Guidehouse

ComEd Advanced Thermostat Evaluation

Presentation to Michigan Energy Waste Reduction (EWR) Collaborative

January 19, 2021

Research Overview

- Guidehouse's research for ComEd focused on Advanced Thermostats (measure 5.3.16 of the Illinois Technical Reference Manual (IL TRM)) and was partially motivated by a stipulation signed as part of the update process for v7 of the IL TRM.
  - The Stipulating Parties agreed to work collaboratively on this research, and included: Ameren Illinois Company, Commonwealth Edison, Illinois Attorney General's Office, Staff of the Illinois Commerce Commission (ICC), Natural Resources Defense Council, Environmental Law and Policy Center (ELPC), and Citizen's Utility Board.
- The primary goals of the study was to produce evaluated estimates of ***annual cooling electric savings*** and coincident peak demand savings* to inform the Technical Advisory Committee (TAC) update process, coordinated by Vermont Energy Investment Cooperative (VEIC), for version 9.0 (v9) of the IL TRM.
- Guidehouse engaged with Opinion Dynamics (evaluator for Ameren Illinois), the Stipulating Parties, and other interested parties (the Advanced Thermostat Subcommittee) to collaboratively develop Illinois-specific advanced thermostat evaluation methods for this study.
- The full report was published on November 10, 2020 can be found on the Illinois SAG website: https://ilsag.s3.amazonaws.com/ComEd-Adv-Thermostat-Research-Report-Final-2020-11-10.pdf

* The summer coincident peak period is defined as 1-5 PM on non-holiday weekdays from June – August. See IL TRM, v9, volume 1, page 54.

Analysis Pathways

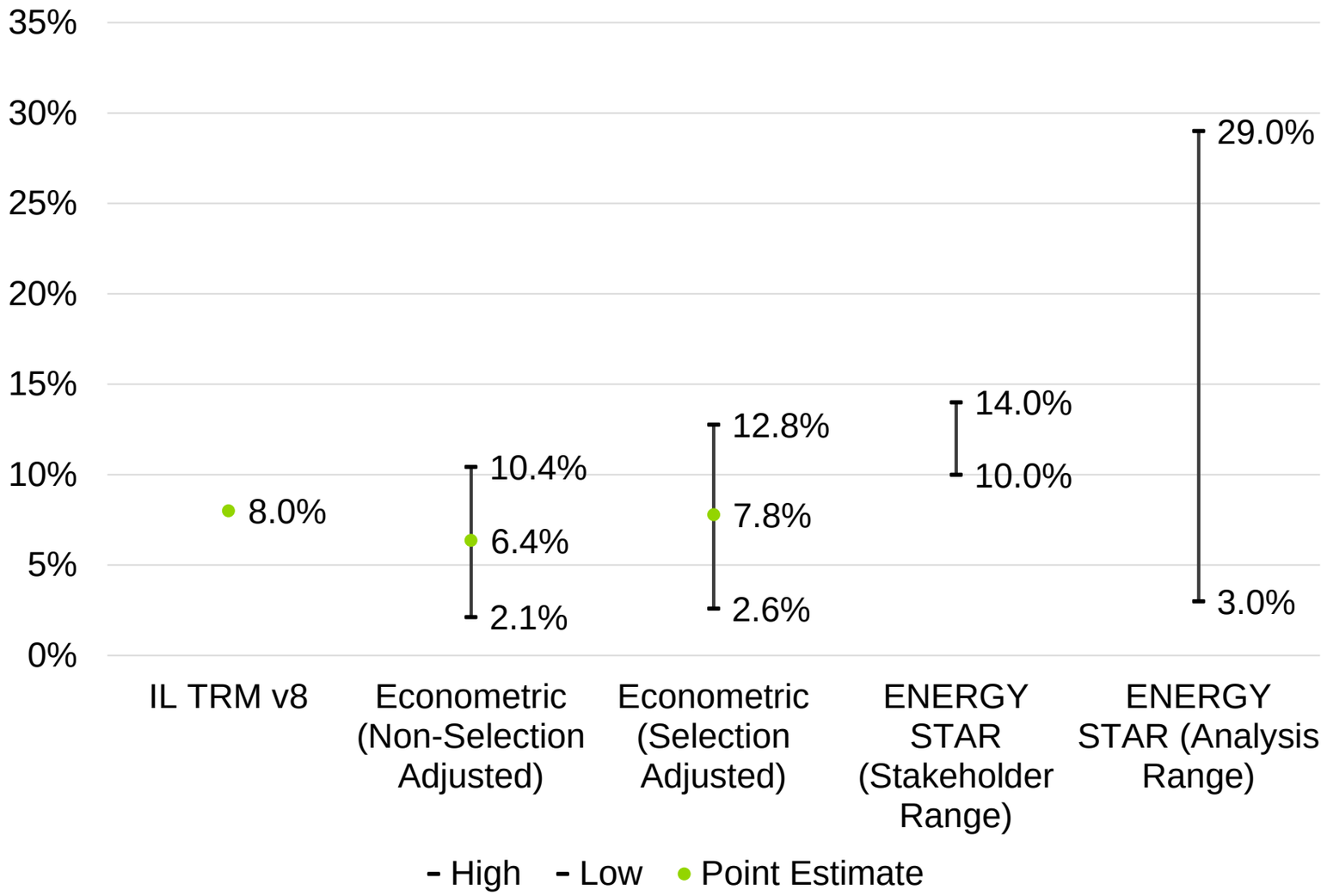
The study involved two analysis pathways that stakeholders were interested in comparing:

Category	Econometric Analysis	Adjusted ENERGY STAR*
Sample Population	• 13,388 study participants, 22,630 future participants • Entire population is HER participants • Includes thermostats from multiple manufacturers	• 500 participants (250 HER, 250 Non-HER) from one manufacturer
Key Data	• Whole-home consumption Advanced Metering Infrastructure (AMI) data (half hourly kWh) • Aggregated to hourly for comparison group selection and daily for regression analysis • Includes 2017 (pre-installation) and 2018 (post-installation) data • PRIZM demographic customer segmentation	• Thermostat telemetry data (e.g. hourly cooling runtime, set point) • Includes 2018-2019 (post-installation) data • Participant survey responses (inform assumed set point behavior)
Estimation Method	• Lagged Dependent Variable (LDV) model using participants and a comparison group of future participants • Estimates difference between pre- and post-consumption attributable to the smart thermostat	• Site-specific Heating, Ventilation, and Air Conditioning (HVAC) model (function of indoor / outdoor temperature) • Estimates difference between actual post-runtime and estimated pre-runtime based on assumed baseline behavior • Adjusted for different scenarios of baseline behavior, including different preferred comfort temperature and setbacks.
Savings Output	• Average whole-home energy savings	• Average HVAC runtime savings

* ENERGY STAR Connected Thermostat Products Method to Demonstrate Field Savings Version 1.0 (rev. Dec-2016). Available at: https://www.energystar.gov/sites/default/files/Version%201.0%20Method%20to%20Demonstrate%20Field%20Savings%20of%20ENERGY%20STAR%20Connected%20Thermostats.pdf

Comparison of Analyses (Energy Savings)

- Savings estimates from the econometric analysis are shown with those from the ENERGY STAR analysis and IL TRM v8
  - All econometric and ENERGY STAR estimates are based on 2018 weather
  - Econometric results include all post-regression adjustments
- The two analyses are different in a number of ways. Caution should be used when comparing these savings estimates.



