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Memorandum

To: **Massachusetts Program Administrators and EEAC Consultants**

From: **Molly Podolefsky, Oxana Petritchenko, Eric Stern, Navigant**

Date: **September 20, 2018**

Re: **Wi-Fi Thermostat Impact Evaluation--Secondary Research Study**

Background and Overview

The Massachusetts Program Administrators (PAs) and the Energy Efficiency Advisory Council (EEAC) consultants have approved Navigant to begin a Wi-Fi thermostat impact evaluation study in 2018, however the results of this study will not be available in time to inform 2019-2021 planning. Accordingly, the PAs and EEAC have asked Navigant to perform this comprehensive secondary literature review, utilizing existing research performed for other jurisdictions, to summarize savings findings around the country, by year, thermostat type, fuel type and other key considerations, and that we provide recommended savings values for interim use based on these secondary findings. Our review also takes into consideration additional thermostat savings which may be achieved through Seasonal Savings algorithms or direct install/audit-based delivery channels.

This memo includes a comprehensive annotated bibliography, in Excel workbook form, facilitating searches and summarization of findings by different categorizations (similar climate zones, most recent studies, etc.). The bibliography includes a section on recent Seasonal Savings studies for reference.

Navigant recommends annual savings values of 160.9 kWh and 31.1 Therms for use until primary research and analysis findings are complete. These values should be applied prospectively for 2019 and future planning.

Secondary research does not provide sufficient detail or granularity to subdivide savings by AC system type, fuel mix, household type or other considerations, but the PAs may decide to adjust the interim savings values proportionally to the assumptions for these differences reflected in current savings values in Massachusetts.

Summary of Findings

Our main finding, which aligns with findings in Navigant's 2017 RES 17 study, is that Wi-Fi and smart thermostat savings vary dramatically based on jurisdiction, climate zone, technology,

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program distribution channel and other considerations. This finding is illustrated in Table 1, which shows the minimum and maximum values for the 49 studies included in this literature review. Most studies report findings for one or two of these categories, but not for all, further complicating findings. For example, many studies will report savings in total annual kWh but not as a percent of use. For example, in Table 1, the minimum value for Therms savings is negative, but the minimum value for percent savings is zero, because studies reported one or the other value, but not both.

Table 1. Savings Value Summary Table

Study Value	Annual Electric Savings (kWh)	Annual Gas Savings (Therms)	Annual Electric Savings (%)	Annual Gas Savings (%)
Minimum Value	0	-24	0.0%	0.0%
Maximum Value	841	69	6.0%	9.3%

Additionally, studies generic to Wi-Fi thermostats are increasingly rare, as current research focuses on the subset of Wi-Fi thermostats termed smart thermostats.[1] As a result, generic Wi-Fi thermostat-specific findings are limited. Accordingly, we encourage the PAs to exercise caution and take a conservative approach to planning based on the secondary literature review findings provided, as savings for Wi-Fi thermostats in Massachusetts may be considerably higher or lower than our secondary research suggests.

Massachusetts currently claims 104 kWh and 66 Therms per year in electric and gas savings for Wi-Fi thermostats. Based on Energy Information Administration (EIA) data for the Northeast[2], these savings values translate to approximately 1.3% and 9.6% of total annual household electric and gas use, respectively. Comparing savings currently claimed by MA to the recent literature helps put our findings in context.

By filtering results to recent primary research studies (2015 to the present) conducted in similar climate zones by independent third-party evaluators, where results were reported as the percent of annual use, we obtained our best estimate of average annual savings values applicable to MA:

- Total Annual Electric Savings (as % of whole home electric use) --2.0%
- Total Annual Gas Savings (as % of whole home gas use) --4.5%

Based on the EIA data cited above, these values translate to 160.9 kWh and 31.1 Therms. Navigant suggests using these as interim savings values for planning and prospectively until primary research results are obtained.

As requested by the PAs, we've implemented an interim approach to breaking out electric savings into its component heating and cooling elements, and these results can be used to apportion electric savings between these two categories until primary savings results are obtained. Combining data from the 15 secondary literature review studies most appropriate to MA with data

[1] Smart thermostats are devices that are not only Wi-Fi enabled (i.e. internet connected) but have other advanced features which may include learning, geofencing, weather optimization, pre-cooling, economizer optimization, fan "free cooling, and other "smart" features. Within smart thermostats there is also significant variation, with a subset of "advanced smart" thermostats representing the top tier of today's advanced thermostat abilities. For the purposes of this study we differentiate between simply "Wi-Fi" thermostats and "smart" thermostats.

