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CT EEB

X1941 Multifamily Impact Evaluation

Prepared for:

CT Energy Efficiency Board (EEB) Evaluation Committee

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1 Abstract

The **Multifamily (MF) Impact Evaluation (X1941)** project conducted by TRC (the research team) contains two main elements related to updating the PSD with improved results from primary and secondary sources:

- A review of the array of CT PSD values related to multifamily measures, involving extensive research of the evaluation literature nationwide and regionally, and a review of leading TRMs / PSDs in other states. Previously, CT's MF PSD values were based on single-family or commercial values. This work, completed in summer 2020, included specific recommendations for updated MF PSD values, and was included in a separate report[1] and is briefly summarized in Chapter 3.
- An impact evaluation of Eversource and United Illuminating's (UI) Multifamily Initiative for program years 2017-2019. Impact evaluations are the key source for CT-specific PSD updates, and an impact evaluation of multifamily retrofit programs had not been conducted for Eversource and UI for at least ten years. This provides multifamily-specific values for measure level savings, and this work is the subject of this report.

The research team proposed updates to the **2020 CT PSD** focused on providing multifamily-specific values for measure-level savings. Based on the findings from the data-driven engineering review, the research team proposed revisions to the 2020 PSD to reflect the accepted engineering assumptions for multifamily building characteristics and operations. The following is an overview of recommendations:

- Updates to hours of use specific to multifamily buildings.
- Clarifications for how certain measures should be applied in multifamily projects.
- Update to coincidence factors for some measures so they are specific to multifamily common areas.
- Different assumptions for multifamily buildings for some measures, such as base case gas usage for heating savings and capacity assumptions for Wi-Fi thermostats due to the smaller size of multifamily dwelling units (compared with single-family), and default efficiency values for multifamily equipment,
- Multifamily-specific equations for a few measures, including for central furnaces and air conditioners (due to different usage patterns compared to commercial buildings) and low-flow fixtures (due to typically lower numbers of bathrooms per unit than in single-family homes)

Note that almost none of these recommendations are incorporated into this impact evaluation, because these recommendations would be incorporated into future versions of the PSD. The two exceptions were the recommendation to adjust the low-flow fixture equation, because the research team believed the equation in the 2020 PSD was not mathematically correct, and to adjust the residential lighting baseline so it aligns with a federal regulation (Energy and Security Independence Act – EISA) that has been effective since 2014.

The Multifamily Initiative includes multiple energy efficiency retrofit programs that support multifamily buildings or complexes with five or more units. This impact evaluation is focused on projects tracked

[1] ERS. [X1931] PSD Review.

through the Home Energy Solutions (HES) and HES-Income Eligible (HES-IE) programs,[2] which this study found to provide the vast majority (if not all) savings for the Multifamily Initiative[3].

The **main objectives** of this study were to:

- Calculate program-level realization rates,
- Calculate measure level realization rates (only possible for Eversource, since the UI program database does not track savings at the measure-level), and
- Identify opportunities to improve realization rates in the future, and for additional savings opportunities.

The research team calculated prospective (based on the 2020 PSD) and retrospective (based on the PSD for each program year that the measures were installed: 2017 through 2019 PSD) realization rates. This report only shows prospective results since retrospective results were very similar to prospective for almost all measures.

In addition, the research team conducted a "deep dive" investigation of the air sealing measure, a commonly installed in-unit measure within the HES and HES-IE programs, to develop recommendations to improve the robustness of savings claims from air sealing, and the persistence of savings from this measure.

The research team verified savings as well as calculated retrospective and prospective realization rates using data from a sample of facility managers[4] on measures installed at a sample of project sites. The research team verified the savings at the measure and site level, and extrapolated site-level savings to program-level results for annual energy (kWh, ccf, and BTU), demand, and lifetime savings; and project-level savings for delivered fuels. For Eversource, which tracks savings in its database at the measure-level, the research team also calculated measure-level realization rates for commonly installed measures.

Results:

Program level realization rates: At the program level, the realization rates (RRs) were moderately high or high, and similar for HES and HES-IE for both utilities for most metrics (annual kWh, lifetime kWh and annual CCF), with the exception of summer kW for both utilities. These results are shown in Table 1 and Table 2, where * indicates the value met or exceeded 90% confidence, 10% precision. Specifics follow:

- Installation count issues and calculation errors: Most of the adjustments made to the realization rates were the result of either a misapplication of the correct values in the ex ante calculations, or adjustments made to the installation counts. This latter problem occurs often with instances of double-counting misspecification, or omission of measures in the records.

[2] HES and HES-IE provide incentives for energy efficiency measures for existing multifamily projects using a deemed savings approach. Multifamily customers can enroll in these programs, which provide tiered incentives for a variety of lighting; heating, ventilation, and air conditioning (HVAC); domestic hot water (DHW); and envelope measures.

[3] While two other commercial programs, Energy Opportunities and Small Business Energy Advantage (SBEA), can serve multifamily common areas, this study found that those savings are tracked through the HES and HES-IE databases.

[4] Since onsite data collection was not possible in many cases due to COVID-19, the research team used a combination of approaches to data collection, including facility manager photos, facility manager interviews, file reviews, and on-site data collection where possible.

- Coincidence factor issue: For demand savings, HES had a much higher realization rate for summer demand (summer kW), while HES-IE had a much higher realization rate for winter demand (winter kW). The study found the HES-IE program had more savings from common area and exterior lighting compared to HES. The research team decreased summer demand and increased winter demand savings to correct the fact that the *ex ante* claims had used incorrect coincidence factors for the measure.
- Gas Saving vs. kW savings issue: Eversource had a moderately lower realization rate for winter kW and had a much higher realization rate for annual CCF. Eversource had a lower winter demand savings realization rate because there were 27 projects in which Eversource claimed winter demand but realized demand savings were zero (0), in part because Eversource had misapplied peak *natural gas* savings to peak *demand (kW)* savings in several cases. UI had a lower annual gas (CCF) savings realization rate because UI awarded gas savings to one lighting project and claimed two gas savings measures that could not be documented as installed.

Table 1. Program level realization rates

	By Program	Mean Realization Rate (90% Confidence Interval)
Annual kWh	HES-IE	87%* (81 - 94%)
	HES	84%* (79-89%)
Lifetime kWh	HES-IE	82% (72-92%)
	HES	86%* (80-92%)
Summer kW	HES-IE	56% (39-73%)
	HES	75% (68-81%)
Winter kW	HES-IE	89%* (81-97%)
	HES	61% (47-76%)
Annual CCF[5]	HES-IE	93% (79-108%)
	HES	91% (71-111%)

[5] The research team did not calculate Lifetime CCF, because UI does not track it (and the team calculated savings across programs at both utilities) and because the team's understanding was that annual savings and demand savings are more critical than lifetime savings. The research team suggests it be incorporated into a future project if the EEB believes lifetime gas savings are valuable to calculate.

Table 2. Program level realization rates by utility

Program level realization rate by Utility		Mean Realization Rate (90% Confidence Interval)
Annual kWh	UI	85% (75-95%)
	Eversource	86%* (81-90%)
Lifetime kWh	UI	83% (70-96%)
	Eversource	86%* (81-91%)
Summer kW	UI	58% (40-77%)
	Eversource	58% (49-66%)
Winter kW	UI	87% (77-97%)
	Eversource	75% (64-86%)
Annual CCF	UI	80% (61-100%)
	Eversource	102% (89-116%)

Measure-level ex post realization rates: The research team developed measure-level ex post RRs for Eversource only because UI does not currently collect savings data at the measure level. Results are showing in Table 3. Realization rates for the top savings measures are summarized here:

- Common area and exterior lighting: The research team found a high realization rate for annual electricity savings (97%) and winter demand (118%), and a low realization rate for summer demand (47%).
- Dwelling unit lighting: This measure showed a moderately high rate for annual electricity (67%) and demand savings (70% summer, 81% winter).
- Air sealing: Air sealing shows a very high realization rate for annual kWh (98%), annual CCF (172%), and summer demand (100%); the realization rate was lower but still high for winter demand (86%).
- Refrigerators: This measure had a moderately high realization rate (80% for annual electricity, summer, and winter demand).
- Other measures: The insulation measure also had a high realization rate for annual electricity (100%), gas savings (100%), and demand (100%). Other measures, like ECM pumps, showed a low realization rate for annual electricity savings (59%) and winter demand (68%).

The study found more diversity of gas saving by measure type than for electricity. Specifically, the combination of common area/ exterior and dwelling unit lighting comprises 80% of the program's ex ante electricity savings. The PSD review phase of this project found that realization rates and attributable savings (relative to baselines) for lighting are declining significantly, and savings opportunities will sunset because the market is naturally adopting LEDs. This threatens the future viability of the program at its current electricity and demand savings levels, since continued reliance on

lighting will lead to lower savings if the market baseline is accounted for in the PSD. However, the Conservation and Load Management (C&LM) Plan does assume lower savings from this program after 2018, so this decline is anticipated[6].

Table 3. Measure Level Ex Post Savings Results (Eversource only)

Measure	Annual kWh	Annual CCF	Lifecycle kWh	Summer Demand	Winter Demand
Common Area and Exterior Lighting	97%*	-	96%	47%	118%*
Dwelling Unit Lighting	67%	-	45%	70%	81%
Refrigerators	80%	-	67%	80%	81%
Air Sealing	98%	172%	104%	100%	86%
ECM Pumps	59%	-	67%	-	68%
Windows	83%	-	83%	-	79%
HVAC Heat Pumps	100%	-	100%	100%	60%[7]
Boilers	-	80%	-	-	-
Insulation	100%	100%	80%	-	100%
Low Flow Fixtures	88%	107%	130%	-	14%

The research team developed recommendations to improve realization rates in the future and for additional savings opportunities. The recommendations are described in detail in the report.

Recommendations for Eversource:

- Develop a final review process for each project to verify the following:
  - All measure installations are documented,
  - The number of measure installations align with the correct PSD calculations,
  - The correct heating fuel is identified,
  - Winter demand is claimed only for electric measures, and

[6] 2021 Plan Update to the 2019-2021 Conservation & Load Management Plan. D2 – Eversource CT Electric Historical and Projected Annual kWh (000s) (2012-2021)

[7] As described in section 6.7, winter demand savings were removed for one project that was a common area heat pump, since the PSD does not award winter demand savings for common area heat pumps. In addition, the adjustments to the annual savings affected the winter demand savings for three other projects. Two other heat pump projects correctly did not claim winter demand savings. So only one of the five projects that claimed winter demand savings was verified to have winter demand savings.

  - All measure installations are documented,
  - The number of measure installations align with the correct PSD calculations,
  - The correct heating fuel is identified,
  - Winter demand is claimed only for electric measures, and
  - The presence of air conditioning is captured correctly.
- Correct measure-level program calculators as noted in Section 6, including:
  - Correct coincidence factors for demand calculations
  - Ensure that ECM Pump projects follow calculation for that measure
  - Update the low-flow fixture calculation to align with the 2021 PSD.
- Consider "rolling up" the savings for measures listed twice for the same site. Several projects had the same measure listed twice in the databased, and the second entry often had a zero or low realization rate.

Recommendations for UI:

- Track savings at the measure level in the database.
- Add a comparison of measure-level roll-up savings to the project-level claimed savings for each project.
- Update the data management system to include the service address in all tracking records.
- Develop a process so the tracking systems maintain a consistent link between electric and gas work on the same projects.
- Provide some sort of clarification in files to distinguish outdated files from files with updated (correct) information, such as archiving old files, adding dates to file names, or adding "final" to file name of final documentation.
- Similar to the first recommendation for Eversource, develop a final review process for each project to verify the accuracy of information compared to the final documented information.

Recommendations for Both Utilities:

- Phase out savings from lighting. Consider removing the dwelling unit lighting incentive immediately, since LEDs are standard practice and incumbent technologies (incandescent) have short measure lives. Consider phasing out common area and exterior lighting in the next few years; these incumbent technologies (fluorescent and high intensity discharge fixtures) have longer measure lives, so are likely still serving as installed fixtures. However, these should also be sunset in a few years, given the market's natural adoption of LEDs.
- Continue to offer the comprehensive bonus and potentially increase it, or provide an additional kicker for non-lighting measures, like HVAC or domestic hot water (DHW) replacements, duct insulation, or for ≥ 15% savings. In addition, the utilities could consider that a maximum portion of a project's savings (e.g., < 50% savings max) come from lighting.
- Highlight case studies of HVAC or DHW measures at annual meeting and/ or provide annual awards for projects with diverse scopes of work or that installed a less commonly installed measure.
- Investigate measures with future savings opportunities. This should include an investigation of electrification measures (e.g., estimates of energy and carbon impacts from moving from fossil-fueled based HVAC and DHW measures to electric sources such as heat pumps) to inform policy discussions that could consider allowing fuel switching in the program.

2 Executive Summary

The **Multifamily Impact Evaluation (X1941)** includes an impact evaluation of Eversource and United Illuminating's (UI) Multifamily Initiative for program years 2017-2019. The Multifamily Initiative is a portfolio of energy efficiency retrofit programs that support multifamily buildings or complexes with five or more units. The Initiative aims to treat multifamily buildings holistically, providing incentives for in-unit and common area measures through a combination of residential and commercial efficiency programs. This impact evaluation focused on projects tracked through the Home Energy Solutions (HES) and HES-Income Eligible (HES-IE) programs, which provide incentives for energy efficiency measures for existing multifamily projects using a deemed savings approach[8]. The HES-IE program serves customers who meet income-eligibility requirements and the HES program serves other customers, including market-rate buildings[9]. Multifamily customers can enroll in these programs, which provide tiered incentives for a variety of lighting; heating, ventilation, and air conditioning (HVAC); domestic hot water (DHW); and envelope measures. Connecticut Green Bank also provides financing solutions for the development and implementation of energy upgrades for multifamily housing, including loans and power purchase agreements.