Advanced Thermostats Agreement for IL TRM v9

- In September 2020, stakeholders reached agreement regarding consensus on the cooling reduction value for advanced thermostats for the IL TRM v9.
- Specifically, in an effort to resolve any remaining potential disputes regarding the cooling reduction value for advanced thermostats, ***the Stipulating Parties agreed that 8.42% will be used as the updated cooling reduction value for advanced thermostats in the IL TRM v9, in fulfillment of the October 2018 Stipulation***.
- The 8.42% is based on a specific weighting, agreed upon by the Stipulating Parties, of the econometric and adjusted ENERGY STAR metric values produced by the research documented in this report. The result is the econometric result with selection-adjustment (7.8%) weighted at 90%, and the ENERGY STAR result (10-14% range chosen as reasonable by stakeholders; however 14% is used to account for increased Thermostat Optimization* (TO)) weighted at 10%.
  - For a “default” home in ComEd’s territory, this is roughly 139 kWh per device for the summer season (May – September), excluding in-service rate and net to gross factors which are applied separately.

* Thermostat Optimization refers to opt-in programs such as Nest Seasonal Savings and ecobee eco+, which algorithmically optimize users' thermostat to save additional HVAC usage.

ENERGY STAR
Analysis Results

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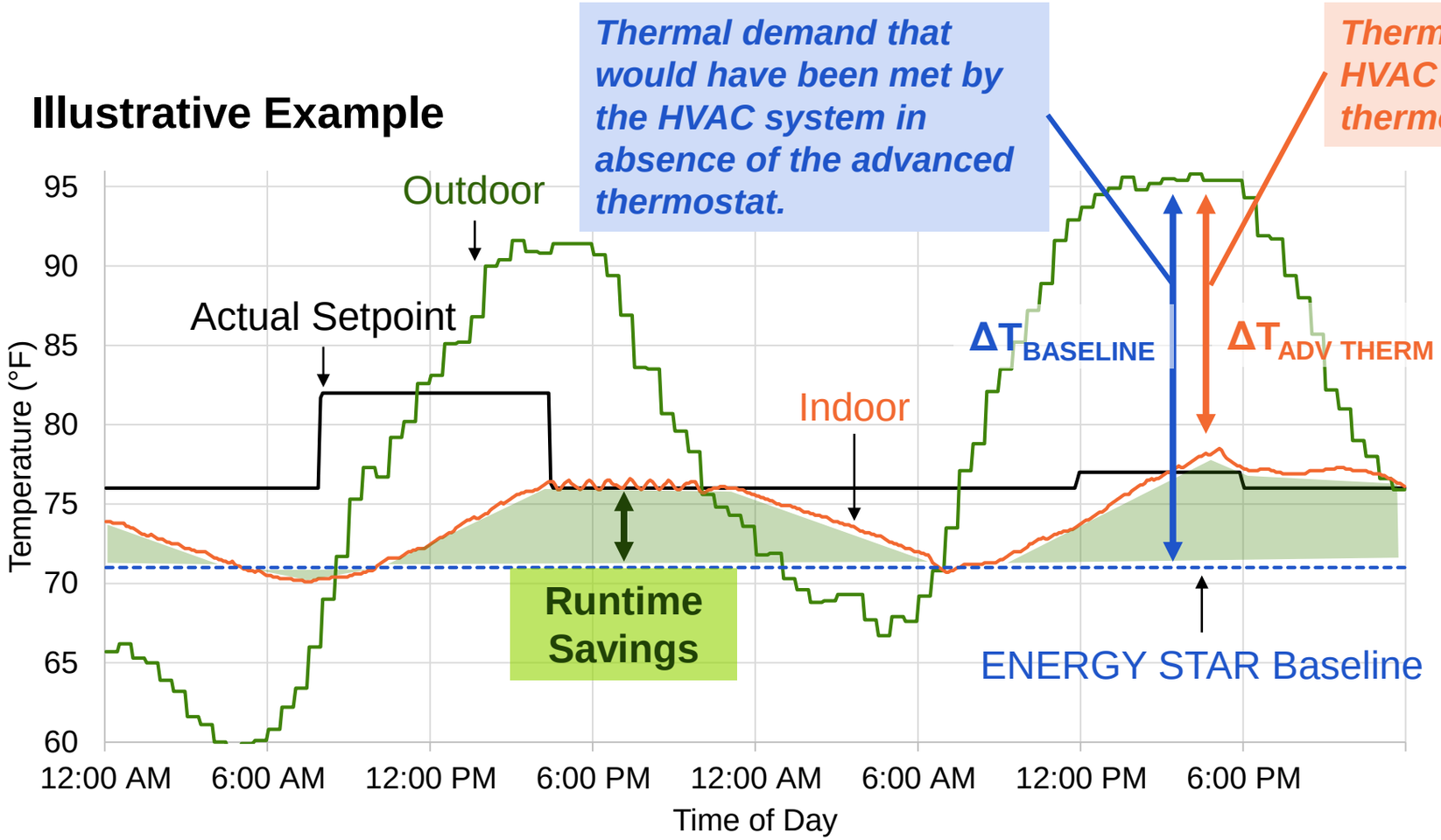
ENERGY STAR Analysis Overview

- The EPA's ENERGY STAR program prescribes a method for demonstrating field savings (decreased HVAC runtime),* which is used to certify products as Connected Thermostats.
- Some stakeholders expressed a strong desire to leverage the ENERGYSTAR method for evaluation purposes.
  - Therefore, Guidehouse, in collaboration with Opinion Dynamics and stakeholders, developed adjustments to the ENERGY STAR method to potentially improve the accuracy of the method.
- The objectives of the ENERGY STAR analysis were:
  - To estimate a range of savings associated with ***different assumptions about baseline behavior*** (i.e., before installation of an advanced thermostat)
  - Identify the relative importance of different assumptions that affect estimated savings using the ENERGY STAR algorithm
- Assumptions regarding baseline behavior were based on ***survey responses*** regarding how customers used their thermostat before advanced thermostat installation
- Guidehouse ran the adjusted algorithm on a sample of anonymized telemetry data for 500 devices provided by Google for HER and non-HER customers.

