,101	7,201
	Match participants who have at least 8 out of 12 months in the matching period	5,985	6,532
	Drop participants who have average annual usage more than 2 standard deviations from median usage for their building type	11,523	
	Drop observations where usage is outside the heating season and where usage or pre-usage are missing	11,365	
	Final Data for Building Type Analysis	**11,635**	
	Drop observations before 2013 because these do not have square footage	3,921	
	Final Data for Square Footage Analysis	**3,921**	

Source: Navigant analysis

In order to make accurate comparisons of the billing analysis savings estimates and the MEMD savings estimates, the MEMD deemed savings values must be adjusted for the part-use factor (PUF), the net-to-gross ratio (NTGR), and the installation rate adjustment factor (IRAF). Additionally, the MEMD values must be converted from per 1000 square feet to per building values.

Table A-4. C&I Programmable Thermostat MEMD Adjustments for Statistically Significant Building Types

Building Type	MEMD Electric Savings per 1000 Square Feet[1]	MEMD Gas Savings per 1000 Square Feet[1]	IRAF – Electric[2]	IRAF – Gas[2]	PUF[3]	NTG[4]	Adjusted MEMD Electric Savings per 1000 Square Feet	Adjusted MEMD Gas Savings per 1000 Square Feet	1000 Square Feet per Building[5]	MEMD Electric Savings per Building[5]	MEMD Gas Savings per Building
Assembly	-	484.6	-	0.93	0.89	0.9	-	361.0	7.282	-	2,629
Small Office	-	77.3	-	0.93	0.89	0.9	-	57.6	2.266	-	130
Small Retail	1,036	250.5	0.99	0.93	0.89	0.9	822	186.6	2.239	1,839	418
All Other Types Combined (Gas)	-	177.8	-	0.93	0.89	0.9	-	132.4	4.516	-	598
All Other Types Combined (Elec)	601	-	0.99	-	0.89	0.9	477	-	3.404	1,622	-

Source: Navigant analysis

Table A-5. C&I Programmable Thermostat MEMD Adjustments for Building Types with the Potential to Produce Statistically Significant Savings

Building Type	MEMD Electric Savings per 1000 Square Feet[1]	MEMD Gas Savings per 1000 Square Feet[1]	IRAF - Electric[4]	IRAF – Gas[4]	PUF[2]	NTG[3]	Adjusted MEMD Electric Savings per 1000 Square Feet	Adjusted MEMD Gas Savings per 1000 Square Feet	1000 Square Feet per Building[5]	MEMD Electric Savings per Building[5]	MEMD Gas Savings per Building
Light Industrial	-	80.7	-	0.93	0.89	0.9	-	60	5.903	-	355
Full Service Restaurant	-	499	-	0.93	0.89	0.9	-	372	2.917	-	1,084
Small Office	748	-	0.99	-	0.89	0.9	593	-	2.266	1,344	-

Source: Navigant analysis

[1] Average savings in the Detroit City Airport weather zone for each building type from the 2014 Weather Sensitive MEMD. All system types were equally weighted.
[2] The fuel specific stratum-level (Direct Install Thermostat) Installation Rate Adjustment Factor was developed in PY2013 DTE C&I Prescriptive evaluation.
[3] Part-use factor was developed in PY2013 evaluation for the DTE C&I Prescriptive program.
[4] Net-to-gross value deemed 0.90 by Michigan Public Service Commission.
[5] Average square footage comes from the PY2013-PY2014 DTE and Consumers program tracking data.

Matching was performed using a t-16 to t-5 month matching period, retaining months t-1 to t-4 for a test period. In cases where usage between participants and controls diverged during the test period, we used t-12 to t-1 matches to ensure the highest quality match leading into the program period.

» Matching is a data "pre-processing" step in regression analysis that helps to ensure the explanatory characteristics of treatment and control customers are similar

» Letting t_{k-0} denote the month of program enrollment by customer k, we match treatments and controls based on energy usage over the 12-month period t_{k-16} to t_{k-5} , and then compare average energy use for participants and their matches in the four month test window from t_{k-4} to t_{k-1} .

» In cases where the match diverged during the t_{k-4} to t_{k-1} test period, a matching period of t_{k-12} to t_{k-1} was used instead to ensure the highest quality match leading into the program period.