In addition to the impact evaluation that is the focus of this report, project x1941 also included a review of the Program Savings Document (PSD) for multifamily applications, to recommend changes to the PSD to make it more accurate for the multifamily sector. While the **PSD review** is not the focus of this report, this document summarizes that process, and the analysis in this impact evaluation leveraged the PSD review recommendations in two instances where the research team believed that the previous PSD was technically incorrect: for the low-flow fixture savings calculation, and for the dwelling unit lighting baseline.

A primary **impetus for the study** was that an impact evaluation of multifamily retrofit programs had not been conducted for Eversource and UI for at least ten years. The HES and HES-IE Impact Evaluation of 2015-2016 program years included only single-family projects[10]. This was in part because that study relied on billing analysis, and multifamily dwelling units could not reliably be identified in the billing data for enough projects[11]. Other recent studies that have included the Multifamily Initiative have either

[8] According to utility staff interviews and the research team's review of a sample of projects, multifamily projects that enroll through commercial programs such as Energy Opportunities (EO) or Small Business Energy Advantage (SBEA) are tracked through the HES and HES-IE databases were not included in this evaluation. There were a few EO and SBEA projects flagged as multifamily in the databases provided to the research team, but they were assisted living facilities or other types of commercial facilities.

[9] The HES-IE program serves multifamily buildings where 75% of residents meet income qualifications.

[10] West Hill Energy and Computing. CT Home Energy Solutions Impact Evaluation Program Years 2015-2016, Final Report R1603, May 22, 2019.

[11] Ibid.

been process evaluations[12] or have only studied net-to-gross assumptions[13], so did not estimate gross energy savings from multifamily retrofit projects.

The **main objectives** of this study were to:

- Calculate program-level realization rates,
- Calculate measure level realization rates where possible, and
- Identify opportunities to improve realization rates in the future, and for additional savings opportunities.

Additionally, the research team conducted a "deep dive" investigation of the **air sealing measure**, a commonly installed in-unit measure within the HES and HES-IE programs, to gain a better understanding of this measure. The research team developed recommendations to improve the robustness of savings claims from air sealing, as well as the persistence of savings from this measure.

Methods Used

To verify savings and calculate realization rates for HES and HES-IE, the research team recruited facility managers to **collect data** for the measures installed at a sample of 80 project sites out of 993 project sites in the tracking system for years 2017-19, verified the savings at the site level, and extrapolated site-level savings to program-level results. Since onsite data collection was not possible in many cases due to COVID-19, the research team used a combination of approaches to data collection, including facility manager photos, facility manager interviews, file reviews, and on-site data collection where possible.

The research team submitted data requests to both utilities for the **program databases** covering all multifamily projects and all measures for HES and HES-IE for program years 2017-2019. Both utilities track savings for each site (i.e., multifamily site) in their program databases. There is no overarching Multifamily Initiative database: the utilities track each program (e.g., HES, HES-IE) separately. The research team combined databases across the Multifamily Initiative programs for this analysis. Within each database, Eversource provides savings by measure, while UI does not organize savings by measure. UI instead reports savings at either the site level (for some projects) or dwelling unit level (for other projects). For analysis, the research team aggregated to the site level for sampling and reporting for each utility. Where sufficient confidence and precision allowed, the research team reported savings at the measure-level for Eversource.

This study calculated both prospective (based on the 2020 PSD) and retrospective (based on the PSD for each program year that the measures were installed: 2017 through 2019 PSD) realization rates at the measure level. However, since this is a forward-looking evaluation and prospective realization rates were more important, and because retrospective realization rates were the same or similar to prospective realization rates for almost all measures, only prospective realization rates are reported here. The prospective and retrospective are provided in the project-level findings linked in the Appendix B. Adjustments to Projects. All realization rates provided in the body of the report are prospective.

To validate savings for all sampled projects, the research team confirmed the count of measures installed, reviewed all savings computations against the PSD calculation, checked all input values in the

[12] NMR Group, Inc. Multifamily Initiative Process Evaluation Program Years 2013-2015, Final Report R157, March 8, 2016

[13] NMR Group, Inc. HES/HES-IE Process Evaluation and [R31] Real-Time Research Program Year 2015, Final Report R4, April 13, 2016

formulae, and adjusted savings where appropriate. The research team then compared claimed (ex ante) savings to the savings calculated by this study (ex post) to calculation realization rates at the measure level (for Eversource, which reports savings at the measure level) and at the program level for both utilities. The research team then applied sampling weights to extrapolate from the site-level and (for Eversource only) measure-level to the program level.

Results

Overall, the program-wide **realization rates** were moderately high for most metrics for both utilities, except for summer kW for both utilities and annual CCF for UI, as shown in Table 4. The realization rates were very similar between HES and HES-IE for annual kWh, lifetime kWh, and annual CCF. For demand savings, HES had a higher realization rate for summer demand (summer kW), while HES-IE had a higher realization rate for winter demand (winter kW). This is because the HES-IE program had more savings from common area and exterior lighting compared to HES; for the common area and exterior lighting measure, the research team decreased summer demand and increased winter demand savings because the ex ante claims had used incorrect coincidence factors for that measure. Most of the **adjustments made to the realization rates** were either a misapplication of the correct values in the ex ante calculations, or adjustments made to the installation counts. This latter problem occurs often with instances of double-counting misspecification, or omission of measures in the records.

Table 4. Program-level realization rates

	By Program	Mean Realization Rate (90% Confidence Interval)
Annual kWh	HES-IE	87%* (81 - 94%)
	HES	84%* (79-89%)
Lifecycle kWh	HES-IE	82% (72-92%)
	HES	86%* (80-92%)
Summer kW	HES-IE	56% (39-73%)
	HES	75% (68-81%)
Winter kW	HES-IE	89%* (81-97%)
	HES	61% (47-76%)
Annual CCF[14]	HES-IE	93% (79-108%)
	HES	91% (71-111%)

[14] The research team did not calculate Lifetime CCF, because UI does not track it (and the team calculated savings across programs at both utilities) and because the team's understanding was that annual savings and demand savings are more critical than lifetime savings. The research team suggests it be incorporated into a future project if the EEB believes lifetime gas savings are valuable to calculate.

*Realization rate met or exceeded 90/10 confidence/precision

Comparison of the **utility-specific realization rates** showed they were similar across the utilities for annual kWh, lifetime kWh, summer kW, as shown in Table 5. Eversource had a moderately lower realization rate for winter kW because there were 27 projects in which Eversource claimed winter demand but realized demand savings were zero (0). Eversource had a higher realization rate than UI for annual CCF, in part because UI awarded gas savings to one lighting project and claimed two gas savings measures that could not be documented as installed.

Table 5. Program level realization rates by utility

Program level realization rate by Utility		Mean Realization Rate (90% Confidence Interval)
Annual kWh	UI	85% (75-95%)
	Eversource	86%* (81-90%)
Lifecycle kWh	UI	83% (70-96%)
	Eversource	86%* (81-91%)
Summer kW	UI	58% (40-77%)
	Eversource	58% (49-66%)
Winter kW	UI	87% (77-97%)
	Eversource	75% (64-86%)
Annual CCF	UI	80% (61-100%)
	Eversource	102% (89-116%)

The research team calculated the **measure level ex post realization rates** for Eversource only, as shown in Table 6. For common area and exterior lighting, the research team found a high realization rate for annual electricity savings and winter demand, and a low realization rate for summer demand due to a correction to the coincidence factors. For dwelling unit lighting, the research team found a moderately high rate for annual electricity and demand savings; the research team's main adjustment was reducing savings to account for a baseline that met federal regulations (Energy Savings and Independence Act – EISA), since all replaced bulbs should have been EISA-compliant[15] and since a Connecticut study found that over half of bulbs available for sale from 2017 to 2019 were LEDs. For air sealing, we found a very high realization rate for annual kWh, annual CCF, lifetime kWh, and summer demand (kW); the realization rate was lower but still high for winter demand (kW). The insulation measure also had a high

[15] As described in the timeline in Section 6.2, EISA phased out manufacturing of traditional incandescent light bulbs in 2014, and bulb availability data shows they were no longer shipped by 2015. The last incandescent light bulbs installed in 2015 would have burned out by 2016 given the hours of use (HOU = 2.5) assumed in the PSD, or would have been installed in areas with very low HOU so should not be credited with the PSD savings. This evaluation covered program years 2017-2019, so all removed bulbs should have been EISA compliant.

realization rate for annual electricity and gas savings and demand. For other measures, like ECM pumps, we found a low realization rate for annual electricity savings and winter demand, due in part to calculation errors.

Table 6. Measure Level Ex Post Savings Results (Eversource only)

Measure	Annual kWh	Annual CCF	Lifetime kWh	Summer Demand	Winter Demand
Common Area and Exterior Lighting	97%*	-	96%	47%	118%*
Dwelling Unit Lighting	67%	-	45%	70%	81%
Refrigerators	80%	-	67%	80%	81%
Air Sealing	98%	172%	104%	100%	86%
ECM Pumps	59%	-	67%	-	68%
Windows	83%	-	83%	-	79%
HVAC Heat Pumps	100%	-	100%	100%	60%[16]
Boilers	-	80%	-	-	-
Insulation	100%	100%	80%	-	100%
Low Flow Fixtures	88%	107%	130%	-	14%

Table 7 and Table 8 show annual electricity and natural gas savings from the HES and HES-IE programs for multifamily projects only. Neither utility maintains a database specific to the Multifamily Initiative. The research team developed the ex ante savings shown in the tables by aggregating savings in the databases provided by the utilities that were identified as multifamily projects, and after removing several projects that the research team identified as not multifamily. For example, the research team removed "projects" that were savings from the upstream lighting (which were flagged because the address was the utility's address), and projects that were nursing homes (which the research team identified as such from web searches and the utilities confirmed). The research team investigated these projects (that were ultimately determined to be out of scope and removed) because they had high savings, or because they listed the utility's address as the project address. There are almost one

[16] As described in section 6.7, winter demand savings were removed for one project that was a common area heat pump, since the PSD does not award winter demand savings for common area heat pumps. In addition, the adjustments to the annual savings affected the winter demand savings for three other projects. Two other heat pump projects correctly did not claim winter demand savings. So only one of the five projects that claimed winter demand savings was verified to have winter demand savings.

thousand projects that were identified as multifamily in the databases that the utilities provided. It was beyond the scope to check that all projects met the definition of multifamily, so there may be other projects included in these savings totals that are not multifamily.

These tables show annual electricity and natural gas savings and combined MMBtu savings, which the research team used to develop a sample. The research team did not aggregate lifetime or demand savings since these were not used for sampling, and additional data cleaning would be necessary to determine these. Note that because these savings are from multifamily projects only, the savings represent a portion of projects across the HES and HES-IE programs, which serve single family as well as multifamily. It was outside the scope of this project to estimate percent of use that these savings represent, since that was not included in the project application and the research team did not do billing analysis.

Table 7. Ex ante and ex post savings by utility

Utility	Annual kWh			Annual CCF			Annual MMBtu		
	Ex Ante	RR	Ex Post	Ex Ante	RR	Ex Post	Ex Ante	RR	Ex Post
UI	4,982,282	85%	4,251,902	1,208,345	80%	970,361	18,253	85%	15,514
Eversource	32,398,486	86%	27,702,566	873,131	102%	894,593	111,449	86%	95,449

Table 8. Ex ante and ex post savings by program

Program	Annual kWh			Annual CCF			Annual MMBtu		
	Ex Ante	RR	Ex Post	Ex Ante	RR	Ex Post	Ex Ante	RR	Ex Post
HES	13,269,965	84%	11,146,298	250,725	91%	228,905	45,537	84%	38,269
HES-IE*	23,770,117	87%	20,770,952	1,612,574	93%	1,505,494	82,776	88%	72,432

*The UI database refers to this as LIN for low income, we changed to be consistent with Eversource nomenclature

Lighting (both common area/exterior and dwelling unit) comprises 80% of ex ante annual electricity savings[17]. The PSD review phase of this project found that realization rates and attributable savings (relative to baselines) for lighting are declining significantly, and savings opportunities will sunset because the market is naturally adopting LEDs. This threatens the future viability of the program at its current electricity and demand savings levels, since continued reliance on lighting will lead to lower

[17] While the research team did not calculate the *weighted* contribution of lighting to lifetime savings or to total fuel savings, the *unweighted* results showed that lighting contributed 64% of lifetime kWh savings and 51% of the *unweighted* annual savings converting all fuels to BTU.

savings if the market baseline is accounted for in the PSD and the programs phase out lighting offerings over time. The Conservation and Load Management (C&LM) Plan does assume reduced savings from the core measures – which includes lighting – for 2019 and beyond.[18] There is more diversity of gas savings by measure type than for electricity.

The research team developed recommendations to improve realization rates in the future and for additional savings opportunities. Based on results, the research team provided separate recommendations for data improvement for each utility.

Recommendations for Eversource: The research team adjusted the savings for approximately one-fifth of the Eversource projects in the sample, as well as all dwelling-unit lighting and low-flow fixture measures. Some projects had no documentation in the file. Others had multiple entries in the database for the same measure – in these cases, the second entry often had zero or low realization rate. To reduce or eliminate these issues, the research team recommends that the Eversource program staff make the following process changes:

- Develop a final review process for each project to verify the following:
  - All measure installations are documented,
  - The number of measure installations align with the correct PSD calculations,
  - The correct heating fuel is identified,
  - Winter demand is claimed only for electric measures, and
  - The presence of air conditioning is captured correctly.
- Correct measure-level program calculators as noted in Section 6, including:
  - Correct coincidence factors for demand calculations
  - Ensure that ECM Pump projects follow calculation for that measure
  - Update the low-flow fixture calculation to align with the 2021 PSD.
- Consider "rolling up" the savings for measures listed twice for the same site. As noted above, several projects had the same measure listed twice in the databased, and the second entry often had a zero or low realization rate.