What is the ENERGY STAR Method

Illustrative Example



- Runtime savings are calculated based on the actual observed indoor and outdoor temperatures as recorded by the advanced thermostat, and the assumed ENERGY STAR baseline.

* ENERGY STAR Connected Thermostat Products Method to Demonstrate Field Savings Version 1.0 (rev. Dec-2016). Available at: https://www.energystar.gov/sites/default/files/Version%201.0%20Method%20to%20Demonstrate%20Field%20Savings%20of%20ENERGY%20STAR%20Connected%20Thermostats.pdf

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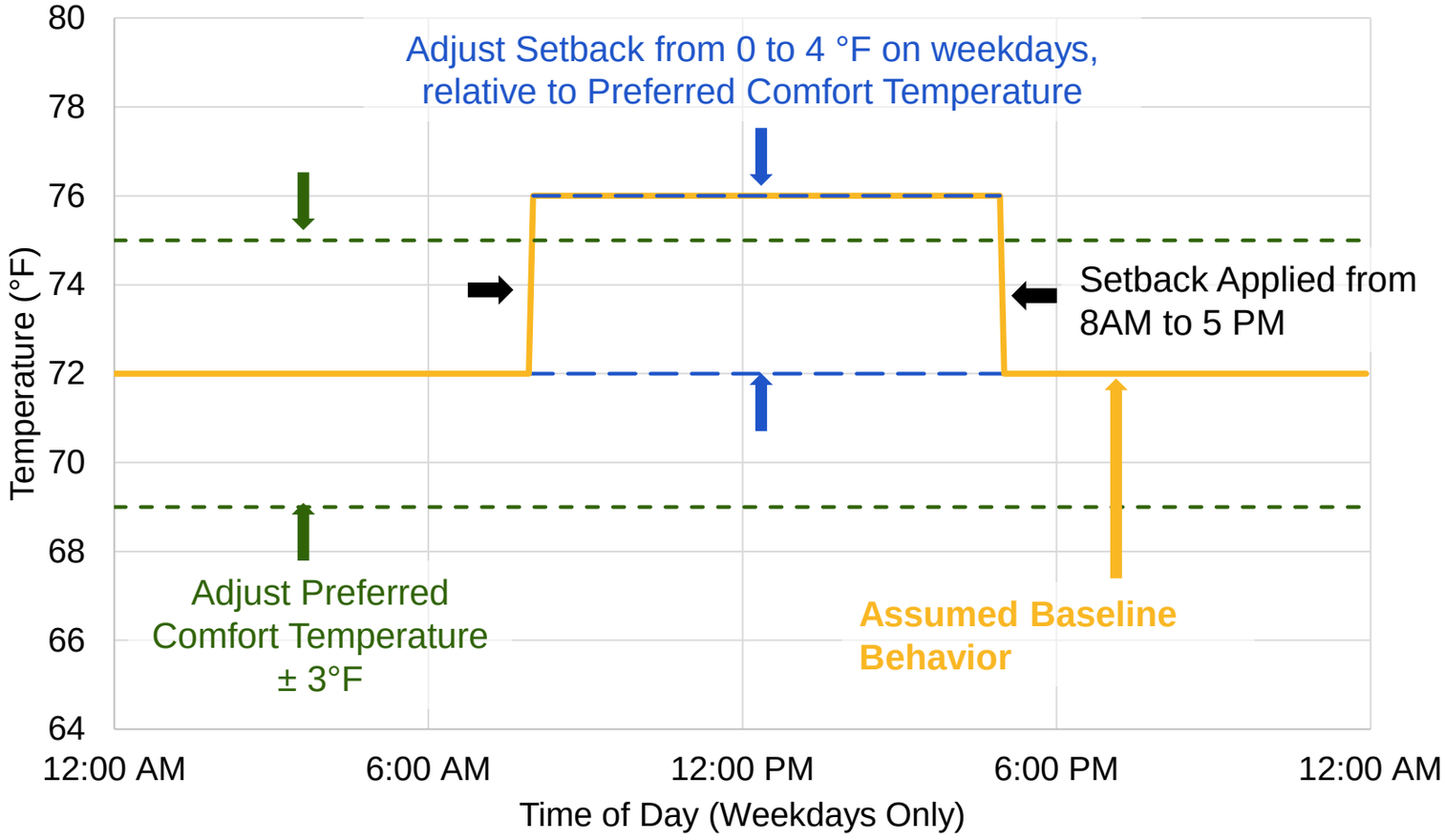
Adjustment Summary - Illustration

Adjustments focused on two key questions

The adjustments to the ENERGY STAR method are illustrated for a single weekday:

- Baseline Comfort Temperature:
  - Defined as the ***10th percentile (for cooling) and 90th percentile (for heating) of indoor temperature history*** based on core heating and cooling days
  - How accurate is this approach to identify the true baseline comfort temperature for each customer?
- **Setback Behavior**
  - The method assumes a ***constant baseline temperature*** in absence of an advanced thermostat
  - To what extent are customers using a programmed setback schedule or a more efficient constant temperature prior to installation of an advanced thermostat?