[2] The U.S. Energy Information Administration (EIA)'s most recent Residential Energy Consumption Survey (RECS) reports that homes in the Northeast consume on average 8,211 kWh of electricity and 687 Therms of gas per year. This report can be accessed at: https://www.eia.gov/consumption/residential/data/2015/index.php?view=consumption#by%20fuel

from the 2018 RES 1 MA Residential Baseline Loadshape study[3], we concluded that 40% of total annual electric savings should be attributed to cooling-related end uses, and 60% to heating.[4]

Recent Massachusetts HES program secondary research findings were included in this study, but because the interim values reported at the time of this study were not primary research-based (draft values were literature review-based), they are not reflected in the average values provided.

An important consideration when properly considering the cost-effectiveness of thermostat measures is their potential to generate higher energy efficiency savings through new functionality and particular delivery channels, in addition to the potential to generate significant demand response (DR) and load management benefits. Many advanced thermostats offer functionality such as Nest's Seasonal Savings algorithm, which remotely adjusts customers' setbacks gradually during a season to increase energy efficiency savings above what the thermostat itself would have generated.

These studies find Seasonal Savings (SS) generates 5-8% savings as a percent of cooling load, in addition to base energy efficiency savings generated by Nest thermostats without Seasonal Savings.[5] Using an average annual energy consumption value of 1,224 kWh for central air conditioning (CAC) and heat pump (HP) cooling units derived from the recent MA (RES 1) baseline loadshape study,[6] these percentages translate to an additional 61 to 98 kWh per year in potential SS savings (beyond EE savings from the thermostat itself). Moreover, programs using direct install channels, education components or targeting specific HVAC configurations may generate high savings. A 2018 PG&E study direct-installing Nest thermostats using an experimental design found annual electric savings of 159 kWh.[7] A direct install experiment by Bonneville Power Administration (BPA) in 2016 targeted homes with heat pumps and found total annual electric savings of 841 kWh, representing 4% of total electricity use, and over 12% of the combined electric heating and cooling load.[8]

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[3] RES 1 Baseline Loadshape Study (Navigant 2018) can be accessed at: http://ma-eeac.org/wordpress/wp-content/uploads/RES-1-FINAL-Comprehensive-Report-2018-07-27.pdf.

[4] We make the reasonable simplifying assumption that all Wi-Fi thermostat installers have central AC/HP cooling systems. From the Baseline study we have 1,200 kWh/year as the typical annual consumption for a CAC/HP system. Our literature review findings estimated electric savings to be 5% of the total annual electric load using only those 15 studies that contributed to the final electric savings value of 160.9 kWh per year electric savings and basing the number on only the subset of those studies reporting electric savings directly as a percentage of cooling load. Applying the 5% value to the 161 kWh total electric savings yields an estimate of 60 kWh for electric cooling. The other 161 - 60 kWh equals 101 kWh for electric heating-related end uses. Thus the proportions for cooling and heating out of total annual electric savings are 37% cooling, and 63% heating. Due to the numerous assumptions incorporated in this study we suggest simplifying this proportion to 60% heating and 40% cooling savings, as a proportion of total annual electric savings.

[5] ComEd's Seasonal Savings impact study can be downloaded here: http://ilsagfiles.org/SAG_files/Evaluation_Documents/ComEd/ComEd_EPY9_Evaluation_Reports_Final/ComEd_PY9_Nest_Seasonal_Savings_Impact_Evaluation_Report_2018-06-28_Final.pdf; While National Grid's Massachusetts and Rhode Island Seasonal Savings studies can be downloaded here: http://ma-eeac.org/wordpress/wp-content/uploads/2017-NGrid-TO-Eval-Final-Report-2018-04-23.pdf

[6] The average annual consumption value of 1,530 kWh/year for CAC/HP cooling in MA can be found on page 19 of the RES 1 Baseline Loadshape Study (Navigant 2018) can be accessed at: http://ma-eeac.org/wordpress/wp-content/uploads/RES-1-FINAL-Comprehensive-Report-2018-07-27.pdf. We assume 80% of this AC use falls during the key summer months when SS is active (typically 3 to 4 months between mid-June and early October--SS program duration depends on how hot a particular summer is), which implies 1,224 kWh/year in cooling usage during the SS season. Applying the range of 5% to 8% of cooling savings to this annual usage figure results in potential SS savings from 61 to 98 kWh per summer. For comparison, the 2017 Seasonal Savings Evaluation for MA and RI (Navigant 2018) finds total SS savings in MA and RI to be 22.7 and 29.2 kWh, respectively. This represents the lower end of potential savings from SS, as the summer was relatively cool, and the SS program only ran for 2 months that summer. National Grid's Massachusetts and Rhode Island Seasonal Savings studies can be downloaded here: http://ma-eeac.org/wordpress/wp-content/uploads/2017-NGrid-TO-Eval-Final-Report-2018-04-23.pdf