Recommendations for UI: The research team adjusted approximately one-third of UI project savings, as well as all dwelling-unit lighting and low-flow fixture measures. For most UI projects in the sample, the "bottoms up" savings in the measure calculators did not sum to the project savings in the database. This made it very difficult for the research team to identify the source of the discrepancies between the ex post and ex ante project-level savings. In addition, many projects also had numerous files with conflicting information, including different values for the same installed measures. On a positive note, UI's calculators typically followed the PSD. To reduce these issues, the research team recommends that the UI program staff make the following process changes:

- Track savings at the measure level in the database.
- Add a comparison of measure-level roll-up savings to the project-level claimed savings for each project.
- Update the data management system to include the service address in all tracking records.
- Develop a process so the tracking systems maintain a consistent link between electric and gas work on the same projects.

[18] 2021 Plan Update to the 2019-2021 Conservation & Load Management Plan. D2 – Eversource CT Electric Historical and Projected Annual kWh (000s) (2012-2021)

- Provide some sort of clarification in files to distinguish outdated files from files with updated (correct) information, such as archiving old files, adding dates to file names, or adding "final" to file name of final documentation
- Develop a final review process for each project to verify the accuracy of information compared to the final documented information (as shown in invoices and post-inspection reports).

The research team provides the following **recommendations for both utilities**. These recommendations are aimed at reducing the reliance of program savings on lighting, for which opportunities are dwindling as the market naturally adopts LEDs. Note that the research team found that – for both UI and Eversource – most sites had several measures installed. However, lighting was typically the primary driver of savings. Other measures were frequently installed, such as air sealing and/or low-flow fixtures, but these were lower savings measures and so contributed less savings.

With almost one thousand sites enrolled across the two utilities for program years 2016-2019 (872 from Eversource and 121 from UI[19]), **the Multifamily Initiative appears to be successful in reaching many multifamily projects,** which is a sector that typically requires proactive outreach. In addition, approximately two-thirds of participating sites participated in the HES-IE program, indicating that the Initiative is impacting many buildings with income eligible customers. However, note that the measure providing the most electricity savings is common area or exterior lighting, so residents would not enjoy energy bill reductions from this measure. Even though HES-IE is serving multifamily projects, it has a larger proportion of projects that are common area and exterior lighting compared to HES, which do not directly serve the residents.

Table 9 provides recommendations for both utilities to diversity savings across measures beyond lighting.

[19] This does not include approximately 300 projects in the UI database that showed only gas savings. With those, there are approximately 1300 total projects.

Table 9. Findings and recommendations for both utilities to diversify future savings

Finding(s)	Recommendation
Lighting contributes 80% of ex ante annual electric savings in the Eversource database, but these measures are sunsetting as most customers are choosing LEDs without the program.	Sunset dwelling unit lighting measures as soon as possible, and sunset common area and exterior lighting in the next few years, although incentives could continue for controls and networked lighting. • Continue to incentivize common area and exterior lighting short term, since this serves retrofits and incumbent technologies (fluorescent indoors, and HID outdoors) which have long measure lives. But as natural market adoption replaces these incumbent technologies with LEDs, phase out this measure. The utilities could continue to incentive lighting controls that exceed code requirements, particularly networked lighting controls. • Consider removing the dwelling unit lighting incentive, since LEDs are standard practice and incumbent technologies (incandescent) have short measure lives. If the utilities continue to subsidize these measures, change the baseline wattage to an EISA-compliant lamp[20], and require photo documentation for a sample (10%) of removed lamps to show they are incandescent/halogen.

[20] For the current programs, the baseline should reflect a baseline compliant with the EISA regulations currently in effect, or a market baseline – whichever is more stringent. If future programs continue to incentivize residential lighting measures, they should use new code requirements, including any updates to EISA requirements.

Finding(s)	Recommendation
Contractors reported the comprehensive bonus allows them to install deeper savings measures, such as boilers and extensive lighting. Other MF programs outside of Connecticut are struggling to move away from lighting. One requires ≤ 50% savings from lighting, one provides kicker for heat pumps, and two require ≥ 15% whole building savings from electric, natural gas and other fuels on a BTU-basis which necessitates other end uses. Other frequently installed measures in these programs include some that are installed often in the Multifamily Initiative (HVAC and attic insulation) and others that are rarely installed in the Multifamily Initiative (DHW replacement, duct insulation).	Encourage installation of non-lighting measures and discourage reliance on lighting. • Continue to offer the comprehensive bonus and potentially increase it, or provide an additional kicker for non-lighting measures, like HVAC or DHW replacements, duct insulation, or for ≥ 15% whole building savings on a BTU-basis. • Consider requiring < 50% annual savings max from lighting. • Highlight case studies of HVAC or DHW measures at annual meeting and/ or provide annual awards for projects with diverse scopes of work or that installed a less commonly installed measure. • Investigate measures with future savings opportunities. This should include an investigation of electrification measures (e.g., estimates of energy and carbon impacts from moving from fossil-fueled based HVAC and DHW measures to electric sources such as heat pumps) to inform policy discussions that could consider allowing fuel switching in the program. • Ensure that a diversity of in-unit measures are provided for HES-IE participants[21], particularly HVAC and envelope measures which can reduce energy bills and provide better comfort, to improve equity and inclusion.

[21] It was beyond the scope of this project to determine why a more diverse measure mix is not provided to more projects in the HES-IE program. A process evaluation could potentially explore issues such as how often contractors recommend multiple in-unit measure types to HES-IE projects, conversion rates of HES-IE multifamily participants moving forward with these recommendations, and other potential obstacles.

3 PSD Update: Multifamily-specific values

In addition to the Multifamily Impact Evaluation, the research team proposed updates to the 2020 Connecticut Program Savings Document (PSD) focused on providing multifamily-specific values for measure-level savings. Until now, many of the CT PSD assumptions for multifamily buildings had been based on single-family residential and commercial building studies.

The research team conducted a data-driven engineering review of the PSD to validate algorithms for multifamily measures. Through this review, we examined the basis of the PSD's engineering assumptions and the applicability of the source documents, as well as the savings methodologies, inputs, values, references, and savings calculations for each fuel type, as appropriate. We compared the data sources and calculation methods with approaches employed in Technical Resource Manuals (TRMs) from other regions and states, including New York, Massachusetts, Rhode Island, MidAtlantic, and Wisconsin.

Based on the findings from the engineering review, the research team proposed revisions to the 2020 PSD to reflect the accepted engineering assumptions for multifamily building characteristics and operations. While the primary deliverable for the PSD update was a suggested list of redlines to the PSD (provided separate from this report), the research team provides the following overview of recommendations:

- Updates to hours of use specific to multifamily buildings.
- Clarifications for how certain measures should be applied in multifamily projects.
- Update to coincidence factors for some measures so they are specific to multifamily common areas.
- Different assumptions for multifamily buildings for some measures, such as base case gas usage for heating savings and heating and cooling capacity assumptions for Wi-Fi thermostats due to the smaller size of multifamily dwelling units (compared with single-family), and default efficiency values for multifamily equipment,
- Multifamily-specific equations for a few measures, including for central furnaces and air conditioners (due to different usage patterns compared to commercial buildings) and low-flow fixtures (due to typically lower numbers of bathrooms per unit than in single-family homes)

Note that almost none of these recommendations are incorporated into this impact evaluation, because these recommendations would be incorporated into future versions of the PSD. The one exception was the recommendation to adjusting the low-flow fixture equation, because the research team believed the equation in the 2020 PSD was not mathematically correct. In addition, the research team used an EISA-compliant baseline for residential lighting to ensure results were rigorous and technical defensible.

Updated PSD Recommendations: The earlier (secondary data) work conducted for this project recommended several changes to the 2020 PSD for multifamily projects. Based on the results of CT-specific multifamily data of this impact evaluation, the research team proposes a few revisions to those recommendations. Those revised recommendations are listed here, and the research team provides them to the utilities in a separate excel workbook.

Dwelling unit lighting: As described in Section 6.2 on dwelling unit lighting, the research team found that projects were claiming a baseline light bulb that does not comply with the Energy Savings and Independence Act (EISA). In addition, a Connecticut study found that over half of screw-in bulbs

available for sale from 2017 to 2019 were LEDs (NMR 2019, R1963A). As illustrated in Section 6.2, the research team does not believe that a non-EISA compliant baseline is accurate so adjusted the residential baselines to be EISA-compliant in our ex post calculations. The 2020 PSD directs users to use a baseline of the reported value where known, and for unknown direct install, to assume 24 W for light bulbs and 26.3 W for luminaires. The finding of this impact evaluation is that some participants are claiming a non-EISA compliant baseline as their "known" value, which does not seem reasonable given the timeline of EISA implementation shown in Figure 5 in Section 6.2. The research team recommends that the 2021 PSD specify a "backstop" for the baseline that is EISA-compliant. This backstop should apply even for "known" values of the replaced bulbs, given the difficulty discerning a halogen vs. incandescent bulb in the field, and since a bulb that is truly incandescent would have been installed more than five years ago, so would most likely have a much lower HOU than the PSD assumes.

In addition, the 2020 PSD currently shows the heating interactive effects calculation for dwelling unit light bulbs under a Non-Energy Benefits section of this measure. Based on the results of this impact evaluation, no projects applied heating interactive effects. The research team recommends that the 2021 PSD move the heating interactive effect calculation out of the Non-Energy Benefits section and into the main body of the measure calculation description, to clarify that heating interactive effects should be applied to all projects using fossil fuel heating.

ECM Pumps: The 2020 PSD does not have a central ECM pump measure for an ECM pump serving multiple dwelling units. Projects should follow the VFD calculation, since a VFD also modulates the speed of a motor, and the VFD calculation includes custom inputs (such as motor horsepower) for an accurate calculation.

Reduced Infiltration (Blower Door): To account for leakage from conditioned spaces, instead of using the building factor (BF) in the PSD, all multifamily projects should use the Steven Winter and Associates (SWA) excel-based calculator in the Eversource 2020 Multifamily Fill-out Form workbook. The SWA calculator determines the allowable cfm reduction that can be claimed based on a calculator that was calibrated based on guarded blower door test values[22]. The research team views the SWA calculation method based on the SWA prescriptive calculator (used by Eversource 2019 through March 2020) as preferred because it is based guarded blower door data, and it requires inputs that are easier to determine (e.g., ceiling height, square footage, number of stories) than the 2020 PSD BF calculation inputs (shared surface area and envelope perimeter).

The PSD Multifamily Measure Review and Recommendations workbook is in Appendix A.

[22] A guarded blower door test neutralizes the pressure with adjacent spaces to measure only the leakage from the exterior.

4 Methodology

4.1 Overall Approach

The **Multifamily Impact Evaluation (X1941)** includes an impact evaluation of Eversource and United Illuminating's (UI) Multifamily Initiative for program years 2017-2019. The Multifamily Initiative is a portfolio of energy efficiency retrofit programs that support multifamily buildings or complexes with five or more units. The Initiative aims to treat multifamily buildings holistically, providing incentives for in-unit and common area measures through a combination of residential and commercial efficiency programs. This impact evaluation focused on projects tracked through the Home Energy Solutions (HES) and HES-Income Eligible (HES-IE) programs, which provide incentives for energy efficiency measures for existing multifamily projects using a deemed savings approach[23]. The HES-IE program serves customers who meet income-eligibility requirements and the HES program serves other customers, including market-rate buildings[24]. Multifamily customers can enroll in these programs, which provide tiered incentives for a variety of lighting; heating, ventilation, and air conditioning (HVAC); domestic hot water (DHW); and envelope measures. Connecticut Green Bank also provides financing solutions for the development and implementation of energy upgrades for multifamily housing, including loans and power purchase agreements.

The research team took the following approach to verify savings and calculate realization rates:

1. Requested program databases from utilities
2. Identified a representative sample of sites
3. Recruited sites for data collection
4. Collected data for the sampled measures installed at each site and determined realized savings using a combination of facility manager photos, facility manager interviews, file reviews, and on-sites
5. Analyzed data to verify savings at the site level
6. Applied sampling weights to extrapolate site-level results to program-level results

Additionally, the research team conducted a "deep dive" review of the air sealing measure to gain a better understanding of how it is currently implemented, to inform recommendations to improve robustness of savings. This involved interviewing the representatives from the utilities and air sealing contractors, as well as reviewing the utilities' calculators.

It was not possible for the research team to conduct a billing analysis. Based on discussions with the authors of the HES and HES-IE single family impact evaluation of 2015-2016 program years, there is no

[23] According to utility staff interviews and the research team's review of a sample of projects, multifamily projects that enroll through commercial programs such as Energy Opportunities (EO) or Small Business Energy Advantage (SBEA) are tracked through the HES and HES-IE databases were not included in this evaluation. There were a few EO and SBEA projects flagged as multifamily in the databases provided to the research team, but they were assisted living facilities or other types of commercial facilities.

[24] The HES-IE program serves multifamily buildings where 75% of residents meet income qualifications.

way to disaggregate between in unit and common area billing data.[25] In addition, there would have been too small of a signal to reliably detect for most projects, since lighting was the primary source of savings.

As described, the research team experimented with different approaches since onsite data collection was not possible in many cases due to COVID-19. This report describes both the successful and unsuccessful approaches, to inform future data collection activities that the CT utilities may undertake under other unusual circumstances.