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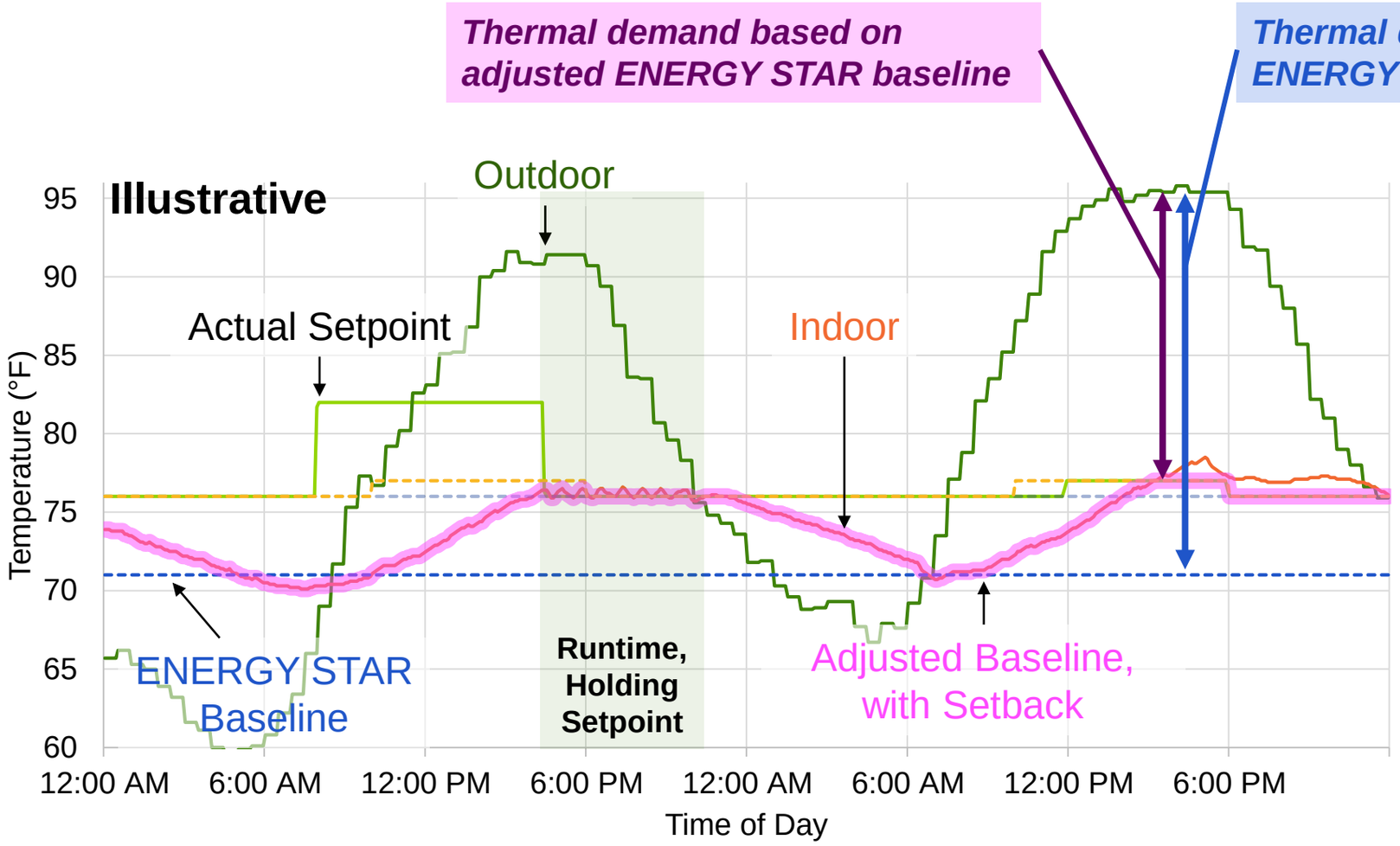
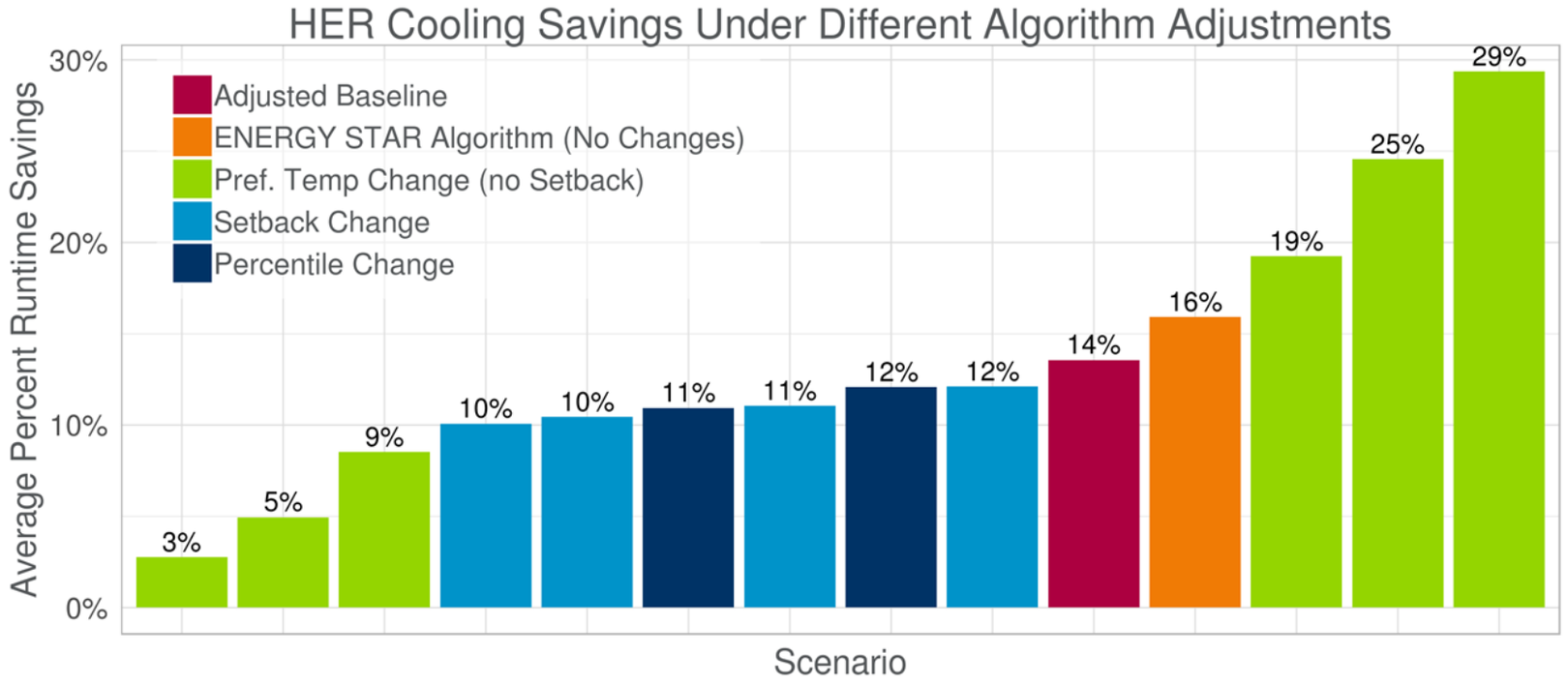
Adjustments to the ENERGY STAR Method



- The adjustments to the ENERGY STAR method involve
  - Selecting the baseline comfort temperature based on time periods where the system is running and holding the desired setpoint,
  - Applying an assumed "setback" – an increase in setpoint – during the day.

ENERGY STAR Analysis

Range of Savings (HER, Guidehouse found similar savings estimates for non-HER customers)



Adjusted Baseline, Preferred temperature +1 to +3°F

Adjusted Baseline, Setback 0 to 4°F

Adjusted Baseline, 15th and 20th Percentile

Adjusted Baseline, Preferred Temperature -1 to -3°F

- Estimated savings vary based on assumptions made regarding how customers used their thermostat. The true savings estimate would depend on determining verified assumptions about how participants behaved prior to installing an advanced thermostat
- Savings estimates for analyzed scenarios range from 3% to 29% of cooling runtime.
  - Guidehouse acknowledges that some stakeholders assert a range of parameters that they consider to be a reasonable range of expected behavior, which results in savings estimates between 10% and 14% of cooling runtime.
- Guidehouse did not estimate coincident peak demand savings using the ENERGY STAR method.

