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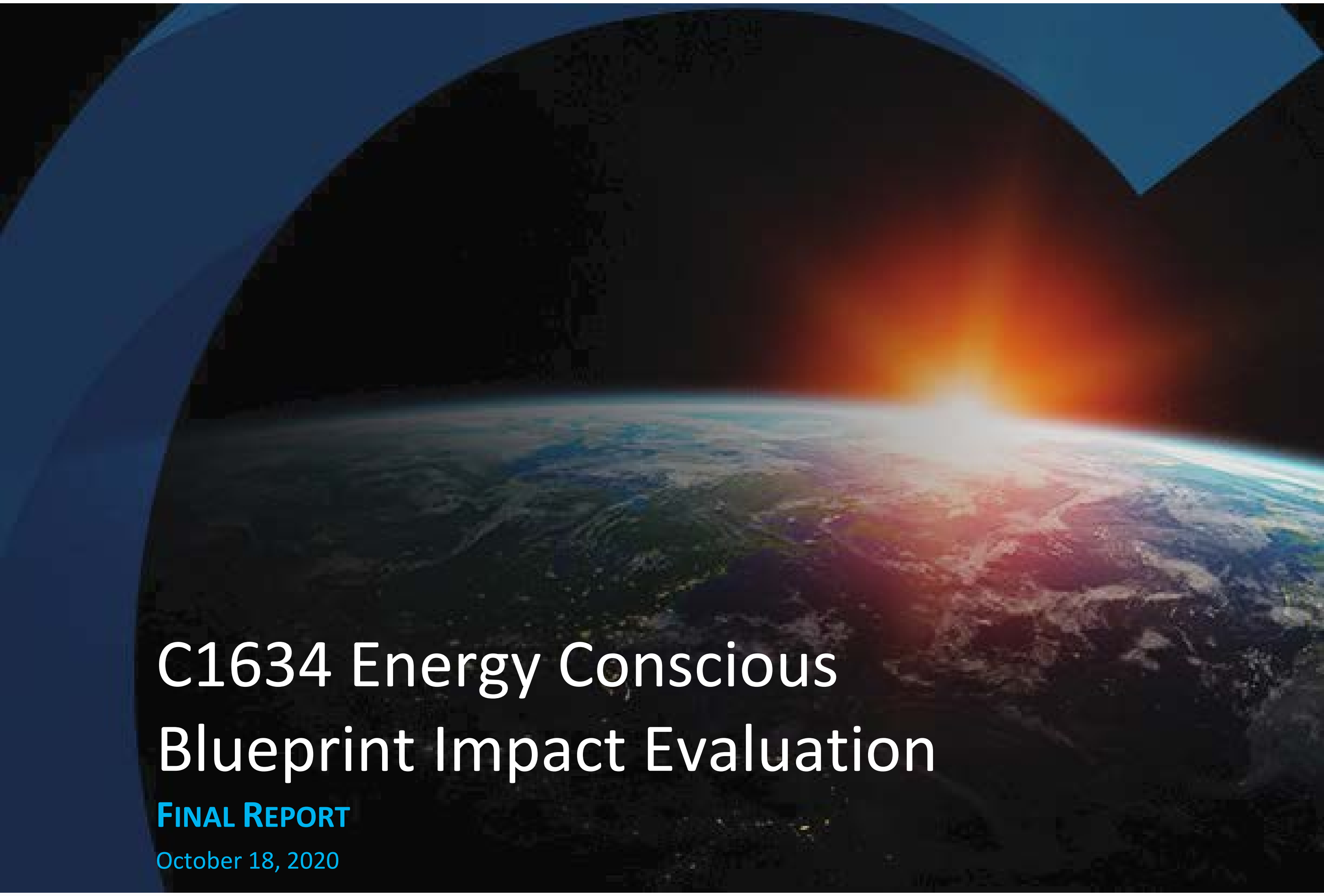

C1634 Energy Conscious Blueprint Impact Evaluation

FINAL REPORT

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And Evaluation Administrator Team

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Abstract

The Connecticut Energy Efficiency Board contracted with the Evaluation Administrators and Cadmus (the Team) to conduct an impact evaluation of Energize Connecticut's Energy Conscious Blueprint (ECB) program for the 2017 and 2018 years. Four utilities—Eversource, United Illuminating, Connecticut Natural Gas, and Southern Connecticut Gas Company—participate in the ECB program to provide incentives for new construction, major renovation, tenant fit-out measures, and new (or end of useful life) equipment measures for commercial, industrial, or municipal customers throughout Connecticut. The goals for this evaluation were to assess the retrospective and prospective savings impacts of electric energy, electric demand, and natural gas through the ECB program.

The Team reviewed the ECB program tracking databases and stratified the population into five electric strata (cooling, lighting, heating, custom/other, process) and three natural gas strata (heating, domestic hot water, custom). The Team then performed on-site inspections and engineering analysis for 274 measures,[1] which contributed 27% of the 2017 and 2018 program electric consumption savings and 18% of the 2017 and 2018 program natural gas savings. The data collected from site visits included information from interviews, spot measurements, site observations, building management trend data, power metering trend data, and utility bills. The Team analyzed the data and calculated evaluated energy savings using the methodologies described in the Program Savings Document (PSD) or the most appropriate technical reference manual (TRM). For complicated or custom measures, the Team calculated evaluated energy savings based on custom engineering spreadsheet analysis, energy modeling, or a utility bill analysis.

Overall, the two program years achieved gross realization rates of 101.4% for electric savings, 98.6% for seasonal peak summer electric demand savings, 110.6% for seasonal peak winter electric demand savings, and 94.6% for natural gas savings, though some variability occurred between measure categories.

The Team calculated 104,605,400 kWh of evaluated electric energy savings, 16,279 kW of summer electric demand savings, 11,721 kW of winter electric demand savings, and 1,979,081 therms of natural gas savings. Prospective realization rates were calculated as 101.1% for electric savings, 132.5% for seasonal peak summer electric demand savings, 169.6% for seasonal peak winter electric demand savings, and 103.7% for natural gas savings.

The following table presents the prospective realization rates for each stratum.

[1] Sampling was performed at the measure level, and multiple measures were sampled for some sites.

Strata	Total Measures	Electric Energy Savings (kWh) Prospective Gross Realization Rate	Summer Demand Savings (kW) Prospective Gross Realization Rate	Winter Demand Savings (kW) Prospective Gross Realization Rate	Natural Gas Savings (therms) Prospective Gross Realization Rate
Cooling, Electric	643	86.2%	89.7%	151.1%	N/A
Lighting, Electric	721	129.0%	104.6%	116.6%	N/A
Heating, Electric	117	97.8%	94.4%	93.0%	N/A
Custom/Other, Electric	222	98.5%	97.4%	106.3%	N/A
Process, Electric	449	80.3%	114.1%	112.5%	N/A
Heating, Gas	515	N/A	0%	N/A	97.0%
Domestic Hot Water, Gas	101	N/A	0%	N/A	88.7%
Custom/Other, Gas	45	100%	0%	N/A	90.7%
Total	**2,813**	**102.0%**	**102.5%**	**114.7%**	**94.6%**

Based on the evaluation findings, the Team compiled the following recommendations for consideration with the PSD.

1. Remove dual enthalpy economizer measures from the PSD and ECB-offered measures.
2. Combine results from this study and the C1635 Energy Opportunities Impact Evaluation study to assess and update hours of use (HOU) by building type for a future version of the Connecticut PSD.
3. Calculate chiller savings using an annual 8,760 hourly calculation method or an energy simulation model to account for the variable temperatures and change in average demand during summer and winter peak periods.

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Acronyms

ccf	Hundred cubic feet
ECB	Energy Conscious Blueprint
EEB	Connecticut Energy Efficiency Board
EOL	End of life
EWT	Entering water temperature
HOU	Hours of use
IECC	International Energy Conservation Code
IMPVP	International Performance Measurement and Verification Protocol
kW	Kilowatt
kWh	Kilowatts per hour
M&V	Measurement and verification
MMBtu	Million British thermal units
PSD	Program Savings Document
TMY	Typical meteorological year
TNC	True New Construction
TRM	Technical Reference Manual
UI	United Illuminating
VFD	Variable frequency drive
VRF	Variable refrigeration flow

Executive Summary

Energize Connecticut's Energy Conscious Blueprint (ECB) program provides incentives for new construction; major renovation; tenant fit-out measures; and new (or end of useful life) equipment measures for commercial, industrial, or municipal customers throughout Connecticut. Four utilities—Eversource, United Illuminating, Connecticut Natural Gas, and Southern Connecticut Gas Company—participate in the ECB program.

The ECB program contributed 18% of annual energy savings (kWh) and 20% of natural gas savings (ccf) to Energize Connecticut's program portfolio in 2016. During the 2017 and 2018 years, incentives were provided for 2,813 unique measures through the ECB program, and 103,192,682 annual energy savings (kWh) and 2,091,506 natural gas savings (therms) were reported in Connecticut.

The Connecticut Energy Efficiency Board contracted with the Evaluation Administrators and Cadmus (the Team) to conduct an impact evaluation of its ECB program for the 2017 and 2018 years. The goals for this evaluation are to assess the savings impacts of electric energy, electric demand, and natural gas through the ECB program. This report provides the results of the Team's evaluation.

Key Findings

Key Evaluation Findings

The Team performed on-site inspections and engineering analysis for 274 measures,[2] which contributed 27% of the 2017 and 2018 program electric consumption savings and 18% of the 2017 and 2018 program natural gas savings. Overall, the two program years achieved gross realization rates of 101.4% for electric savings, 98.6% for seasonal peak summer electric demand savings, 110.6% for seasonal peak winter electric demand savings, and 94.6% for natural gas savings, though variability occurred between measure categories.

The Team calculated 104,605,400 kWh of evaluated electric energy savings, 16,279 kW of summer electric demand savings, 11,721 kW of winter electric demand savings, and 1,979,081 therms of natural gas savings. Prospective realization rates were calculated as 101.1% for electric savings, 132.5% for seasonal peak summer electric demand savings, 169.6% for seasonal peak winter electric demand savings, and 103.7% for natural gas savings.

Table 1, Table 2, Table 3, and Table 4 provide reported and evaluated savings, realization rates, and precision for each strata. Specific details and findings per strata are described in the report's *Evaluated Gross Savings Results by Strata* section.

[2] Sampling was performed at the measure level, and multiple measures were sampled for some sites.

Table 1. 2017 and 2018 ECB Program Electric Energy Savings

Strata	Total Measures	Reported Gross Savings (kWh)	Evaluated Gross Savings (kWh)	Retrospective Gross Realization Rate	Precision[a]	Prospective Gross Realization Rate
Cooling, Electric	643	10,906,169	7,612,779	69.8%	12.9%	86.2%%[b]
Lighting, Electric	721	41,405,184	53,410,487	129.0%	16.3%	129.0%
Heating, Electric	117	1,285,371	1,257,713	97.8%	9.0%	97.8%
Custom/Other, Electric	222	12,405,684	12,221,278	98.5%	3.9%	98.5%
Process, Electric	449	36,031,608	28,944,477	80.3%	7.4%	80.3%
Heating, Gas	515	0	-	N/A	N/A	N/A
Domestic Hot Water, Gas	101	0	-	N/A	N/A	N/A
Custom/Other, Gas	45	1,158,666	1,158,666	100%	0%	100%
Total	**2,813**	**103,192,682**	**104,605,400**	**101.4%**	**8.4%**	**102.0%**

[a] Strata precision is based on 80% confidence; overall precision is based on 90% confidence.
[b] Enthalpy economizers were removed from the prospective realization rate consistent with study recommendation.

Table 2. 2017 and 2018 ECB Program Summer Demand Savings

Strata	Total Measures	Reported Summer Demand Savings (kW)	Evaluated Summer Demand Savings (kW)	Retrospective Gross Realization Rate	Precision[a]	Prospective Gross Realization Rate
Cooling, Electric	643	3,808.8	2,774.3	72.8%	21.9%	89.7%[b]
Lighting, Electric	721	7,148.7	7,477.1	104.6%	11.2%	104.6%
Heating, Electric	117	30.9	29.2	94.4%	27.0%	94.4%
Custom/Other, Electric	222	1,803.2	1,757.1	97.4%	22.7%	97.4%
Process, Electric	449	3,716.6	4,241.3	114.1%	15.2%	114.1%
Heating, Gas	515	-	-	0%	0.0%	0%
Domestic Hot Water, Gas	101	-	-	0%	0.0%	0%
Custom/Other, Gas	45	-	-	0%	0.0%	0%
Total	**2,813**	**16,508**	**16,279**	**98.6%**	**7.7%**	**102.5%**

[a] Strata precision is based on 80% confidence; overall precision is based on 90% confidence.
[b] Enthalpy economizers were removed from the prospective realization rate consistent with study recommendation.

Table 3. 2017 and 2018 ECB Program Winter Demand Savings

Strata	Total Measures	Reported Winter Demand Savings (kW)	Evaluated Winter Demand Savings (kW)	Retrospective Gross Realization Rate	Precision[a]	Prospective Gross Realization Rate
Cooling, Electric	643	410.7	195.5	47.6%	267.1%	151.1%[b]
Lighting, Electric	721	5,454.6	6,360.2	116.6%	21.7%	116.6%
Heating, Electric	117	361.7	336.5	93.0%	13.3%	93.0%
Custom/Other, Electric	222	1,343.9	1,429.2	106.3%	12.3%	106.3%
Process, Electric	449	3,022.4	3,399.2	112.5%	17.5%	112.5%
Heating, Gas	515	-	-	N/A	N/A	N/A
Domestic Hot Water, Gas	101	-	-	N/A	N/A	N/A
Custom/Other, Gas	45	-	-	N/A	N/A	N/A
Total	**2,813**	**10,594**	**11,721**	**110.6%**	**12.9%**	**114.7%**

[a] Strata precision is based on 80% confidence; overall precision is based on 90% confidence.
[b] Enthalpy economizers were removed from the prospective realization rate consistent with study recommendation.

Table 4. 2017 and 2018 ECB Program Natural Gas Savings

Strata	Total Measures	Reported Gross Natural Gas Savings (therms)	Evaluated Gross Natural Gas Savings (therms)	Retrospective Gross Realization Rate	Precision[a]	Prospective Gross Realization Rate
Cooling, Electric	643	0	N/A	N/A	N/A	N/A
Lighting, Electric	721	0	N/A	N/A	N/A	N/A
Heating, Electric	117	0	N/A	N/A	N/A	N/A
Custom/Other, Electric	222	0	N/A	N/A	N/A	N/A
Process, Electric	449	0	N/A	N/A	N/A	N/A
Heating, Gas	515	1,345,263	1,304,631	97.0%	8.5%	97.0%
Domestic Hot Water, Gas	101	108,869	96,541	88.7%	12.9%	88.7%
Custom/Other, Gas	45	637,374	577,908	91.1%	19.4%	90.7%[b]
Total	**2,813**	**2,091,506**	**1,979,081**	**94.6%**	**7.7%**	**94.6%**

[a] Strata precision is based on 80% confidence; overall precision is based on 90% confidence.
[b] Difference due to 2020 Program Savings Document (PSD) update for foodservice equipment.

Recommendations

Based on the evaluation findings, the Team compiled the following recommendations. (This report's *Conclusions and Recommendations* section provides a more complete discussion of the findings and associated recommendations.)

Savings Considerations

Recommendation 1 – Dual Enthalpy Economizers. Electric energy savings for dual enthalpy economizers, which receive incentives from the utilities, used deemed values from the 2017 Connecticut Program Savings Document (PSD). These deemed savings were based on a study performed in 1999. The Team's analysis found that no savings are realized when implementing a dual enthalpy economizer instead of a code-compliant single setpoint dry bulb economizer. The Team recommends removing dual enthalpy economizer measures from the PSD and ECB-offered measures.

Recommendation 2 – Lighting Hours of Use. To assess and update hours of use (HOU) by building type for a future version of the Connecticut PSD, the Team recommends combining the results from this study with the C1635 Energy Opportunities Impact Evaluation. The Team installed light loggers at 18 facilities. Analysis of the data indicated that actual HOU were typically greater than reported. (Light logger data from sampled projects are provided in *Appendix A*.) Reported HOU were typically self-reported. In cases where they were not, HOU were based on the facility type associated with each measure, according to Appendix 5 in the 2017 Connecticut PSD.[3]

Recommendation 3 – Chiller Calculations. Chiller calculations often were reported based on a weather-bin calculator that projects chiller load as a function of outside air temperature and economizer setpoint. Using a weather-bin analysis approach may be appropriate for calculating annual energy use if the chiller load correlates well to outside air temperatures, and this approach is often an improvement over using deemed savings or other prescriptive calculation methods. However, cooling loads for chillers may correlate directly to occupancy schedules, process schedules, thermal mass loading, or other impacts. In these situations, the hourly chiller load may not correlate well to outside air temperature, and a weather-bin analysis approach may not accurately calculate annual energy savings or demand savings. Rather than the weather-bin analysis, the Team recommends calculating chiller savings using an annual 8,760 hourly calculation method or an energy simulation model to account for the variable temperatures and change in average demand during summer and winter peak periods.

Recommendation 4 – Air Compressor Load Profiles. Based on observations during site visits as well as power meter data and trend data from the air compressor measures, the Team found three factors that decreased energy savings compared to reported documentation. These factors were lower HOU, higher average loads or compressor speeds, and lower line pressure. The Team recommends implementing a

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3 Energize Connecticut. 2016. *Connecticut Program Savings Document.* 12th Edition for 2017 Program Year. https://www.puc.nh.gov/EESE%20Board/EERS_WG/ct_trm.pdf

pre- or post-implementation assessment of HOU, average load, and line pressures for air compressor measures by using trend data or power metering post-implementation.

Recommendation 5 – Air Compressor Calculations. The Team recommends calculating electric demand savings calculations as the difference in the average load of the efficient compressor and the average load of the baseline compressor during peak periods. The Team found that, for most measures, electric demand savings was the difference in maximum demand during the peak periods instead of the difference in average demand during peak period.[4] The Team recommends estimating an hourly savings profile for non-weather sensitive measures and weighting the savings at each hour according to the ISO-NE peak demand definition.[5] Additionally, updating the calculations are expected to result in higher reported demand savings because savings are maximized during part load conditions.[6]

Recommendation 6 – Chiller Load Profiles. The Team installed power metering equipment on five chiller measures, for which the resulting energy performance exhibited lower total energy use and associated energy savings than assumed in the reported calculations. The Team derived an average 48% realization rate among all sampled chiller measures. Realization rates ranged from 15% to 134% for electric energy use savings and 24% to 268% for summer electric demand savings. The greatest driver for realization rate variation was because meter data exhibited a different load profile than assumed in the reported documentation. The Team recommends adopting greater scrutiny into the assessment of load profiles for all chiller measures, including pre- or post-implementation metering or trending. By including pre- or post-implementation metering, lower variability in realization rates is expected for incentivized chiller measures. As an alternative to metering or trending, the Team recommends using energy models to simulate chiller performance to improve the accuracy of chiller load profiles.

Recommendation 7 – True New Construction. True New Construction (TNC) measures are defined as energy measures that are part of construction for an entirely new building or new space or as part of a major renovation where energy codes are applicable. The Team recommends the utilities include a TNC designation in the measure tracking database. Measures installed as TNC are not consistently documented in the measure tracking databases from the utilities with this designation. Consequently, the number of measures installed as TNC and their associated energy savings cannot be determined.

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4 Electric demand savings (winter and summer) are defined as the average peak reduction for a measure during the ISO-NE definition for a Seasonal Peak Demand Resource—when the real-time system hourly load is equal or greater than 90% of the most recent “50/50” season peak load forecast for the applicable summer or winter season. The summer season is defined as the non-holiday weekdays during the months of June, July, and August. The winter season is defined as the non-holiday weekdays during December and January.

5 Mapping this definition to the TMY3 long-term average weather data for Hartford, the summer peak demand savings are a weighted average of the savings during the hours ending 13 – 18 and the winter peak demand savings are a weighted average of the savings between hours ending 8 – 22.

6 The average demand for high efficiency, variable speed compressors is much lower than the maximum demand observed during the same period. For reciprocating baseline compressors, the average demand during peak period is much closer to the maximum demand. As such, greater savings are achieved.

Customers who install TNC measures often pursue energy efficiency through a different decision-making process than those who install energy efficiency measures due to equipment failure or end-of-life replacement, and the performance of TNC measures may differ as a result.

Recommendation 8 – Tracking Measure Database Detail. The Team recommends improving the detail provided in the measure description data entry in the measure tracking database for each measure. The measure description in the tracking databases varied in detail and quality. For custom measures, the description often did not provide sufficient detail to understand the measure without reviewing its specific documentation.[7] Without sufficient detail, the total number of measure types remains unknown. ASHRAE research project, 1836-TRP, is intended to develop a standardized system for the characterization and categorization of energy efficiency measures.[8] The Team recommends reviewing and incorporating the results of this research project into the measure categorization of the ECB program.

Recommendation 9 – Baseline Study. The Team recommends using the results of the baseline study to help prioritize quantitative investigations of standard practice baselines in a future study.

Recommendation 10 – Forecast load profile treatment. The Team recommends developing regulatory guidance and policies related to establishing first-year energy savings on measures where occupancy or load is expected to ramp up to full capacity over several years and where first-year energy savings may not be representative of typical future annual energy savings. The Team evaluated multiple measures involving the installation of chillers or air compressors serving facilities where the occupancy or load is expected to ramp up over several years. Because energy savings are directly related to the load profile for chillers and air compressors, the energy savings for these measures may increase over time and the first-year energy savings may not be representative of typical future annual energy savings. Regulatory guidance and policies related to the treatment of these measures will encourage consistency across measure types and evaluation studies.

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7 Measure Category and Measure Description are separate data entry points for each incentivized measure in the tracking databases

8 *1836-TRP—Developing a Standardized Categorization System for Energy Efficiency Measures.* Sponsored by TC 7.6, Building Energy Performance; co-sponsored by BEQ & SSPC 100, Energy Efficiency in Existing Buildings. https://www.ashrae.org/File%20Library/Technical%20Resources/Research/Links/RFP/1836-TRP.PDF

Introduction

Energize Connecticut's Energy Conscious Blueprint (ECB) program provides incentives for new construction, major renovation, tenant fit-out measures, and new (or end of useful life) equipment measures for commercial, industrial, or municipal customers throughout Connecticut. In March 2018, the Team was hired to evaluate the ECB program's impact in Connecticut for 2017 and 2018.

Evaluation Goals and Research Objectives

The Team addressed the following evaluation, measurement, and verification goals and research objectives for the impact evaluation of the ECB program.

Table 5. Evaluation Goals

Evaluation Goals
Provide gross savings (retrospective) realization rates for information purposes for electric and natural gas energy. [9]
Update gross savings (prospective) realization rates for electric energy and demand and natural gas energy. [10]
Evaluate demand savings with appropriate rigor to meet the Independent System Operator New England standards.
Develop realization rates for at least five electric and two natural gas end-use groups.
Investigate developing separate realization rates for true comprehensive new construction measures.
Support future updates to the Connecticut Program Savings Document.

Table 6. Research Objectives

Research Objectives
What are the evaluated summer and winter demand (kW) and electric (kWh) and natural gas energy (therms) savings for a sample of selected electric and natural gas measures?
For measure-level realization rates less than 90% or greater than 115%, what are the primary reasons for differences between *ex post* and *ex ante* savings estimates?
What are the gross savings realization rates for each sampled measure?
What are the updated values that should be incorporated into the PSD from this evaluation?
Are the current applicable Connecticut Program Savings Document methods and values being used appropriately for each measure?
Are applicable baselines properly applied to savings estimates?

Evaluation Activities

The Team implemented several steps to achieve the evaluation goals and research objectives. This section describes the activities and processes we used throughout the impact evaluation of the 2017 and 2018 ECB program. To determine gross savings, the Team applied the steps outlined in Table 7.

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9 Retrospective realization rates indicate the realized energy savings when compared to the reported energy savings for the evaluated time period.

10 Prospective realization rates indicate the predicted realized energy savings when compared to the reported energy savings for a future time period.

Table 7. Impact Steps to Determine Evaluated Gross Savings

Step	Action
1	**Tracking Database Review:** Validate the accuracy of data in the participant database
2	**Stratification and Sampling:** Develop strata from participant database and perform sampling
3	**Evaluation, Measurement, and Verification Plan Development:** Review sample measure data and identify appropriate International Performance Measurement and Verification Protocol methodology to apply for each sampled measure
4	**Site Visits, Metering:** Perform site visits, install power meters or light loggers, interview facility staff, collect measure data
5	**Analysis:** Validate reported savings using engineering calculations, model simulations, meter data, and other forms of analysis techniques
6	**Realization Rates:** Extrapolate realization rates to population and summarize findings

Step 1: The Team reviewed the program tracking database to verify the accuracy of the reported energy savings, participant counts, measure descriptions, and incentive dates. Where discrepancies were found, the Team communicated with the utilities to review and update the participant database.