4.2 Program Database Request

To inform the database request, including identifying the primary programs in the Multifamily Initiative, the research team reviewed HES and HES-IE program materials and interviewed the program managers at Eversource and UI. Then, the research team submitted data requests to both utilities for the program databases covering all multifamily projects and all measures for HES and HES-IE for program years 2017-2019.

4.3 Sampling

Once the program databases were obtained, the research team developed a representative sample of projects for verification. The team identified a total of 872 Eversource sites and 121 UI sites[26] in these three program years. The team sampled at the site level rather than measure level because – while the Eversource database tracks savings at the measure-level, the UI database tracks savings only at the site level. In addition, the main challenge for verification is connecting with the facility manager to allow for verification (either virtually or on-site), so sampling at the site level reduces the number of facility managers that must be recruited. However, as described in step 5, the team checked that the sample would include a mix of measure types.

The team used the following steps to develop a representative sample:

1. Stratified the sites into three (3) strata of roughly equal electricity savings for each utility.
2. Additionally, stratified by “lighting-only” (defined as sites with at least 90% of annual electricity savings from lighting) vs. sites with multiple measures for Eversource. This enabled us to focus on sites with high savings from non-lighting measures but include enough lighting-only sites to meet the targeted confidence (90%) and precision level (10%).
3. Additionally, stratified projects from UI that were “gas-savings-only” (defined as projects where the UI database only showed gas savings). The research team stratified these gas-only savings projects based on size (gas savings) and included projects from the highest savings strata in our sample. The research team did not include projects from the lower two strata of gas-only

[25] The utilities and single-family impact evaluators reported that billing data is often assigned to one unit in a building. This would have made billing analysis more challenging, since not all measures received the same measures. In addition, common area billing data and dwelling unit data were often aggregated. Many projects had the bulk of savings come from common area measures, so the inclusion of dwelling unit energy use in the billing analysis would have made it difficult to detect savings from only the common areas (low signal-to-noise ratio).

[26] Does not include the approximately 300 sites from UI that had only natural gas savings. Since UI provides electricity, the research team targeted projects with electricity savings, or with both electricity and gas savings.

savings projects in our sample[27], to focus resources on UI projects with electricity only or electricity *and* gas savings. Of the fourteen (14) UI projects that were verified, ten (10) included both electricity *and* natural gas measures, three (3) included electricity measures only, and one (1) included natural gas measures only. The research team did review a sample of the UI gas-savings-only projects to confirm they were truly gas-savings only measures, and to look for an accompanying electricity-savings project at the same site. Section 5.1.1 provides results of that review.

4. Identified projects in the initial sample.
5. Checked expected confidence and precision for UI vs. Eversource sites in the sample.
6. Used the Eversource sample to estimate electricity and gas savings by measure in the sample.
7. Identified backup sites for each sampling strata. Note that the team pulled heavily from backup sites due to non-responsiveness of facility managers due to COVID-19.

The number of sites sampled in each stratum varies, dependent on the number of sites in the stratum and the expected variation in realization rate results across sites within the stratum.

The total number of sampled sites was 80.

4.4 Recruitment

The research team recruited sites for data collection to allow for onsite or virtual verification that claimed measures were installed and remained in operation.

Due to COVID-19, the research team modified the originally proposed method of on-site data collection to primarily rely on remote data collection. Our approach was as follows: the research team members contacted the facility managers listed in the project application using multiple methods to request photo documentation of common area and exterior measures:

1. Eversource or UI sent an advance email introducing the research team and the research study and offering the facility manager an incentive for their participation.
2. A member of the research team emailed a request for photo documentation specifically for the site, including measures installed and instructions on how to take the requested photos. The research team member also offered the facility manager the option to participate in a video conference or complete a phone interview.
3. The team member followed up with a phone call.
4. If the facility manager listed on the application was not responsive after three attempts, the research team searched for other contacts at the project (i.e., by contacting the property's leasing office or the management company's main office) and made up to three attempts before dropping the project and moving on to the backup site.

The incentives offered to facility managers varied depending on the verification method:

[27] Because of the sampling method, the realization rates and confidence intervals for UI gas savings are based on projects with savings from both electricity and gas, and for large gas-savings-only projects. The realization rates results may not reflect small gas-savings-only projects.

- Facility manager photos of common area measures: $200
- Facility manager video conference: $200
- On-site visit: $100
- Facility manager interview: $75
- Facility manager photos of dwelling units (up to 10 units): $25 per unit

The research team reached out to facility managers at a total of 178 sites (in some cases, one facility manager was responsible for multiple sites).

Despite these efforts and the incentive offered, many facility managers were not responsive to these requests. This non-responsiveness was due to COVID-19 in many cases. Some facility managers cited that their workload increased for various reasons, while others cited that they were not allowed in the buildings except for emergency maintenance during the data collection period.

The research team also collected data for exterior lighting measures without recruitment since verification of measures did not require building entry.

The research team also attempted to gather information from residents for in-unit measure installation. To gather photo documentation of in-unit measures, the research team sent postcards to residents requesting they send photos or participate in a video conference in exchange for an incentive. The research team either mailed postcards directly to the apartments listed in the project files or mailed a packet of postcards to the facility manager if they agreed to distribute them to targeted residents. The goal of having the facility manager distribute the postcards was to increase resident participation based on the trusted relationship with the facility manager. After sending 500 postcards, only three residents responded and participated. Some facility managers provided photos of in-unit installations. The low response rate may have been due to postcards being lost in the shuffle of mail, occupants not wanting to take the time, or other reasons. Due to this low response rate, the research team abandoned this method and switched to file review for in-unit data collection.

4.5 Data Collection for Sampled Sites

The purpose of data collection was to verify that measures were installed, collect applicable equipment quantities and nameplate data, gather information regarding operating hours, and assess measure functionality. For each site in the sample, the research team reviewed the project files, including the ex ante energy savings analysis. Through the file review, the research team identified key aspects of the site, including measures installed to determine the appropriate data collection approach for the site.

Depending on the mix of measures installed at a site, the research team collected data through either file review, facility manager photos or interviews, on-site visits, or a combination, as shown in Table 10.

Table 10. Data Collection Approaches

Approach	Measures Typically Verified Using This Approach
File reviews, and facility manager photos or facility manager interviews	Common area measures, including common area lighting, and central HVAC equipment
File reviews, and on-site visits	Exterior lighting, and a few central HVAC equipment where facility manager provided access
Primarily file review*	In-unit measures: dwelling unit lighting, air sealing, low flow fixtures, unitary HVAC equipment; and common area measures where facility manager could not be reached

* As noted in the Recruitment section, the research team attempted to collect photos from residents, but the response rate was very low (3 residents submitted photos out of 500 contacted through post cards). A few facility managers also provided photos of in-unit installations.

The 80 sampled sites had a total of 314 total measures. This is because most projects had multiple measures installed. Table 11 shows the number of measures verified using each approach, and the percent of savings those measures represented. While file review was the most common verification method, savings from those measures represented just over half of total savings, since most of those measures were smaller, in-unit savings projects. Note that the measures verified by facility manager photos, interviews, or on-sites also received a file review.

Table 11. Measures Verified by Primary Data Collection Approach

	File Review	Facility Manager Photos	Facility Manager Interview	Visits On-site
Number of measures verified with this approach	204	58	38	22
Percent of savings from measures verified with this approach	57%	9%	8%	25%

Facility Manager Photos and Interviews

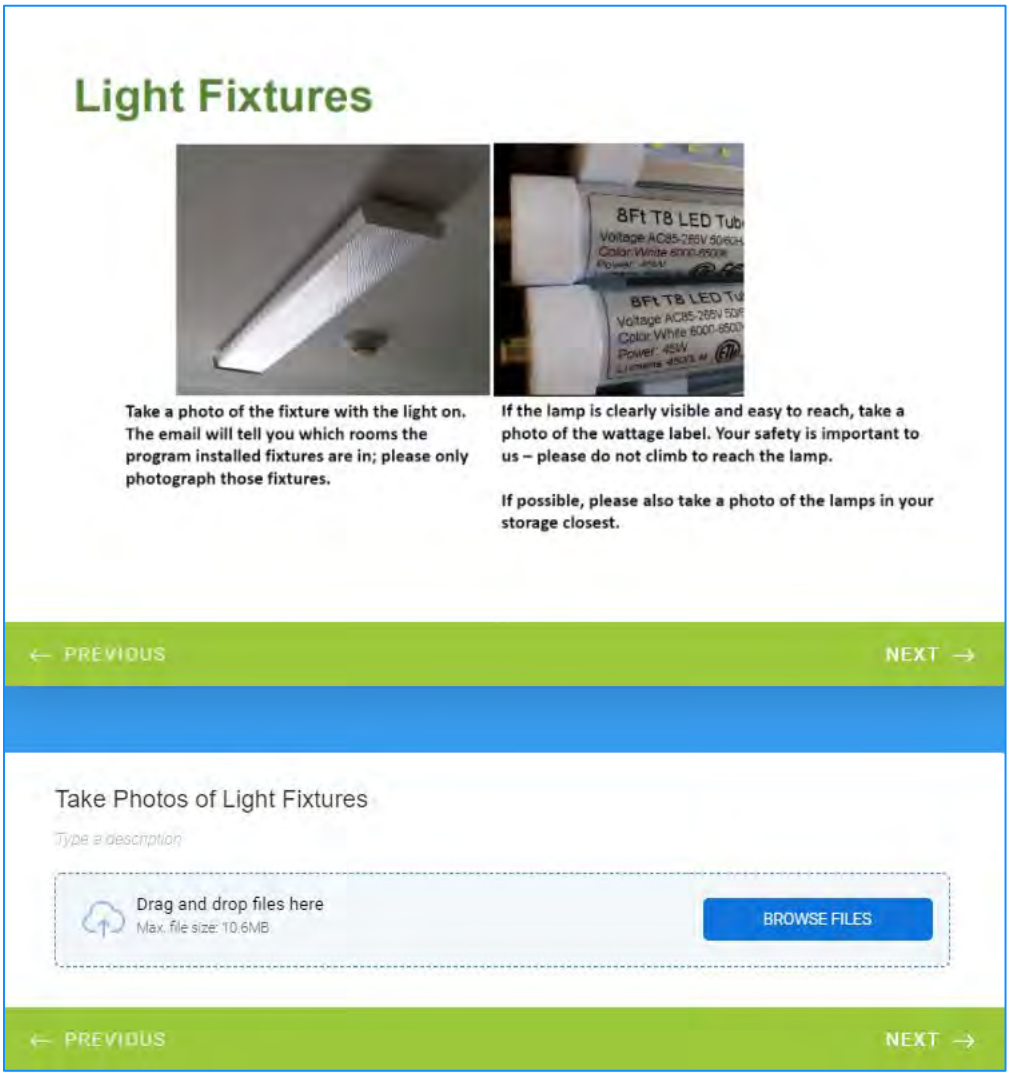
The research team administered a brief phone survey to facility managers who responded to the recruitment efforts. The survey had three sections:

- General questions to be asked of all facility managers,
- Questions for projects that received common area lighting measures, and
- Photo-documentation Instruction Guidance

The research team gave the facility managers the option to submit photographs of common area measures, participate in a video conference using Zoom or Microsoft Teams, or complete a phone interview.

To improve the quality of the photos received and ensure that the necessary information was captured, the research team provided photo instructions for facility managers in an emailed pdf or link to a fillable online form (Jot Form).

Figure 1. Example of a Jot Form



The research team members also offered guidance over the phone. In most cases, facility managers emailed photos of the installed equipment. Another purpose of using the Jot form was to reduce the burden on facility managers. While this should have been an easy application, since the facility manager could follow and link and open it in a web browser, the low use of these forms indicates they were not appealing. This may have been because facility managers wanted to use a method they were familiar with (email), some facility managers passed the instructions on to a colleague but did not forward the Jot Form (even though the research team requested that they do), or for other reasons. One chose to join a video conference, where the research team member guided the facility manager on how to focus their phone on installed equipment and took screen shots of the equipment.

If the facility manager was not willing to provide photos, the research team conducted phone interviews with him or her to confirm that measures were installed and still operating. The interview questions included:

- Do you know where the [installed measure] was installed in this property?
- Was it installed through a utility incentive program?
- Were there any issues that caused you to replace it?

This method was only used for facility mangers who chose to participate but were unable to provide photo documentation due to either technical barriers or time constraints.

Ultimately, the research team had the most success with collecting data from facility managers by asking them to email photos and collecting information verbally (through interviews).

File Reviews

For in-unit measures, the research team verified ex post savings using information from the project files through a file review. To document the baseline condition, the research team reviewed the application, Multifamily (MF) Fill Out Form, and the Letter of Agreement (LoA) Generator. The MF Fill Out Form and the LoA Generator are populated by the contractors with the existing conditions and proposed measures. To verify each measure was installed, the research team reviewed the invoices, post-inspection reports, and cutsheets, as available. While the shift to an approach that used only file reviews, instead of onsite verification reduced the robustness of the results, the files typically provided enough documentation to document the key elements of each measure, including quantity and efficiency of equipment installed. Due to the reduction in scope for in-unit measure verification, the research team added the air sealing deep dive investigation, described later in this report.

On-site visits

Where possible, the research team conducted on-site verification, see Table 12. This was primarily done for exterior lighting measures, since this did not require coordination with the facility manager (although the research team notified him/her of our upcoming visit) where customers allowed us to enter the site (which was rare), and for measures that could be verified while adhering to COVID-19 safety protocols. The site visits collected the quantity of equipment installed and (for HVAC equipment) efficiency of the installed equipment.