Econometric Analysis Results

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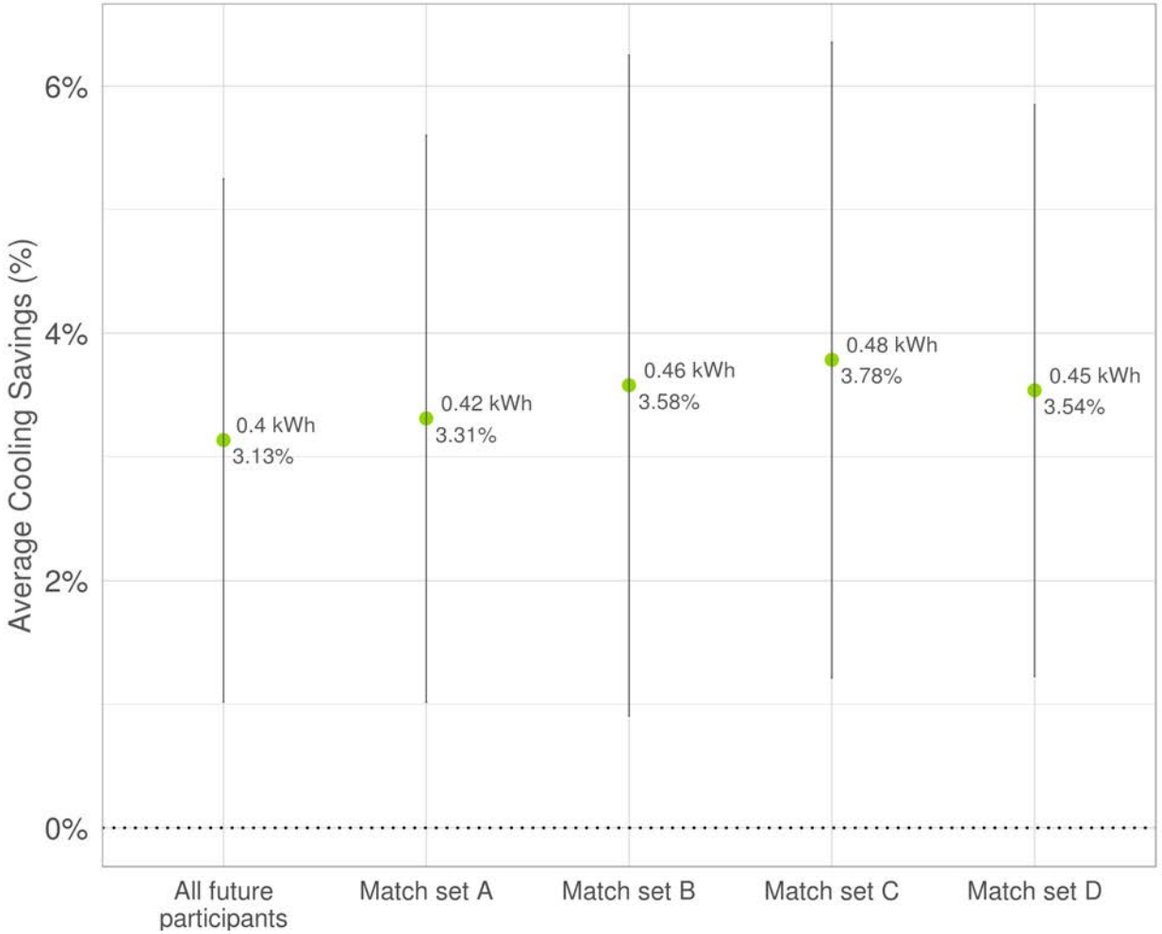
Econometric Analysis Overview

- **Study objectives:** Estimate annual cooling electric savings and coincident peak demand savings.
- **Study participants:** Guidehouse performed a regression analysis of AMI data for 13,388 ComEd participants who received a rebate for an advanced thermostat between October 2017 and March 2018, to estimate savings over the 2018 cooling season (May – September 2018). Savings estimates from the econometric analysis are based on study participants who were enrolled in the Home Energy Report (HER) program.
- **Study comparison group:** Guidehouse leveraged a comparison group of 22,630 future ComEd participants who received a rebate for an advanced thermostat after September 2018 and were enrolled in the HER program. Guidehouse found that matching was not necessary to further refine our future participant comparison group. The purpose of a comparison group is to account for trends in energy use that are not related to the rebate of an advanced thermostat.
  - Study and future participants have generally similar distributions of key demographic variables (household composition, life stage, location, and wealth), geographic location, and usage patterns in the pre-installation summer. The evaluators note that a comparison group does not need to provide perfect alignment across all variables to be considered high-quality.
  - To account for remaining discrepancies between study and future participants as best as possible, usage during the pre-installation summer and demographic characteristics are included in the regression model.
- **Robustness:** Guidehouse found the study results to be robust to several changes to the analysis, including:
  - Comparison group: Tested four matched comparison groups, employing a variety of demographic variables and usage patterns
  - Model specification: Tested three alternative models, including two versions of a fixed effects model and a within-subject model
  - Prior study: Analysis methods differed with respect to data frequency, weather, matching method, model specification