Step 2: The Team stratified the population from the ECB program database into five electric strata (cooling, lighting, heating, custom/other, process) and three natural gas strata (heating, domestic hot water, custom). Within each stratum, the Team designed a sample to achieve ±10% precision at the two-tailed 90% confidence level for the ECB portfolio. The Team selected the sampled measures and requested the sample measure documentation from the utilities. Some customers implemented multiple measures as part of a single project application. In these cases, the utilities provided documentation for all measures implemented with the specific project application. The measures that were not specifically sampled but included with the project documentation were identified as convenience measures. The Team evaluated and reviewed convenience measures with the same rigor as the directly sampled measures to meet confidence and precision sample targets.

Step 3: The Team received and reviewed the sample measure documentation from the utilities to understand how savings were calculated, identify the site-specific variables that could be collected during site visits, and develop the appropriate evaluation measurement and verification (M&V) plans. The M&V plans are based on methods established by the International Performance Measurement and Verification Protocol (IPMVP).

Step 4: The Team performed site visits to verify the installation, specification, and operation of rebated measures. The Team installed light loggers and power metering equipment at 106 of the 274 customer sites within the sample. The Team intended to install power metering equipment for all sampled measures within the Electric stratum (Cooling, Lighting, Heating, Custom/Other, Process) where energy savings varied based on independent variables such as time of day, outside air temperature, production/process schedules, or variable loads. However, in some cases, we did not install metering equipment for the following reasons: at the site contact's request, the equipment characteristics prohibited the metering equipment to be installed safely, the metered equipment was not in service, or the historical trend data were available and we could spot test and retrieve the data on site. In the absence of meter installations and where possible, we collected equipment performance trend data on site from the customer's monitoring and/or control system. The Team collected trend data at eight customer sites. Additionally, the Team interviewed facility staff to understand the operation, control strategy, and installation success of incentivized measures.

Step 5: The Team analyzed the collected data from site visits including interview data, spot measurements, site observations, building management trend data, power metering trend data and utility bills. The team calculated evaluated energy savings utilizing the methodologies outlined with the Program Savings Document (PSD) or the most appropriate technical reference manual (TRM). For complicated or custom measures, the Team calculated evaluated energy savings based on custom engineering spreadsheet analysis, energy modeling, or a utility bill analysis if the energy savings from the sampled measure exceeded 10% of the total facility's electric energy consumption. For sites where light loggers or power meters were installed, the Team used logger data to determine hours of use (HOU) or power consumption for the metered equipment types. In some instances, customers provided trend data from their building management systems, which the Team used to determine equipment load profiles, HOU, and performance characteristics.

Step 6: The Team extrapolated the results from the sampled measures to each respective stratum population and identified trends and commonalities among the findings.

Database Review

The evaluation team reviewed the 2017 and 2018 program databases for missing data, unrealistic values, inconsistencies and anomalies. When discrepancies were found, the Team coordinated with the utilities to discuss the issues and collect updated data.

Sampling and Extrapolation Methodology

The Team developed a sample design intended to support analysis of measures implemented through the ECB program over the 2017 and 2018 program years. The design included the following parameters:

- Program-level estimates of electric and natural gas gross energy savings realization rates with ±10% precision at the two-tailed 90% confidence level.
- Electric demand estimates that meet Independent System Operators New England (ISO-NE) requirements for bid into the forward capacity market. [11]

The Team developed a sample design based on 2017 customer data, then updated the sample design with 2018 customer data once available in March 2019. The final sample design was based on 2017 and

[11] The ISO-NE requirements specify electric demand savings as the average peak demand reduction for a Seasonal Peak Demand Resource—when the real-time system's hourly load is equal or greater than 90% of the most recent "50/50" season peak load forecast for the applicable summer or winter season. The summer season is defined as the non-holiday weekdays during the months of June, July, and August. The winter season is defined as the non-holiday weekdays during December and January. For weather-dependent measures, the Team installed power meters on incentivized measures during each applicable season to measure and calculate peak demand savings. Specific requirements for the forward capacity market are defined in the *ISO New England Manual for the Forward Capacity Market (FCM) Manual M-20.* https://www.iso-ne.com/static-assets/documents/2018/10/manual_20_forward_capacity_market_rev25_20181004.pdf

2018 program-level tracking data provided by the two program sponsors: Eversource and United Illuminating (UI). The data included measure savings, site locations, nonstandard measure categories (different classifications are used by each utility), and similar administrative data.[12]

Table 8 summarizes the combined 2017 and 2018 data from Eversource and UI. The Team created its own measure-category schema and classified each program measure from the constituent data based on known information. The Team calculated total energy savings (in units of MMBtu) from provided electric (kWh) and natural gas (therms) data, along with a conversion factor provided by Eversource (0.1029 ccf per MMBtu).

Table 8. 2017 and 2018 Program Reported Savings

Strata	Quantity of Measures	Reported Savings (kWh)	Reported Savings (summer kW)	Reported Savings (winter kW)	Reported Savings (therms)
Cooling, Electric	643	10,906,169	3,808.8	410.7	N/A
Lighting, Electric	721	41,405,184	7,148.7	5,454.6	N/A
Heating, Electric	117	1,285,371	30.9	361.7	N/A
Custom/Other, Electric	222	12,405,684	1,803.2	1,343.9	N/A
Process, Electric	449	36,031,608	3,716.6	3,022.4	N/A
Heating, Gas	515	N/A	N/A		1,345,263
Domestic Hot Water, Gas	101	N/A	N/A	N/A	108,869
Custom/Other, Gas	45	1,158,666	N/A	N/A	637,374
Total	**2,813**	**103,192,682**	**16,508.2**	**10,593.3**	**2,091,506**

The Team developed the strata based on each utility's unique schema, captured in the program tracking data. The utilities defined 126 measure categories in the 2017 and 2018 tracking databases. The Team mapped each of the 126 measure categories to one of the eight strata used in this evaluation.

Within each of the eight strata, the Team used probability proportional to size (a stratified sampling scheme) to select measures for site visits. This sampling scheme uses energy savings as the size factor, either electric or natural gas (depending upon the given stratum), and randomly selects measures for evaluation energy savings for the associated strata and year. By using this sampling scheme, the chance of randomly selecting a measure is directly related to the total energy savings reported by the measure.

Table 9 shows the total quantity of measures sampled, the associated reported energy savings, and the percentage that this sample represented out of the population.

[12] Sampling was performed at the measure level for all incentivized measures within the ECB program. Evaluation of sampled projects at the IOU level may result in misleading conclusions.

Table 9. 2017 and 2018 ECB Program Sampling Summary

Strata	# of Unique Measures	Population Reported Savings (kWh or therms)	Sampled Measures	Sampled Measures Reported Savings (kWh or therms)	Sampled Reported Savings (% of Population)
Cooling, Electric	643	10,906,169	43	2,350,748	22%
Lighting, Electric	721	41,405,184	33	6,915,628	17%
Heating, Electric	117	1,285,371	17	452,331	35%
Custom/Other, Electric	222	12,405,684	48	5,855,699	47%
Process, Electric	449	36,031,608	78	11,996,550	33%
Heating, Gas	515	1,345,263	30	179,697 (therms)	13%
Domestic Hot Water, Gas	101	108,869	11	14,096 (therms)	13%
Custom/Other, Gas	45	637,374	15	186,005 (therms)	29%
Total Electric	**2,152**	**103,192,682**	**218**	**27,570,956**	**27%**
Total Gas	**661**	**2,091,506**	**56**	**379,798**	**18%**

Measurement and Verification Plan Development

the Team reviewed all measure documentation available from Eversource and UI, including measure applications, equipment invoices, reports published by third-party energy engineering consultants, and savings calculation spreadsheets. We calculated energy savings for 187 of the 274 sampled measures using standardized calculation spreadsheets. For each sampled measure, we applied M&V methods established by the IPMVP. A summary of IPMVP options follows, including the Team' logic in assigning respective methods.

- **IPMVP Option A, Retrofit Isolation: Key Parameter Measurement.** The Team used engineering calculations and partial site/device measurements (such as fixture wattages with lighting runtimes) to verify savings resulting from specific measures where equipment energy demand would not vary over time (such as non-dimming light bulbs). Generally, the Team used Option A for lighting circuits where power metering was not feasible and where logging secondary variables (current or run time) would support accurate savings estimates. However, the Team generally favored IPMVP Option B over Option A for most measures, as it reduced uncertainty associated with proxy and secondary variables.
- **IPMVP Option B, Retrofit Isolation: All Parameter Measurement.** The Team used engineering calculations and time series true kilowatt measurements to verify savings resulting from the affected system's change in energy use. Generally, the Team used Option B for distinct non-lighting measures and lighting circuits where power logging was feasible.

- **IPMVP Option C, Whole Facility.** The Team generally used whole-facility monthly or interval energy consumption data to evaluate savings when a given measure represented a significant portion of a metered load (such that the signal-to-noise ratio allowed the Team to detect changes between pre- and post-installation consumption). This approach was contingent upon sufficient available data, generally judged as a minimum of eight months pre- and post-install or outside air temperature data from the metered period that satisfied 90% of the entire range of outside air temperatures identified in typical meteorological year data sets for the measure installation location. Option C was limited to sites where savings were reported as at least 10% of total consumption on the affected meter.
- **IPMVP Option D, Calibrated Simulation.** The Team used Option D for new construction and retrofit measures where a simulation model was used as the basis for claimed savings, and where the claimed-savings modeling files were available. We updated energy simulation models based on site observations for independent variables that impacted energy use, occupancy rates or schedules, and production data. The Team paid close attention to key parameters that drove savings and to measure baselines that might vary from energy code requirements or other baseline requirements.

Site Visits and Engineering Measurements

The Team performed on-site visits and engineering analyses for 274 measures. For each sampled measure, we performed a site visit to execute the following tasks:

- Verify installation and operation of equipment receiving incentives, confirming that installed equipment met program eligibility requirements and verifying that the quantity of installed measures matched program documentation.
- Interview facility staff regarding the installation, operation and maintenance of equipment. The interviews were also intended to aid in understanding of any operational changes (planned or unplanned) that could impact the associated equipment's energy use.
- Install power metering or light logging equipment where possible to collect true power measurements.

The site activities were based on the M&V plans developed as part of the measure documentation review process. The Team identified any metering or trend logging prior to the site visit and collected true power measurements for most measures. Additionally, we installed logging equipment to collect temperature or flow data for measures where equipment performance was impacted by variables independent of outside air temperatures. Outside air temperature data were based on temperature loggers installed at four facilities and on local climatological data available from the National Oceanic and Atmospheric Administration for 10 weather stations in Connecticut.

Where equipment was found to operate at a continuous constant load, with no control methodology, the Team performed spot measurements rather than installing power metering equipment. When equipment was found to be out of service, we did not install power meters. In some cases, the Team could not install power metering equipment for the following reasons:

- An electrical disconnect was too small to fit a power meter.
- Voltage taps could not be completed successfully or safely.
- An existing sensor data feed was available and known to be accurate.
- A participant site would not allow temporary logging.

In addition to installing power metering equipment, the Team took spot measurements of temperature, flow, true power (kW), power factor, and amperage during installation site visits and removal site visits. The Team also collected trend data from customers' building automation systems, when these were available.

Where an M&V plan was based on whole-building analysis and an energy model used by the project team to predict energy savings were available, the Team collected building performance information, such as glass U-values and solar heat gain coefficient ratings, equipment efficiencies, and occupancy schedules, to update the energy model variables, using whole-building energy data to calibrate the as-built model to actual building performance.

Analysis and Reporting

The Team analyzed data collected on site and calculated savings based on the IPMVP option established through the M&V plan development process. When data logging equipment was deployed or trend data were obtained from a participant's control system, we used a variety of approaches, including bin analysis, regression analysis, utility bill analysis, energy modeling, and custom spreadsheet analysis. Advanced tools, such as Python, were utilized when data files were very large or when non-linearities in system parameter relationships made more complex analytics necessary.

In general, the Team followed the savings methodology outlined in the PSD. When sampled measure types were not identified in the PSD, we utilized savings methodologies outlined from the most relevant and recently updated TRMs within the region. These TRMs include the following:

- Massachusetts Technical Reference Manual, 2016–2018 Program Years, Plan Version[13]
- New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs Version 6[14]

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13 Massachusetts Electric and Gas Energy Efficiency Program Administrators. 2015. *Massachusetts Technical Reference Manual for Estimating Savings from Energy Efficiency Measures.* http://ma-eeac.org/wordpress/wp-content/uploads/2016-2018-Plan-1.pdf

14 New York State Joint Utilities. January 1, 2019. *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs – Residential, Multi-Family, and Commercial/Industrial Measures Version 6.* http://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/72c23decff52920a85257f1100671bdd/$FILE/TRM%20Version%206%20-%20January%202019.pdf

- 2018 Mid-Atlantic Technical Reference Manual Version 8[15]
- Wisconsin Focus on Energy 2017 Technical Reference Manual[16]

Often, the Team collected site-specific data on-site through spot measurements, data logger data, trend data, or observations that deviated from the calculation inputs assumed in the PSD or TRMs for the associated measure type. In such cases, analysis utilizing site-specific data resulted in evaluated savings that differed from reported savings.

The utilities reported savings for measures incentivized through the ECB program based on the application date. The state of Connecticut adopted the 2012 International Energy Conservation Code (IECC) as part of the Connecticut State Building Code for commercial buildings, effective October 1, 2016. The 2012 IECC incorporates the ASHRAE 90.1-2010 Standard by reference and requires commercial building projects to comply with its commercial requirements or with the ASHRAE 90.1-2010 Standard. Approximately 31% of measures incentivized through the ECB program were initiated prior to the effective code date change of October 1, 2016. Because of this, baseline energy use, reported energy savings, and evaluated energy savings may vary between identical measures within the program, depending on the application date.

The Team sampled 274 measures, spanning eight unique strata. Among the sampled measures, 23 unique measure types were identified. Table 10 describes the sampled measure types, reported savings calculation methodology, and evaluated savings calculation methodology. In general, the prescriptive calculators used as the reported savings calculation methodology followed the associated measure type from the PSD with varying levels of rigor in terms of use of site-specific inputs and assumptions.

Table 10. Measure Type Savings Calculation Methodology

Measure Type (Qty)	Reported Savings Calculation Methodology	Evaluated Savings Calculation Methodology
Air Conditioners (16)	Prescriptive Calculators	2017 PSD Measure 2.2.2: Unitary Air Conditioners and Heat pumps Energy Model simulations
Air Compressors (64)	Prescriptive Calculators	Custom calculations
Appliance (10)	Custom, Prescriptive Calculators	Department of Energy's ENERGY STAR®-Certified Commercial Kitchen Equipment Calculator
Boilers (16)	Custom, Prescriptive Calculators	2017 PSD Measure 2.2.6: Gas Fired Boiler and Furnace
Chillers (12)	Custom, Prescriptive Calculators	2017 PSD Measure 2.2.1: Chillers

15 Northeast Energy Efficiency Partnership. 2018. *Mid-Atlantic Technical Reference Manual Version 8.* https://neep.org/sites/default/files/resources/Mid_Atlantic_TRM_V8_0.pdf

16 Public Service Commission of Wisconsin. 2017. *Wisconsin Focus on Energy 2017 Technical Reference Manual.* https://focusonenergy.com/sites/default/files/Focus%20on%20Energy%20TRM%20-%20PY2017_1%28Archive%29.pdf

Measure Type (Qty)	Reported Savings Calculation Methodology	Evaluated Savings Calculation Methodology
Controls (16)	Energy Model, Custom	Custom calculations
Custom (1)	Custom	Custom calculations
Dehumidification (1)	Custom	Custom calculations
Electronically Commutated Motors (6)	Prescriptive Calculators	2017 PSD Measure 3.4.3 Evaporator Fans Motor Replacement
Envelope (9)	Custom	Custom calculations
Energy Recovery Units (3)	Prescriptive Calculators	Custom or Focus on Energy 2019 Measure: Energy Recovery Ventilator
Furnace (4)	Custom, Prescriptive Calculators	2017 PSD Measure 2.2.6: Gas Fired Boiler and Furnace
Heat Pumps (7)	Prescriptive Calculators	2017 PSD Measure 2.2.2: Unitary ACs and Heat pumps
Heat Recovery (5)	Prescriptive Calculators	Custom calculations
Infrared/Unit Heater (2)	Custom, Prescriptive Calculators	2017 PSD Measure 2.2.7: Gas Fired Radiant Heater
Lighting (33)	Prescriptive Calculators	2017 PSD Measure 2.1.1: Standard Lighting 2017 PSD Measure 3.1.1: Standard Lighting
Motors (1)	Custom	Custom calculations
Process (7)	Custom	Custom calculations
Pumps (2)	Custom	Custom calculations
Refrigeration (12)	Custom, Prescriptive Calculators	Custom, 2019 Focus on Energy TRM measure Retrofit Open Multi-Deck Cases with Doors
Variable Frequency Drives (25)	Custom, Prescriptive Calculators	2017 PSD Measure 2.4.1: HVAC Variable Frequency Drives
Variable Refrigerant Flow Systems (7)	Energy Model, Prescriptive Calculators	Energy Model, Custom calculations
Water Heating (15)	Prescriptive Calculators	2017 PSD Measure 2.2.8: Gas Fired Domestic Hot Water Heater

Expansion Analysis

Expansion analysis is a process for aggregating sampled site-level data to develop program-level findings. The Team calculated retrospective realization rates based on measures in the evaluation sample, dividing evaluated (*ex post* gross) savings by claimed (*ex ante*) savings for all sampled measures in a given end-use category (strata). These realization rates incorporated sample weight factors. These realization rates were then multiplied by the total claimed (*ex ante*) savings for an end-use category to produce a program-level savings estimate. This process was applied for demand and energy savings, and these values were considered retrospective realization rates, based on conditions at the time of implementation (for example, the PSD, or the energy code at that time).

Prospective realization rates are impacted by the measure population mixture (quantities of measures and reported savings per measure type), changes in state energy codes, and updates to the PSD. The Team based the evaluation on the PSD in effect at the measure application date and identified changes between the 2017 PSD and the 2020 PSD. The changes affecting commercial lost opportunity measures were largely due to the adoption of IECC 2016 in October of 2018. Additional changes included these:

- Lighting: Change in gas interactive effects multiplier
- Boilers: Addition of a heat equivalent full load hours value for spaces occupied 24/7
- Variable Refrigeration Flow (VRF) HVAC Systems: Added a new measure section
- Foodservice Equipment: Added a new deemed savings table
- Cool Roof: Measure eliminated
- Dual Enthalpy Economizers: Measure eliminated from prospective realization rate calculation based on our recommendation to eliminate the measure from the 2021 PSD.

Energy efficiency measures are adopted based on expected energy savings above code. As the PSD evolves each year, new energy efficiency codes are adopted and the baseline energy efficiencies may increase. To maintain savings by measure, the Team expects the utilities to improve minimum efficiency requirements of their programs. The prospective realization rates assume savings are maintained for all measures as codes change based on this relationship.

Other PSD changes affecting the sampled measures were limited to foodservice equipment. We substituted the deemed savings from the 2020 PSD for the program-reported savings and recalculated the savings for the Custom Other/Gas stratum.[17] The impact on the Custom Gas/Other and overall program realization rates were minimal.

Connecticut is expected to adopt the next state energy code update in October 2021. Changes to baseline energy use and savings by measure type are expected to have minimal effects on prospective realization rates as long as savings margins are maintained. These changes do not affect the 2020 PSD but will likely affect the 2021 or 2022 PSD.

[17] Prospective realization rates for the Custom Other/Gas stratum should be used for PSD updates starting in 2021.

Impact Evaluation

For the impact evaluation, the Team analyzed 274 measures that contributed 27% of the 2017 and 2018 program savings. Overall, the two program years achieved gross retrospective realization rates of 101.4% for electric energy savings, 98.6% for summer peak demand savings, 110.6% for winter peak demand savings, and 94.6% for natural gas savings.

Overall Evaluated Gross Savings Results

Table 11 shows reported and evaluated gross savings results, along with realization rates and precisions by measure type.

Table 11. 2017 and 2018 ECB Program Reported and Evaluated Savings by Measure Category

Strata	Electric Gross Savings		Electric Summer Peak Demand Savings		Electric Winter Peak Demand Savings		Natural Gas Savings	
	Realization Rate	Precision	Realization Rate	Precision	Realization Rate	Precision	Realization Rate	Precision
Cooling, Electric	69.8%	12.9%	72.8%	21.9%	47.6%	267.1%[a]	N/A	N/A
Lighting, Electric	129.0%	16.3%	104.6%	11.2%	116.6%	22.1%	N/A	N/A
Heating, Electric	97.8%	9.0%	94.4%	27.0%	93.0%	4.0%	N/A	N/A
Custom/Other, Electric	98.5%	3.9%	97.4%	22.7%	106.3%	18.7%	N/A	N/A
Process, Electric	80.3%	7.4%	114.1%	15.2%	112.5%	17.1%	N/A	N/A
Heating, Gas	N/A	N/A	0%	N/A	N/A	N/A	97.0%	8.5%
Domestic Hot Water, Gas	N/A	N/A	0%	N/A	N/A	N/A	88.7%	12.9%
Custom/Other, Gas	100%	N/A	0%	N/A	N/A	N/A	91.1%	19.4%
Total	**101.4%**	**8.4%**	**98.6%**	**7.7%**	**110.6%**	**12.9%**	**94.6%**	**7.7%**

[a] Very high variability observed within the sampled Cooling, Electric stratum resulted in poor precision.

Evaluated Gross Savings Results by Strata

Cooling, Electric

The ECB program offers incentives for 23 unique measure types within the Cooling, Electric stratum. During 2017 and 2018, the ECB program provided incentives for 643 measures in this stratum. The Cooling, Electric stratum achieved 10,906,169 kWh in electric energy savings, accounting for 11% of all reported energy savings in the ECB program.

Sampled Measures

The Team evaluated 43 measures, representing eight equipment types—air conditioners, chillers, envelope measures, energy recovery units, heat pumps, heat recovery measures, variable frequency drives (VFD), and variable VRFs—and accounting for 22% of reported energy savings within the Cooling, Electric stratum. Savings were reported based on deemed savings for one measure, energy models for three measures, and prescriptive calculators for 39 measures. The Team installed power meters or collected trend data for 15 of 43 sampled measures.

Findings

Table 12 shows reported and evaluated gross savings results, along with realization rates by measure type.

Table 12. 2017 and 2018 ECB Program Reported and Evaluated Savings for Cooling, Electric Stratum

Stratum: Cooling, Electric	Electric Gross Savings (kWh)	Electric Summer Peak Demand Savings (kW)	Electric Winter Peak Demand Savings (kW)	Natural Gas Savings (therms)
Stratum Savings (% of ECB program)	11%	25%	4%	N/A
Sampled Measures (% of Stratum)	22%	20%	32%	N/A
Realization Rate (%)	70%	73%	48%	N/A

Figure 1, Figure 2, and Figure 3 show realization rates and associated energy savings for all sampled measures within the Cooling, Electric stratum.