Figure A-1. C&I Programmable Thermostat Illustration of Matching, Test, and Program Periods with t_{k-16} to t_{k-5} Matches
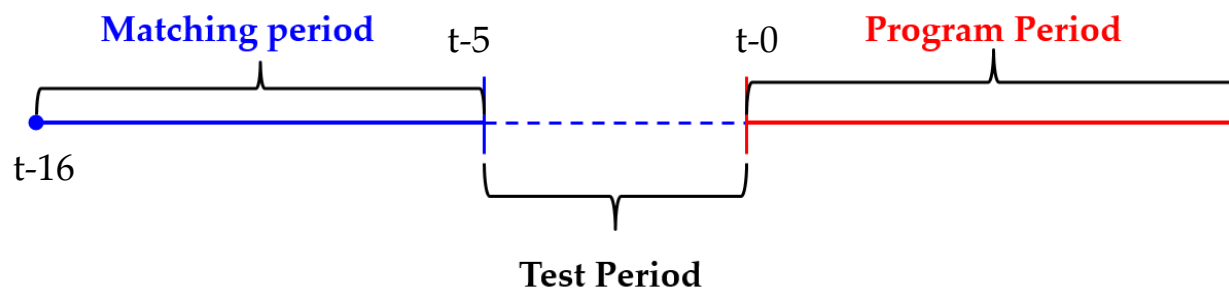
» In nearly all cases, matches diverged in the t_{k-4} to t_{k-1} test period, so for uniformity, the t_{k-12} to t_{k-1} matches were used throughout our regression analysis.

  » Both gas and electric savings diverged by approximately 2% in the test period.

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Gas matches based on usage in 16 to 5 months before enrollment diverged by approximately 2% during the test period from 4 to 0 months before enrollment. Because our gas savings regression is a heating season model, this graph shows match performance in the heating season.

Figure A-2. C&I Programmable Thermostat Gas Match Comparison
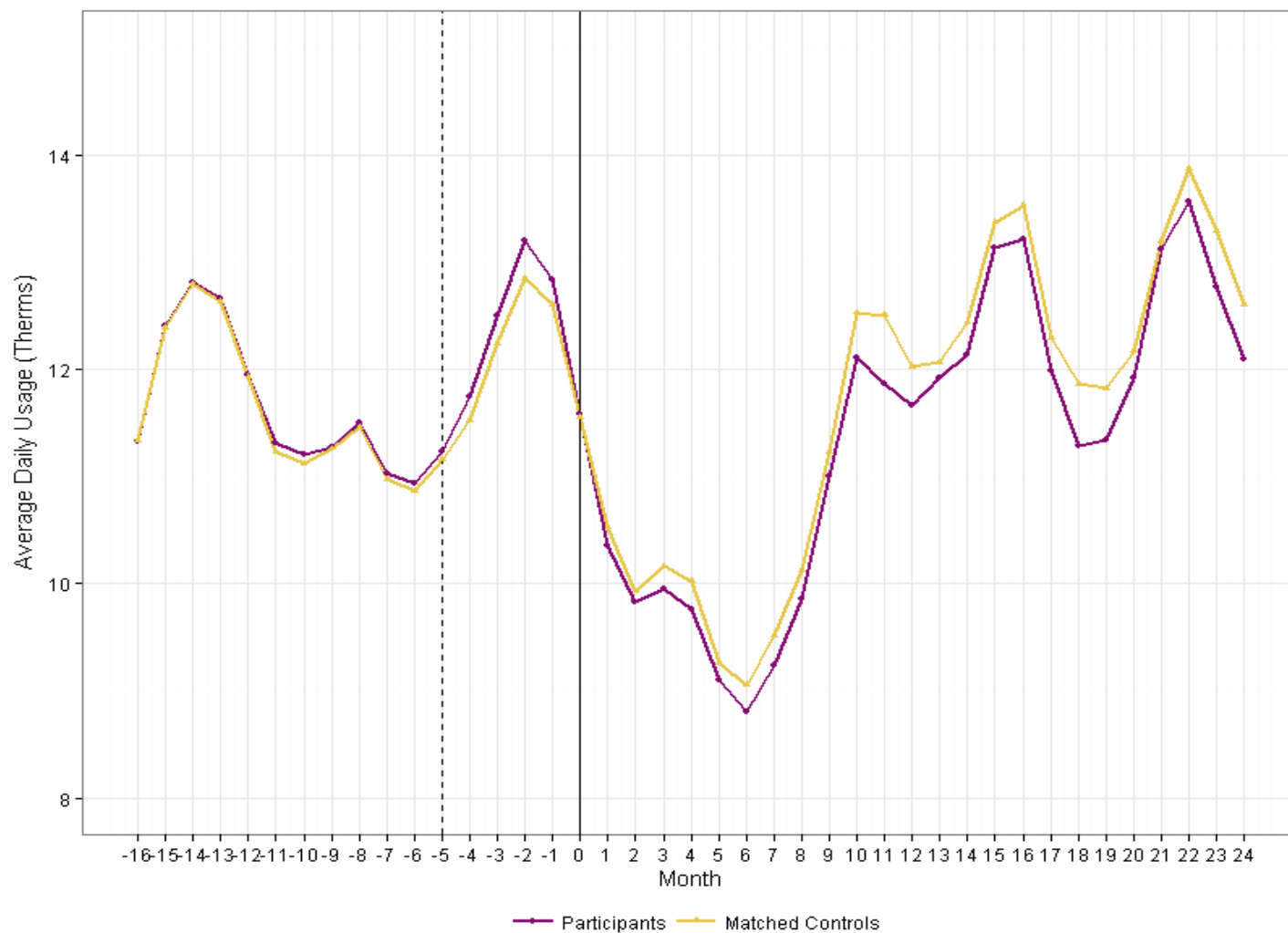
Source: Navigant analysis