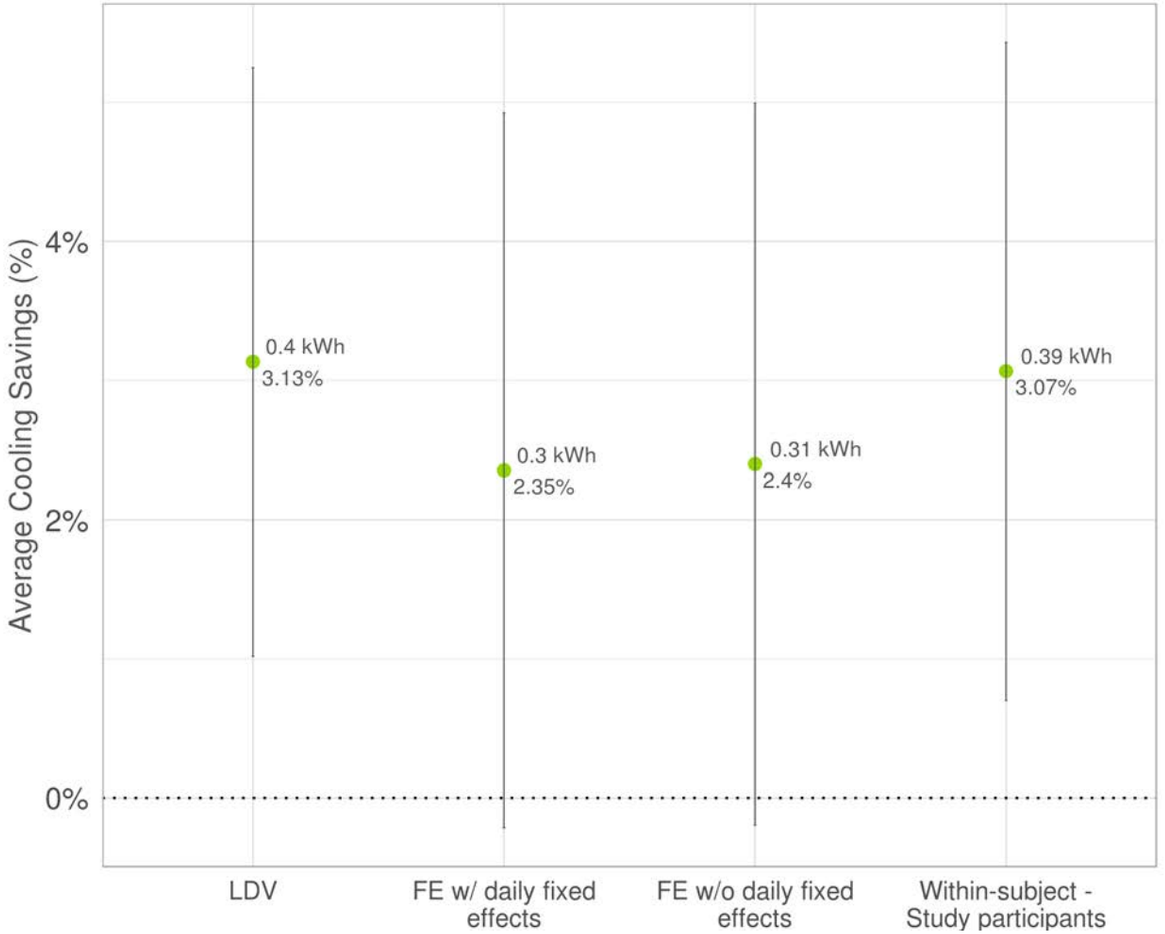
Study Results Are Robust to Changes in Analysis Methods

Results were not sensitive to different comparison groups and model specifications

Comparison Group



Model



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Adjustments

Some factors could not be directly implemented in the regression analysis due to data limitations or the timing of this research. Guidehouse applied the adjustments to estimated savings in the following order:

Self-Selection*

- Issue: With observational studies, there are potential inherent, unobserved differences between treatment and comparison groups.
- Resolution: Attribute change in estimated baseload use from pre- to post-rebate to self-selection; apply same percentage trend to estimated cooling load.
- Disclaimer: This adjustment may not be accurate.

Percent Air Conditioning

- Issue: Study participants who did not have AC connected to their thermostat generated no cooling savings.
- Resolution: Adjust energy savings for the percentage of customers with cooling, based on program tracking data.

In-Service Rate

- Issue: Program tracking data contains the rebate date but not the installation date. The gap between the rebate and installation may span months or years for some customers.
- Resolution: Adjust energy savings for participants who did not install at all or installed during study post-period, using information provided by the thermostat vendor.

Thermostat Optimization

- Issue: TO programs have recently been offered or expanded, which have changed savings achieved by advanced thermostats since the study period.
- Resolution: Adjust energy savings using TO savings rates from past evaluation reports and enrollment rates from thermostat vendors.

* Guidehouse used future installers as the comparison group to mitigate self-selection bias related to the decision to purchase a rebated advanced thermostat. Guidehouse made the self-selection adjustment per agreement with stakeholders, following the approach taken by DNV GL in a 2020 study. Guidehouse acknowledges that this adjustment is a coarse method of addressing potential bias and may not be accurate or applicable for future studies of this type.

Econometric Analysis Results

Result	Energy Savings (Percent of Cooling Load)		Coincident Peak Demand Savings* (Percent of Cooling Load)	
	Non-Selection Adjusted	Selection Adjusted	Non-Selection Adjusted	Selection Adjusted
Regression Model	3.24%	-	10.37%	-
Selection Bias	3.24%	4.45%	10.37%	10.99%
Percent Air Conditioning	3.27%	4.49%	10.47%	11.10%
In-Service Rate	3.91%	5.38%	12.48%	13.22%
Thermostat Optimization	6.36%	7.79%	15.70%	16.41%

* The coincident peak demand period is defined in the Illinois TRM as 1-5 PM on non-holiday weekdays, June – August.

- On average, study participants who received an advanced thermostat rebate saved energy. This result is based on study participants who are enrolled in the HER program.
- Daytime sayings (9 AM – 5 PM) were found to be statistically significant at 10.48% of cooling load. Nighttime savings (5 PM – 9 AM) were negative at -2.48%, but not statistically significant.
- Guidehouse made the self-selection adjustment per agreement with stakeholders, following the approach taken by DNV GL in a 2020 study. Guidehouse acknowledges that this adjustment is a coarse method of addressing potential bias and may not be accurate or applicable for future studies of this type.