4.6 Analysis Processes for Savings Verification

The Multifamily Initiative uses a deemed savings approach. The research team used spreadsheet-based engineering analysis to verify savings using the following process:

- **Review ex ante calculators**: The research team looked for deviations from the 2020 PSD ("Prospective" savings) and the PSD for each program year that the measures were installed (2017 through 2019 PSD: "Retrospective" savings). Through this process, the research team investigated whether the calculators followed the PSD used at the time the savings were claimed, including baseline and installed efficiency levels, hours of use, and adjustments for system interactions (e.g., between lighting and heating, ventilation, and air conditioning equipment). Deviations from the PSD calculations are discussed in Section 6.

- **Recalculate savings**: Where sufficient data was available, the research team recreated the algorithms from the Prospective PSD to calculate the ex post savings for electricity (kWh), natural gas (CCF), summer demand (Summer kW) and winter demand (Winter kW). The research team adjusted project-specific inputs based on data collection findings to calculate ex post energy savings. This relied on complete data from the project files, including invoices documenting quantity and nameplates documenting equipment make and model. The research team also checked what the savings would have been under the Retrospective calculation. The goal of this check was to verify that the algorithms were properly documented in the utilities' forms and to quantify the impact of changes in input assumptions. For most measures, prospective and retrospective savings were the same. Adjustments to calculations are discussed in Section 6.
- **Lighting calculator reviews and reasonableness check**: The research team reviewed the lighting calculators for each year, for each utility, to investigate if they followed the PSD at the time of project implementation. The research team also did a reasonableness check of all lighting projects. If the savings value was similar to ex ante, the research team awarded ex ante. If the savings value deviated greatly from ex ante, the research team used the ex post estimate based on the quantity in the invoice, where available.
- **Calculate measure level realization rates:** Using the results from these methods, the research team found the realization rate of each measure, where possible.
- **Extrapolate findings**: The research team extrapolated the project-level findings[28] from the sample to find the realization rate for the HES and HES-IE programs, and for each utility, based on sample weighting.

Based on this analysis, the research team developed recommendations to improve realization rates in the future and for additional savings opportunities.

4.7 Air Sealing Measure Investigation

Air sealing is a commonly installed in-unit measure within the HES and HES-IE programs. However, several factors were unknown regarding this measure prior to this investigation, including:

- What building elements contractors typically seal,
- How contractors identify a sample of units to test to verify savings,
- Whether the utilities consistently follow the Program Savings Document (PSD) savings calculation,
- How the utilities adjust air leakage testing results to account for leakage from adjoining conditioned spaces, e.g., other units, hallways, etc., and

[28] The research team verified project-level savings for delivered fuels (propane and oil) but did not calculate weighted realization rates at the program or utility-level for delivered fuels, because there were too few projects that used these fuels. In general, the research team did not find systematic differences between results for delivered fuels and results for natural gas and electricity.

- Whether the calculation for the blower door factor is reasonable[29]

The research team investigated this measure to gain a better understanding of these questions and to inform recommendations to improve the robustness of savings. This was an addition to the scope, that was added when the research team shifted to a file review approach for in-unit verification.

To gather data for the air sealing investigation, the research team:

1. Conducted interviews with air sealing contractors, and staff at each utility,
2. Reviewed the air sealing calculators for each utility, and
3. Reviewed air sealing measure calculations for the sampled projects.

Of the 88 air sealing projects[30] reviewed, there were 13 separate companies, approximately half (43 projects) were done by one contractor, another 15% (13 projects) were done by another contractor, another 9% were done by a third contractor, and there were nine (9) contractors with four or fewer projects. The research team interviewed nine staff from six air sealing contractor companies. The research team interviewed all three of the contractors responsible for the largest number of projects (which represented approximately three-quarters of the sampled air sealing projects), and three of the contractors that provided four or fewer projects. Consequently, the research team estimates that the interviews represented roughly three-quarters or more of the air sealing projects. To check for consistency within each organization, the research team interviewed multiple staff at companies that implement the majority of air sealing. To encourage participation in the interviews, the research team provided a $200 gift card to the contractors for completing an interview.

Table 12 shows the dispositions of interviews for air sealing contractors. As shown, the research team interviewed staff representing just over half of the companies that provide air sealing through the program. These interviews also included two staff from the company that provided the highest number of air sealing projects, based on the sample of projects reviewed by the research team.

Table 12. Disposition table of air sealing contractor interviews

Air Sealing Contractor Interview Dispositions	Companies	Individual Staff
Number of participating contractor companies	12	Unknown
Number contacted	11	14
Number interviewed	6	9

The research team also interviewed staff from each utility to discuss air sealing calculations.

[29] It was beyond the scope of this project to investigate whether the blower door factor calculation is accurate, since that would require field testing. In particular, it would require testing a significant number of dwelling units using a "guarded blower door test", in which a blower door test is set up for the test unit and pressure in adjacent units is neutralized with other blower door or duct blaster equipment, to isolate leakage from the exterior.

[30] In addition to the sampled projects, the research team reviewed 22 projects for the air sealing measure to identify contractors.

Contractor interviews covered the following topics:

- How do contractors develop a scope of work for air sealing?
- What processes do contractors follow for air sealing units?
- How rigorous and consistent is their air sealing process?
- What is the process that contractors follow for measuring the improvement of air sealing?
- How rigorous and consistent in their air sealing measurement process?
- What process do contractors follow for determining energy savings from air sealing units?
- Does their energy savings calculation process align with the PSD? If not, why not?
- What are drivers and barriers to air sealing?
- For each research question above, how much variation exists among contractors?

The Contractor Interview Guide is in Appendix C.

Utility interviews covered the following topics:

- What processes do the utilities follow for determining savings from air sealing units?
- Does their energy savings calculation process align with the Program Savings Document (PSD)? If not, why?

The Utility Interview Guide is in Appendix D.

5 Program-level Verification Findings

5.1 Data Structure and Ex Ante Savings

5.1.1 Database Structure for Each Utility

Both utilities track savings by site (i.e., multifamily site) in their program databases. There is no overarching Multifamily Initiative database: the utilities track each program (e.g., HES, HES-IE) separately. The research team combined databases across the Multifamily Initiative programs for this analysis.

During interviews, the program managers from each utility stated that they vary in how they track savings for HES and HES-IE. Eversource reports they track all savings for multifamily sites through the HES and HES-IE programs. This is consistent with the research team's database review.

UI reported that they track in-unit measures through the HES and HES-IE programs, and common area measures through commercial programs, including Energy Opportunities and Small Business Energy Advantage (SBEA). However, based on the sample of projects reviewed, the research team found that several UI projects in the HES and HES-IE programs had common-area only measures. When we requested project documentation for multifamily projects in the commercial program databases, we found that:

- Multifamily sites are tracked in HES and HES-IE program databases
- Commercial program databases did not include multifamily sites. Sites flagged as multifamily in these databases included large assisted living facilities that are on a large power time use rate, not residential rates, and other types of buildings on commercial rates.

Because the HES and HES-IE programs served the multifamily market while the others did not, this evaluation only sampled sites from the HES and HES-IE databases.

Within each database, Eversource provides savings by measure, while UI does not organize savings by measure. UI instead reports savings at either the site level (for some projects) or unit level (for other projects). For analysis, the research team aggregated to the site level for sampling and reporting for each utility. Where sufficient confidence and precision allowed, the research team reported savings at the measure-level for Eversource.

As noted in Section 4.3, the UI database includes 300 projects that indicate gas-savings-only measures. The research team cannot tell if these 300 projects are really stand alone or they are in fact projects that have an electric savings component that is listed separately. It is worth noting that the sample of Eversource projects verified by the research team did not indicate any projects that were gas-savings-only. This suggests that many if not all of these 300 gas-only are in fact gas and electric projects that are not linked properly in the UI tracking system.

Unfortunately, another deficiency in the UI database is that UI does not track the project site address consistently in the program database. While the Eversource database includes a "Service Address" field, which reflects the postal address of the site, the., there was no field similar to a "Service Address" in the UI database provided to the research team. Sometimes the UI project name included the site address, but sometimes it reflected the owner's address, and sometimes it did not reflect the address at all. This

made it impossible to match the UI gas-savings-only projects to a companion electric listing in either the Eversource or UI database of electric-only projects.

The sampling plan research team requested six gas-savings-only project files (three in the sample, and three back-up sites); and UI provided three. These program records do have a service address, so the research team was able to try to match these three records to the Eversource electric-only records. One of those was a match. The research team could not confirm as to whether the other two match to a UI electric only record. All three files showed gas savings-only measures installed.

Because this issue was only discovered after the sampling plan had been accepted and the verification completed, the sample treats UI gas-only projects as stand-alone projects even if they were not. This means that the weighted results also treat these projects as stand-alone projects, and the results are applicable to the UI results as they were originally delivered. Had the 300 gas-only projects been properly connected to an electric project in cases that were not gas only, there would likely have been a slightly different distribution of project in the sample. More importantly, many of the projects that were classified as electric only may have been in fact combine projects and the large number of electric-only projects may be overstated. Or, the UI program includes a large number of projects that are not comprehensive, i.e., that achieve only low or moderate gas savings.

As described in Section 8.2, the research team recommends that UI update their data management system to include the service address in all tracking records. Furthermore, the tracking system must maintain a consistent link between electric and gas work on the same projects.

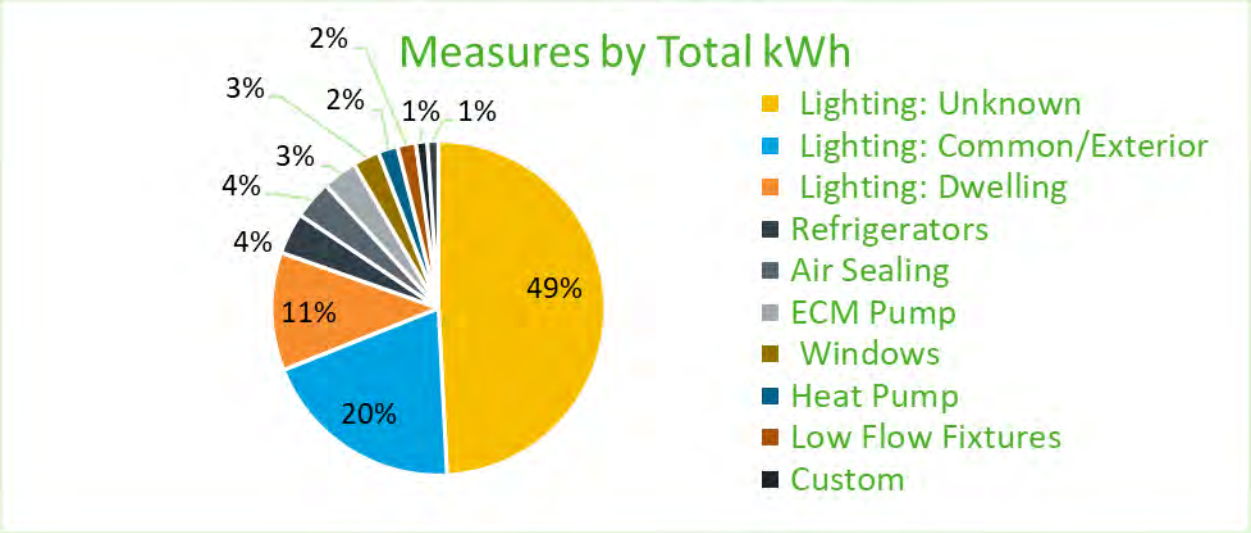
5.1.2 Ex ante Savings for Electricity by Measure

The ex ante saving for electricity by measure for Eversource is shown in Figure 2.

Lighting (common area/exterior and dwelling unit) comprises 80% of total kWh savings, followed by refrigerators and air sealing (4% each), ECM pumps and windows (3% each), heat pumps and low flow fixtures (2% each), and insulation and custom measures (1% each). For context for the measures that affected cooling savings, of the sampled projects, 43% had dwelling unit air conditioning based on the file review.

Savings attributed simply to “lighting” comprises 49% of the ex ante electricity savings – this is shown in Figure 2. as “Lighting: Unknown.” The savings from these lighting measures was not categorized as common/exterior or dwelling unit in the program databases for Eversource. (As a reminder, UI did not track savings at the measure-level.)

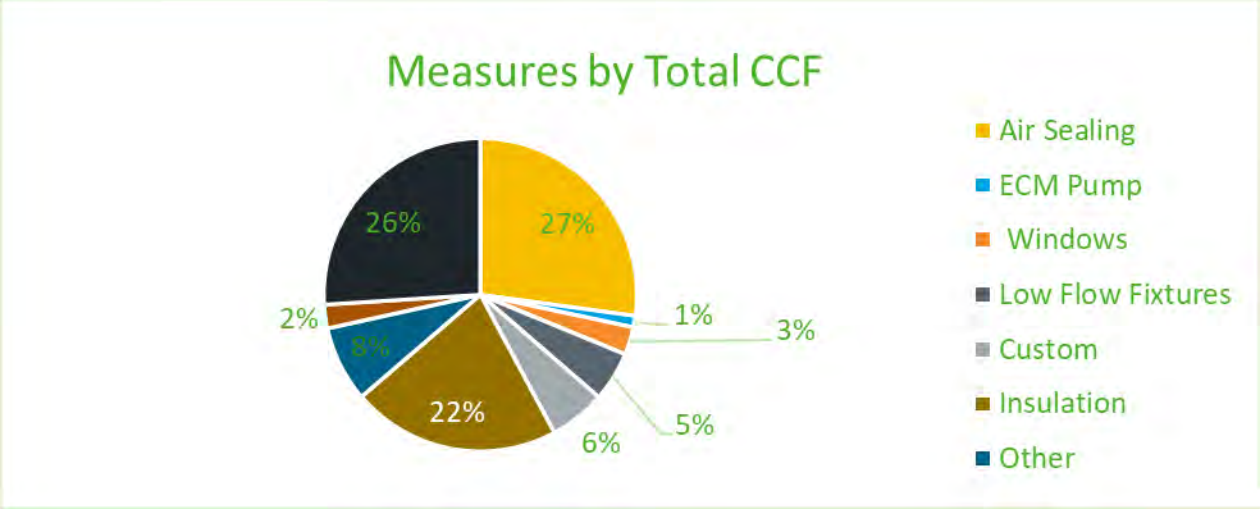
Figure 2. Ex Ante Savings for Electricity by Measure for Eversource



5.1.3 Ex ante Savings for Natural Gas by Measure

The ex ante saving for gas by measure for Eversource is shown in Figure 3. There is more diversity of gas savings by measure type than for electricity. Air sealing (27%), boiler replacements (27%), and insulation (22%) provide the highest savings. Other measures, including ECM pumps[31], windows, low flow fixtures, duct seal, and custom measures, each comprise less than 10% each. For context for measures affecting heating savings: of the projects sampled, 52% had gas heat, 29% had electric heat, 9% had fuel oil heat, 1% had propane heat, and the heating fuel could not be determined for 9% of projects.