Electric matches based on usage in 16 to 5 months before enrollment diverged by approximately 2% during the test period from 4 to 0 months before enrollment. Because our electric savings regression is a cooling season model, this graph shows match performance in the cooling season.

Figure A-3. C&I Programmable Thermostat Electric Match Comparison

Source: Navigant analysis

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A pooled gas model was estimated first including all 10 building types and then including just those building types that were statistically significant at the 90% level and a more inclusive Other category of all non-significant building types. The treatment coefficients are per building and were quite similar across the two models.
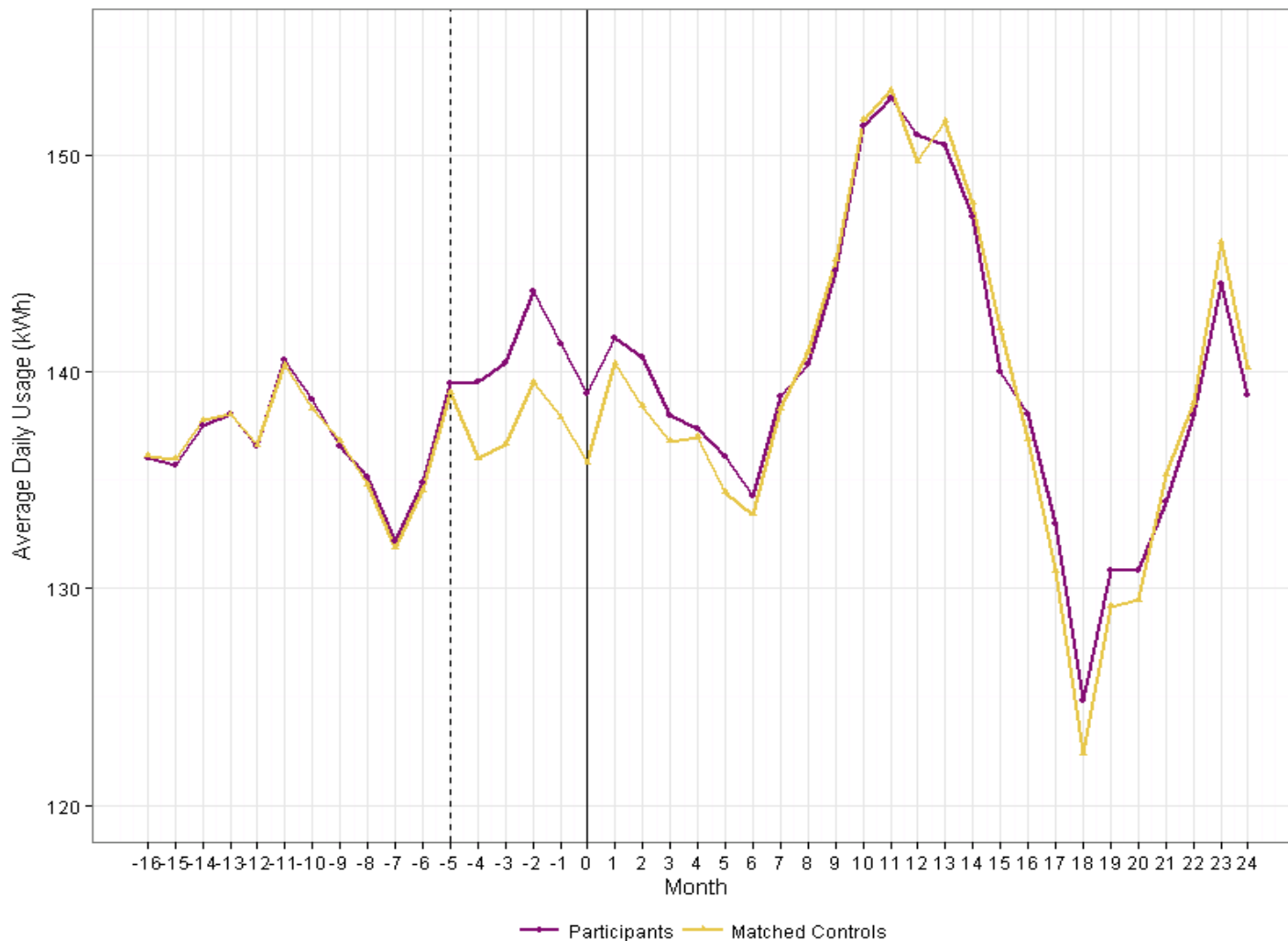
Table A-6. C&I Programmable Thermostat Treatment Coefficients from Gas Model with All Building Types