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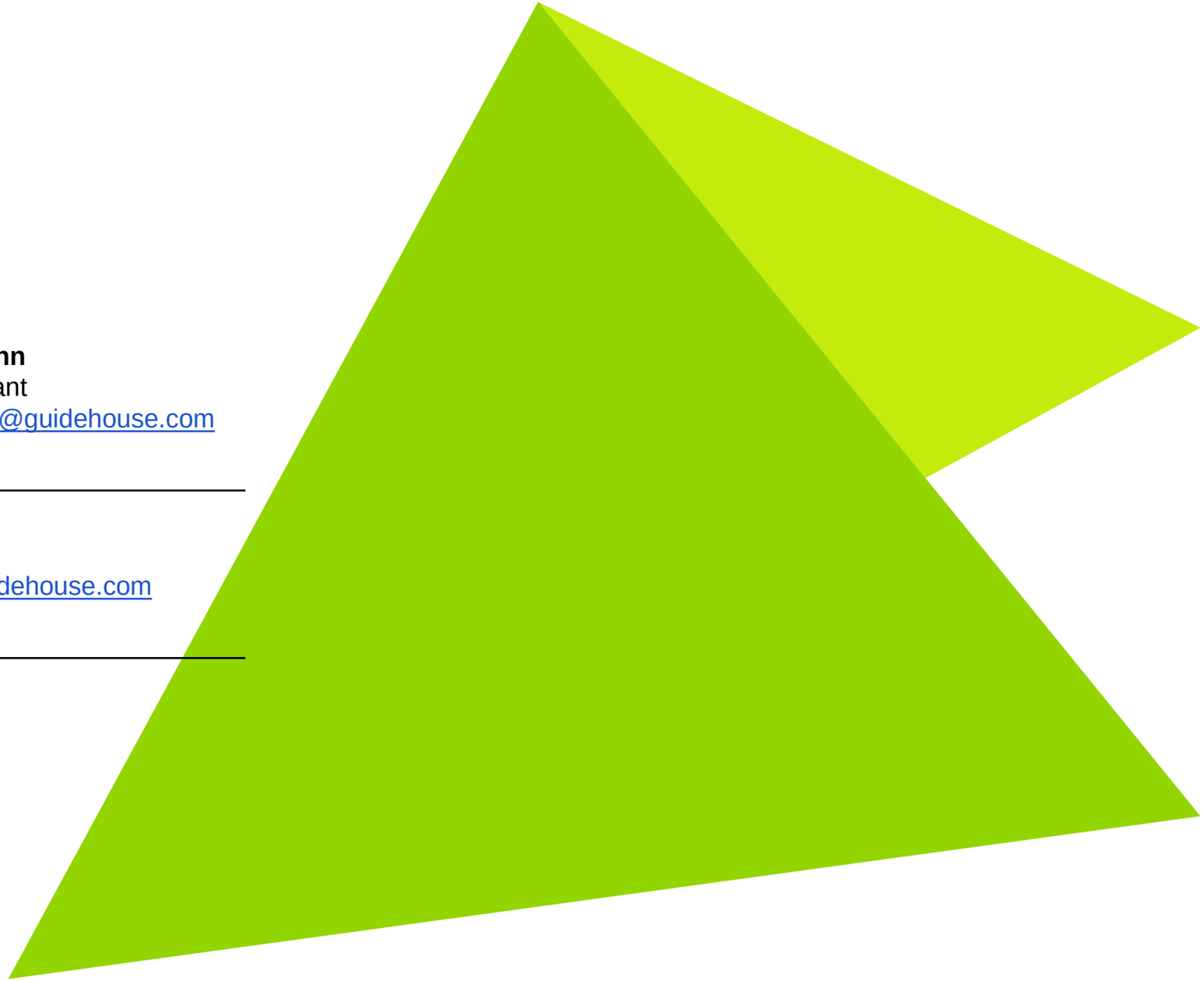

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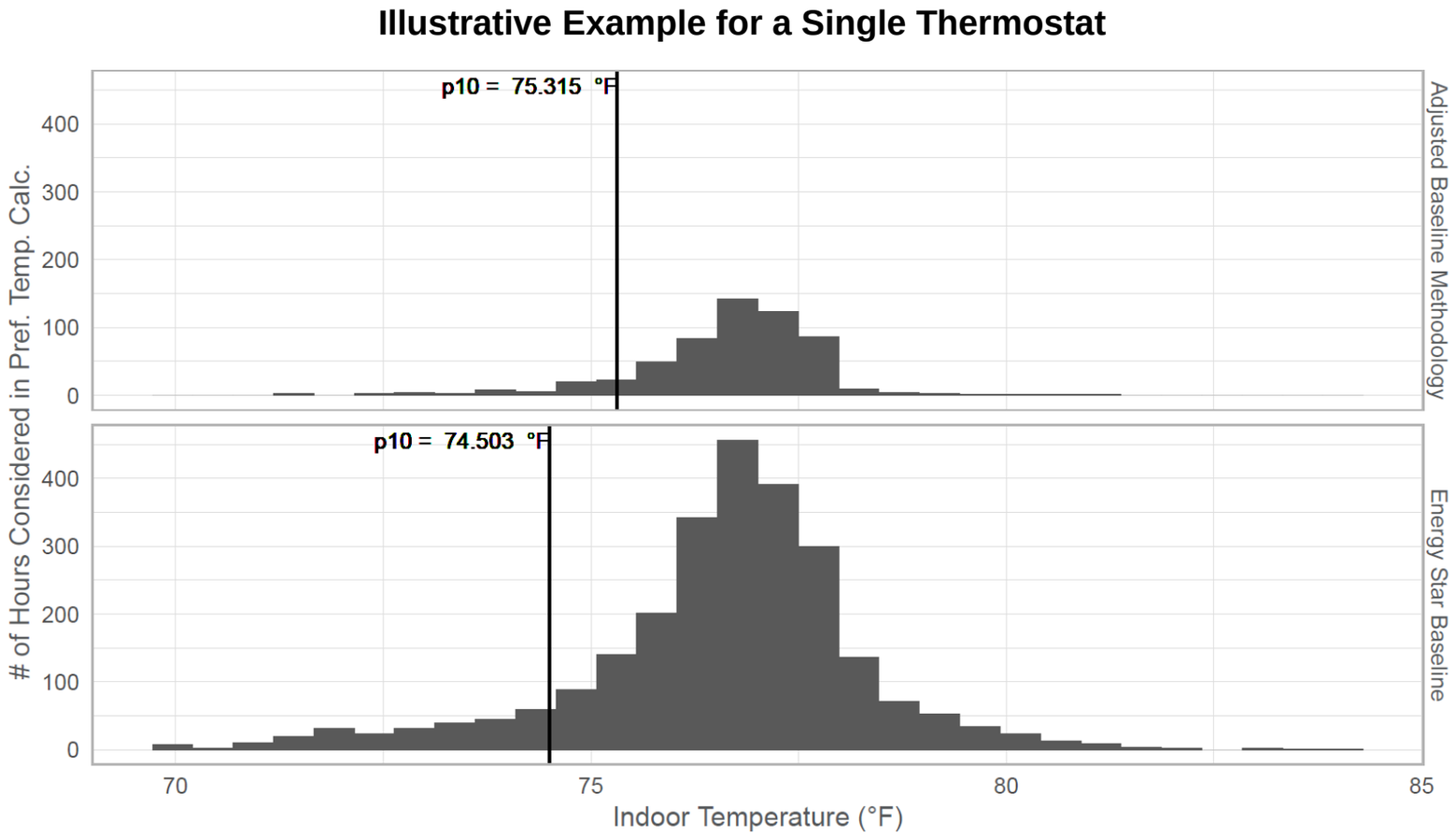
Appendix

Baseline Comfort Temperature

What is the true baseline?



- This slide and the next slide show indoor temperature history for two example households, to show the variation in customer behavior.
- The top panel shows just hours included in the adjusted methodology (where the system is holding the setpoint), while the bottom panel shows all hours. In each panel, the vertical line shows the selected preferred comfort temperature selected by the algorithm.
- In the ENERGY STAR Algorithm, this temperature is used as a constant baseline from which savings are estimated. This constant baseline is sufficient for comparisons between devices. However, evaluated energy savings estimates require a more accurate understanding of the baseline to accurately estimate savings.
- The assumption of the 10th percentile may or may not accurately reflect actual baseline behavior.