Figure 3. Ex Ante Savings for Natural Gas by Measure for Eversource



[31] Electronically Commutated Motors (ECM) pumps adjust the speed of the motor based on demand, thereby savings electricity savings.

5.1.4 Project File Structure

Eversource and UI typically had the same types of documentation in their project files. Documentation can be broken out into two types: planning files, which include the MF Fill Out Form and the Letter of Agreement (LoA) Generator[32], and installed files, which include the invoices and cut sheets. Some project files also had post-inspection reports – this was typically for larger projects. While reviewing the measure level savings in calculators, the research team found that UI often did not sum to the site-level savings in its database, as discussed in more detail in Section 5.1.1.

5.2 Overview of Verification Results

5.2.1 Program Level Realization Rates

A realization rate is the ratio (given as a percentage) of verified savings (from the evaluation) to program estimated (claimed) savings. A value greater than 100% indicates that the program under-estimated savings, while a value less than 100% indicates that savings were over-estimated. Realization rates different than 100% can result from any of the parameters used to estimate measure savings.

The research team examined each calculation for the sampled buildings in detail, including all parameters, and updated the measure counts using data collected during the evaluation. The consultants adjusted realization rates due to deviations in algorithms in the utilities' calculators from the PSD, measure count deviations, incorrect inputs, or other parameters found during data collection compared to the claimed values.

The research team calculated both prospective and retrospective realization rates for all sampled projects. "Prospective" savings were calculated according to the 2020 PSD. "Retrospective" savings were calculated based on the PSD that was in effect the year that a project was installed: so, the 2017, 2018, or 2019 PSD depending on the project. The prospective realization rate represents savings relative to the current PSD. It captures all adjustments made in this evaluation, including under and overcount of measures, under and overclaimed savings, corrections to fuel types, and corrections to the calculations. This last issue – corrections to the calculations – occurred under two scenarios: For some measures, projects used a calculation that deviated from the PSD (both the PSD in effect at the time the project was installed, *and* the 2020 PSD). For other measures, projects used a calculation that was correct based on the PSD in effect at the time the project was installed, but that calculation has since changed in the 2020 PSD – categorized as "Adjustments for Prospective PSD". The retrospective realization rates captured all adjustments *except* the Adjustments for Prospective PSD. As described in Section 6, most of the research team's adjustments were for reasons other than Adjustments for Prospective PSD. In other words, the retrospective and prospective realization rates were the same or similar for almost all measures. Consequently, while both prospective and retrospective realization rates are presented at the *project-level* in the Appendix B. Adjustments to Projects, this study did not apply sampling weights to

[32] This file was a letter of agreement signed by the owner that showed the intended measures for installation through the program. Based on the research team's review of the LoA Generator compared with the invoices, post-inspection reports, and data collected from the facility manager or onsite. the measures shown in the LoA Generator were usually installed. For example, sometimes a measure in the LoA Generator was not installed, or occasionally a measure not in the LoA Generator was installed. Based on the research team's experience as an evaluator an implementer, it is common for some projects to change plans during the project.

calculate *program-level* realization rates. **All program-level realization rates presented in this report (including in the abstract, executive summary, and in this section) are prospective.** Prospective realization rates capture all adjustments made in this evaluation, represent the utilities' claimed savings relative to the current (2020) PSD. The prospective realization rates are the best predictor available of the percent of future claimed savings that would be realized for this program until the utilities address the issues identified here, including better application review and an improved accounting and tracking system.

Adjustments to the annual energy savings and the summer and winter demand were made for both utilities based on specific deviations regarding:

- **Undercount of measures:** The savings from the measure was not claimed in the database, but it was documented in invoices and, in some cases, the facility manager confirmed it was installed through the program.
- **Overcount of measures:** The savings from the measure was claimed, but either the research team was not able to verify it was installed, the utilities claimed more savings than the research team verified was installed, or the utilities used incorrect calculations.
- **Underclaimed savings**: The savings from the measure was claimed in the database, but the quantity in the invoices did not support the amount of savings claimed (i.e., more equipment was installed).
- **Overclaimed savings**: The savings from the measure was claimed in the database, but the quantity in the invoices did not support the amount of savings claimed (i.e., less equipment was installed).
- **Corrected fuel type:** The research team reduced savings for projects where savings was claimed under the incorrect fuel type (i.e., gas heated building with claimed oil savings)
- **Corrected calculation:** The project used an incorrect calculation that did not align with the PSD in effect at the time the project was installed.
- **Adjustment for Prospective PSD:** The 2020 PSD used a different calculation for the measure than the PSD in effect at the time of the project installation (the 2017, 2018, or 2019 PSD)
- **Lifecycle adjustments:** The research team adjusted calculations where the utilities' calculators used a different expected useful life than assumed in the PSD.
- **Demand adjustments:** The research team adjusted calculations where the utilities' calculators used the incorrect coincidence factor, peak savings was claimed under the incorrect fuel type, or savings was claimed in the database when the PSD assumes no demand savings. The research team also added demand savings for projects that did not claim it.

All adjustments are described by measure type in Section 6.

Realization Rates by Program

The following table shows realization rates by program (i.e., for the HES-IE and HES programs). As a reminder, the HES-IE program serves customers who meet income-eligibility requirements and the HES program serves other customers, including market-rate buildings. As shown, the realization rates were very similar between the two programs for annual kWh, lifetime kWh, and annual CCF. For demand savings, HES had a much higher realization rate for summer demand (summer kW), while HES-IE had a much higher realization rate for winter demand (winter kW). This is because the HES-IE program had more savings from common area and exterior lighting compared to HES; for the common area and

exterior lighting measure, the research team decreased summer demand and increased winter demand savings because the ex ante claims had used incorrect coincidence factors for that measure.

Table 13. Program level realization rates by program

	By Program	Mean Realization Rate (90% Confidence Interval)
Annual kWh	HES-IE	87%* (81 - 94%)
	HES	84%* (79-89%)
Lifecycle kWh	HES-IE	82% (72-92%)
	HES	86%* (80-92%)
Summer kW	HES-IE	56% (39-73%)
	HES	75% (68-81%)
Winter kW	HES-IE	89%* (81-97%)
	HES	61% (47-76%)
Annual CCF	HES-IE	93% (79-108%)
	HES	91% (71-111%)

*Realization rate met or exceeded 90/10 confidence/precision

Realization Rates by Utility

The following table shows the realization rates by utility. The realization rates were similar across the utilities for annual kWh, lifetime kWh, summer kW. Eversource had a moderately lower realization rate for winter kW and had a much higher realization rate for annual CCF. The main reason Eversource had a lower winter demand savings realization rate was because there were 27 projects in which Eversource claimed winter demand but realized demand savings were zero (0). A common reason was that Eversource erroneously listed the peak CCF savings as winter demand savings. The reasons why UI had a lower annual gas savings realization rate included:

- UI awarded gas savings to one lighting project,
- UI claimed two gas savings measures that could not be documented as installed, and
- In the UI database the gas savings claimed at the site level for two sites were greater than the sum of measure-level savings shown in those projects' calculators.

Table 14. Program level realization rates by utility

	Program level Realization Rate by Utility	Mean Realization Rate (90% Confidence Interval)
Annual kWh	UI	85% (75-95%)
	Eversource	86%* (81-90%)
Lifecycle kWh	UI	83% (70-96%)
	Eversource	86%* (81-91%)
Summer kW	UI	58% (40-77%)
	Eversource	58% (49-66%)
Winter kW	UI	87% (77-97%)
	Eversource	75% (64-86%)
Annual CCF	UI	80% (61-100%)
	Eversource	102% (89-116%)

Overall, the realization rates were high for most metrics, except for summer kW for both utilities and annual CCF for UI.

5.2.2 Comparison to Similar Multifamily Programs

The research team interviewed program managers of three other programs available to multifamily buildings:

1. New York State Energy Research and Development Authority's (NYSERDA) Multifamily Performance Program (MPP) for Existing Buildings,
2. New Jersey's Clean Energy Program - Pay for Performance (Existing Buildings), and
3. Energy Savings Assistance: Common Area Measures (ESA CAM) program administered by Pacific Gas and Electric Company (PG&E) in California.

The measure applications across the programs are similar to the Multifamily Initiative. In all programs, lighting is a prominent measure, and most projects include at least one additional measure. In the other programs investigated, however, a lower percentage of electric savings comes from lighting than in the Multifamily Initiative. The programs investigated promote scopes of work with more diverse measure mixes.

NYSERDA's MPP is a whole building program that requires projects achieve 15% whole building savings from electric, gas, and other fuels on a BTU-basis compared to existing conditions[33]. Lighting is the dominant measure, but heating and insulation measures are installed to achieve the required level of

[33] This report does not have the savings percent for electricity and gas use, because billing analysis was outside the scope of this project.

savings. NYSERDA encourages electrification through the Heat Pump Demonstration Study, which provides an incentive adder for MPP projects that install heat pumps. This funding is layered on top of MPP's per unit incentive and the NYS Clean Heat incentive available through the statewide utilities to projects that install heat pumps. The scope of work for projects participating in the Heat Pump Demonstration Study must include an assessment of common area and in-unit measures that can improve thermal performance of the building, such as air sealing and insulation upgrades, appliance and lighting replacements, and low-flow fixture installations. (While these measures must be assessed, they are not required to be installed.) In addition, MPP has switched from reporting in source savings to site savings, because source savings penalized electrification.

In New Jersey, multifamily projects find the program that is the best fit for the project type. Multifamily projects can mix and match commercial and residential programs to cover common area and exterior measures; they can also participate in the Pay for Performance (Existing Buildings) program. Like MPP, the Pay for Performance (Existing Building) program requires 15% savings compared to the existing conditions. While lighting is still prominent, it is one of many measures because program requirements do not allow it to dominate. The total savings from lighting and lighting controls cannot comprise more than half the project's savings. For the program to consider >50% savings from lighting, the project must assess the cost effectiveness of installing other measures in each of the following: heating systems, cooling systems, ventilation systems, domestic hot water system, and building envelopes. Measures in these categories must be installed, or the project team must explain why implementation would not be practicable.

The ESA CAM program covers 100% of common area measure costs (including additional services and ancillary costs). While most savings is from lighting, most projects also include HVAC measures, both heating and cooling measures. Unlike the Pay for Performance (Existing Buildings) program, there are no restrictions on the measure mix in a particular project currently.

The CT Multifamily Initiative provides incentives on a per measure basis with a comprehensive bonus available for projects that install measures with high savings. Unlike NYSERDA's MPP or New Jersey's Pay for Performance (Existing Buildings) program, the Multifamily Initiative does not have a minimum whole building savings requirement. While the comprehensive bonus encourages projects to install more than one measure (i.e., air sealing in addition to lighting), it does not set a limit on the amount of savings from lighting, like the New Jersey's Pay for Performance (Existing Buildings) program does. Recommendations based on best practices from these programs are included in Section 8.3.

5.2.3 Comparison with Other Impact Evaluations

The research team compared the results of this impact evaluation with other Connecticut evaluations and evaluations of other multifamily programs: Connecticut's Energy Opportunities and HES and HES-IE, and NYSERDA's MPP.

- The Energy Opportunities Impact Evaluation (C1635), by DNV-GL published in 2020, found an electricity realization rate of 94% and a gas realization rate of 76% across all measures using onsite verification of measure installation and engineering calculations to verify savings. While Energy Opportunities is a commercial program, similar to the programs evaluated by the

research team, lighting was the primary electricity savings driver in the Energy Opportunities evaluation.[34]

- The HES and HES-IE Single-family Impact Evaluation (R1603), by West Hill published in 2019, found lower realization rates than the research team found in this study: 50 to 79% for natural gas, and 36-56% for electricity. The main reason for the low realization rate is that the single-family study used billing analysis to analyze savings, and for several measures, the billing analysis found the claimed savings were overestimated. This included lighting, which was the main contributor of ex ante savings in both the Single-family Impact evaluation study and the research team's study.[35]
- The NYSERDA Multifamily Performance Program (MPP) Impact Evaluation, by ERS published in 2020, found a realization rate for all fuels of 81%. This study used a combination of desk reviews, interviews with facility managers, and (for a small sample) billing analysis.