Building Type	Number of Treatment Customers	Number of Control Customers	Treatment Coefficient[1]	Treatment Standard Error	Treatment T-statistic	Statistically Significant at 90% Confidence Level[2]
Assembly	449	447	-0.72	0.28	-2.52	✓
Fast Food Restaurant	147	144	-0.39	0.44	-0.88	
Full Service Restaurant	381	361	-0.30	0.28	-1.07	●
Large Office	355	345	-0.33	0.34	-0.98	
Light Industrial	729	697	-0.42	0.29	-1.46	●
Other	5,719	4,998	-0.29	0.07	-4.00	✓
Small Office	1,439	1,286	-0.38	0.07	-5.20	✓
Small Retail	2,146	1,853	-0.38	0.08	-5.04	✓

Source: Navigant analysis

Table A-7. C&I Programmable Thermostat Treatment Coefficients from Gas Model with Statistically Significant Building Types and All Other Building Types Combined

Building Type	Number of Treatment Customers	Number of Control Customers	Treatment Coefficient[1]	Treatment Standard Error	Treatment T-statistic	Statistically Significant at 90% Confidence Level[2]
Assembly	449	447	-0.71	0.28	-2.52	✓
Small Office	1,439	1,286	-0.38	0.07	-5.19	✓
Small Retail	2,146	1,853	-0.38	0.08	-5.04	✓
All Other Types Combined	7,331	6,545	-0.31	0.07	-4.35	✓

Source: Navigant analysis

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[1] The treatment coefficient represents the reduction in average daily usage per building from being a participant in the programmable thermostat program.
[2] Checks (✓) indicate building type/fuel combinations that produced statistically significant savings results at the 90% confidence level. Solid dots (●) indicate combinations that potential to produce statistically significant results given one additional year of data.

A pooled electric model was estimated first including all 10 building types and then including just those building types that were statistically significant at the 90% level and a more inclusive Other category of all non-significant building types. The treatment coefficients are per building and were quite similar across the two models.