Figure 1. Cooling, Electric Sample Gross Electric Savings Results

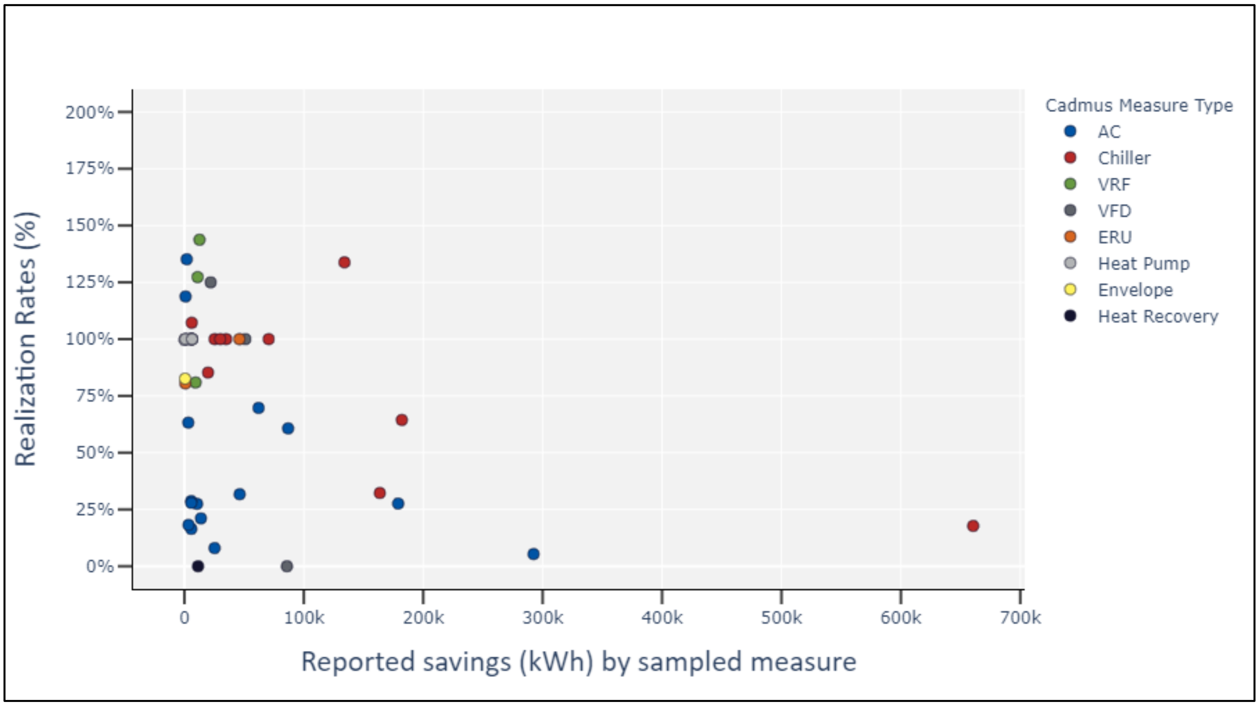

Figure 2. Cooling, Electric Sample Peak Summer Demand Savings Results

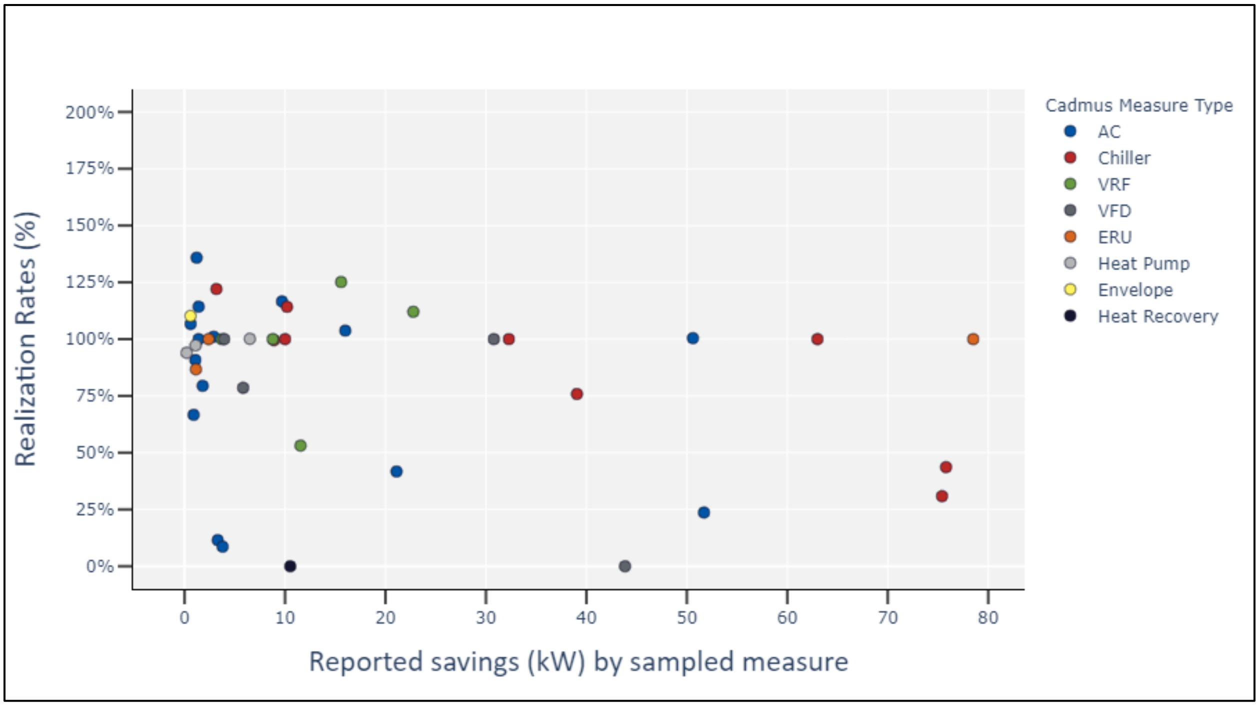

Figure 3. Cooling, Electric Sample Peak Winter Demand Savings Results

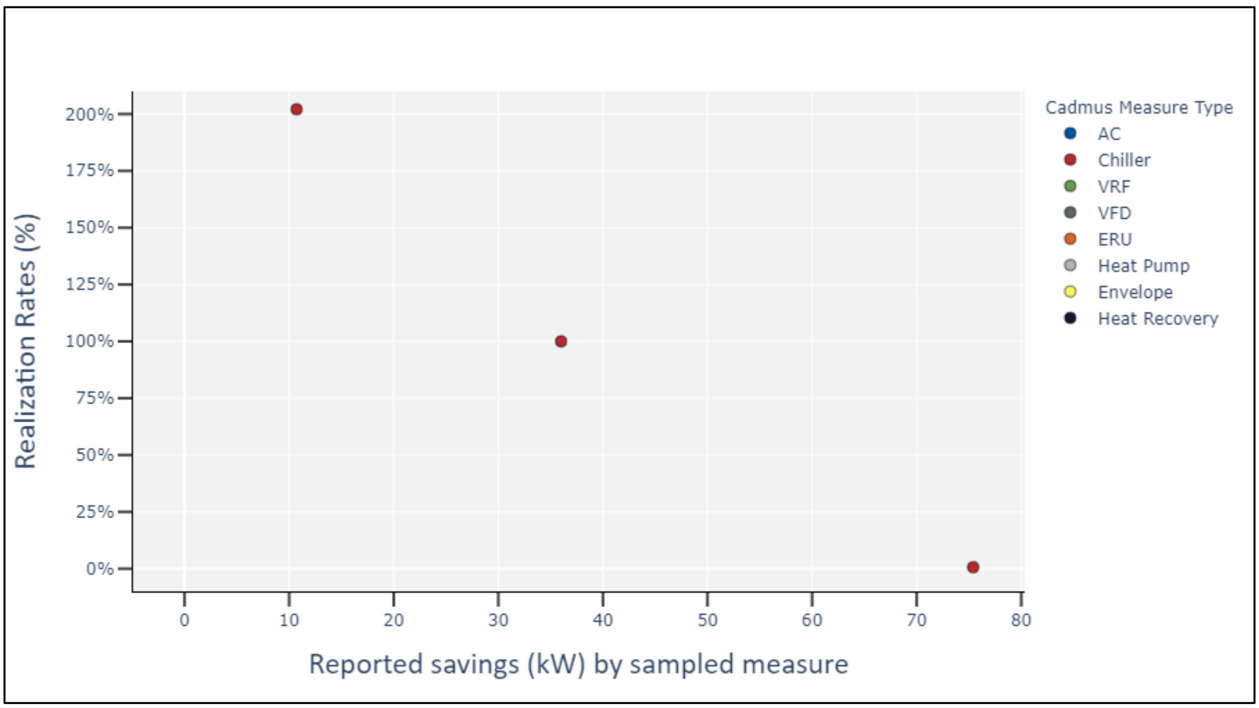

Table 13 provides the quantity of measures sampled, reported savings, evaluated savings, and common reasons for discrepancies.

Table 13. Cooling, Electric Sample Detailed Findings

Measure Type	Sampled Measures	Reported kWh	Evaluated kWh	Realization Rate (%)	Common Reasons for Discrepancy
Air Conditioners	16	747,411	198,771	27%	Ten sampled Air Conditioner measures included dual enthalpy economizers, which were evaluated using eQuest energy models by facility type and location. Energy models indicate economizers save, on average, 0-2.1 kWh/ton, while reported savings utilize a deemed value of 276 kWh/ton based on the PSD.[a] Metered data for 10 sites indicated lower energy savings on average than estimated in the reported documentation
Chillers	10	1,326,824	650,737	49%	Metered data for four sites indicated much lower chiller loads than estimated in the reported documentation, resulting in low realization rates. One sampled chiller, accounting for 50% of all sampled chiller measure kWh savings, served a data center that was minimally loaded, resulting in very low evaluated savings.[b]
Energy Recovery Units	3	47,432	47,279	100%	Minimal discrepancies found.
Envelope Upgrades	1	534	441	83%	No calculations were provided with reported documentation. Evaluated savings were based on the Berkley Lab WINDOW computer program.[c]
Heat Pumps	3	7,181	7,181	100%	No discrepancies found.
Heat Recovery	1	11,379	0	0%	This measure involved the installation of ductwork to remove heat from conditioned areas produced by air compressors. The Team found that air compressors were installed in a dedicated unconditioned space for air compressors, resulting in no cooling savings realized.
Variable Frequency Drives	4	165,345	85,002	51%	The condensing pumps served by VFDs at one site were found to have failed, and the facility was running on rented constant-speed pumps.
Variable Refrigerant Flow Systems	5	44,642	51,378	115%	Metered data for two sites indicated greater evaluated energy savings due to higher average loads. Observed energy efficiency ratio values were found to deviate slightly from reported Energy Efficiency Ratio values, with minimal impact on evaluated savings.

[a] Enthalpy economizer measures are removed from the prospective realization rates.

[b] All measures were evaluated for first year savings based on as surveyed conditions. The removal of the largest chiller project would have increased the realization rate to 80.1% for this measure type within the Cooling, Electric strata.

[c] Berkeley Lab WINDOW is a publicly available computer program for calculating total window thermal performance indices. https://windows.lbl.gov/software/window

These are explanations for a few of the more atypical measure-level realization rates.

High efficiency air conditioners and dual enthalpy economizers. Incentives were provided separately for high efficiency air conditioners and dual enthalpy economizers.

The reported savings for dual enthalpy economizers were based on deemed savings from the 2017 PSD. The Team evaluated these by creating eQuest energy models of representative building types and simulated energy use of a dry bulb economizer and a dual enthalpy economizer. All sampled dual enthalpy economizer measures were installed at small office, industrial, and retail facility types. The Team calculated savings as the reduction in energy use between an air conditioner with a dual enthalpy economizer and an air conditioner with a dry bulb economizer.[18] The Team found no savings realized for the small office and industrial building types and minimal savings (2.1 kWh/ton) for the retail building type.

Most air conditioner measures sampled included both a high efficiency air conditioner unit and a dual enthalpy economizer. Reported savings for dual enthalpy economizers were, on average, much greater than reported savings for air conditioners. Consequently, the realization rate for air conditioner measures was highly impacted by the low realized savings from dual enthalpy economizers.[19]

Chiller measures. The Team evaluated 10 chiller measures where high efficiency variable speed chillers were installed as new construction or end-of-life replacement. The Team installed power metering equipment on three large chiller measures, where the resulting energy performance exhibited lower total energy use and the associated energy savings than assumed in the reported calculations.

For one measure, the incentivized chiller served a new data center facility, where the average chiller load was significantly lower than reported. The Team observed the data center equipment inventory was approximately 25% of maximum capacity. The low inventory infers the chiller load profile in the reported calculations may have assumed a fully loaded data center. Therefore, the total chiller energy use for both the baseline and efficient conditions was significantly lower than reported, resulting in low realized energy savings.

This chiller measure accounted for 50% of electric energy savings for all sampled chiller measures in the Cooling, Electric stratum, and it heavily impacted the overall realization rate for measure categories containing chillers.[20]

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18 Single point dry bulb economizers are required by code, and the difference between dual enthalpy and correctly installed single point dry bulb economizers is minimal.

19 Enthalpy economizers removed from prospective realization rate was based on recommendation to avoid double counting

20 All measures were evaluated for first-year savings based on as-surveyed conditions. Removal of the largest chiller project would have increased the realization rate to 80.1% for this measure type in the Cooling, Electric strata.

Lighting, Electric

The ECB program offers incentives for 21 unique measure types in the Lighting, Electric stratum. During 2017 and 2018, the ECB program provided incentives for 721 measures in this stratum. The lighting, electric stratum achieved 41,405,184 kWh in energy savings, which accounts for 40% of all reported energy savings in the ECB program.

Sampled Measures

The Team evaluated 33 lighting measures, representing interior lighting, exterior lighting, and custom lighting measures. The sampled measures accounted for 17% of reported energy savings within the Lighting, Electric stratum. Savings were reported to be based on prescriptive calculators for 20 measures, energy models for two measures, and custom calculations for one measure. The Team installed light loggers on 17 of 33 sampled measures, and evaluated lighting measures based on the savings methodology outlined in the PSD for lighting.

Findings

Table 14 shows reported and evaluated gross savings results, along with realization rates by measure type.

Table 14. 2017 and 2018 ECB Program Reported and Evaluated Savings by Measure Category

Stratum: Lighting, Electric	Electric Gross Savings (kWh)	Electric Summer Peak Demand Savings (kW)	Electric Winter Peak Demand Savings (kW)	Natural Gas Savings (therms)
Stratum Savings (% of ECB program)	40%	45%	56%	N/A
Sampled Measures (% of Stratum)	17%	23%	19%	N/A
Realization Rate (%)	129%	105%	117%	N/A

Figure 4, Figure 5, and Figure 6 show realization rates and associated energy savings for all sampled measures within the Lighting, Electric stratum.

Figure 4. Lighting, Electric Sample Gross Electric Savings Results

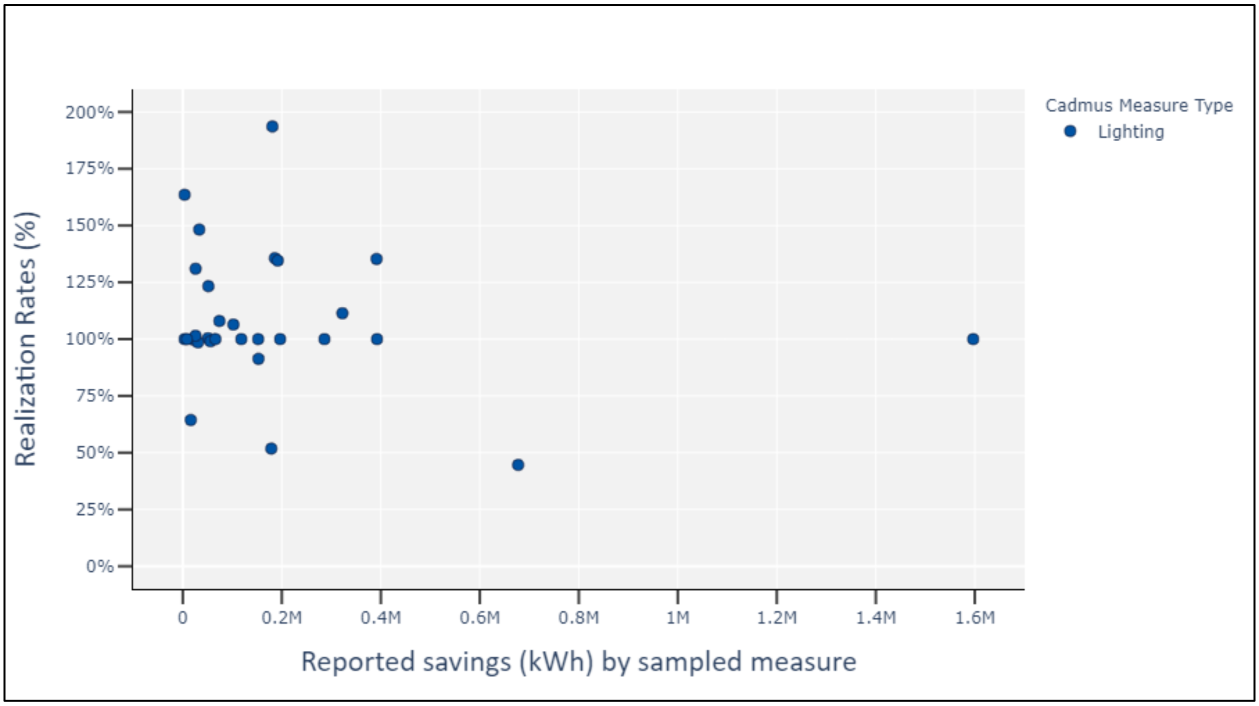

Figure 5. Lighting, Electric Sample Peak Summer Demand Savings Results

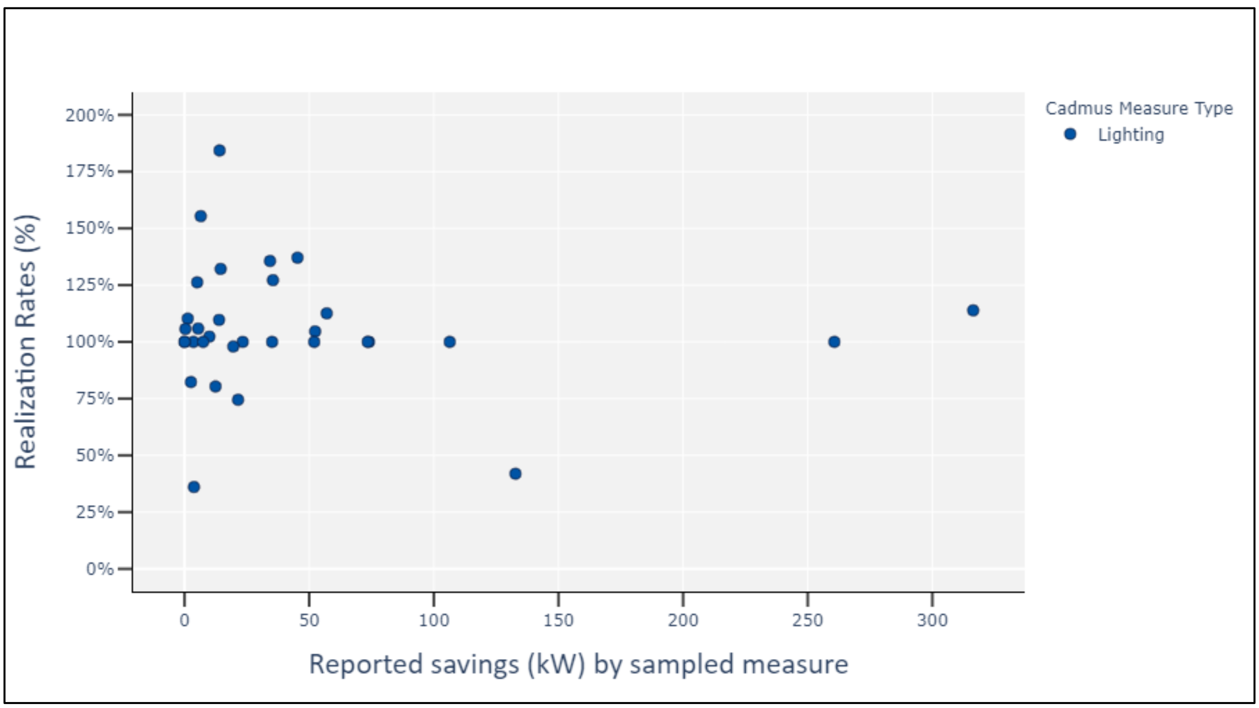

Figure 6. Lighting, Electric Sample Peak Winter Demand Savings Results

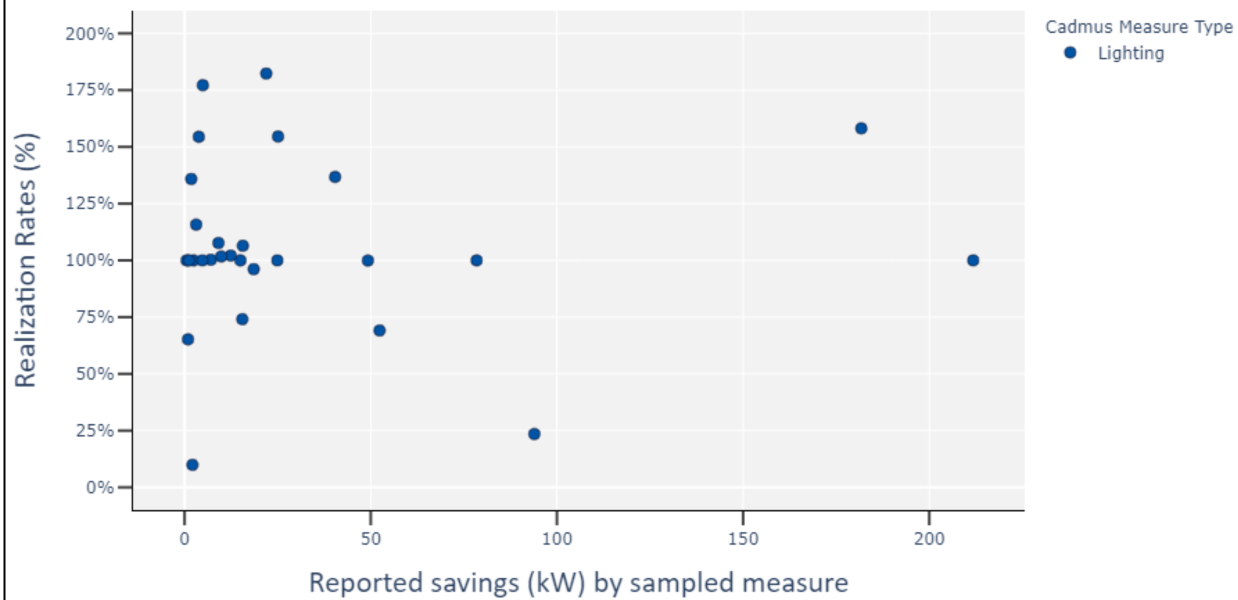

Table 15 provides the quantity of measures sampled, reported savings, evaluated savings, and common reasons for discrepancies.

Table 15. Lighting, Electric Sample Detailed Findings

Measure Type	Sampled Measures	Reported kWh	Evaluated kWh	Realization Rate (%)	Common Reasons for Discrepancy
Lighting	33	6,915,628	9,103,207	132%	The Team installed light loggers at 16 facilities. The analyzed HOU from the light loggers served as the main driver behind differences in evaluated savings and reported savings.

Thirteen of the 33 sampled lighting measures exhibited realization rates greater than 110%, and three exhibited realization rates lower than 90%. The Team found minimal discrepancies with observed quantities, types, and wattages of incentivized lighting measures. The Team did not find errors in reported calculations, based on prescriptive calculators created by the utilities.[21]

The Team installed light loggers at 16 facilities. *Appendix A* provides light logger data from sampled projects. Analysis of data for 12 of the facilities indicated actual HOU greater than reported. Light logger data for four facilities indicated actual HOU were lower than reported. Reported HOU were typically self-reported or based on the measure's associated facility type, based on Appendix 5 in the 2017 PSD.

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21 Most measures used self-reported HOU, and misclassification of sites using deemed HOU was not a consistent issue.

Heating, Electric

The ECB program offers incentives for eight unique measure types within the Heating, Electric stratum. During 2017 and 2018, the ECB program provided incentives for 117 measures in this stratum. The Heating, Electric stratum achieved 1,285,371 kWh in energy savings, accounting for 1% of all reported electric energy savings in the ECB program.

Sampled Measures

The Team evaluated 17 measures, representing five equipment types—controls, envelope, heat pumps, VFDs serving hot water pumps, and VRF systems—and accounting for 35% of reported electric energy savings within the Heating, Electric stratum. Savings were reported based on prescriptive calculators for 12 measures, energy models for two measures, and custom calculations for three measures. The Team installed power meters or collected trend data for three of 17 sampled measures.

Findings

Table 16 shows reported and evaluated gross savings results, along with realization rates by measure type.

Table 16. 2017 and 2018 ECB Program Reported and Evaluated Savings by Stratum

Stratum: Heating, Electric	Electric Gross Savings (kWh)	Electric Summer Peak Demand Savings (kW)	Electric Winter Peak Demand Savings (kW)	Natural Gas Savings (therms)
Stratum Savings (% of ECB program)	1%	0%	4%	N/A
Sampled Measures (% of Stratum)	35%	90%	27%	N/A
Realization Rate (%)	98%	94%	93%	N/A

Figure 7, Figure 8, and Figure 9 show realization rates and the associated energy savings for all sampled measures within the Heating, Electric stratum.