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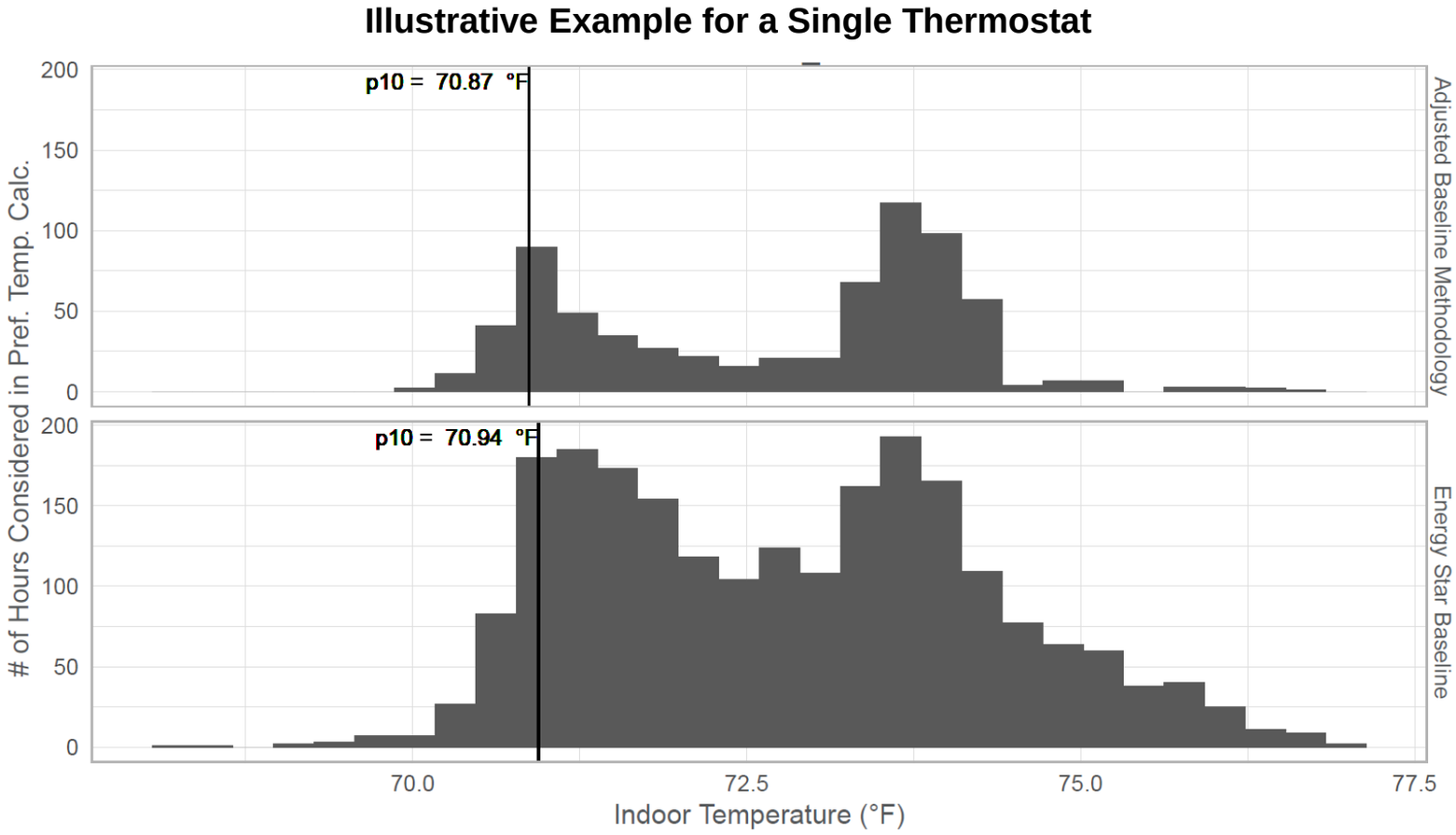
Baseline Comfort Temperature

What is the true baseline?



- This household shows a different distribution of temperatures, with two peaks representing different common temperatures. This suggests that the household may change its preferences and behavior based on different factors.
  - Possible explanations might include a daytime setback, or different preferences by season.
- The variation in customer behavior is a challenge for inferring baseline behavior – how a household would use a non-advanced thermostat.

Comparison of Analyses

The following table (continued on the next slide) summarizes the features and differences of both analyses.

Category	Econometric	ENERGY STAR
Sample Population	• 13,388 study participants, 22,630 future participants • Entire population is HER participants • Includes thermostats from multiple manufacturers	• 500 participants (250 HER, 250 Non-HER) from one manufacturer
Key Data	• Whole-home consumption Advanced Metering Infrastructure (AMI) data (half hourly kWh) • Aggregated to hourly for comparison group selection and daily for regression analysis • Includes 2017 (pre-installation) and 2018 (post-installation) data • PRIZM demographic customer segmentation	• Thermostat telemetry data (e.g. hourly cooling runtime, set point) • Includes 2018-2019 (post-installation) data • Participant survey responses (inform assumed set point behavior)
Estimation Method	• Lagged Dependent Variable (LDV) model using participants and a comparison group of future participants • Estimates difference between pre- and post-consumption attributable to the smart thermostat	• Site-specific Heating, Ventilation, and Air Conditioning (HVAC) model (function of indoor / outdoor temperature) • Estimates difference between actual post-runtime and estimated pre-runtime based on assumed baseline behavior • Adjusted for different scenarios of baseline behavior, including different preferred comfort temperature and setbacks.
Savings Output	• Average whole-home energy savings	• Average HVAC runtime savings

Comparison of Analyses (Continued)

The following table (continued from the previous slide) summarizes the features and differences of both analyses.

Category	Econometric	ENERGY STAR
Conversions for IL TRM	• Convert whole home to cooling load energy savings • Adjustments for customers without connected AC • Adjustments for customers who installed during or after study period • Adjusted for expected future TO savings (as applicable) due to wider deployment	• Convert runtime to energy savings
In-Service Rate	• Uses separate in-service rate (ISR)	• Uses separate ISR
Net to Gross *Gross – not accounted for* *Net – fully accounted for*	• Free-ridership: gross* • Participant spillover: net* • Non-participant spillover: gross* • Applicable net-to-gross adjustments to these factors were determined as part of the annual Stakeholder Advisory Group (SAG) net-to-gross process	• Free-ridership: gross • Participant spillover: gross • Non-participant spillover: gross • Applicable net-to-gross adjustments to these factors were determined as part of the annual SAG net-to-gross process
Additional Considerations	• Potential self-selection issues related to time of installation (now vs future)	• ENERGY STAR model doesn't capture potential secondary effects (e.g. increased fan consumption, more energy efficient behavior, or other spillover effects) • Includes only historical TO savings (if applicable)

* In IL TRM v8, Volume 4, Section 5.3.1, Table 5-3, regression using a comparison group of future participants produces an estimate that is gross to free ridership and non-participant spillover but net to participant spillover.