Table 15. Comparison with other impact evaluations

Study	Annual Energy Realization Rates	Verification Methods	Notes
CT C1635 (2020) Energy Opportunities Impact Evaluation By DNV GL	Electric: 94%	onsite verification, engineering calculations	Lighting was main driver of electricity savings
CT R1603 (2019) HES and HES-IE Single-family Impact Evaluation By Westhill	Electric: HES-IE: 36%, HES: 56% Natural Gas: HES-IE: 50% HES: 79%	billing analysis	claimed savings overestimated for several measures including lighting, lighting was main driver of savings
NYSERDA (2020) Multifamily Performance Program Impact Evaluation By ERS	All Fuels: 81%	desk reviews, interviews with facility managers, billing analysis (for small sample)	

While none of the impact evaluations reviewed is a perfect match in program type or verification methods, they illustrate the range of realization rates for this and comparable sectors. The two studies that primarily relied on deemed calculations - the Energy Opportunities and NYSERDA MPP evaluations - found annual kWh realization rates that were similar to this evaluation (although slightly higher for Energy Opportunities). The realization rate for the Single family HES and HES-IE evaluation had a lower

[34] DNV-GL. Energy Opportunities Impact Evaluation, Final Report R1635, August 27, 2020.

[35] West Hill Energy and Computing. CT Home Energy Solutions Impact Evaluation Program Years 2015-2016, Final Report R1603, May 22, 2019.

realization rate, probably because it used billing analysis. If a similar analysis had been conducted here, the realization rate may also have been lower. This illustrates the importance of the utilities improving the data collection for multifamily billing, so that a future evaluation can use billing analysis for verification.

6 Detailed Verification Results by Measure

6.1 Common Area and Exterior Lighting

Overview: This measure describes lighting fixtures or bulbs installed in multifamily common areas, such as corridors, foyers, interior stairwells, laundry rooms, and other common areas; as well as the manager's office, maintenance rooms, or other areas. It also describes exterior lighting, such as fixtures or bulbs installed in parking lots, landscaping, or walkways, on the exterior of buildings, or in other exterior areas. Among the sampled projects, almost all instances were LED fixtures, although a few were LED bulbs.

Table 16. Example of common area lighting

Table 17. Example of exterior lighting

Savings contribution in Eversource Database: This measure provides the largest fraction of electricity savings. The research team's best estimate is it provided approximately half (52%) of annual electricity savings. That estimate is based on:

- 20% of ex ante annual electricity savings was attributed to common area or exterior lighting,
- 11% of ex ante annual electricity savings was attributed to dwelling unit lighting, and
- 49% of ex ante annual electricity savings was attributed simply to "lighting".

Assuming that the "lighting" savings followed the same split as common area / exterior vs. dwelling unit (so 65% to common area / exterior and 35% to dwelling unit), 65% of 49% or 32% was common area / exterior lighting. Adding the savings attributed directly to common area or exterior (20%) with the portion of "lighting" that we estimate was common area or exterior (32%) provided 52%.

Number of Occurrences in Sample: This was one of the most installed measures, with 53 total instances in the sampled 80 (yes?) projects (across both Eversource and UI). This represented 40% of the total ex

ante electricity savings in the sample. Note that the research team intentionally under-sampled common area and exterior lighting, to oversample other measure types. This was at the client's request since the program plans to de-emphasize lighting savings in the future.

Table 18. Common Area and Exterior Lighting: Instances in Sample and Ex Ante Savings in Sample (Both Eversource and UI)

Instances in Sample	Sampled kWh Savings from Measure (%)
53	40%

Savings calculation overview (2020 PSD Section 3.1.1):

The 2020 PSD calculates savings from this measure as follows:

- Annual electricity savings is comprised of three components:
    1. Savings from the retrofit, which depends on delta Watts (Wattage of removed [baseline] fixture or lamp minus Wattage of the installed fixture or lamp) and Hours of Use [HOU]),
    2. Savings from occupancy sensors for common area lighting and daylight sensors for exterior lighting where applicable, and
    3. Interactive effects (cooling savings), for lighting measures installed in indoor, conditioned areas.
- A natural gas savings penalty is applied for interactive effects in indoor, conditioned common area projects with natural gas heating.
- Winter and summer demand savings depend on a coincidence factor (CF). For multifamily common areas, the CF is 17% (summer demand) and 90.4% (winter demand). For exterior lighting, the research team applied CF for parking lot lighting, since most exterior lighting was installed in these areas: 1.5% (summer demand) and 67% (winter demand).
- Lifetime electricity savings are calculated by multiplying annual savings by the lifetime, which the PSD assumes as 13 years for fixtures, as well as lamp and ballast replacements (which applies to most common area and exterior lighting), and 4 years for lamps (which applied to a small number of common area installations).[36]

Changes in savings calculation from PSDs in evaluated years (2016-2019) and 2020 PSD

The energy savings calculation did not vary in the PSD calculations from 2016-2019 to 2020. For demand savings, the 2017 PSD did not have a CF specific to multifamily common areas. The 2018 and 2019 PSDs included a multifamily common area CF, which were the same values as those found in the 2020 PSD.

Verification methodology: The research team:

1. Confirmed the measure was installed through a file review; and (where available) an onsite visit (particularly for exterior lighting), a facility manager interview, or photos provided by the facility manager at the request of the research team; and
2. Reviewed lighting calculators for each year to identify any deviations from the 2020 PSD; and

[36] There is no change in the baseline over time, and the PSD shows the remaining useful life as "N/A" for all lamps and fixtures. In other words, the PSD does not use a dual-baseline approach for lighting measures.

3. Conducted a reasonableness check of lighting savings based on the quantity of fixtures or lamps in invoices for all projects where available

Verified Savings and Adjustments: The research team found a high realization rate for annual electricity savings and winter demand, and a low realization rate for summer demand.

Table 19. Common Area and Exterior Lighting: Ex Post Savings Results (Eversource only)

Annual kWh	Annual CCF	Lifetime kWh	Summer Demand	Winter Demand
97%* (93-101%)	-	98% (94-103%)	47% (37-57%)	118%* (111-126%)

* Met or exceeded 90% confidence, 10% precision. Range in parenthesis show 90% confidence interval.

The research team's adjustments to **Eversource** measure-level savings included the following:

- Undercount of Measures: The research team added savings for two (2) projects not claimed in the database but documented in invoices and confirmed as installed through the program by the facility manager.
- Overcount of Measures: Removed savings for one (1) project claimed in the database but not installed, and for one (1) project which claimed positive savings for "interactive effects". Note that the calculator included interactive effects as part of the calculation, so this project essentially double-counted savings from these cooling interactive effects.
- Adjustment for Prospective PSD: None
- Demand Adjustments: Adjusted demand savings for 2018 and 2019 common area (interior) projects. The research team found that the ex ante calculators for all program years used the CFs for grocery stores: for summer, 90.4% (instead of 17% for multifamily common areas), and for winter, 77% (instead of 90.4% for multifamily common areas). Note that, for 2017 projects, this was not a utility error, since the 2017 PSD did not provide a CF specific to common areas. However, it was an error for the 2018 and 2019 projects to not switch to the multifamily common area CFs. The research team's adjustments to the CFs decreased summer demand and slightly increased winter demand savings.

For the **UI** calculator review, the research team found that:

- The UI calculator generally followed the PSD for this measure. But one (1) project claimed positive gas savings from a lighting measure, one (1) project claimed cooling interactive effects and had no air conditioning, and one (1) project used the wrong coincidence factor.

Measure-level Recommendations: Eversource should update the coincidence factors in its calculator. Eversource should also improve documentation to ensure that all claimed projects have invoices, and that all installed projects are claimed and allocate all lighting measures as either common area or in unit, rather than "Other Lighting".

6.2 Dwelling Unit Lighting

Overview: This measure describes light bulbs and fixtures installed in multifamily dwelling units. Among the sampled projects, almost all instances were LED bulbs, although a few were LED fixtures.

Figure 4. Example of LED bulbs installed in dwelling units

Savings contribution in Eversource Database: This measure provides the second largest fraction of electricity savings. The research team's best estimate is it provided approximately 28% of annual electricity savings. That estimate is based on:

- 11% of ex ante annual electricity savings was attributed to dwelling unit lighting, and
- 20% of ex ante annual electricity savings was attributed to common area or exterior lighting,
- 49% of ex ante annual electricity savings was attributed simply to "lighting".

Assuming that the "lighting" savings followed the same split as dwelling unit vs. common area / exterior (so 35% to dwelling unit and 65% to common area / exterior), 35% of 49% or 17% was dwelling unit lighting. Adding the savings attributed directly to dwelling unit (11%) with the portion of "lighting" that we estimate was dwelling unit (17%) provided 28%.

Number of Occurrences in Sample: This was one of the most commonly installed measures, with 71 total instances in the sampled projects (across both Eversource and UI). This represented 32% of the total ex ante electricity savings in the sample.

Table 20. Common Area and Exterior Lighting: Instances in Sample and Ex Ante Savings in Sample (Both Eversource and UI)

Instances in Sample	Sampled kWh Savings from Measure (%)
71	32%

Savings calculation overview (2020 PSD Section 4.1.1):

The 2020 PSD calculates savings from this measure as follows:

- Energy savings = Delta Watt x HOU x 365/1000 x 1.04
  - The Delta Watt is the Wattage of removed fixture or lamp (baseline) minus Wattage of the installed fixture or lamp.
  - HOU varies by room. For example, kitchen HOU is 4.1 hours/ day while bathroom HOU is 1.7 hours / day. Excluding exterior spaces (which follow the parking lot lighting HOU in multifamily buildings), the average HOU for interior spaces in multifamily units is 2.5 hours per day.
  - The 1000 factor converts savings from Watts to KW.

    - The 1.04 is the cooling interactive effect. Note there is no natural gas penalty in the 2020 PSD for this measure for increased heating usage. Consequently, the 2020 PSD is currently inconsistent in its treatment of interactive effects, since it directs projects to claim cooling savings, but not claim a heating penalty.
- Summer Demand = 1.05 x 13% x Delta Watt / 1000, where 1.05 is an average capacity factor due to lighting interactive effect, and 13% is the residential lighting summer CF
- Winter Demand = 20% x delta W/1000, where 20% is the residential lighting winter CF
- Lifetime electricity savings are calculated by multiplying annual savings by the lifetime, which the PSD assumes as 4 years for lamps (applies to most in-unit measures) and 5 years for luminaires (i.e., fixtures - applies to a small subset of in-unit measures).[37]

In terms of the delta Watt calculation, the 2020 PSD does *not* require the baseline wattage to be compliant with the Energy Independence and Security Act (EISA). This is not best practice, since

- EISA phased out traditional incandescent bulbs between 2012 to 2014[38].
- The CT PSD does require an EISA-compliance baseline for its commercial lighting measure (PSD 4.1.1) for all A-lamps, but not for residential measures.
- Finally, recent data indicates that most residential customers are purchasing LEDs[39], even in the absence of a program, so even an EISA-compliant baseline may be too generous in terms of savings. Since this program focuses on early retirement of bulbs, and many bulbs purchased by residential customers are used to replace burned-out bulbs, the research team used the EISA-compliant baseline (and not a baseline based on current sales).

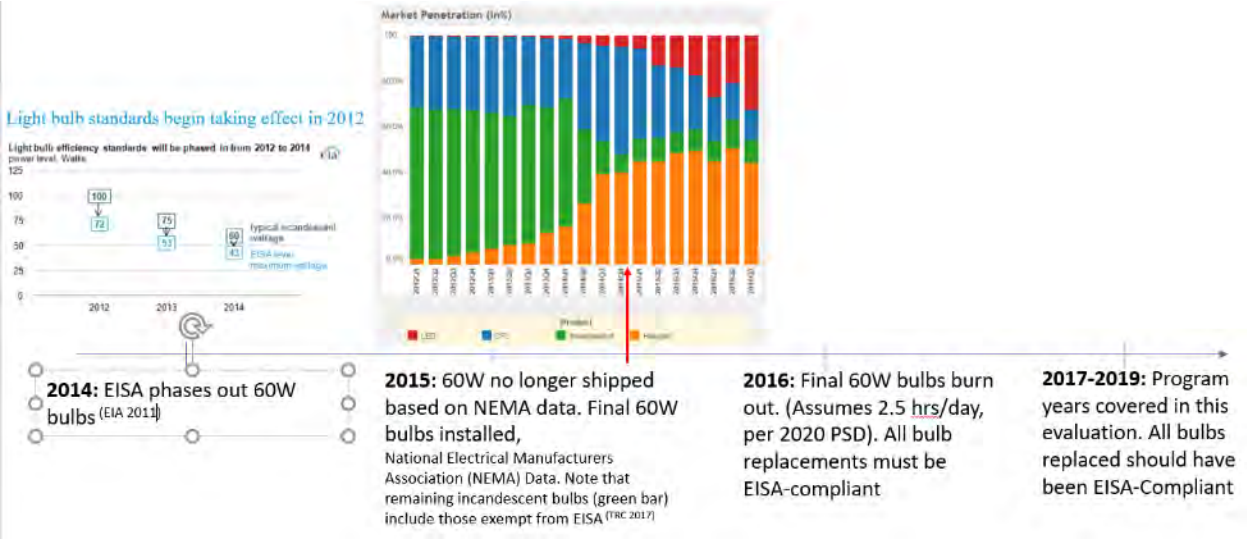
The following figure illustrates how, by 2017, a large majority of bulb replacements would have been EISA-compliant. Consequently, the research team adjusted the baseline of all dwelling unit light bulbs by multiplying the baseline wattage by 25%, as the research team requires in the commercial section.

[37] As with commercial lighting, there is no change in the baseline over time, and the PSD shows the remaining useful life as "N/A" for all lamps and fixtures. The PSD does not use a dual baseline for lighting measures.