Figure 7. Heating, Electric Sample Gross Electric Savings Results

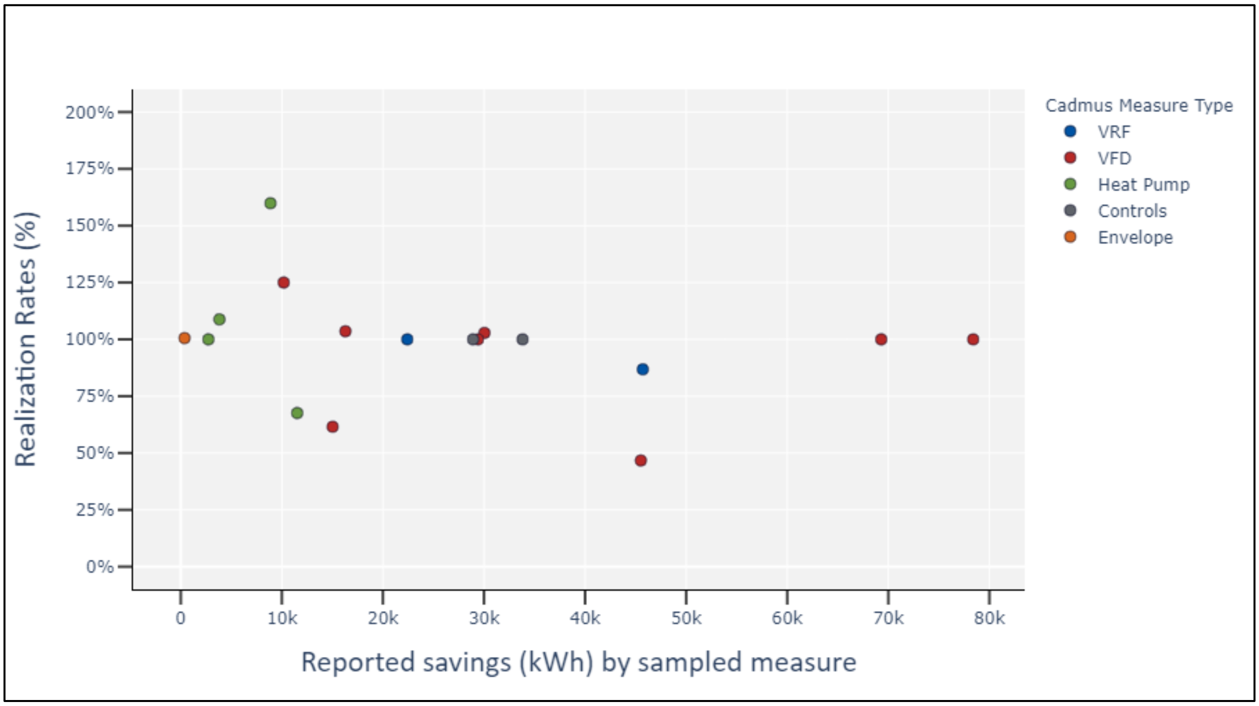

Figure 8. Heating, Electric Sample Peak Summer Demand Savings Results

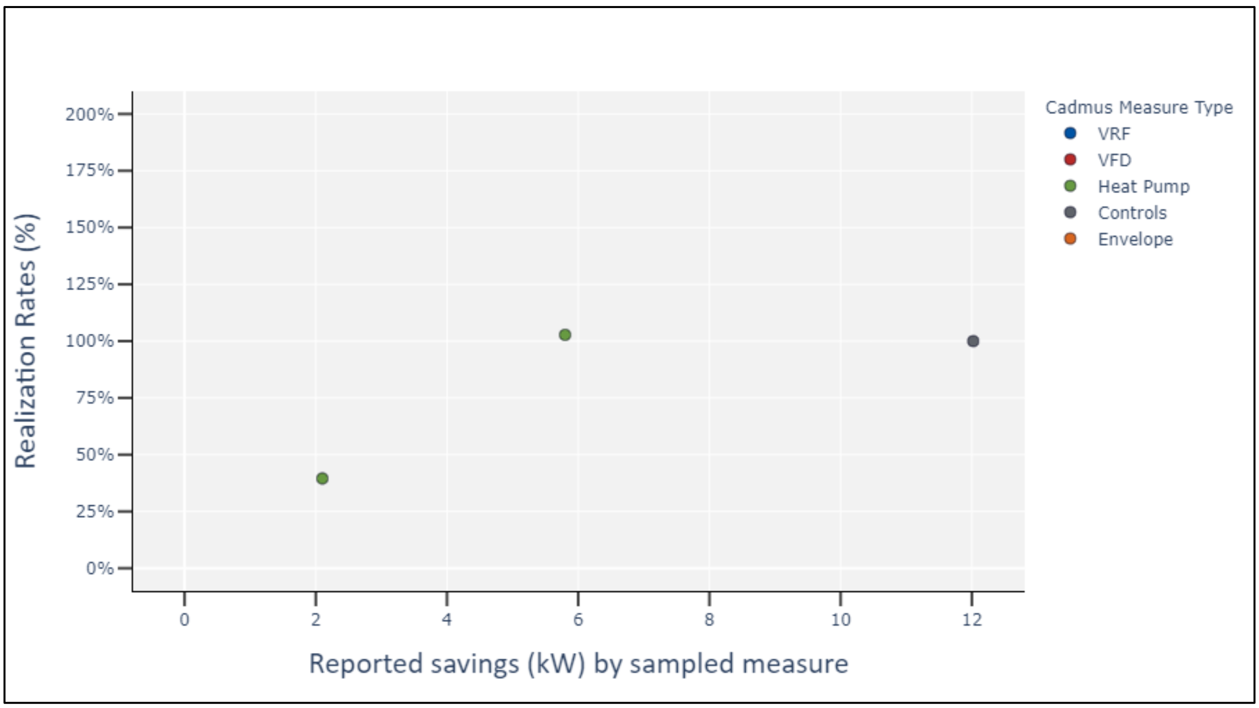

Figure 9. Heating, Electric Sample Peak Winter Demand Savings Results

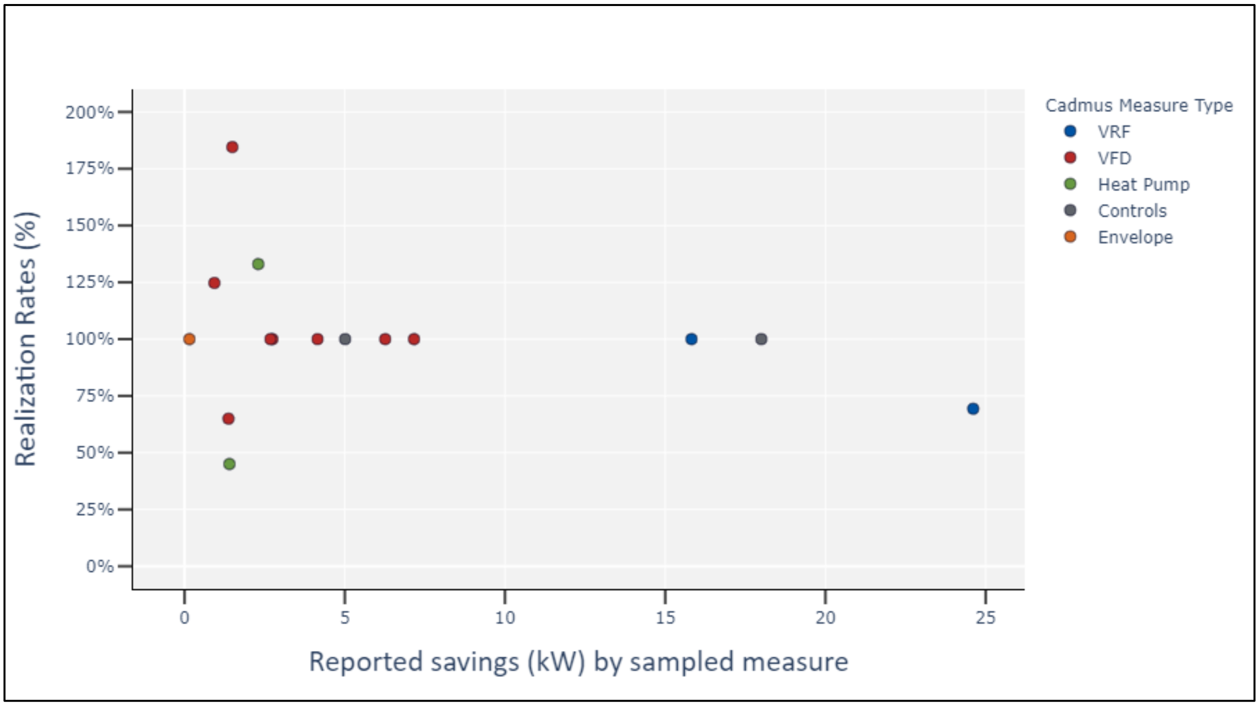

Table 17 provides the quantity of measures sampled, reported savings, evaluated savings, and common reasons for discrepancies.

Table 17. Heating, Electric Sample Detailed Findings

Measure Type	Sampled Measures	Reported kWh	Evaluated kWh	Realization Rate (%)	Common Reasons for Discrepancy
Controls	2	62,736	62,736	100%	No discrepancies found.
Envelope Upgrades	1	375	377	101%	Minimal discrepancies found.
Heat Pumps	4	26,950	28,869	107%	The Team observed higher installed heat pump efficiencies than reported for two sampled measures.
Variable Frequency Drives	8	294,154	268,087	91%	Metered performance indicated load profiles that often deviated from the reported documentation.
Variable Refrigerant Flow Systems	2	68,116	62,091	91%	Metered data indicated lower energy use and load profiles for VRF systems at one of two sampled measures.

Realization rates among sampled measures in the Heating, Electric stratum exhibited low variability and were typically near 100%. Realization rates for the most sampled measure (VFDs) exhibited the greatest variability within the Heating, Electric stratum with one measure realizing electric energy savings greater than 110% and two measures realizing electric energy savings lower than 90%. The sampled incentivized

VFDs in the Heating, Electric stratum served hot water pumps. Both measures with low realization rates are a result of power metering data indicating low hours of use during the meter period.

Custom/Other, Electric

The ECB program offers incentives for 29 unique measure types within the Custom/Other, Electric stratum. During 2017 and 2018, the ECB program provided incentives for 222 measures in this stratum. The Custom/Other, Electric stratum achieved 12,405,684 kWh in energy savings, accounting for 12% of all reported energy savings in the ECB program.

Sampled Measures

The Team evaluated 43 measures, representing 11 equipment types—appliances, boilers, controls, custom, electronically commutated motors, envelope, motors, pumps, refrigeration, VFDs, and water source heat pumps—and accounting for 47% of reported electric energy savings within the Custom/Other, Electric stratum. Savings were reported based on prescriptive calculators for 23 measures, energy models for two measures, and custom calculations for 18 measures. The Team installed power meters or collected trend data for five of 43 sampled measures.

Findings

Table 18 shows reported and evaluated gross savings results, along with realization rates and precisions by measure type.

Table 18. 2017 and 2018 ECB Program Reported and Evaluated Savings by Stratum

Stratum: Custom/Other, Electric	Electric Gross Savings (kWh)	Electric Summer Peak Demand Savings (kW)	Electric Winter Peak Demand Savings (kW)	Natural Gas Savings (therms)
Stratum Savings (% of ECB program)	12%	4%	4%	N/A
Sampled Measures (% of Stratum)	47%	135%[a]	198%[a]	N/A
Realization Rate (%)	99%	97%	112%	N/A

[a] Multiple measures reported negative demand savings.

Figure 10, Figure 11, and Figure 12 show realization rates and associated energy savings for all sampled measures within the Custom/Other, Electric stratum.

Figure 10. Custom/Other, Electric Sample Gross Electric Savings Results

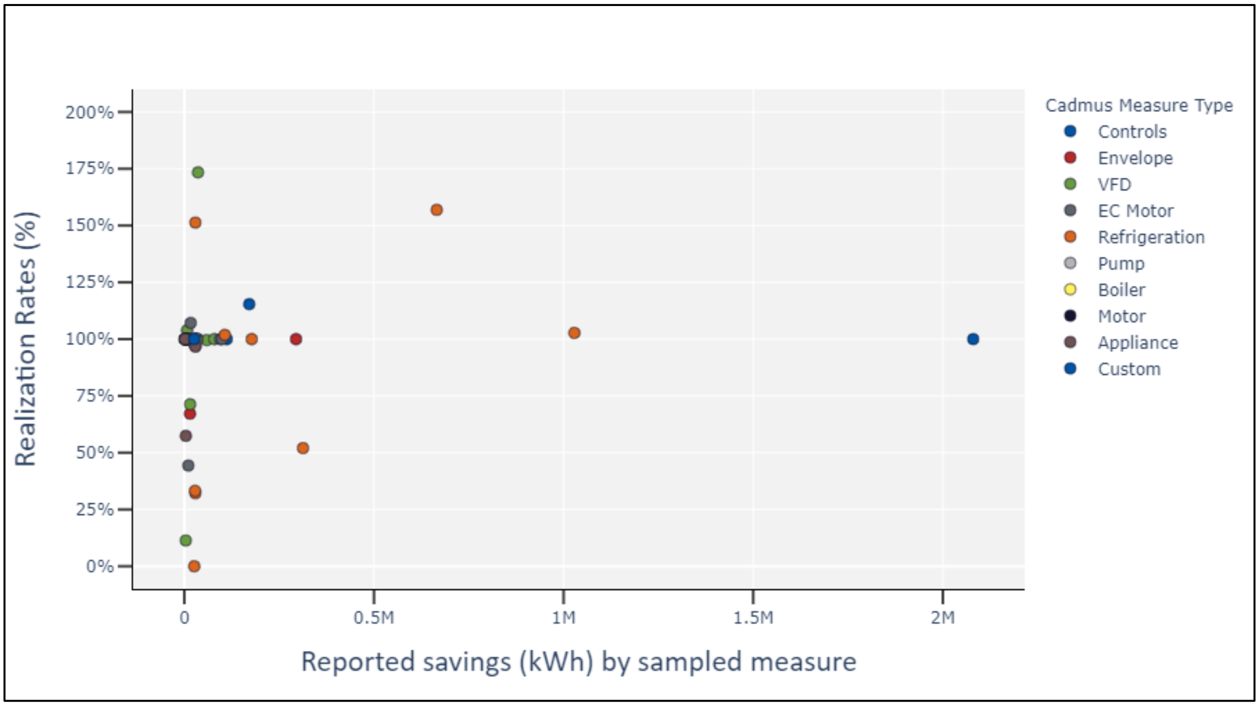

Figure 11. Custom/Other, Electric Sample Peak Summer Demand Savings Results

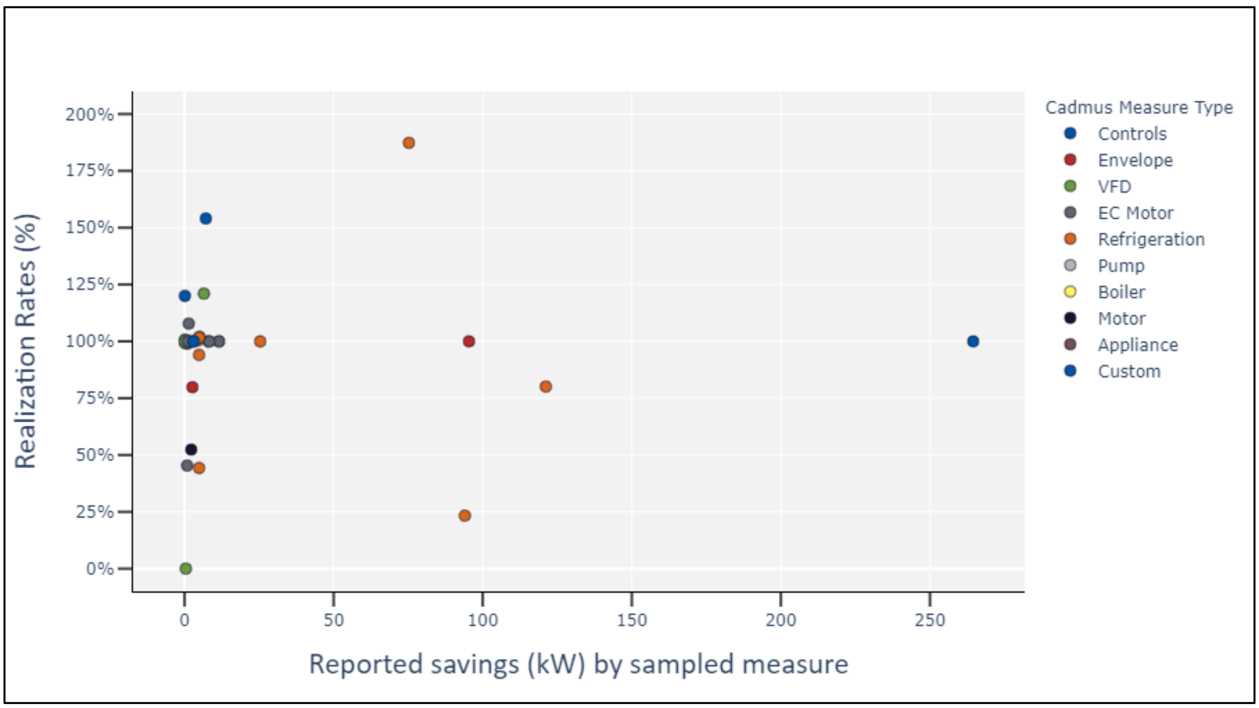

Figure 12. Custom/Other, Electric Sample Peak Winter Demand Savings Results

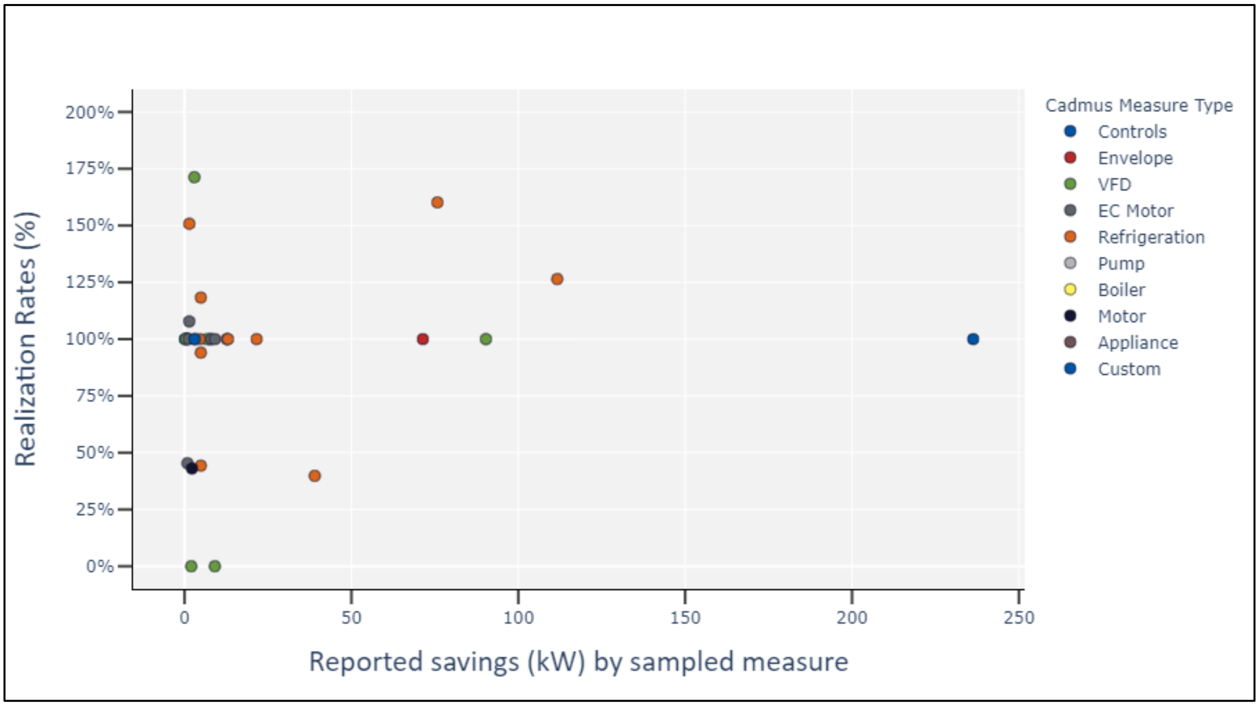

Table 19 provides the quantity of measures sampled, reported savings, evaluated savings, and common reasons for discrepancies.

Table 19. Custom/Other, Electric Sample Detailed Findings

Measure Type	Sampled Measures	Reported kWh	Evaluated kWh	Realization Rate (%)	Common Reasons for Discrepancy
Appliance	6	45,386	42,696	94%	Evaluated savings for one measure involving an incentivized high-efficiency dishwasher were calculated based on site observations and staff interview data, resulting in reduced HOU and loads. Minimal discrepancies were observed at five of six evaluated measures.
Boiler	1	27,800	27,181	98%	Minimal discrepancies found.
Controls	6	2,415,887	2,442,253	101%	Minimal discrepancies found.
Custom	1	25,942	25,942	100%	No discrepancies found.
Electronically Commutated Motor	6	269,412	264,748	99%	For one measure, the Team found fan amperages utilized by the reported calculations did not match installed conditions.
Envelope Upgrades	2	309,543	304,627	98%	Minimal discrepancies found.
Motor	1	8,777	8,777	100%	No discrepancies found.
Pump	2	55,892	55,892	100%	No discrepancies found.

Measure Type	Sampled Measures	Reported kWh	Evaluated kWh	Realization Rate (%)	Common Reasons for Discrepancy
Refrigeration	12	2,472,252	2,680,390	108%	The Team found discrepancies at 7 of 12 sampled measures. Verified wattages for high-efficiency cool and freezer display doors were higher than reported for two measures. The Team found that control strategies and setpoints differed at two sampled measures. Metered power load profiles differed from reported assumptions for one sampled measure.
Variable Frequency Drives	11	224,808	243,421	108%	Metered load profiles differed from reported assumptions.

The majority of measures sampled involved VFDs, Refrigeration, or Controls measure types, serving unique and custom processes and equipment. Due to the nontraditional nature of the measures, custom calculations were often utilized when reporting savings. While savings calculation methodologies followed traditional engineering concepts and accepted practices, inputs and assumptions were often unique to each specific application.

In general, the Team found few discrepancies for measures where custom calculations were utilized to report savings. The greatest impacts to the stratum realization rate are the result of two refrigeration and controls measures. One measure involved a large refrigeration plant upgrade including the installation of new refrigeration equipment and optimized control strategies. The Team found that one control strategy was not implemented during the site visit.

Instead, facility staff controlled the refrigeration system based on a less-efficient control strategy, resulting in lower realized energy savings. Another measure involved a new refrigerated warehouse facility. Custom calculations were used to report energy savings. The Team reviewed the custom calculation workbooks and updated the inputs and load profiles based on site observations, which increased energy savings.

Process, Electric

The ECB program offered incentives for eight unique measure types within the Process, Electric stratum. During 2017 and 2018, the ECB program provided incentives for 449 measures in this stratum. The Process, Electric stratum achieved 36,031,608 kWh in energy savings, accounting for 35% of all reported energy savings in the ECB program.

Sampled Measures

The Team evaluated 78 measures, representing six equipment types—air compressors, chillers, controls, heat recovery, process, and VFDs—and accounting for 3% of reported energy savings within the Process, Electric stratum. Savings were reported based on prescriptive calculators for 64 measures and on custom calculations for 14 measures. The Team installed power meters or collected trend data for 44 of 78 sampled measures.

Findings

Table 20 shows reported and evaluated gross savings results, along with realization rates and precisions by measure type.

Table 20. 2017 and 2018 ECB Program Reported and Evaluated Savings by Stratum

Stratum: Process, Electric	Electric Gross Savings (kWh)	Electric Summer Peak Demand Savings (kW)	Electric Winter Peak Demand Savings (kW)	Natural Gas Savings (therms)
Stratum Savings (% of ECB program)	35%	24%	32%	N/A
Sampled Measures (% of Stratum)	33%	33%	33%	N/A
Realization Rate (%)	80%	114%	112%	N/A

Figure 13, Figure 14, and Figure 15 show realization rates and associated energy savings for all sampled measures within the Process, Electric stratum.