[7] PG&E's direct install study results can be accessed here: https://www.etcc-ca.com/reports/smart-thermostat-study

[8] BPA's report on the results of its direct install study with heat pump systems can be accessed here: http://aceee.org/files/proceedings/2016/data/papers/1_351.pdf

The literature does not provide enough evidence to determine how savings may vary based on the type of HVAC systems controlled by the thermostat or other household characteristics. The PAs may decide to apply a proportional increase or decrease to the recommended values based on single versus multifamily units, oil versus gas heating and other considerations, and may use existing Massachusetts savings values differences as a guide until primary research findings are available.

Methodology

Our team began this secondary literature review with findings presented in the RES 17 study prepared for the PAs in 2017, which summarized a large number of the secondary literature Wi-Fi and smart thermostat study findings up to that point in time. While that study was not comprehensive, and also focused on other connected devices, it provided a solid starting point for this research. We leveraged the research foundation laid in that study and conducted additional research to update those findings to include additional studies, both prior to 2017 and through mid-2018.

In total, our team reviewed and summarized 49 thermostat studies, including both studies in the RES 17 report and new studies. For thoroughness, we re-reviewed the studies cited in RES17 to ensure accurate representation of findings, and add additional secondary findings included in some studies. As an example, some studies provided findings for multiple sub-populations in addition to overall findings, and we included these in our Excel workbook for the PAs information but excluded them from average values we created to avoid double counting.[9]

In the accompanying Excel summary workbook, we've included hyperlinks to all publicly available studies to facilitate easy access by the PAs. For each study included, we recorded information in the Workbook on the following characteristics which provided the ability to disaggregate and filter savings values based on different study characteristics:

- Thermostat type
- Thermostat details
- Third-party evaluator (Y/N)
- Evaluator name
- State/Region
- Northeastern U.S. (Y/N)
- Climate zone similar to MA (Y/N)[10]
- Fuel type
- Publication year
- Methodology
- Baseline
- Sample size
- Primary research study (Y/N)

We utilized the categorization scheme in the Excel workbook organizing our findings, to filter to specific study characteristics or groups of characteristics, and we present detailed findings on the most relevant of these in the following section.

We also included a tab in the Excel workbook summarizing several recent Seasonal Savings studies. While these additional benefits are not part of our main study, they are relevant to the

[9] A recent primary research study by an independent evaluator in the United Kingdom, *Evaluating the Nest Learning Thermostat*, 2017, is included in our study. While the report was published under a single report name, it consists of three completely separate studies with different methodologies and study sample populations. As a result, we include all three findings as "primary" findings in our literature review and report findings.
[10] Based on US IECC 7 Climate Zone Map https://basc.pnnl.gov/images/iecc-climate-zone-map

PAs as they consider future program offerings. Moreover, studies of thermostats with the Seasonal Savings algorithm activated have shown significant savings above the savings generated purely through the installation of the thermostat itself.

Detailed Findings

As explained above, the main finding of this literature review is that estimated Wi-Fi enabled and advanced smart thermostat savings vary greatly by jurisdiction, analysis type, thermostat vendor, climate zone, program distribution channel, and other study characteristics. As an example, based on the full set of 49 studies included in our literature review, electric savings as a percent of cooling load range from -4.7% to 17.6%, while gas heating savings as a percent of the gas heating load vary between -3.1% and 24.0%. Sub-setting findings to specific study types reduces this variation somewhat.

Within this context, the PAs should consider the results and findings on average savings for each subset presented below as setting likely upper and lower bounds on savings that primary research might generate within the subset. We focused on the following subsets of research findings which we felt would provide PAs with the greatest insights into drivers of variation in study findings, and findings most likely to be applicable to their territory. In Table 2 we present average values for primary research studies based on the following key categories:

- Wi-Fi communicating (not “smart”) thermostats only
- Smart thermostats
- Conducted by independent third-party evaluators
- Similar climate zones
- Recent studies (2017 and 2018)
- Best fit for Massachusetts: Recent primary research studies (2015 and later) in similar climate zones conducted by independent third-party evaluators