Table A-8. C&I Programmable Thermostat Treatment Coefficients from Electric Model with All Building Types

Building Type	Number of Treatment Customers	Number of Control Customers	Treatment Coefficient[1]	Treatment Standard Error	Treatment T-statistic	Statistically Significant at 90% Confidence Level[2]
Assembly	316	311	-0.62	1.62	-0.38	
Fast Food Restaurant	148	144	3.85	9.97	0.39	
Full Service Restaurant	369	356	1.89	4.61	0.41	
Large Office	241	231	-0.54	4.05	-0.13	
Light Industrial	623	607	-2.08	4.60	-0.45	
Other	3,136	2,963	-2.30	1.04	-2.21	✓
Small Office	1,422	1,310	-1.10	0.77	-1.43	●
Small Retail	1,721	1,595	-3.81	1.51	-2.52	✓

Source: Navigant analysis

Table A-9. C&I Programmable Thermostat Treatment Coefficients from Electric Model with Statistically Significant Building Types and All Other Building Types Combined

Building Type	Number of Treatment Customers	Number of Control Customers	Treatment Coefficient[1]	Treatment Standard Error	Treatment T-statistic	Statistically Significant at 90% Confidence Level[2]
Small Retail	1,721	1,595	-3.83	1.51	-2.54	✓
All Other Types Combined	6,255	5,922	-1.52	0.83	-1.82	✓

Source: Navigant analysis

[1] The treatment coefficient represents the reduction in average daily usage per building from being a participant in the programmable thermostat program.
[2] Checks (✓) indicate building type/fuel combinations that produced statistically significant savings results at the 90% confidence level. Solid dots (●) indicate combinations that suggest potential to produce statistically significant results given one additional year of data.

A pooled gas model using only 2013-2014 data was estimated first including all 10 building types and then including just those building types that were statistically significant at the 90% level and a more inclusive Other category of all non-significant building types. The treatment coefficients are per building and were quite similar across the two models.

Table A-10. C&I Programmable Thermostat Treatment Coefficients from 2013-2014 Gas Model with All Building Types

Building Type	Number of Treatment Customers	Number of Control Customers	Treatment Coefficient[1]	Treatment Standard Error	Treatment T-statistic	Statistically Significant at 90% Confidence Level[2]
Assembly	52	52	-0.87	0.85	-1.02	●
Fast Food Restaurant	43	40	1.11	0.85	1.31	●
Full Service Restaurant	42	42	-0.59	1.26	-0.47	
Large Office	27	26	0.56	1.76	0.32	
Light Industrial	122	121	-0.69	0.77	-0.89	
Other	3,174	2,849	0.11	0.10	1.13	●
Small Office	147	147	-0.35	0.22	-1.62	●
Small Retail	314	308	-0.58	0.17	-3.38	✓

Source: Navigant analysis

Table A-11. C&I Programmable Thermostat Treatment Coefficients from 2013-2014 Gas Model with Statistically Significant Building Types and All Other Building Types Combined

Building Type	Number of Treatment Customers	Number of Control Customers	Treatment Coefficient[1]	Treatment Standard Error	Treatment T-statistic	Statistically Significant at 90% Confidence Level[2]
Small Retail	314	308	-0.58	0.17	-3.36	✓
All Other Types Combined	3,607	3,277	0.03	0.10	0.32	

Source: Navigant analysis

[1] The treatment coefficient represents the reduction in average daily usage per building from being a participant in the programmable thermostat program.
[2] Checks (✓) indicate building type/fuel combinations that produced statistically significant savings results at the 90% confidence level. Solid dots (●) indicate combinations that suggest potential to produce statistically significant results given one additional year of data.

A pooled electric model using only 2013-2014 data was estimated first including all 10 building types and then including all building types combined since no types were statistically significant. The treatment coefficients are per building.