Figure 13. Process, Electric Sample Gross Electric Savings Results

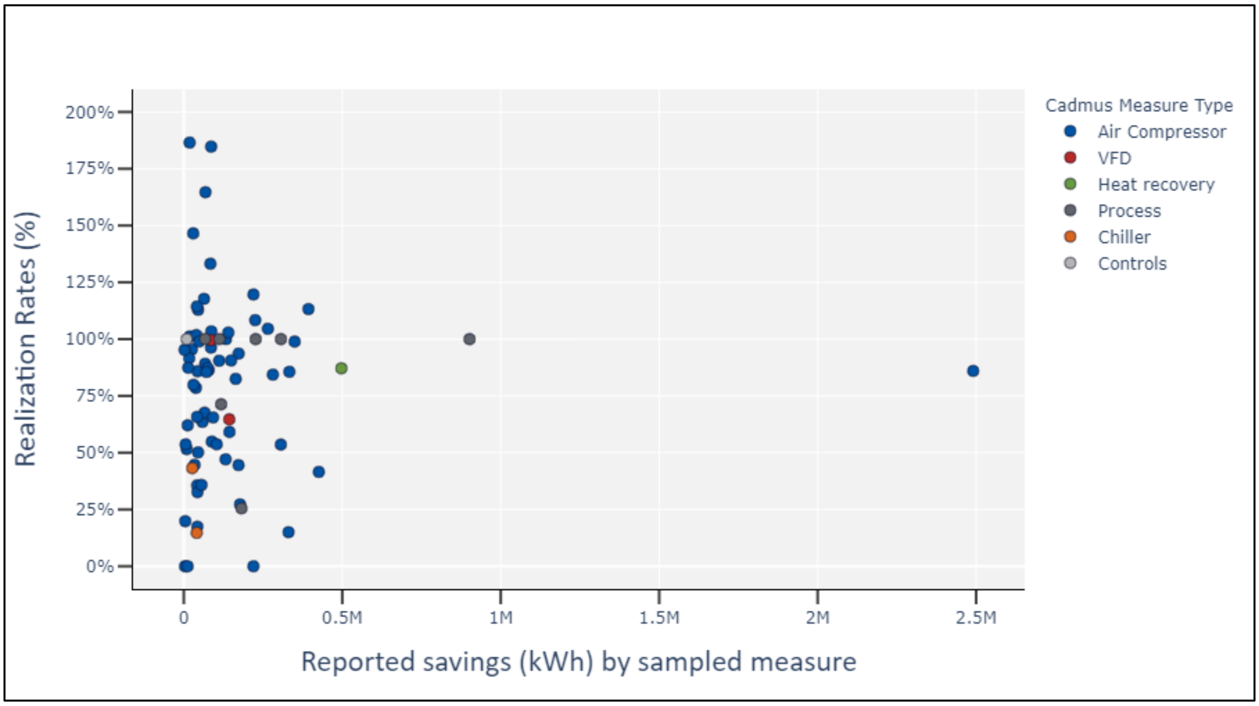

Figure 14. Process, Electric Sample Peak Summer Demand Savings Results

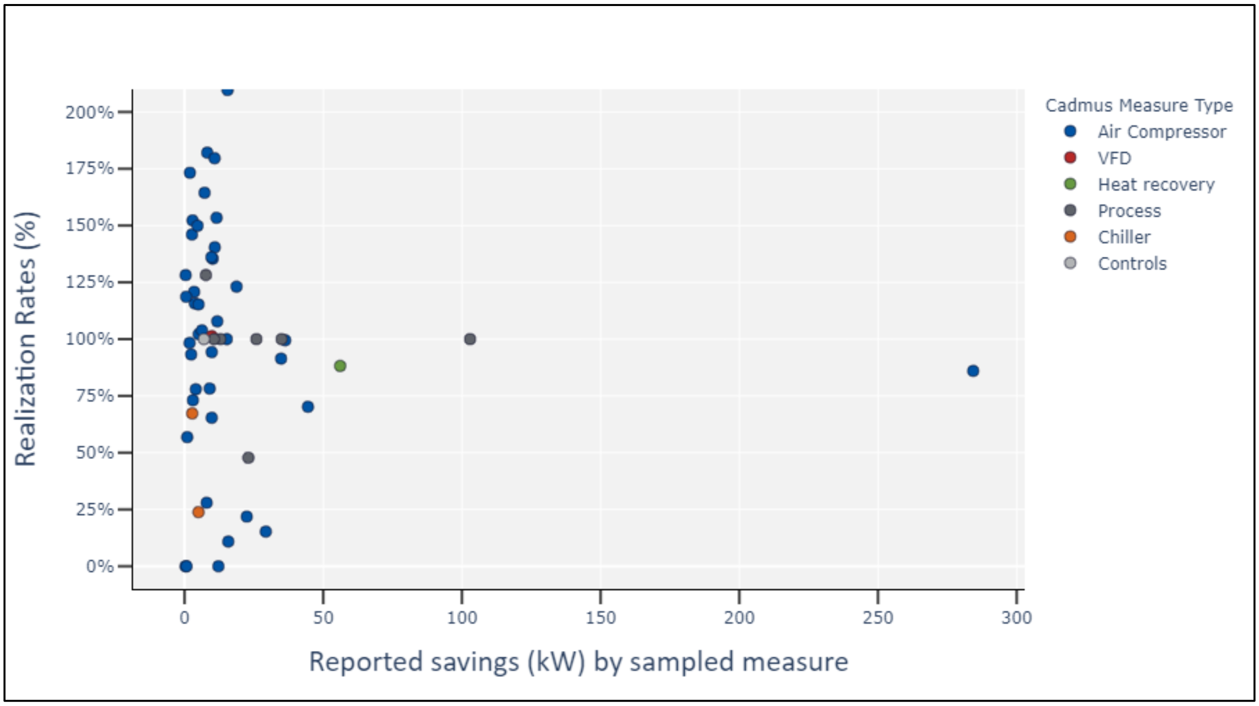

Figure 15. Process, Electric Sample Peak Winter Demand Savings Results

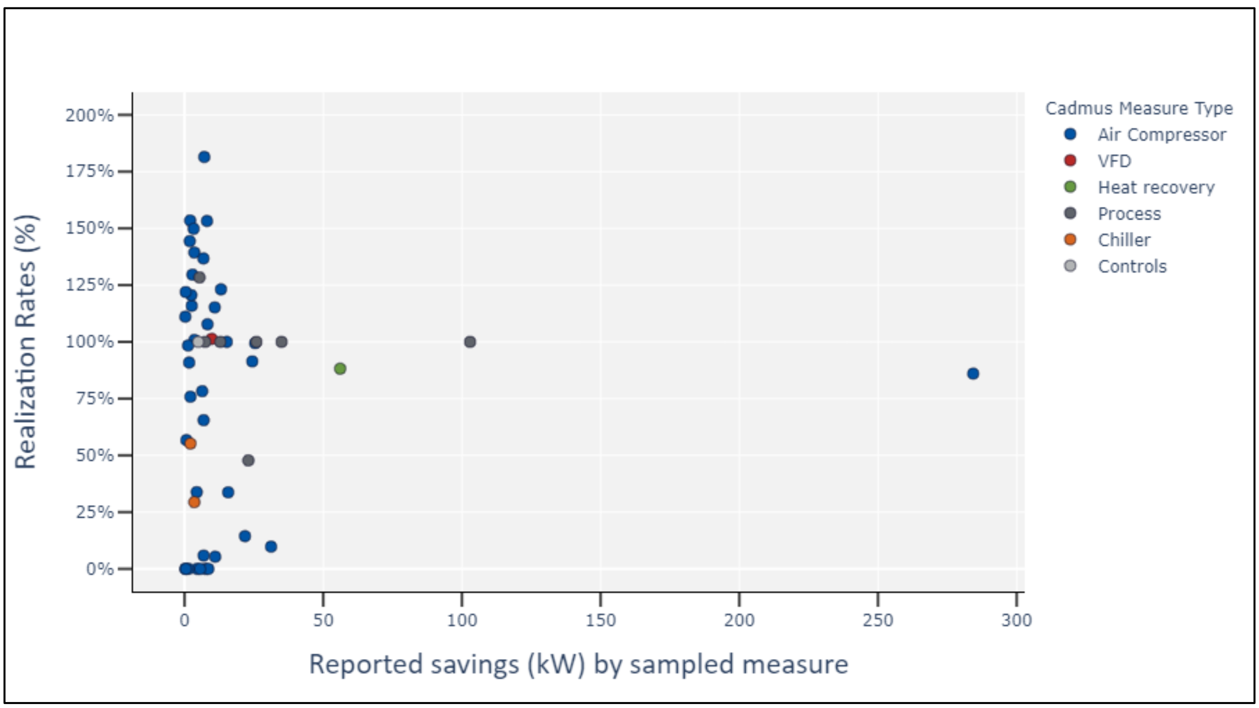

Table 21 provides the quantity of measures sampled, reported savings, evaluated savings, and common reasons for discrepancies.

Table 21. Process, Electric Sample Detailed Findings

Measure Type	Sampled Measures	Reported kWh	Evaluated kWh	Realization Rate (%)	Common Reasons for Discrepancy
Air Compressor	64	9,279,238	7,414,299	80%	Metered load profiles differed from reported assumptions. Variations in load profiles were often due to lower observed line pressure than assumed and on differences in production/system use between reported and evaluated calculations.
Chillers	2	67,298	17,468	26%	Metered data from the process chillers at both sampled customer sites indicated lower peak demand and lower HOU, resulting in reduced energy savings.
Controls	1	9,072	9,072	100%	No discrepancies found.
Heat recovery	1	497,312	433,378	87%	Reported calculations did not account for additional fan energy use from installing a VFD, resulting in lower evaluated savings compared to reported savings.[22]
Process	7	1,914,390	1,745,030	91%	The Team found the installation of incentivized process equipment had only been partially implemented, resulting in reduced energy savings.
Variable Frequency Drives	2	229,240	178,190	78%	The Team found the incentivized VFD at one customer site was offline during the site visit, and the associated well pump would not be returned to service until fall. The Team interviewed the facility contact and calculated savings, based on expected HOU when the well pump is redesigned and reinstalled.

The majority of sampled measures involved high-efficiency air compressor systems. Based on site visit observations as well as on power meter data and trend data from the air compressor measures, the Team found three driving factors that decreased energy savings when compared to reported documentation:

- The Team found HOU were lower, on average. The compressed air systems sampled operated fewer hours than expected. Fewer HOU typically result in lower realized energy savings as baseline equipment was expected to provide the same production capacity and associated HOU as the installed equipment.
- Average loads or compressor speeds were higher. In general, variable speed compressed air systems save more energy than traditional compressed air systems when operating in part-load conditions. As the average speed approaches 100%, the energy savings decrease. Customers typically provided an estimated load profile, based on four expected speed positions and on the total hours the compressors are expected to operate at the associated speeds. The Team found the average load was typically higher than expected in the reported documentation, resulting in lower energy savings.

[22] The evaluated heat recovery project in the Process, Electric strata was not required by code to install a VFD.

- Line pressure was lower. Lower line pressure reduces total energy required by a compressor to maintain system pressures. The Team found the line pressure setpoints at many sampled measures were lower than indicated in the reported documentation. This reduction in line pressure resulted in lower energy use by the baseline and installed compressors, ultimately resulting in total energy savings.

Besides a reduction in total energy savings for compressed air measures, the Team found demand savings calculations were typically not representative of actual operations. The majority of measures reported demand savings to be the difference in the maximum demand of installed and baseline compressed air systems. Based on site visit observations and meter data from 44 compressed air measures, the Team found average demand during peak periods to be lower than maximum demand expected by the system. As demand savings were calculated as average demand reduction during peak periods, compressed air measures realized more savings than reported for most sampled measures.

The Team sampled and metered two-process chiller measures and found the average load significantly below the expected load. For one measure, the process chiller served a newly constructed data center. The Team observed that the data center was partially filled, and meter data proved that the chiller operated at very low load. As the reported documentation assumed a nearly fully loaded data center, lower first-year energy savings were realized.

Heating, Natural Gas

The ECB program offered incentives for 19 unique measure types within the Heating, Natural Gas stratum. During 2017 and 2018, the ECB program provided incentives for 515 measures in this stratum. The Heating, Natural Gas stratum achieved 1,345,263 therms in natural gas savings, accounting for 63% of all reported natural gas savings in the ECB program.

Sampled Measures

The Team evaluated 30 measures, representing six equipment types—boilers, controls, envelope, furnaces, heat recovery, infrared/unit heaters—and accounting for 63% of reported energy savings within the Heating, Natural Gas stratum. Savings were reported based on prescriptive calculators for 21 measures, custom calculations for seven measures, and energy models for two measures. The Team installed power meters or collected trend data for two of 30 sampled measures.

Findings

Table 22 shows reported and evaluated gross savings results, along with realization rates by measure type.

Table 22. 2017 and 2018 ECB Program Reported and Evaluated Savings by Stratum

Stratum: Heating, Natural Gas	Electric Gross Savings (kWh)	Electric Summer Peak Demand Savings (kW)	Electric Winter Peak Demand Savings (kW)	Natural Gas Savings (therms)
Stratum Savings (% of ECB program)	N/A	N/A	N/A	64%
Sampled Measures (% of Stratum)	N/A	N/A	N/A	13%
Realization Rate (%)	N/A	N/A	N/A	97%

Figure 16 shows realization rates and associated energy savings for all sampled measures within the Heating, Natural Gas stratum.

Figure 16. Heating, Natural Gas Sample Natural Gas Savings Results

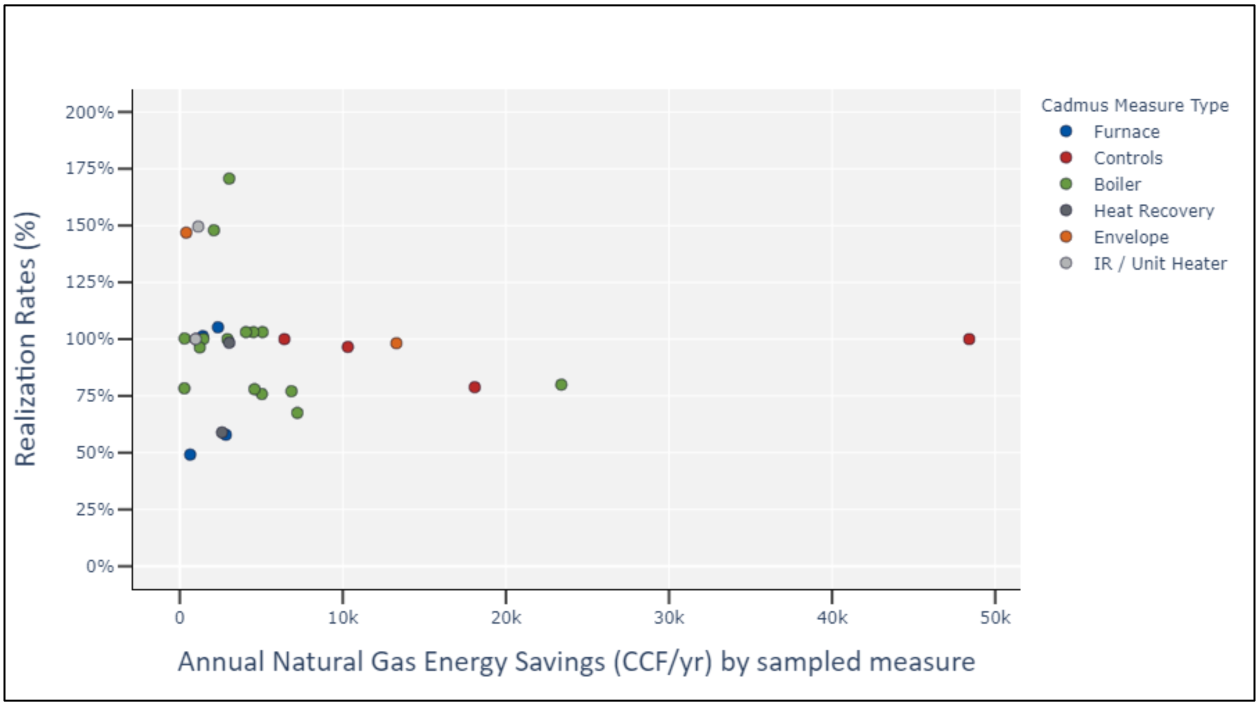

Table 23 provides the quantity of measures sampled, reported savings, evaluated savings, and common reasons for discrepancies.

Table 23. Heating, Natural Gas Sample Detailed Findings

Measure Type	Sampled Measures	Reported Therms	Evaluated Therms	Realization Rate (%)	Common Reasons for Discrepancy
Boiler	15	72,040	64,676	90%	The Team performed combustion tests for most sampled measures and found installed efficiency consistently lower than reported[23].
Controls	5	84,216	80,034	95%	Metered data from one measure involving a dust collection system indicated fewer HOU than reported, resulting in lower evaluated savings.
Envelope Upgrades	2	13,684	13,632	100%	Minimal discrepancies found.
Furnace	4	7,228	5,852	81%	Installed capacities for furnaces for one sampled measure were 48% lower than reported. Installed efficiencies varied slightly from the reported documentation for three sampled measures.
Heat Recovery	2	5,628	4,514	80%	Metered data from one measure indicated lower air compressor loads than assumed, resulting in lower heat recovery and lower evaluated savings.
Infrared Heater	2	2,112	2,675	127%	Installed capacity for infrared heaters at one facility were 43% greater than indicated in the reported documentation.

In general, the majority of reductions in realized energy savings resulted from lower installed efficiencies, lower operating output, and lower HOU. Explanations for these discrepancies follow in more detail:

- The Team performed combustion tests for the majority of sampled measures, finding that boilers and furnaces operated below the associated advertised efficiency. For one measure, the Team collected trend data on the entering water temperature (EWT) for a condensing boiler and calculated boiler efficiency, based on EWT and supply water temperatures. Because EWT directly impacts condensing boilers' efficiency, and trend data exhibited consistently high EWTs, the condensing boiler operated at a lower efficiency than expected.
- Meter data for a sampled heat-recovery measure and controls measure indicated lower HOU and average operating loads than reported. The heat-recovery measure reported savings based on recovery of compressed air heat. As the compressed air operated at a lower average speed, less heat was recovered, resulting in lower realized savings. Similarly, a sampled measure involving a dust collection system operated at fewer hours than expected, resulting in reduced realized energy savings.

Domestic Hot Water, Natural Gas

The ECB program offered incentives for four unique measure types within the Domestic Hot Water, Natural Gas stratum. During 2017 and 2018, the ECB program provided incentives for 101 measures in

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[23] Installed efficiency can vary from the rated efficiency, especially if the return water temperature varies from the test conditions assumed in the efficiency rating.

this stratum. The Domestic Hot Water, Natural Gas stratum achieved 108,869 therms in natural gas savings, accounting for 5% of all reported natural gas savings in the ECB program.

Sampled Measures

The Team evaluated 11 measures—all represented natural gas water heaters and accounted for 13% of reported energy savings within the Domestic Hot Water, Natural Gas stratum. Savings reported were based on prescriptive calculators for all measures. The Team installed power meters or collected trend data for four of 11 sampled measures.

Findings

Table 24 shows reported and evaluated gross savings results, along with realization rates and precisions by measure type.

Table 24. 2017 and 2018 ECB Program Reported and Evaluated Savings by Stratum

Stratum: Domestic Hot Water, Natural Gas	Electric Gross Savings (kWh)	Electric Summer Peak Demand Savings (kW)	Electric Winter Peak Demand Savings (kW)	Natural Gas Savings (therms)
Stratum Savings (% of ECB program)	N/A	N/A	N/A	5%
Sampled Measures (% of Stratum)	N/A	N/A	N/A	13%
Realization Rate (%)	N/A	N/A	N/A	89%

Figure 17 lists realization rates and associated energy savings for all sampled measures within the Domestic Hot Water, Natural Gas stratum.

Figure 17. Domestic Hot Water, Natural Gas Sample Natural Gas Savings Results

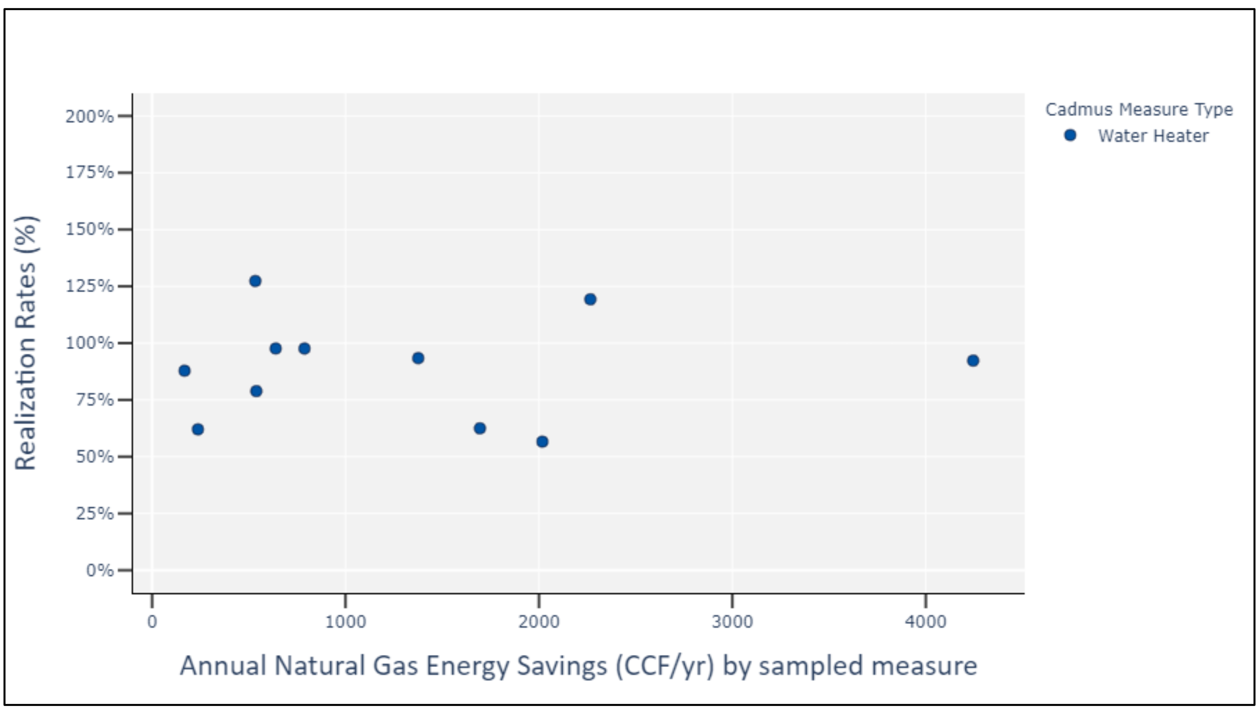


Table 25 provides the quantity of measures sampled, reported savings, evaluated savings, and common reasons for discrepancies.

Table 25. Domestic Hot Water, Natural Gas Sample Detailed Findings

Measure Type	Sampled Measures	Reported Therms	Evaluated Therms	Realization Rate (%)	Common Reasons for Discrepancy
Water Heater	11	14,505	12,901	89%	The Team found differences in installed efficiency based on combustion test results and nameplate efficiencies. Additionally, the Team installed meters at two customer sites and found reduced hot water use when compared to the expected hot water use in the PSD. The efficiency differences were the major driver of the realization rate.

Custom/Other, Natural Gas

The ECB program offered incentives for 13 unique measure types within the Custom/Other, Natural Gas stratum. During 2017 and 2018, the ECB program provided incentives for 45 measures in this stratum. The Custom/Other, Natural Gas stratum achieved 637,374 therms in natural gas savings, accounting for 30% of all reported natural gas savings in the ECB program.

Sampled Measures

The Team evaluated 15 measures, representing six measure types—appliances, water heaters, controls, dehumidification, envelope upgrades, and heat recovery, accounting for 29% of reported energy savings within the Custom/Other, Natural Gas stratum. Savings reported were based on prescriptive calculation workbooks, custom calculations, or energy models. The Team installed power meters or collected trend data for one of 15 sampled measures.

Findings

Table 26 shows reported and evaluated gross savings results, along with realization rates by measure type.

Table 26. 2017 and 2018 ECB Program Reported and Evaluated Savings by Stratum

Stratum: Custom/Other, Natural Gas	Electric Gross Savings (kWh)	Electric Summer Peak Demand Savings (kW)	Electric Winter Peak Demand Savings (kW)	Natural Gas Savings (therms)
Stratum Savings (% of ECB program)	N/A	N/A	N/A	30%
Sampled Measures (% of Stratum)	N/A	N/A	N/A	29%
Realization Rate (%)	N/A	N/A	N/A	91%

Figure 18 lists realization rates and associated energy savings for all sampled measures within the Custom/Other, Natural Gas stratum.