Table 2. Summary of Findings by Study Category

	Number of Studies (#)	Total Electric Savings (kWh/yr)	Total Gas Savings (Therms/yr)	Electric Savings as % of Electric Heating Load (% of kWh)	Electric Savings as % of Electric Cooling Load (% of kWh)	Gas Savings as % of Gas Heating Load (% of Therms)	Electric Savings as % of Whole Home Electric Energy Use (% of kWh)	Gas Savings as % of Whole Home Gas Energy Use (% of Therms)	Peak Demand Savings (kW)
Non-Smart Wi-Fi Thermostats	2	104	66	N/A	16.0%	8.0%	N/A	N/A	N/A
Smart Wi-Fi Thermostats	32	285	30	7.4%	8.2%	8.4%	3.1%	3.1%	0.56
Independent Third Party	31	250	31	7.4%	8.1%	8.2%	3.1%	3.1%	0.39
Similar Climate Zone	19	313	40	7.7%	6.8%	8.7%	2.4%	4.5%	N/A
Recent (2015-2018)	25	262	30	6.3%	5.9%	8.4%	2.8%	2.9%	0
Best Fit for Massachusetts	15	246	35	5.5%	5.2%	8.6%	2.0%	4.5%	N/A

Table 2 summarizes values based on the following study categories: all studies (1) of non-smart Wi-Fi thermostats, (2) of smart Wi-Fi thermostats, (3) conducted by independent evaluators, (4) conducted in similar climate zones, (5) recent (2015-2018), and (6) best fit for Massachusetts. Several notable conclusions and observations can be drawn from the average values summarized in this table. While focusing in on primary research studies (e.g., not including TRM studies based on secondary literature) tightens the range of researched savings values considerably, notable differences between savings values for different study categories remain, especially for electric savings as a percent of electric cooling load.

Some of this variation is driven by the small number of existing studies in a given category. As an example, there are only two studies specific to generic Wi-Fi thermostat savings, as opposed to smart Wi-Fi thermostats, and so the values on the first line of Table 2 are only based on two studies. Comparing this to the thirty-plus studies of smart Wi-Fi enabled thermostats, it would not

be accurate to conclude that generic Wi-Fi thermostats generate higher savings--this is likely a function of the small sample size of existing studies.

Average savings values are roughly comparable across all studies of Wi-Fi enabled smart thermostats and studies conducted only by third-party independent evaluators. In each of these study subsets summarized in Table 2, total annual electric savings are between the upper 200 kWh/yr range, while Therms savings range in the low 30's per year. Similarly, the percent savings for these categories are roughly aligned, with electric and gas savings as a percent of whole house electric use approximately 3%.

Savings values overall appear slightly smaller when only considering studies in similar climate zones, and studies from 2015 or later. In these categories, electric savings as a percent of whole home electricity usage fall between 2% and 3%, and gas savings as a percent of whole home gas usage fall between 3% to 4.5%.

In the last row of Table 2 we combined the characteristics we felt were most likely to generate average savings values applicable to Massachusetts, and reported average values for only recent primary research studies (2015 or later) conducted by independent third party evaluators in similar climate zones to Massachusetts. In this case we find electric savings is 2% of annual whole home electric usage, and annual gas savings as a percent of whole home usage is 4.5%.

Conclusion and Recommendations

Navigant's secondary research findings on Wi-Fi thermostat savings suggest wide variation and no consensus in overall findings, or findings by study category. As a result of the large number of divergent study values presently available, Navigant recommends the PAs use caution when selecting savings values to use for planning purposes, as forthcoming primary research could either increase or decrease savings relative to the values of 104 kWh and 66 Therms per year currently used in the state. Studies in 2017 and 2018 show a considerable decline in researched savings values relative to earlier studies. Furthermore, the divergent findings in this literature review again point to the need for primary research specific to Massachusetts to generate reliable and robust estimates of savings specific to the state's customers, existing baseline, climate zone and other salient factors.

Until primary research-based values are available, Navigant suggests the PAs adopt a conservative approach to interim savings values for planning purposes, based on the most appropriate average values summarized for recent (later than 2015) primary research studies conducted by independent evaluators in similar climate zones, where savings were presented as a percentage of whole home usage. Until primary research can be completed, Navigant recommends using 160.9 kWh and 31.1 Therms as interim annual savings values.

The literature does not provide enough evidence to make a determination about how savings may vary based on the type of HVAC systems controlled by the thermostat or other household characteristics. The PAs may decide to apply a proportional increase or decrease to the recommended values based on single versus multifamily units, oil versus gas heating and other considerations, and may use existing Massachusetts savings values differences as a guide until primary research findings are available.