Table A-12. C&I Programmable Thermostat Treatment Coefficients from 2013-2014 Electric Model with All Building Types

Building Type	Number of Treatment Customers	Number of Control Customers	Treatment Coefficient[1]	Treatment Standard Error	Treatment T-statistic	Statistically Significant at 90% Confidence Level[2]
Assembly	38	37	-1.55	4.18	-0.37	
Fast Food Restaurant	41	40	29.43	28.28	1.04	●
Full Service Restaurant	28	27	42.35	33.95	1.25	●
Large Office	20	20	-13.19	10.50	-1.26	●
Light Industrial	114	111	-7.19	4.93	-1.46	●
Other	674	660	1.38	2.21	0.62	
Small Office	132	128	-0.09	2.24	-0.04	
Small Retail	271	264	-4.97	5.04	-0.99	

Source: Navigant analysis

Table A-13. C&I Programmable Thermostat Treatment Coefficients from 2013-2014 Electric Model with All Building Types Combined

Building Type	Number of Treatment Customers	Number of Control Customers	Treatment Coefficient[1]	Treatment Standard Error	Treatment T-statistic	Statistically Significant at 90% Confidence Level[2]
All Building Types Combined	1,318	1,287	0.40	2.56	0.15	

Source: Navigant analysis

[1] The treatment coefficient represents the reduction in average daily usage per building from being a participant in the programmable thermostat program.
[2] Solid dots (●) indicate combinations that suggest potential to produce statistically significant results given one additional year of data.

The square footage model was estimated separately for gas and electric using 2013-2014 data and only those building types found to be significant in the 2013-2014 building type model and all other building types combined. The average treatment effect is per 1000 square feet.

Table A-14. C&I Programmable Thermostat Treatment Coefficients from 2013-2014 Gas Square Footage Model

Building Type	Number of Treatment Customers	Number of Control Customers	Treatment Coefficient	Treatment Standard Error	Treatment T-statistic	Treatment *Sqft Coefficient	Treatment *Sqft Standard Error	Treatment *Sqft T-Statistic	Average Treatment Effect (ATE)[1]	ATE Standard Error	ATE T-statistic	Statistically Significant at 90% Confidence Level[2]
Small Retail	314	308	-0.49	0.25	-1.94	-0.04	0.10	-0.40	0.53	0.19	2.79	✓
All Other Types Combined	3,607	3,277	0.20	0.20	1.04	-0.04	0.05	-0.80	-0.17	0.16	-1.06	

Source: Navigant analysis

Table A-15. C&I Programmable Thermostat Treatment Coefficients from 2013-2014 Electric Square Footage Model

Building Type	Number of Treatment Customers	Number of Control Customers	Treatment Coefficient	Treatment Standard Error	Treatment T-statistic	Treatment *Sqft Coefficient	Treatment *Sqft Standard Error	Treatment *Sqft T-Statistic	Average Treatment Effect (ATE)[1]	ATE Standard Error	ATE T-statistic	Statistically Significant at 90% Confidence Level[2]
All Building Types Combined	1,318	1,287	3.12	3.08	1.01	-0.81	0.64	-1.27	-2.31	2.76	-0.84	

Source: Navigant analysis

[1] The average treatment effect represents the reduction in average daily usage per 1000 square feet from being a participant in the programmable thermostat program. This value is calculated by taking the Treatment*Sqft coefficient multiplied by 1000 and adding it to the Treatment coefficient.
[2] Checks (✓) indicate building type/fuel combinations that produced statistically significant savings results at the 90% confidence level.

The savings values estimated by the billing analysis are much lower than the 2014 and 2015 MEMD deemed savings values after adjusting for the Part-Use Factor (PUF), the net-to-gross (NTG) ratio, and the installation rate adjustment factor (IRAF).

Table A-16. C&I Programmable Thermostat Billing Analysis and MEMD Deemed Savings[1] after adjusting for PUF, NTG, and IRAF Comparison

Measure	Gas (Therms)			Electric (kWh)		
	Billing Analysis Savings per 1000 Square Feet	Adjusted 2014/15 MEMD Deemed Savings[2]	Percent Reduction	Billing Analysis Savings per 1000 Square Feet	Adjusted 2014/15 MEMD Deemed Savings[2]	Percent Reduction
Assembly	20.8	361.0	94%	-	-	
Small Office	35.6	57.6	38%	-	-	
Small Retail	36.4	186.6	81%	263	822	68%
All Other	14.8	132.4	89%	69	477	86%

Source: Navigant analysis, 2014 and 2015 Weather Sensitive MEMDs

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[1] Based on the average savings in the Detroit City Airport weather zone for each building type from the 2014 and 2015 Weather Sensitive MEMDs.
[2] No changes were made to the MEMD savings for this measure in the Detroit City Airport weather zone between 2014 and 2015.