Figure 18. Custom/Other, Natural Gas Sample Natural Gas Savings Results

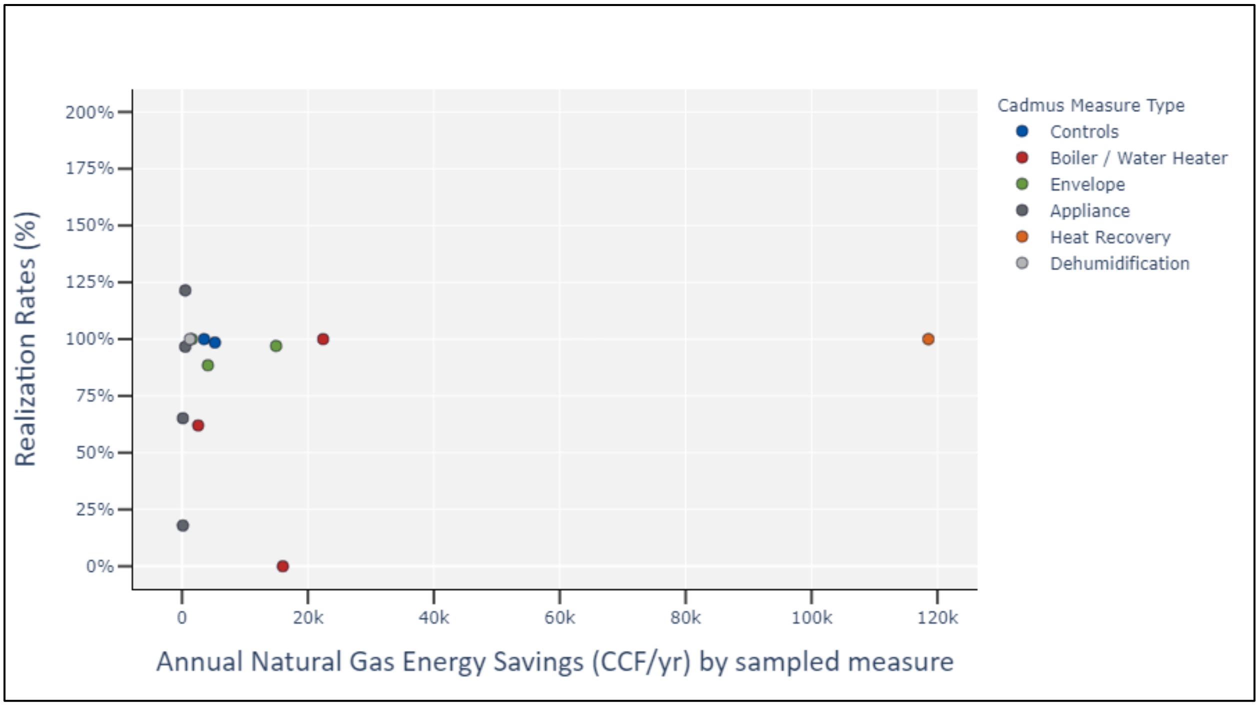


Table 27 provides the quantity of measures sampled, reported savings, evaluated savings, and common reasons for discrepancies.

Table 27. Custom/Other, Natural Gas Sample Detailed Findings

Measure Type	Sampled Measures	Reported Therms	Evaluated Therms	Realization Rate (%)	Common Reasons for Discrepancy
Appliance	4	1,274	1,215	95%	Operation HOU and production capacity differed from reported documentation, based on site observations and staff interviews.
Boiler/ Water Heater	4	41,014	24,212	59%	The Team found an incentivized kettle cooker was not installed at one facility due to construction installation limitations. The cooker was found on site, but will not be installed until 2020.
Controls	2	8,724	8,645	99%	Minimal discrepancies found.
Dehumidific ation	1	1,245	1,245	100%	No discrepancies found.
Envelope Upgrades	3	20,588	19,671	96%	Minimal discrepancies found.
Heat Recovery	1	118,554	118,554	100%	No discrepancies found.

The Team found few discrepancies when evaluating sampled measures in the Custom/Other, Natural Gas stratum. One sampled measure drove the majority of reduced realized energy savings for this stratum. The Team found incentivized equipment was not installed at one facility due to construction limitations. During the site visit, the Team located the equipment, but the facility could not install the equipment without modifying the facility's structure to install the equipment and to realize energy savings.

True New Construction (TNC) Results

TNC measures are defined as energy measures that are part of construction for an entirely new space or as part of a major renovation where energy codes are applicable. True New Construction projects differ from existing equipment replacement projects based on the market actors involved and their decision process. Because of this, installed efficiency levels are expected to vary between the two project types. The ECB participant database did not consistently track TNC measures across the two utilities or each program year. Therefore, total population and associated savings for TNC measures remain unknown.

Sampled Measures

The Team reviewed all sampled measure documentation when determining if each measure qualified as a TNC measure. Of 274 measures sampled for the evaluation, 127 measures were determined to be part of TNC measures. The Team installed power meters or collected trend data for 59 of 127 sampled TNC measures. Sampled measures that were not included in the TNC category are for end-of-life equipment replacement or for incentivized equipment that does not have an energy code mandated baseline energy efficiency. Air compressors are an example of these measures.

Additionally, applications do not always indicate if the incentivized equipment replaced existing equipment or not. If we could not determine if the measure was TNC or not, we did not include it in the TNC category. Non-TNC measures are included in the Normal Replacement (NR) category (Table 29).

Findings

Table 28 shows reported and evaluated gross savings results, along with realization rates. The Team weighted the realization rates to account for the sampling strategy employed on the entire population.

Table 28. True New Construction Sampled Measures Reported and Evaluated Savings

Stratum: True New Construction	Electric Gross Savings (kWh)	Electric Summer Peak Demand Savings (kW)	Electric Winter Peak Demand Savings (kW)	Natural Gas Savings (therms)
Reported Savings	27,570,956	2,216	1,281	136,111
Realization Rate (%)	110%	98%	113%	98%

Table 29 shows TNC realization rates and precision by strata.

Table 29. True New Construction Sampled Measures Realization Rates

Strata	Quantity of Measures	Electric Gross Savings (kWh) Realization Rate		Electric Summer Peak (kW) Demand Savings Realization Rate		Electric Winter Peak (kW) Demand Savings Realization Rate		Natural Gas (therms) Savings Realization Rate	
		TNC	Precision	TNC	Precision	TNC	Precision	TNC	Precision
Cooling, Electric	34	80%	11.7%	81%	18.8%	100%	N/A	N/A	N/A
Lighting, Electric	32	119%	11.3%	104%	11.3%	115%	22.0%	N/A	N/A
Heating, Electric	16	98%	9.7%	86%	181.3%	93%	14.1%	N/A	N/A
Custom/Other, Electric	19	89%	12.3%	105%	12.1%	97%	16.3%	N/A	N/A
Process, Electric	1	86%	N/A	237%	N/A	257%	N/A	N/A	N/A
Heating, Gas	16	N/A	N/A	N/A	N/A	N/A	N/A	99%	12.1%
Domestic Hot Water, Gas	6	N/A	N/A	N/A	N/A	N/A	N/A	89%	24.7%
Custom/Other, Gas	3	N/A	N/A	N/A	N/A	N/A	N/A	97%	1.8%
Total	127	110%	8.9%	98%	8.6%	113%	18.1%	98%	9.5%

Table 29 shows TNC and all measures realization rates by strata.

Table 30. True New Construction and All Measures Realization Rates

Strata	Electric Gross Savings (kWh) Realization Rate		Electric Summer Peak (kW) Demand Savings Realization Rate		Electric Winter Peak (kW) Demand Savings Realization Rate		Natural Gas (therms) Savings Realization Rate	
	TNC	NR	TNC	NR	TNC	NR	TNC	NR
Cooling, Electric	80%	36%	81%	48%	100%	26%	N/A	N/A
Lighting, Electric	119%	447%	104%	64%	115%	248%	N/A	N/A
Heating, Electric	98%	100%	86%	42%	93%	100%	N/A	N/A
Custom/Other, Electric	89%	105%	105%	98%	97%	109%	N/A	N/A
Process, Electric	86%	82%	237%	86%	257%	110%	N/A	N/A
Heating, Gas	N/A	N/A	N/A	N/A	N/A	N/A	99%	89%
Domestic Hot Water, Gas	N/A	N/A	N/A	N/A	N/A	N/A	89%	93%
Custom/Other, Gas	N/A	N/A	N/A	N/A	N/A	N/A	97%	90%
total	110%	87%	98%	86%	113%	106%	98%	90%

Baseline Study

The team conducted research into commercial new construction building standards in the general Connecticut market. This research included a literature review of applicable commercial new construction baseline studies, building codes and standards whitepapers, ASHRAE technical guidelines, and independent research reports. We also conducted in-depth interviews with key market actors holding various roles within Connecticut's commercial new construction industry.

The literature review and interviews focused on true new construction projects and standards in Connecticut.[24] With this research, the team sought to address these objectives:

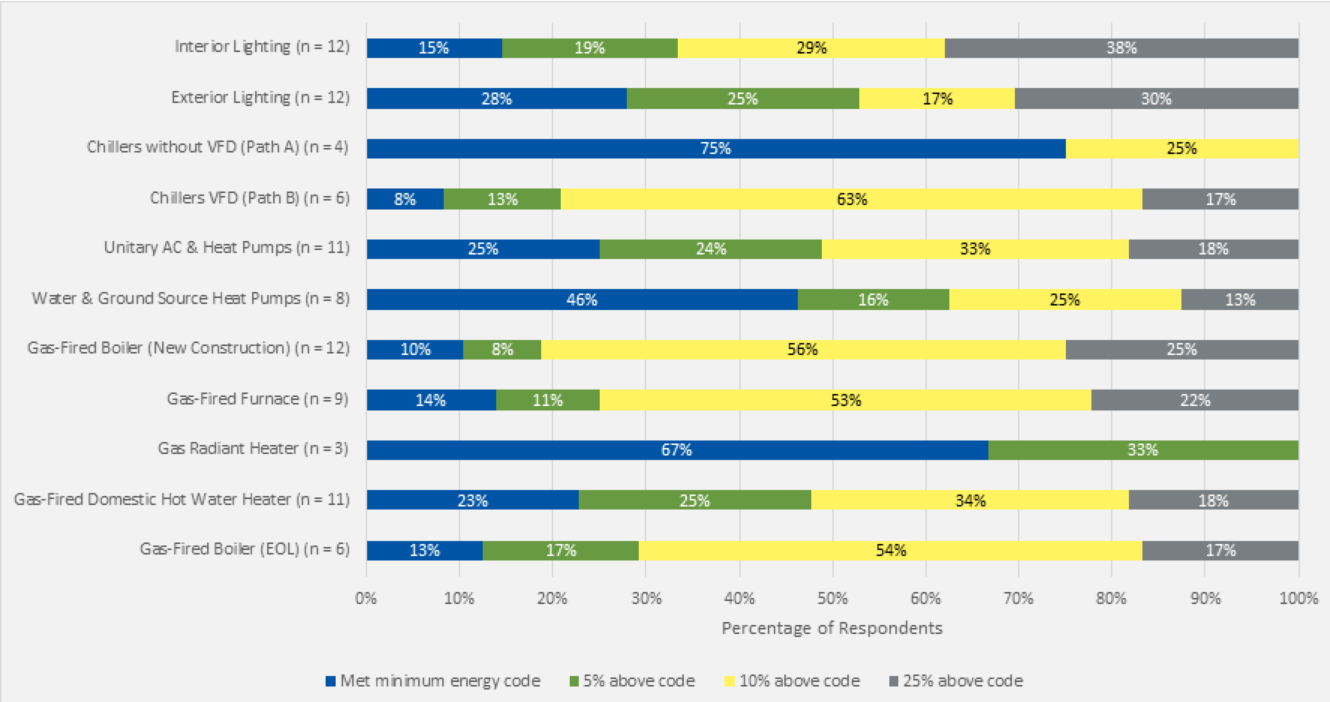
- Investigate recommended baselines for the following equipment:
  - Lighting and lighting power density
  - HVAC equipment efficiency
  - Boiler equipment efficiency and replace-upon-failure projects
- Understand market actor practices and perspectives on new construction baselines
- Identify factors that influence the new construction market in Connecticut
- Determine influences on the ECB program and implications for measuring energy saving impacts

Findings

Based on our market actor interviews, respondents estimated the average installed efficiency level of lighting, HVAC, and boiler equipment types. Respondents more reliably provided estimates for lighting and new construction boilers, which were most likely to be installed above code. Most respondents were unable to provide the installed efficiency levels for chillers, gas radiant heaters, and end-of-life (EOL) replacement gas fired boilers. Figure 19 shows the combined responses of installed efficiency levels by equipment type.

[24] True New Construction projects and existing equipment replacement are different market events that include different actors and decision points. Installed efficiency levels are expected to vary between the two market events. With the exception of boiler replacements, the Team focused on True New Construction, and these results apply only to the True New Construction market event.

Figure 19. Installed Efficiency Level by Equipment Type



Source: Estimate the average installed efficiency level of lighting, HVAC, and boiler equipment types. (n=15)

The resources we reviewed indicated that raising the baselines for certain lighting, HVAC, and boiler equipment is justified. Market actors indicated that interior and exterior lighting, unitary air conditioner and heat pumps, water and ground-source heat pumps, gas-fired boilers (new construction), gas-fired furnaces, and gas-fired domestic hot water heaters were already being installed at least 10% above code, and as high as 25% above code for lighting.

The results of the market actor interviews were not appropriate for making quantitative baseline changes for this study but indicate the need for further research in this area. Additional details regarding the baseline study can be found in *Appendix B*.

Conclusions and Recommendations

The 2017 and 2018 program evaluation yielded overall retrospective realization rates of 101.4% for electric energy savings, 98.6% for summer seasonal peak demand savings, 110.6% for winter seasonal peak demand savings, and 94.6% for natural gas savings. Varying degrees of realization rates and precision fell within each of the nine measure categories. The Team calculated prospective realization rates of 101.4% for electric energy savings, 98.6% for summer seasonal peak demand savings, 110.6% for winter seasonal peak demand savings, and 94.6% for natural gas savings. This section provides the Team's conclusions and recommendations, based on findings presented in this report.

PSD-Related Conclusions and Recommendations.

Conclusion—Dual Enthalpy Economizers

The utilities provided incentives for dual enthalpy economizers, which were included in most of the air conditioners sampled. Reported savings were based on deemed savings from the 2017 PSD. Deemed savings in the PSD were based on a study performed in 1999. The Team evaluated these measures by creating three eQuest energy models of the industrial, office, and retail building types based on sampled measures and simulating energy use of a minimally code-compliant single setpoint dry bulb economizer and a dual enthalpy economizer. No savings were realized for two of three building types, and minimal savings (2.1 kWh/ton) were realized for the retail building type. Most sampled air conditioners included dual enthalpy economizers, and reported savings for dual enthalpy economizers were, on average, much greater than reported savings for air conditioners. Consequently, the realization rate for air conditioners was highly impacted by realized savings from dual enthalpy economizers.

Recommendation—Dual Enthalpy Economizers

Remove the dual enthalpy economizer measure from PSD- and ECB-offered measures. The evaluation found that dual enthalpy economizer measures exhibit minimal energy savings in Connecticut's climate.

Conclusion—Lighting Hours of Use

The Team installed light loggers at 16 facilities. Analysis of light logger data indicated that actual HOU were typically greater than reported. Reported HOU were typically self-reported. In cases where the HOU were not self-reported, the HOU were based on the associated facility type for each measure, per Appendix 5 in the 2017 Connecticut PSD.

Recommendation—Lighting Hours of Use

Consider combining the results from this study with the C1635 Energy Opportunities study for a future version of the Connecticut Program Savings Document to assess and update HOU by building type. For lighting measures where HOU were based on the associated facility type, improving the accuracy of HOU by facility type is expected to improve the accuracy of reported energy savings.

Conclusion—Chiller Calculations

Chiller calculations often were reported based on a weather-bin calculator that projects chiller load as a function of outside air temperature and economizer setpoint. Using a weather-bin analysis approach may be appropriate for calculating annual energy use if the chiller load correlates well to outside air temperatures and this approach is often an improvement over using a deemed savings or other prescriptive calculation methods. However, cooling loads for chillers may correlate directly to occupancy schedules, process schedules, thermal mass loading, or other independent variables. In these situations, the hourly chiller load may not correlate well to outside air temperature, and a weather-bin analysis approach may not accurately calculate annual energy savings or demand savings.

Recommendation—Chiller Calculations

Calculate chiller savings using an annual 8,760 hourly calculation method or an energy simulation model instead of the bin analysis method. Using an 8,760 hourly calculation method will account for variable temperatures and change in average demand during the summer and winter peak periods, resulting in more accurate demand savings calculations.

General Conclusions and Recommendations

Conclusion—Air Compressor Load Profiles

Based on site visit observations, as well as power meter data and trend data from the air compressor measures, the Team found three driving factors decreased energy savings when compared to reported documentation: HOU were lower, average loads or compressor speeds were higher, and line pressure was lower.

Recommendation—Air Compressor Load Profiles

Conduct a pre- or post-implementation assessment of HOU, average loads, and line pressures by utilizing trend data or power metering. Implementing these changes will result in greater accuracy of energy savings calculations.

Conclusion—Air Compressor Calculations

Besides a reduction in total energy savings for compressed air measures, the Team found reported demand savings calculations typically were not representative of actual operations. The majority of measures reported demand savings as the difference in the maximum demand of installed and baseline compressed air systems multiplied by the summer or winter peak coincidence factors identified in Appendix A of the PSD. Based on site visit observations and meter data from 44 compressed air measures, the Team found average demand during peak periods was consistently lower than the reported peak demand expected by the system. As demand savings were calculated as average demand reduction during peak periods, compressed air measures realized more savings than reported for most sampled measures.

Recommendation—Air Compressor Calculations

Update the demand savings calculation methodology for compressed air measures. Savings calculation inputs should be revised, such that the customer provides the expected compressor load for each hour of every weekday and weekend of a typical week. If seasonal or monthly changes are expected to increase or decrease the load, the calculation inputs should provide customers with the ability to provide these seasonal changes. The compressor calculations should be updated so that the average load of the efficient compressor is reduced from the average load of the baseline compressor during the peak period. The average load should be based on trend data, historical observations, or customer judgement. Lastly, we recommend estimating an hourly savings profile for non-weather sensitive measures and weighting the savings at each hour according to the ISO-NE peak demand definition.[25] Making these changes will allow for greater accuracy of annual energy savings, seasonal summer savings, and seasonal winter savings.

Conclusion—Chiller Load Profiles

The Team installed power metering equipment on five chiller measures, where the resulting energy performance exhibited lower total energy use and associated energy savings than assumed in the reported calculations. For one measure, the chiller served a new data center facility, where average chiller loads were observed to be significantly lower than reported. This chiller accounted for 50% of all electric energy savings from chiller measures sampled in the Cooling, Electric stratum and heavily impacted the overall realization rate for the chiller sample. Within the Process, Electric stratum, the realization rate from the two chiller measures exhibited a 26% realization rate due to low hours of use and average loads. Average demand levels during peak periods also were lower than expected, resulting in lower peak demand savings.

Recommendation—Chiller Load Profiles

Adopt greater scrutiny in review of load profiles for all chiller measures, including pre- or post-implementation metering or trending. Improving the accuracy of the load profiles for incentivized chillers will minimize the possibility of over- or under-calculating reported energy savings. As an alternative approach to metering or trending, we recommend using energy models to simulate chiller performance to improve the accuracy of chiller savings.

Conclusion—True New Construction

Measures installed as TNC are not consistently documented in the measure tracking databases from the utilities with this designation. Consequently, the quantity of measures and associated energy savings of measures installed as TNC cannot be determined. Customers who install TNC measures often pursue energy efficiency through a different decision-making process than those who install energy efficiency

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[25] Mapping this ISO-NE definition to the TMY3 long-term average weather data for Hartford, the summer peak demand savings are a weighted average of the savings during the hours ending 13 – 18, and the winter peak demand savings are a weighted average of the savings between hours ending 8 – 22.

measures due to equipment failure or end-of-life replacement, and the performance of TNC measures may differ as a result.

Recommendation—True New Construction

Include a TNC designation within the measure tracking databases. By tracking TNC by application, utilities and evaluators may assess the impact of TNC measures throughout the ECB program.

Conclusion—Tracking Measure Database Detail

The Team received measure tracking databases from both utilities. The data entry values for each measure within the measure tracking databases varied by utility and program year. The measure description data entry within the tracking databases varied in detail and quality. For custom measures, the measure description often did not provide sufficient detail to understand the incentivized measure without reviewing the specific measure documentation. Without sufficient detail in the measure description, the total population of measure types remains unknown.

Recommendation—Tracking Measure Database Detail

Improve the detail provided in the measure description data entry within the measure tracking database for each measure. By including detailed measure descriptions, assigned measure types and measure categories as well as the reliability of measure type stratification for evaluation purposes may be improved. ASHRAE research project, 1836-TRP, is intended to develop a standardized system for the characterization and categorization of energy efficiency measures. We recommend that the results of this research project be reviewed and incorporated into the measure categorization of the ECB program.

Conclusion—Baseline Study

Market actors indicated that standard practice exceeds baseline for several measures included in the baseline study, notable interior and exterior lighting, unitary air conditioner and heat pumps, water and ground-source heat pumps, gas-fired boilers (new construction), gas-fired furnaces, and gas-fired domestic hot water heaters.

Recommendation—Baseline Study

Use the results of the baseline study to help prioritize quantitative investigations of standard practice baselines in a future study.

Conclusion—Forecast load profile treatment

The Team evaluated multiple measures involving the installation of chillers or air compressors that serve facilities where the occupancy or load is expected to ramp up over several years. Because energy savings are directly related to the load profile for chillers and air compressors, the energy savings for these measures may increase over time and the first-year energy savings may not be representative of typical future annual energy savings.

Recommendation— Forecast load profile treatment

Develop regulatory guidance and policies related to establishing first-year energy savings on measures where occupancy or load is expected to ramp up to full capacity over several years and where first-year energy savings may not be representative of typical future annual energy savings. Regulatory guidance will encourage consistent treatment across evaluation studies.

Appendix A. Light Logger Data

Project ID	Quantity of Light Loggers Installed	Facility Type	Reported Hours of Use	Calculated Hours of Use	Measured Summer Peak coincident factor	Measured Winter Peak coincident factor
1	5	Retail	4057	6170	0.96	0.94
2	6	Gymnasium	2586	3664	0.77	0.90
3	11	Warehouse	2602	7149	0.91	0.84
4	5	Retail	4057	5314	0.80	0.65
5	7	Retail	4057	7908	1.00	1.00
6	7	Retail	4057	4806	0.98	0.98
7	9	Warehouse	2602	8757	1.00	1.00
8	5	Workshop	3750	3696	0.71	0.44
9	5	Dining: Cafeteria / Fast Food	6456	3081	0.57	0.43
10	9	Warehouse	2602	8760	1.00	1.00
11	7	Retail	4057	1810	0.80	0.65
12	4	Office	2132	3130	0.80	0.40
13	6	School	2187	2773	0.68	0.68
14	12	Court House	2500	2571	0.96	0.46
15	22	Auto Related	2634	2847	0.61	0.27
16	11	Warehouse	2857	1839	0.24	0.04

Appendix B. ECB Impact Evaluation (C1634) Baseline Additional Scope of Work Memorandum

To: Peter Jacobs, Ralph Prahl, Study Lead, Evaluation Administrator

From: Ryan Hughes, Kaitlyn Teppert, Kean Amidi-Abraham, Cadmus

Subject: ECB Impact Evaluation (C1634) Baseline Additional Scope of Work

Date: April 24, 2020

As part of Energize Connecticut's Energy Conscious Blueprint (ECB) 2017-2018 program evaluation, the Connecticut Energy Efficiency Board (EEB) requested Cadmus conduct research into commercial new construction building standards in the general Connecticut market. This research will inform the ECB impact evaluation and bridge any gaps created by not conducting a baseline study (C1662). This memo summarizes the findings and conclusions from this investigation but is not intended as a formal baseline study that provides recommended baseline efficiency values for identified measures.

This research included a literature review of applicable commercial new construction baseline studies, building codes and standards whitepapers, ASHRAE technical guidelines, and independent research reports. We also conducted in-depth interviews with key market actors holding various roles within Connecticut's commercial new construction industry.

The literature review and interviews focused on true new construction projects and standards in Connecticut. Based on conversations with the EA, true new construction projects are defined as energy projects that are part of the construction of an entirely new space or part of a major renovation (excluding all other types of retrofit or equipment replacement projects) where an energy code is applicable.

Objectives

With this research, Cadmus sought to address these objectives:

- Investigate recommended baselines for the following equipment:
  - Lighting and lighting power density
  - HVAC equipment efficiency
  - Boiler equipment efficiency and replace-upon-failure projects
- Understand market actor practices and perspectives on new construction baselines
- Identify factors that influence the new construction market in Connecticut
- Determine influences on the ECB program and implications for measuring energy saving impacts

Literature Review

As the first step in this research, Cadmus worked with the EA to determine a list of resources—such as baseline and compliance studies from neighboring Northeastern states, technical resource manuals, and past evaluations—to guide our initial understandings of the research objectives and design an informed market-actor interview guide.

Method

Cadmus prepared an Excel spreadsheet with preliminary, proposed resources to conduct a full literature review and submitted it to the EEB for review. Once the EEB approved and appended the list, Cadmus moved forward with the complete literature review. The detailed literature review notes can be found in this memo's companion document, *CT Baseline Secondary Research.xlsx*.

When pulling together the resources, Cadmus and the EEB first prioritized studies and documents focused on Connecticut. Next, we concentrated on Massachusetts, a neighboring state that is well-known for its aggressive energy-efficiency policies, projects, and research. Other secondary states of interest included New York, New Hampshire, Rhode Island, and Vermont due to their regional proximity to Connecticut.

Cadmus conducted a preliminary review of regional code adoption in 2017, Connecticut code for measures of interest, and some high-level research about other states' codes. We then examined studies that had very similar scopes to understand how and why baseline codes may have increased because of existing market activity (particularly within new construction projects, where possible). In supplemental research, we also examined related studies to further understand baseline activity, what market actors may be of interest for subsequent interviews, and potential methodologies to use in the interview guide.

A full list of resources used for this literature review can be found in *CT Baseline Secondary Research.xlsx*.

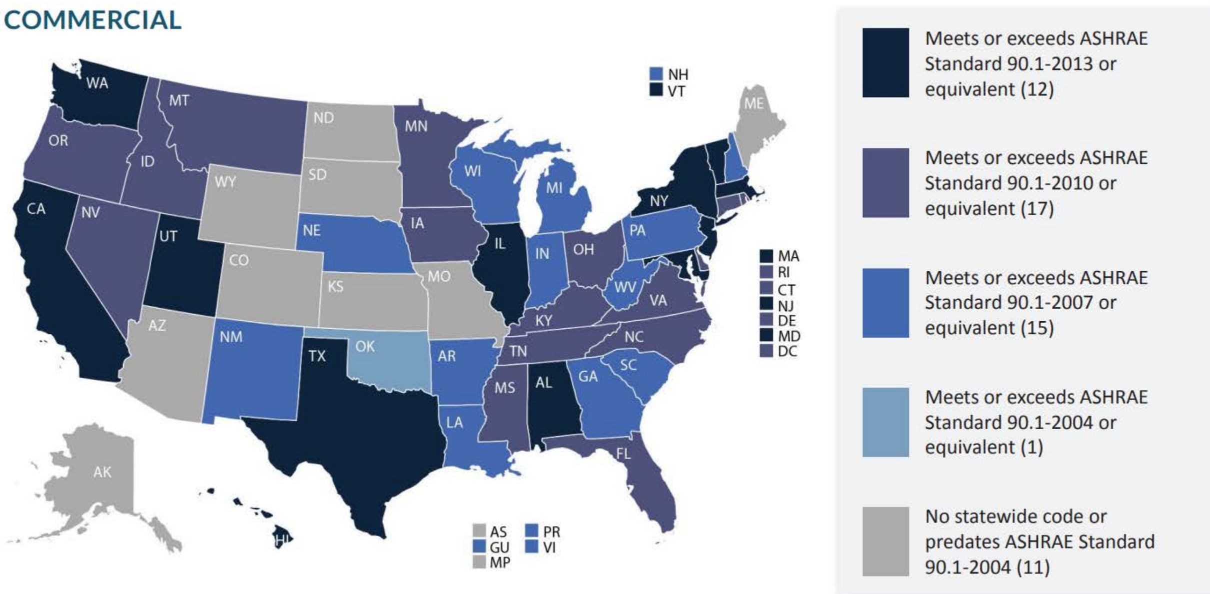
Literature Review Overall Findings

Though much of the literature review helped to inform the interview guide, there were two unique aspects of the review that also helped to contextualize our research. First, the status of regional code adoption in 2017. Second, what previous studies had found regarding baseline equipment assumptions used in evaluations versus what the market was installing, and if those findings justified an upward shift in baselines.

Regional Code Adoption

Since the *C1634 Energy Conscious Blueprint Impact Evaluation* covered projects completed in 2017 and 2018, Cadmus reviewed Connecticut's energy code adoption and compared it to neighboring states. In 2017, Connecticut had adopted the ASHRAE Standard 90.1-2010, which put Connecticut behind every neighboring state except New Hampshire and Rhode Island (Figure 1). However, in 2018, Connecticut adopted ASHRAE Standard 90.1-2013, which was on par with neighboring states.

Figure 1. 2017 ASHRAE Commercial Code Adoption Across the United States



Source: Building Codes Assistance Project. Code Adoption Status: April 2017. http://bcapcodes.org/wp-content/uploads/2015/11/code-status-april-2017.pdf

Standard New Construction Practice versus Minimum Code Compliance

In the past five years, rigorous baseline and code compliance studies have found that many measures installed within new commercial and industrial construction projects exceeded code requirements at the time of construction. For example, in 2015, the *Commercial New Construction Baseline and Code Compliance Study*[26] found that the efficiency of installations of equipment like lighting, air conditioners, heat pumps, and water heaters all exceeded prevailing code requirements and instead adhered to the most current ASHRAE requirements or beyond. Similarly, the *Massachusetts Commercial Energy Code Compliance and Baseline Study for the International Energy Conservation Code (IECC) 2012* (2018), which focused on lighting, found that the code requirement at the time was not reflective of then-standard practices, with higher-efficiency equipment regularly installed.

Beyond standard practices for commercial and industrial projects, the *Massachusetts Commercial and Industrial Impact Evaluation of 2014 Custom CDA (Comprehensive Design Approach) Installations* (2018) explored how participation in an energy efficiency program could impact the baseline assumptions of installed equipment within projects and how those installations affected realization rates and adjusted gross savings. The Custom CDA program in Massachusetts was an energy efficiency program offered within the custom commercial and industrial new construction portfolio intended to encourage a

[26] All of the studies mentioned in this memo are fully cited in the companion document, *Eventual Title of Final Excel document*.

comprehensive, whole-building approach to designing new construction projects. Similarly, this 2018 study found that Custom CDA projects often installed equipment that exceeded code requirements at the time.

All three of these studies recommended increasing baseline efficiencies to reflect standard practices, rather than baselines defined in state codes. These studies asserted that not adjusting evaluation baselines would jeopardize the accuracy of claimed savings. As evaluations of net and gross savings involve a rigorous and variable measurement process to account for freeridership, some of the inherent "noise" in these measurements could be reduced by adjusting baselines to reflect current practices. Additionally, the fact that these markets typically adopted more efficient equipment than required could impact future program design. For example, the *Commercial New Construction Baseline and Code Compliance Study* (2015) recommended that future energy efficiency programs should either lower the incentives for installing at-code efficient equipment and/or raise the efficiency threshold for program-eligible equipment.

In addition to installed equipment becoming more efficient, the *Massachusetts Gas Boiler Market Characterization Study Phase II – Final Report* (2017) found that manufacturers were keeping pace with the demand; most boiler manufacturers, large and small, were produced more high-efficiency models (81%, n=42) than standard and lower-efficiency models.

Literature Review Outputs

Throughout the literature review, it became clear that the scope of baseline and compliance studies needed to be extremely rigorous to justify adjusting the savings baselines. The three baseline studies cited in the *Literature Review Overall Findings* section all included site visits and a much larger scope compared to this study to look at many different data points of completed projects, as well as gathering feedback from industry officials. And even then, recommendations within those studies indicated that further research was needed to determine exactly what new baselines should be. Therefore, Cadmus determined that the outcomes of this study could not on their own inform or justify changing the baselines within the *C1634 Energy Conscious Blueprint Impact Evaluation*.

Cadmus found the literature review findings useful when developing the interview guide for the second half of this research. First, since the reviewed studies confirmed that builders had installed equipment above minimum standards in recent years, this provided justification for moving forward with the interviews. Additionally, since the studies found that manufacturers were keeping pace with the market by providing high-efficiency models, we were motivated to include manufacturers in the interviews. Finally, since the Massachusetts' Custom CDA program experienced similar patterns in the general market—where equipment was installed above code and above requirements for the program—we expanded on the research objectives and added questions to the interview guide about the efficiency levels of the equipment installed within ECB projects versus non-ECB projects.

Interviews

Cadmus conducted 15 market actor interviews (targeting respondents for each end use: lighting, HVAC, and boilers). Our team worked with the EA to identify a representative and knowledgeable cohort of manufacturers, contractors, distributors, engineers, designers, and developers with an understanding of Connecticut (or nearby) market conditions, and a willingness to share their insights.

Method

Cadmus identified eligible market actors through the EA, trade associations, and online searches. We scheduled interviews through email and phone outreach, and we conducted phone interviews between December 2019 and February 2020. Cadmus used Qualtrics to capture interview responses in digital format. We scheduled half of the interviews in advance and recorded these interviews with market actor approval.

Although we were unable to fulfill the original quotas planned for respondent type due to low response rates, we were able to complete 15 interviews. Overall, the respondents were well distributed across types and highly experienced within their roles. Table 1 shows the count of respondent type and average career length.

Table 1. Respondent Types

Respondent Types	Target Number of Respondents	Actual Number of Respondents	Average Career Length (years)
Code Official	2	2	25
Commissioning Agent	2	2	21
Contractor	5	0	N/A
Engineer	5	4	18
Developer	2	2	15
Lighting Designer	2	2	18
Local Distributor	6	3	36

We analyzed responses using frequency bins, which we then developed into bar and column charts for visualization. We used text matching on verbatim responses to develop choices for frequency charts.

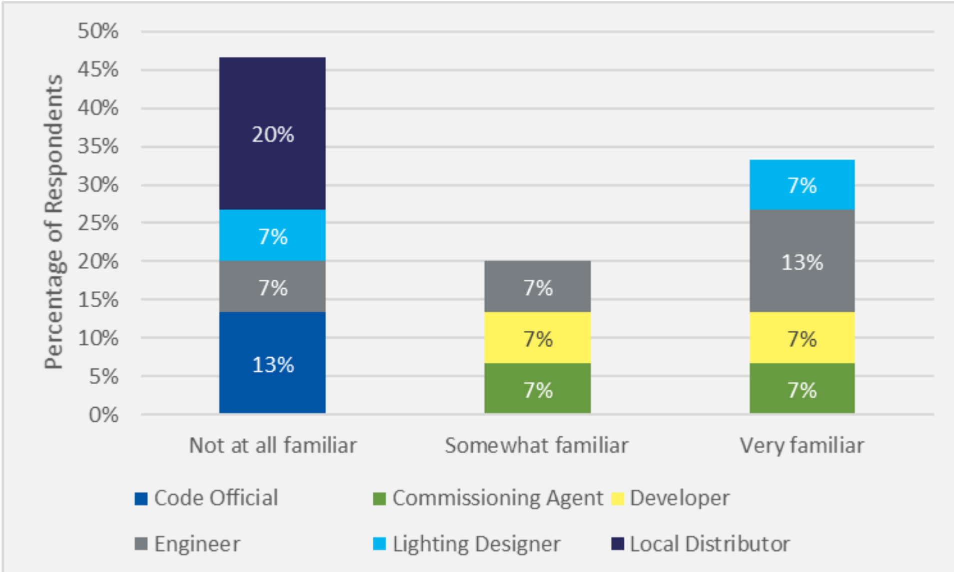
Key Findings from Interviews

In this section, we summarize key findings from the interviews based on our analysis of responses provided.

ECB

Cadmus asked market actors about their familiarity with the ECB program, to which over half (53%) responded that they were at least *somewhat familiar* with the program. On average, commissioning agents and developers were more familiar with the program, while code officials and local distributors were not as familiar. Figure 2 represents the familiarity of the different respondents with the ECB program.

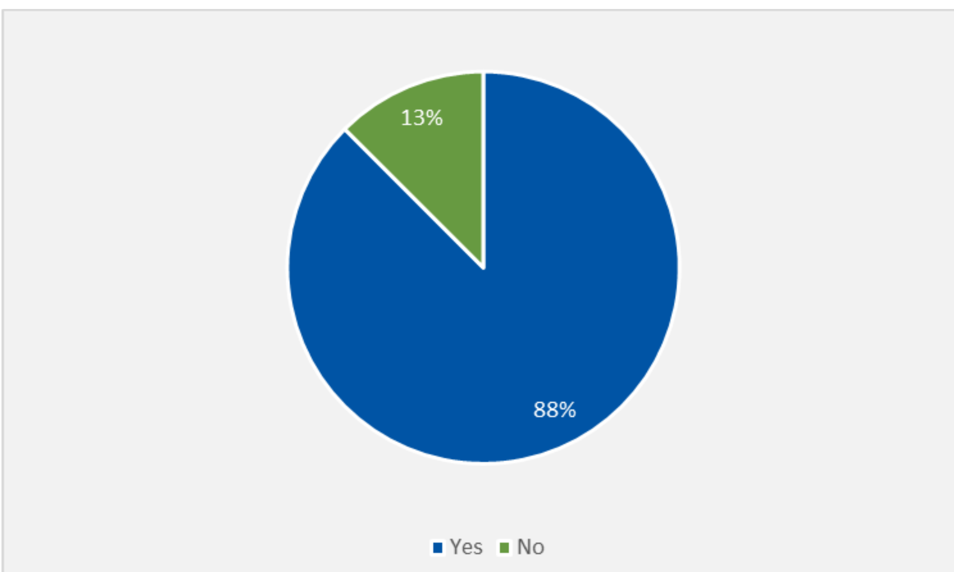
Figure 2. ECB Familiarity



Source: How familiar are you with the Energy Conscious Blueprint program? (n=15)

Of the respondents that were at least *somewhat familiar* with the program, 88% said that ECB projects installed higher-efficiency equipment than non-ECB projects. Figure 3 shows the effectiveness of the ECB program at increasing efficient measure installation.

Figure 3. ECB Increased Efficiency Effectiveness

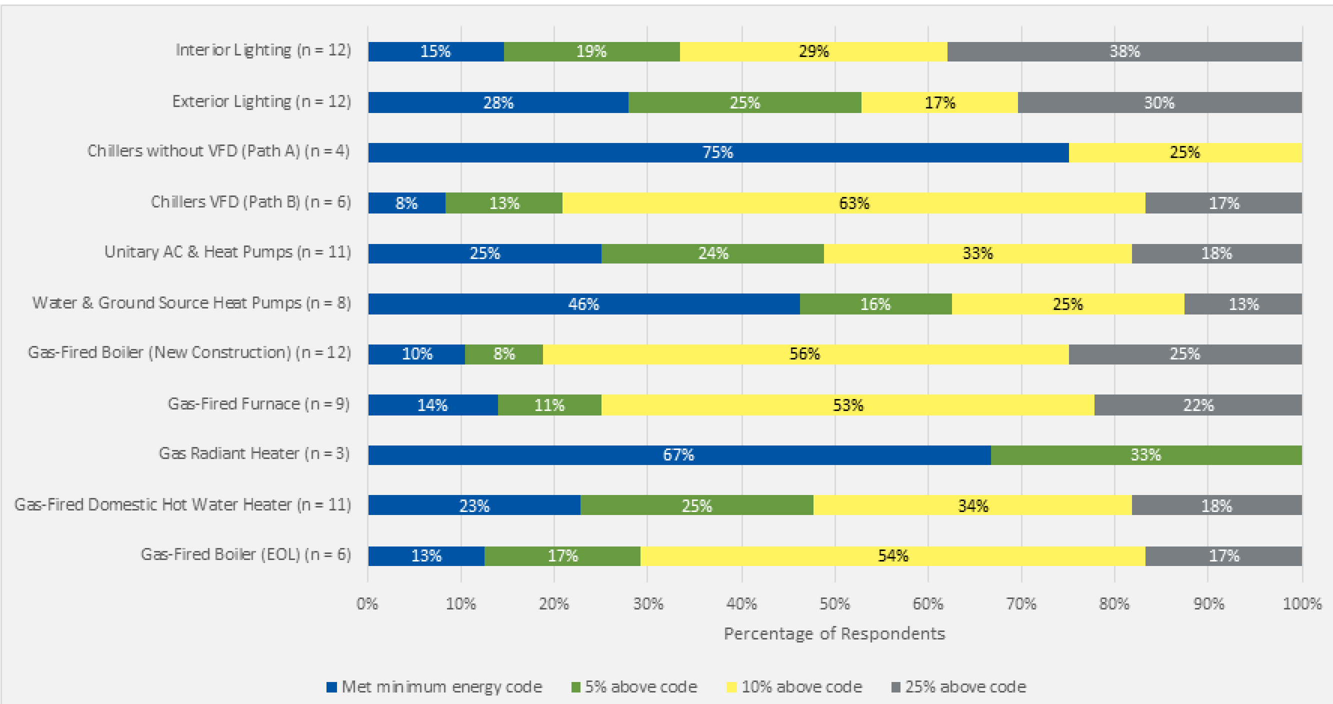


Source: From your experience, have you noticed if projects that participate in the ECB tend to install more energy efficient measures than those that do not participate in the ECB? (n=8)

Installed Efficiency Levels

We asked respondents to estimate the average installed efficiency level of lighting, HVAC, and boiler equipment types. Respondents more reliably provided estimates for lighting and new construction boilers, which were most likely to be installed above code. Most respondents were unable to provide the installed efficiency levels for chillers, gas radiant heaters, and end-of-life (EOL) replacement gas fired boilers. One respondent very familiar with interior lighting mentioned that half of the "25% above code" projects are 50% above code or better, healthcare/research facility projects are 25 to 30% above code, university/school projects are 30% to 50% above code, and corporate office projects are 50% above code. Another respondent mentioned that "water-source heat pumps are mostly in residential, although New York has some commercial applications." Figure 4 shows the combined responses of installed efficiency levels by equipment type.

Figure 4. Installed Efficiency Level by Equipment Type

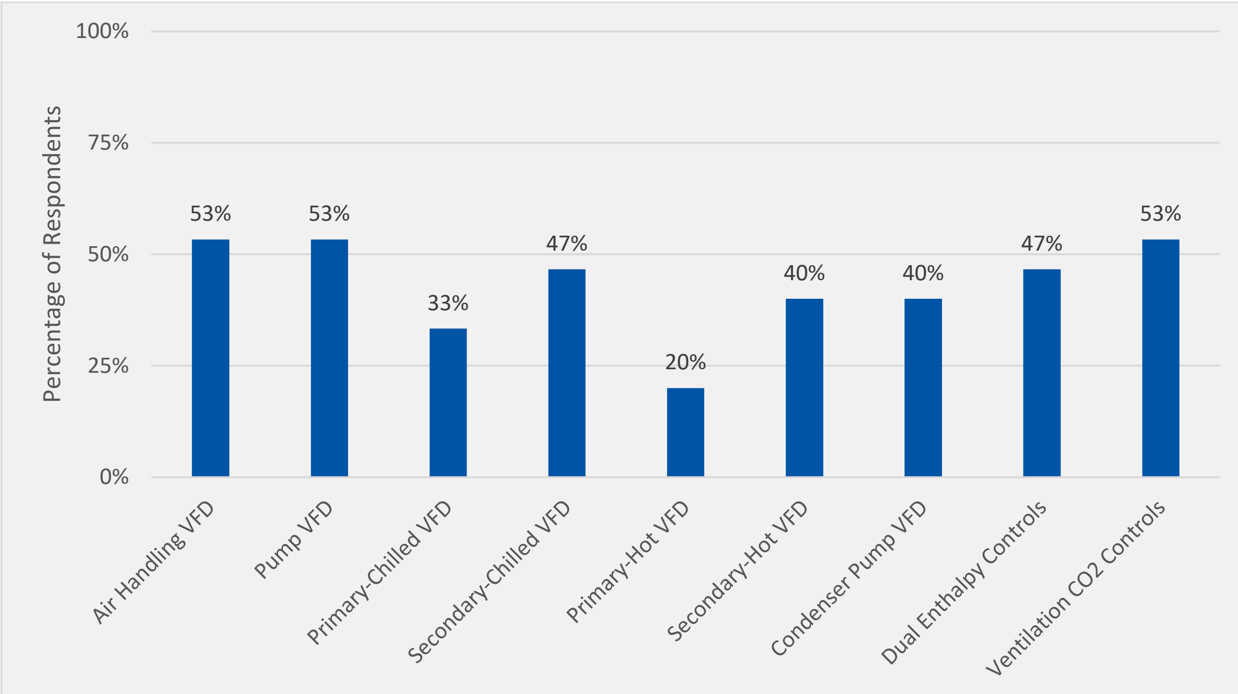


Source: Estimate the average installed efficiency level of lighting, HVAC, and boiler equipment types. (n=15)

Equipment Features

We asked respondents if they plan, install, or sell certain equipment features, such as variable frequency drives (VFD), dual enthalpy controls, and ventilation CO_2 controls. More than half of respondents (53%) said air-handling VFD, pump VFD, and ventilation CO_2 controls were planned when not otherwise required by code. Conversely, primary-hot water VFD were not often planned. In the verbatim section, 43% of respondents mentioned "variable-primary" pumps as more common than "primary-secondary" systems. Figure 5 shows the combined responses of installed equipment features.

Figure 5. Installed Equipment Features

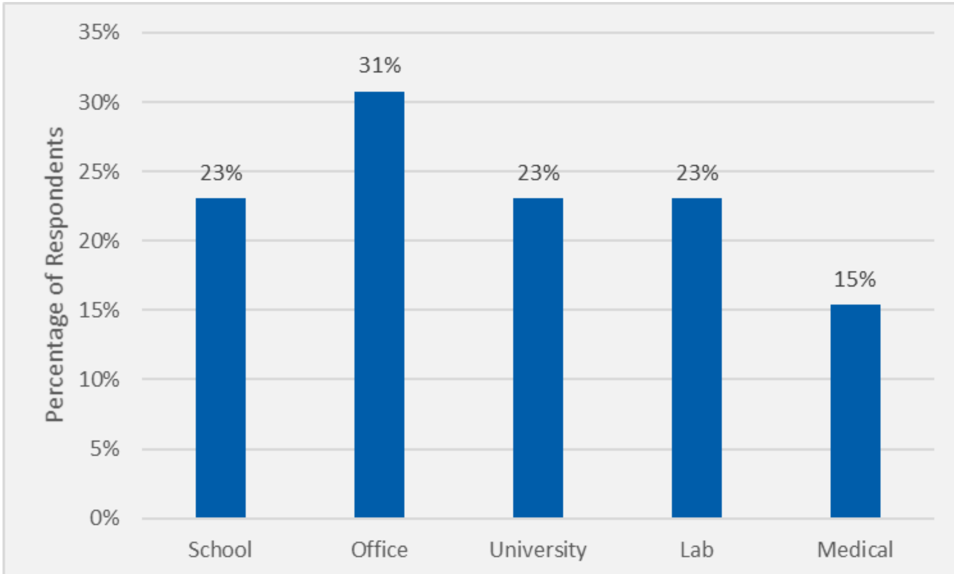


Source: In situations where not required by code in 2017 and 2018, did you typically plan for…? (n=15)

Building Types

We asked respondents about specific building types and their relation to energy-efficient installation measures. Schools, offices, universities, and labs were mentioned as more likely to have efficient measures. Some verbatim answers mentioned that these buildings have high-transiency occupancy and large lighting and equipment loads. Transiency occupancy refers to buildings or structures intended to be occupied at different times for different purposes, with relatively high levels of turnover. One response mentioned "courthouses, schools, universities, places with high-transiency occupancy." Another mentioned "new design thinking has resulted in less obtrusive equipment. Private-sector buildings have higher efficiency than public-sector (municipal, state, county, federal) buildings. Lowest-bid procurement policies result in lower efficiency." The building keywords were extracted from the verbatim responses and combined into Figure 6.

Figure 6. Building Types for Efficient Measures



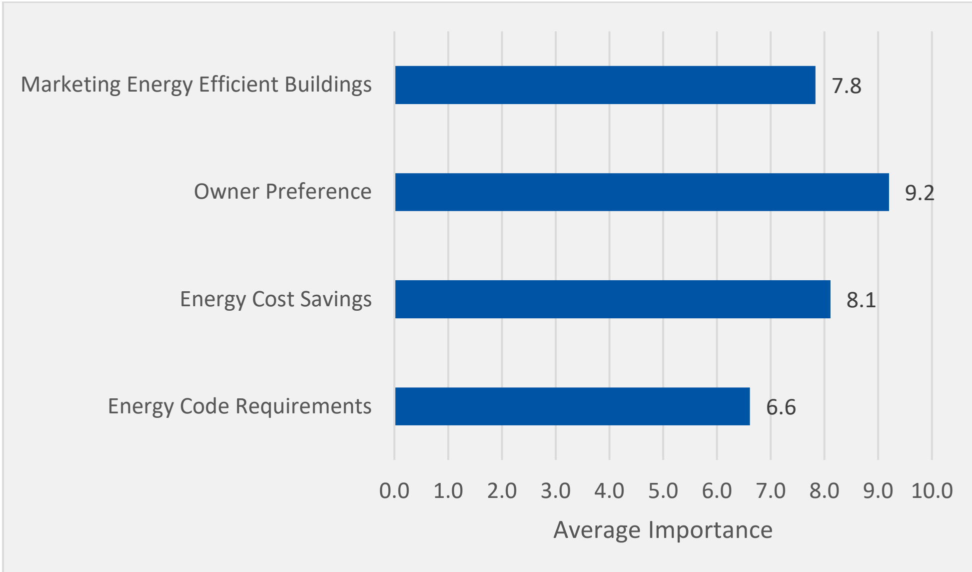
Source: Are there specific building types for which efficient measures are more likely? If so, what kind of buildings, and what type of equipment is typically "above" the minimum code or more efficient relative to other building types? (n=13)

Factors for Exceeding Code

Respondents were asked to list several factors that influence the extent to which new construction projects exceed building and energy codes and standards and then rank the factors from 1 (least influential) to 10 (most influential). Some common factors that were influential were energy code requirements, energy cost savings, owner preference, and marketing of energy efficient buildings.

Some verbatim answers elaborated on the context for the responses. One of these responses mentioned that for projects like schools and hospitals, individual financing entities usually want higher-efficiency measures while a board-run project will want a secure return on investment. Another response mentioned that ownership and responsibility for energy costs is an important challenge for office buildings and other shared buildings. More respondents think that the owner's preference is more important than the cost of the upgrades, although the cost comes in as the second most important factor. Cadmus analyzed the average importance rating for each factor, shown in Figure 7.

Figure 7. Average Importance of Factors for Exceeding Code



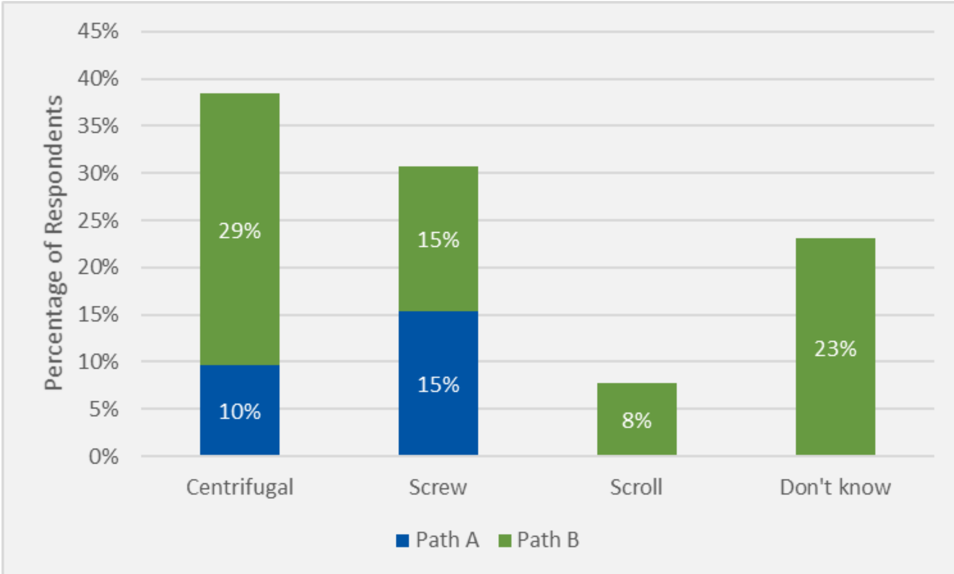
Source: What factors influence the extent to which new construction projects exceed building energy codes and standards? (n=15)

Compliance Strategies

Respondents were asked about their experience with chillers and, if applicable, what chiller types were most common. Most respondents who were familiar with chillers responded that centrifugal chillers were more common. They also mentioned that chillers with VFD (Path B) compliance were more common than non-VFD (Path A) compliance. Figure 8 shows commonly installed chiller types and their compliance distribution.

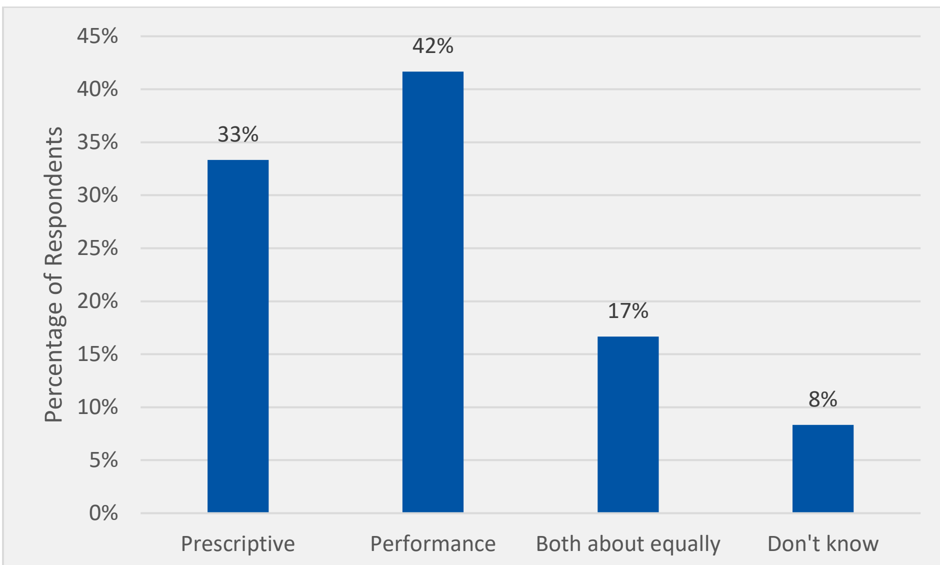
For respondents who were familiar with overall prescriptive and performance compliance strategies, there was not a consensus on what was more common, although performance was slightly more common. Figure 9 shows the distribution of compliance strategies.

Figure 8. Installed Chiller Types



Source: Which chiller types were the most common? Which chiller compliance paths were the most common? (n=9)

Figure 9. Building Compliance Strategies



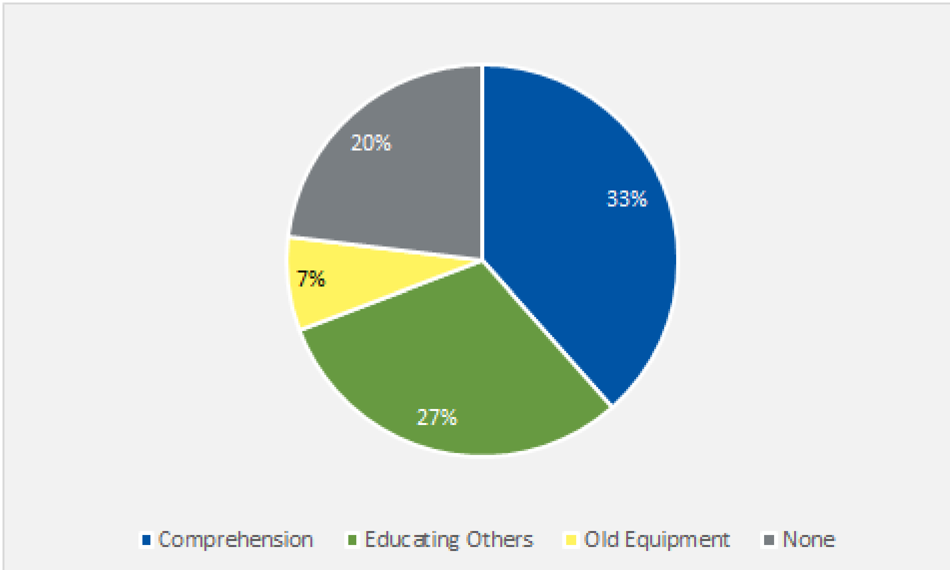
Source: What compliance strategy is most commonly used? (n=12)

Challenges

Respondents were asked about any challenges they face when new energy codes take effect. Comprehension and educating others of the new code were mentioned as the main challenges to remain competitive in a market that quickly adheres to code changes. One respondent mentioned "getting employers, builders, and buyers to understand that it's harder to meet higher energy codes."

Another mentioned "learning new rules, educating architects and builders, overlaying new rules with above-code programs." Decommissioning old equipment was also mentioned as a challenge. The most common keywords from these responses are outlined in Figure 10.

Figure 10. Challenges for New Energy Codes

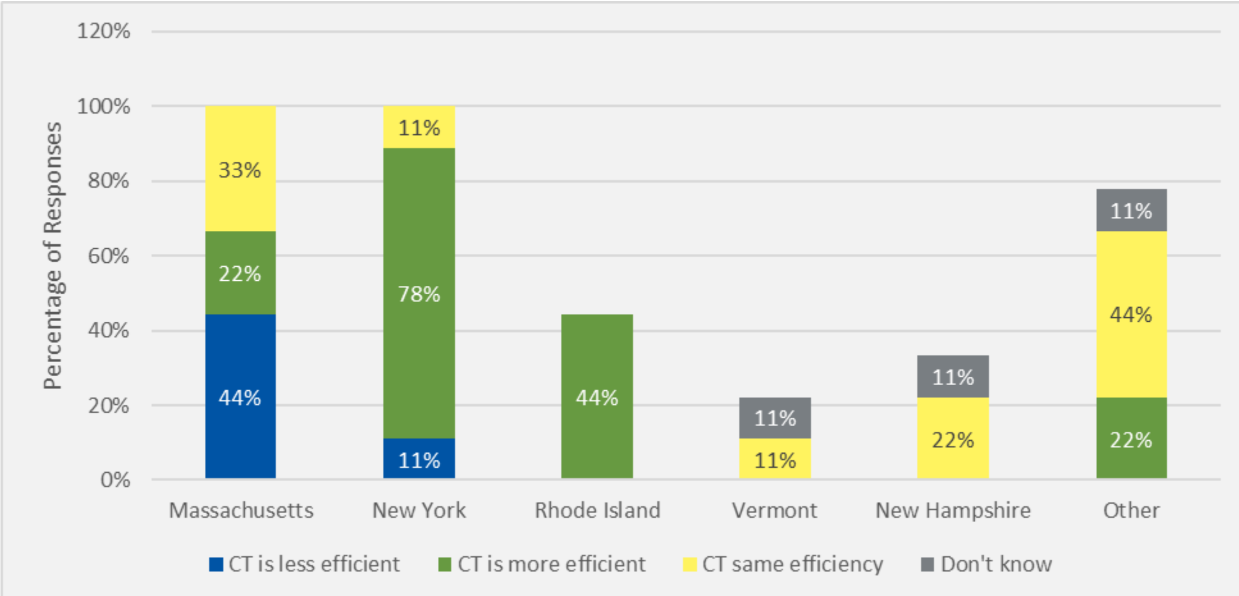


Source: What challenges, if any, does your organization face when new energy codes take effect? (n=15)

State Comparison

Respondents with work experience in states other than Connecticut were asked to compare the efficiency of Connecticut to those other states. Seventy-eight percent of respondents said that Massachusetts was at least as efficient or more efficient than Connecticut, and an equal percentage said New York was less efficient than Connecticut. One respondent mentioned utility programs as more important for installing above-code equipment than state regulations. Another respondent mentioned that electricity rates contribute to the frequency of above-code equipment installations. Figure 11 compares efficiency in Connecticut with various states.

Figure 11. State Efficiency Comparison[27]



Source: Overall, when thinking about your new construction work in Connecticut compared to your work in other states how would you say the standard efficiency levels (for new construction designs and equipment) in Connecticut compares to that in other states? (n=15)

Additional Comments

At the conclusion of the interview, respondents were asked for any additional comments that were not covered earlier in the interview. One respondent said that it is more difficult to convince owners of the value-add of efficiency measures that are out of sight to customers. These include projects that are not public-facing and do not have an added benefit of marketing appeal. Another respondent said that educating contractors in new technologies is key to ensuring that work is properly done. Installed efficiency levels have improved through technology but more tech-savvy contractors are required for proper implementation. Another said that "One of the roadblocks to efficient measures is electric and gas pricing in Connecticut. Gas should be more expensive and electricity cheaper to incentivize electrification. All-electric buildings should be rewarded with cheaper electricity rates." This sentiment indicates that other policy options can be pursued to encourage the adoption of efficient electric and gas measures.

Overall Conclusions and Recommendations

Objective #1: Investigate baselines for lighting, lighting power density, HVAC equipment efficiency, boiler equipment efficiency, and replace-upon-failure projects.

Conclusions

The resources we reviewed indicated that raising the baselines for certain lighting, HVAC, and boiler equipment is justified. Market actors indicated that interior and exterior lighting, unitary air conditioner

[27] The "Other" category includes states such as PA, NJ, MD, VA, and others around the U.S.

and heat pumps, water and ground-source heat pumps, gas-fired boilers (new construction), gas-fired furnaces, and gas-fired domestic hot water heaters were already being installed at least 10% above code, and as high as 25% above code for lighting as shown in Figure 2.

Recommendation

Consider conducting a baseline code compliance study to determine actual baseline efficiency levels for each equipment type.

Objective #2: Understand market actor perspectives and practices on new construction baselines.

Conclusions

The variety of market actor experiences provided a diverse overview of the state of new construction in Connecticut and neighboring states. Many of the respondents reported that office buildings, schools, labs, universities, and medical facilities were more likely to install higher-efficient measures due to their more ambitious goals and high-transiency occupancy. The biggest challenge the market actors faced for complying with new energy codes was understanding them and educating staff.

Objective #3: Understand factors that influence new construction market in Connecticut.

Conclusions

Market actors indicated that owner preference is the most influential driver of efficient measure installation in projects like schools and hospitals, with individual owners being more inclined to install higher-efficient measures than facilities where decisions are made through a group of stakeholders such as a board of trustees. As owners are the primary project decision-makers, information and marketing messages about efficient equipment benefits need to resonate with building owners as the key audience. Equipment/project cost and resulting building marketing appeal are rated as the second highest factors but are inherently linked to the preference of the owner.

Recommendation

Consider targeting building owners for marketing approaches that recognize their concerns and interests associated with installing above-code measures.

Objective #4: Determine influences on the ECB program and implications for measuring energy-saving impacts.

Conclusions

Over half of the respondents were at least somewhat familiar with the ECB program. Of these respondents, a large majority said that ECB projects installed more efficient measures than projects that did not participate in the program. In addition to encouraging the installation of more efficient measures, the program helps design and engineering teams communicate with the owner. Raising minimum baselines for equipment that qualify for the ECB program will result in lower energy savings for existing equipment replacements but will encourage the adoption of higher-efficient equipment into the program. As manufacturers raise efficiencies to meet the demand of energy codes, utility incentives can further drive efficiency levels from baseline adjustments by raising the minimum efficiency criteria.

Recommendation

Consider encouraging utilities to raise minimum efficiency program eligibility criteria to account for a more efficient baseline.

Appendix C. Evaluation Comments and Response

Memorandum

To:	Peter Jacobs, Ralph Prahl, Cx Associates
	Lisa Skumatz, Skumatz Economic Research Associates (SERA)
	Miles Ingram, Eversource
	Richard Oswald, United Illuminating Company
From:	Ryan Hughes, Bonnie Powell, and Brad Jones; Cadmus
Subject:	C1634 ECB Evaluation Report Comments Response
Date:	September 25, 2020

Overview

This memorandum serves as a response to the written comments provided by Miles Ingram of Eversource regarding the C1634 Energy Conscious Blueprint Impact Evaluation Review Draft ("Draft Report"), submitted July 7, 2020 by Cadmus.

Recommendation 1 – Remove Dual Enthalpy Economizers

Eversource offers these economizers because they are the best way to economize and they are more likely to be installed correctly than baseline dry bulb technology. Single dry bulbs have to be set up by installers who must estimate when it would be best to economize based on what they think the return air would be—and depending on the accuracy of this estimate, performance can vary substantially. Dual enthalpy economizers make this decision continually, and do not require installer setpoints. If the evaluated savings were based on a baseline assumption of a correctly installed dry bulb, these savings may not reflect the reality of dry bulb installations. In addition, several projects saw reduced economizer savings based on EQUEST modeling. We would like to confirm that the modeling was based on dual or comparative enthalpy and not just single enthalpy. The magnitude of the results appears closer to what single enthalpy would produce.

In general, we do agree that savings appear to be overstated for these measures based on the evaluation but would request a deemed kWh savings per ton value we could use if we decide to continue offering these measures. For instance, if we remove them from ECB, we would have to consider how to treat them in the other programs that offer them (e.g., EO & SBEA).

Finally, we request information on how the prospective realization rate would change if we were to adopt a lower deemed kWh savings per ton value for economizers, or if we were to stop offering them altogether.

Recommendation 1 – Response

The Team evaluated dual enthalpy economizers by creating three eQuest energy models of the industrial, office, and retail building types based on sampled measures and simulating energy use of a minimally code-compliant single setpoint dry bulb economizer and a dual enthalpy economizer. No savings were realized for two of three building types, and minimal savings (2.1 kWh/ton) were realized for the retail building type. The energy models assume the dry bulb economizer in the baseline condition is installed and controlled correctly. While we agree that dry bulb economizers may not always be set up in an optimal manner, we would need a study of single dry bulb economizer installation and operation characteristics in new buildings to validate the premise that dry bulb economizers are not typically installed correctly and to quantify the associated energy performance impact. We recommend the dual enthalpy economizer measure is removed from PSD- and ECB-offered measures.

Recommendation 2 – Consider commissioning a lighting study to update hours of use (HOU) by building type

Ultimately evaluation planning and scoping decisions are made by the EEB evaluation committee. However, we do not believe further study is needed, since the recent C1635 EO impact evaluation recommended updating HOU for upstream lighting based a large set of leveraged lighting logger data. Given this recommendation, which we plan to implement, we would also plan to use those values for ECB so there is one set of HOU values for both programs.

Recommendation 2 - Response

We have modified our recommendation to instead consider combining the results from this study with the C1635 EO study for a future version of the Connecticut Program Savings Document to assess and update hours of use (HOU) by building type. For lighting measures where HOU were based on the associated facility type, improving the accuracy of HOU by facility type is expected to improve the accuracy of reported energy savings.

Recommendation 3 – Calculate chiller savings using an annual 8,760 hourly spreadsheet calculation method

Eversource engineering staff believe that the recommendation of using a 8,760 hourly spreadsheet would have little to no effect on the accuracy of reported savings. It should be noted that the temperature bin spreadsheet uses 8,760 hours. Also, the major differences between reported and evaluated savings came from the input to the spreadsheet, not the calculations. Engineering will go over the site reports so the verification of input can be modified. In addition, as ERS commented on the PSD review (X1931), they reviewed the chiller savings calculation tool and are making recommendations. We plan to take all recommendations into account before making any significant changes to the calculation methodology.

Recommendation 3 - Response

Using a weather-bin analysis approach may be appropriate for calculating annual energy use if the chiller load correlates well to outside air temperatures and is often an improvement over using a deemed savings or other prescriptive calculation methods. However, cooling loads for chillers may correlate directly to occupancy schedules, process schedules, thermal mass loading, or other independent variables. In these situations, the hourly chiller load may not correlate well to outside air temperature and a weather-bin analysis approach may not accurately calculate annual energy savings or demand savings. We still recommend calculating chiller savings using an annual 8,760 hourly calculation method instead of the bin analysis method. Using an 8,760 hourly calculation method will account for variable temperatures and change in average demand during the summer and winter peak periods resulting in more accurate demand savings calculations.

Recommendation 4 – Implement a post-implementation assessment of air compressor measures by using trend data or power metering post-implementation

We are not sure the added cost and time required for this process would be worth it, considering that there are frequent shift changes and other operational variation over time, and short-term metered load is unlikely to be representative of longer-term usage. In addition, it is unclear what corrective actions would be feasible after getting post-implementation metering results, considering that incentives would already have been paid.

Relatedly, for the air compressor project at site E0001130, the evaluators gave zero evaluated savings for the project because the compressor was not in use at the time of the site visit. The site visit documentation noted that the customer said there were delays in receiving production equipment, but that they would be using the compressor later in the summer. We believe that a 100% reduction in savings is an over-adjustment since the equipment will be used and have considerable savings over its measure life.

Recommendation 4 - Response

We understand the concerns related to cost and time required for post-implementation metering and have revised our report to recommend the option of utilizing pre- or post- implementation metering data when assessing air compressor load profiles. Based on site visit observations, as well as power meter data and trend data from the air compressor measures, the Team found three driving factors decreased energy savings when compared to reported documentation that may be mitigated by utilizing metering data for assessing air compressor load profiles.

Regarding the air compressor project at site E0001130, the evaluated savings are based on first-year savings and the evaluation methodology is consistent with all sampled measures within this evaluation. Prior to the draft report, Cadmus contacted the customer again and the customer confirmed the compressor was not in operation yet.

Recommendation 5 – Update electric demand savings calculations for air compressors

We generally agree with this recommendation, but a specific update for the engineering spreadsheet would be ideal.

Recommendation 5 - Response

Savings calculation inputs should be revised, such that the customer provides the expected compressor load for each hour of every weekday and weekend of a typical week. If seasonal or monthly changes are expected to increase or decrease the load, the calculation inputs should provide customers with the ability to provide these seasonal changes. The compressor calculations should be updated so that the average load of the efficient compressor is reduced from the average load of the baseline compressor during the peak period. The average load should be based on trend data, historical observations, or customer judgement. Lastly, we recommend estimating an hourly savings profile for non-weather sensitive measures and weighting the savings at each hour according to the ISO-NE peak demand definition.[28] Updating the calculations using an estimated hourly profile during these hours for non-weather sensitive measures are expected to improve the analysis. Making these changes will allow for greater accuracy of annual energy savings, seasonal summer savings, and seasonal winter savings.

Recommendation 6 –Adopt greater scrutiny into the assessment of load profiles for all chiller measures, including post-implementation metering or trending

We are not sure the added cost and time required for this process would be worth reduced variability in project savings estimates. It would require significant effort and time period of metering, and chillers generally have relatively small amounts of savings due to high baselines. In addition, it is unclear what corrective actions would be feasible after getting post-implementation metering results, considering that incentives would already have been paid.

Recommendation 6 - Response

We have revised our report to recommend the option of utilizing pre- or post- implementation metering data when assessing chiller load profiles. Improving the accuracy of the load profiles for incentivized chillers will minimize the possibility of over- or under-calculating reported energy savings. As an alternative approach to metering or trending, we recommend utilizing energy models to simulate chiller performance to improve the accuracy of chiller savings.

Recommendation 7 – Include a True New Construction (TNC) designation within the measure tracking database

The tracking data we provided did include designations for true new construction (as well as major renovation, new equipment, and equipment replacement). Specifically, the “Program_Name” field and “Subprogram name” field include designations for program categories including true new construction.

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[28] Mapping this definition to the TMY3 long term average weather data for Hartford, the summer peak demand savings are a weighted average of the savings during the hours ending 13 – 18 and the winter peak demand savings are a weighted average of the savings between hours ending 8-22.

Recommendation 7 - Response

We have modified the language to clarify our findings. Measures installed as TNC are not consistently documented in the measure tracking databases from the utilities with this designation. In total, the Team received 18 tracking dataset workbooks for 2017 and 2018 projects. Many datasets from both utilities contained duplicates and were revised with newer, updated dataset versions. Upon closer review of all datasets, the Program Name field was included in the early sets of Eversource tracking data we received but were not included in the final corrected tracking datasets. Additionally, the UI datasets do not appear to track TNC designation. We recommend including a TNC designation within the measure tracking databases for both utilities. By tracking TNC by application, utilities and evaluators may assess the impact of TNC measures throughout the ECB program.

Recommendation 8 – Improve the detail provided in the measure description data entry within the measure tracking database for each measure

We generally agree that detailed measure descriptions are useful in tracking data. However, for custom measures it may be difficult to track and enter consistent descriptions and it would require tracking system modifications. In addition, custom is not one of our reportable measure categories—they are captured under heating/cooling/other measures based on their end-use attributable savings.

Recommendation 8 - Response

We have modified our language to clarify the recommendation. The Team received measure tracking databases from both utilities. The data entry values for each measure within the measure tracking databases varied by utility and program year. The measure description data entry within the tracking databases varied in detail and quality. For custom measures, the measure description often did not provide sufficient detail to understand the incentivized measure without reviewing the specific measure documentation. Without sufficient detail in the measure description, the total population of measure types remains unknown.

Improve the detail provided in the measure description data entry within the measure tracking database for each measure. By including detailed measure descriptions, assigned measure types and measure categories may be improved and the reliability of measure type stratification for evaluation purposes may be improved. ASHRAE research project, 1836-TRP, is intended to develop a standardized system for the characterization and categorization of energy efficiency measures. We recommend the results of this research project be reviewed and incorporated into the measure categorization of the ECB program.

Recommendation 9 – Use the results of the baseline study to help prioritize quantitative investigations of standard practice baselines in a future study

We agree with this recommendation, although note that evaluation scoping and planning decisions are ultimately made by the EEB evaluation committee. In addition, it is important to note that the CT energy code is expected to change soon, and we are soon launching an updated new construction program.

Recommendation 9 - Response

We understand and have not revised our recommendation to use the results of the baseline study to help prioritize quantitative investigations of standard practice baselines in a future study.