[38] U.S. Energy Information Administration (EIA 2011): https://www.eia.gov/todayinenergy/detail.php?id=4150#:~:text=By%202014%2C%20most%20general%20use,transformation%20for%20common%20light%20bulbs.

[39] From the National Electrical Manufacturers Association website showing lamp shipments, almost 75% were LEDs in the 3rd quarter of 2019: https://www.nema.org/analytics/lamp-indices

Figure 5. Timeline Showing Phase-out of Traditional Incandescent Bulbs Compared to Program Years Evaluated[40], [41]



In conclusion, this timeline shows that, for the program years evaluated, all *removed* bulbs would either have been EISA-compliant baseline, or had a much lower HOU than what the PSD assumes (so would therefore generate less energy savings than what the PSD assumes). The research team notes that it is very difficult to distinguish between halogen and incandescent bulbs when they are installed (i.e., once removed from the package), since they are both filament-based bulbs. The removed bulbs were likely halogen but mistaken as incandescent, or incandescent but in low-HOU areas. In addition, while it is possible that facility managers stock-piled incandescent bulbs at the time of phase out, such as in a maintenance closet, the program replaced multiple bulbs per dwelling unit and claimed early retirement savings. Consequently, the maintenance closet would have needed to store multiple bulbs per dwelling units (typically hundreds or thousands of bulbs), which does not seem realistic.

In addition to the timeline shown above, a residential lighting study done in Connecticut (NMR 2019 in R1963A) found, based on data collected 2017 to 2019, that over half of bulbs available in the market were LEDs.[42]

The 2020 PSD directs users to use a baseline of the reported value where known, and for unknown direct install, to assume 24 W for light bulbs and 26.3 W for luminaires. The finding of this impact evaluation is that some participants are claiming a non-EISA compliant baseline as their "known" value, which does not seem reasonable given the timeline in Figure 5. As discussed in Section 3, the research team recommends that the 2021 PSD specify a "backstop" for the baseline that is EISA-compliant. This backstop should apply even for "known" values of the replaced bulbs, given the difficulty discerning a

[40] EIA 2011: https://www.eia.gov/todayinenergy/detail.php?id=4150#:~:text=By%202014%2C%20most%20general%20use,transformation%20for%20common%20light%20bulbs

[41] TRC 2017: http://www.calmac.org/publications/TRC_PGE_-_LED_A-lamp_Baseline_Final_5-17_CALMAC.pdf

[42] NMR 2019. https://www.energizect.com/sites/default/files/R1963a%20Short-Term%20Lighting%20Analysis_Results%20Presentation_7.1.20.pdf

halogen vs incandescent bulb in the field, and since a bulb that is truly incandescent would have been installed more than five years ago, and most likely has a much lower HOU than the PSD assumes.

Changes in savings calculation from PSDs in evaluated years (2016-2019) and 2020 PSD

The energy savings calculation for this measure varied as shown in the previous PSDs:

- 2017 PSD: Used a wattage reduction ratio instead of delta W. Based on the research team's calculation of a few example projects, the wattage reduction ratio reduced savings by approximately 25% (i.e., was equivalent to a 75% multiplier) compared to the delta Watt method.
- 2018 PSD: Used the same calculation as the 2020 PSD
- 2019 PSD: Used the same calculation as the 2020 PSD

There were no changes in demand calculations in the 2016-2019 PSDs.

Verification methodology: The research team:

1. Confirmed the measure was installed through a file review. In five projects, the facility manager documented these were installed in the manager's unit or empty units through photos provided by the facility manager at the request of the research team
2. Reviewed lighting calculators for each year to identify any deviations from the 2020 PSD; and
3. Conducted a reasonableness check of lighting savings based on the quantity of fixtures or lamps in invoices for all projects where available[43]

Verified Savings and Adjustments:

The research team found a moderately high realization rate for annual electricity savings and winter demand, and a low realization rate for summer demand.

Table 21. Dwelling Unit Lighting: Ex Post Savings Results (Eversource only)

Annual kWh	Annual CCF	Lifetime kWh	Summer Demand	Winter Demand
67% (62-72%)	-	50% (46-55%)	70% (65-75%)	81% (62-101%)

Note: Range in parenthesis show 90% confidence interval.

The research team's adjustments to **Eversource** measure-level savings included the following:

- Overcount of Measures: Removed savings for one (1) project claimed in the database but not installed
- Underclaimed Savings: Increased savings for all Eversource HES projects, because the ex ante calculation multiplied savings by a 90% factor, which does not align with the PSD

[43] Because each project file calculator has various inputs, since HOU varies by room and delta W varies depending on the baseline and installed bulb, the research team did not recreate the calculation for every project.

- Overclaimed Savings: Reduced savings for 2 projects that overclaimed savings, because plans (as shown in the Letter of Agreement [LOA]) differed from installed (as shown in invoices or post-inspection reports)
- Savings Adjustment: Reduced savings by 25% for all projects to reflect an EISA-compliant baseline. Projects had assumed non-EISA compliant baselines, and the research team followed the commercial lighting approach of multiplying savings by 75% to estimate savings compared to an EISA-compliant baseline.
- Adjustment for Prospective PSD: None. The 2017 PSD did include a wattage reduction ratio method that reduced savings by approximately 25% compared to a non-EISA compliant baseline; while projects did not follow this, the research team accounted for this in the Savings Adjustment noted above. The 2018 and 2019 PSD used the same delta Watts method as the 2020 PSD, described above in Savings calculation overview (2020 PSD Section 4.1.1). Again, the research team accounted for this in the Savings Adjustment noted above.
- Lifetime Adjustments: Reduced lifetime savings, because the EUL for bulbs was 8, 6, and 5 years respectively in the 2017, 2018, and 2019 PSD, respectively, compared to the EUL of 4 years in the 2020 PSD. The EUL was slightly higher for fixtures than bulbs.
- Demand Adjustments: No demand-specific adjustments[44].

For 2017 projects, the Eversource calculator did not use the wattage reduction ratio, which was the requirement in the 2017 PSD. Eversource used the delta watts method and did not adjust the baseline (i.e., assumed a non-EISA compliant baseline). As described above, the research team adjusted the baseline by reducing savings by 25%.

For the **UI** calculator review, the research team found that

- The UI calculator did not use the wattage reduction method for the one 2017 project. Instead, the calculator applied a 75% multiplier to the baseline wattage – i.e., reduced savings by 25%, which had approximately the same impact as the wattage reduction ratio. Consequently, the research team did not adjust savings for this project. The 2018 and 2019 UI calculators did not apply the 75% multiplier. Consequently, the research team did not make this adjustment for the 2018 and 2019 projects.
- The UI calculator generally followed the PSD for this measure for 2018 and 2019 projects. The research team reduced savings for one (1) project that overclaimed savings, because plans (LOA) showed more bulbs than installed (invoices).

Measure-level Recommendations:

- Consider phasing out this measure, given the high prevalence of LEDs in the residential market. In the meantime, require all projects to use an EISA-compliant baseline. Given the natural market adoption of LEDs, require documentation that the bulbs removed were not LEDs (i.e., halogens or CFLs), such as requiring photos for a sample of units or showing a box of removed bulbs.
- Both utilities should true up claimed savings based on what was installed (invoices or post-inspection report), instead of what was planned (LOA). Eversource should remove the 90%

[44] The realization rates for demand are slightly different than the realization rates for energy savings because demand savings depend only on delta W, whereas energy savings depends on delta W and HOU.

reduction factor for HES projects in its calculator, because it does not align with the PSD, unless there is data indicating that market-rate projects should have savings reduced by 10%.

6.3 Refrigerators

Overview: This measure describes refrigerator replacements installed in multifamily dwelling units. Among the sampled projects, almost all instances were ENERGY STAR-certified refrigerators replacing existing refrigerators with a higher wattage.

Figure 6. Examples of installed refrigerators

Savings contribution in Eversource Database: This measure provides 4% of annual electricity savings. It is tied for third in terms of electricity savings along with air sealing, behind common area / exterior lighting and dwelling unit lighting.

Number of Occurrences in Sample: This was a fairly common measure, with 18 total instances in the sampled projects (across both Eversource and UI). This represented 5% of the total ex ante electricity savings in the sample.

Figure 7. Refrigerator Replacements: Instances in Sample and Ex Ante Savings in Sample (Both Eversource and UI)

Instances in Sample	Sampled kWh Savings from Measure (%)
18	5%

Savings calculation overview (2020 PSD Section 4.3.1):

The 2020 PSD calculates savings from this measure as follows:

- Energy savings has two terms:
  - The "retrofit" term compares the wattage of an ENERGY STAR unit to the previously installed unit. While the calculation varies by refrigerator configuration (e.g., location of freezer, whether there is a thru-door ice dispenser, etc.), most units sampled were top-mount freezer with no thru-door ice. These used the equation: Annual savings (kWh) = Energy use of removed refrigerator (kWh) – 0.881 * 410.8 kWh, where the 410.8 kWh

    - The "lost opportunities" term compares the installed unit to the ENERGY STAR requirement
- Demand savings are found by applying a multiplier (0.1834 for summer and 0.1031 for winter) to the energy savings
- Lifetime electricity savings are calculated by multiplying annual savings by the lifetime, which the PSD assumes as 5 years for market rate (HES) projects and 10 years for low-income (HES-IE) projects. There is no change in the baseline over time, and the PSD shows the remaining useful life as "N/A" for all lamps and fixtures. In other words, the PSD does not use a dual-baseline approach.

Note that, of all projects reviewed, all met ENERGY STAR certification requirements, but none exceeded ENERGY STAR requirements by the 10% threshold needed to earn the lost opportunity savings.

Changes in savings calculation from PSDs in evaluated years (2016-2019) and 2020 PSD

The energy savings calculation for this measure varied as shown in the previous PSDs:

- 2017 PSD: The energy calculation used a higher assumed savings for some types of units. However, the units in the sample did not have a different value compared to the 2020 PSD assumptions.
- 2018 and 2019 PSDs used the same calculations as 2020 for electricity and demand savings.

Consequently, there were no changes in energy or demand savings for the measures in the sample between prospective and retrospective savings.

Verification methodology: The research team:

1. Confirmed the measure was installed through a file review.
2. Recreated the 2020 calculations and checked that the calculations followed the PSD where the project files showed the number of refrigerators installed and invoices documented their make and model.

Verified Savings and Adjustments:

The research team found a fairly high realization rate for annual electricity savings and demand.

Table 22. Refrigerator Replacements: Ex Post Savings Results (Eversource only)

Annual kWh	Annual CCF	Lifetime kWh	Summer Demand	Winter Demand
80% (65-95%)	-	80% (65-94%)	80% (65-95%)	81% (66-95%)

Note: Ranges in parenthesis show 90% confidence interval.

The research team's adjustments to **Eversource** measure-level savings included the following:

- Overcount of Measures: Removed savings for two (2) projects claimed in the database but not installed
- Overclaimed Savings: Reduced savings for two (2) projects: one that claimed savings beyond ENERGY STAR when it should have just claimed retrofit savings, and one where the plans (from the LOA) showed a more efficient model than what was installed (from invoices)
- Adjustment for Prospective PSD: None

- Lifetime Adjustments: No lifetime-specific adjustments.
- Demand Adjustments: No demand-specific adjustments.

For the **UI** calculator review, the research team found that

- Only one (1) refrigerator project was installed at the 15 sampled UI sites. The research team reduced savings for this project because the ex ante calculator claimed more refrigerators than were installed (from invoices).

Measure-level Recommendations: Improve documentation and set rules in calculator so that lost opportunity savings (savings above ENERGY STAR) are not overclaimed.

6.4 Air Sealing

Overview: This measure describes infiltration reduction in multifamily dwelling units and common areas. As described in Section 7.2, most program contractors reported sealing dwelling units using caulk, spray foam, door kits, backer rod and ROXUL for larger gaps, weatherstripping, fireproof products where required. The contractor verifies reduction in leakage by conducting a blower door test on a sample of units before and after air sealing.

Figure 8. Example of spray foam air sealing around kitchen pipe penetrations (left) and screwed-on door sweep (right)

Savings contribution in Eversource Database: This measure provides 4% of annual electric savings. It is tied for 3rd in terms of electric savings along with refrigerators.

This measure provides 27% of annual gas savings. It has the highest gas savings of all the gas measures.

Number of Occurrences in Sample: This was a very common measure, with 60 total instances in the sampled projects (across both Eversource and UI). This represented 4% of total ex ante electric savings in the sample and 27% of total ex ante gas savings in the sample.

Figure 9. Air Sealing: Instances in Sample and Ex Ante Savings in Sample (Both Eversource and UI)

Instances in Sample	Sampled kWh Savings from Measure (%)	Sampled CCF Savings from Measure (%)
60	4%	27%

Savings calculation overview (2020 PSD Section 4.4.2)

The 2020 PSD calculates savings from this measure as follows:

- Energy savings = REMheating x blower door reduction x BF, where REMheating depends on the heating system type. BF is a "blower door factor" that reduces savings for multifamily units because some infiltration comes from conditioned spaces. In multifamily units, the BF is less than 1. The PSD provides a similar calculation for REMcooling in dwelling units with air conditioning.
- The PSD awards summer demand savings if the dwelling units have air conditioning, and winter demand savings if the units have electric heat (e.g., electric resistance, heat pumps).
- Lifetime savings are calculated by multiplying annual savings by the lifetime, which the PSD assumes as 20 years. There is no change in the baseline over time, and the PSD shows the remaining useful life as "N/A" for all lamps and fixtures. In other words, the PSD does not use a dual-baseline approach.

Changes in savings calculation from PSDs in evaluated years (2016-2019) and 2020 PSD

The energy savings calculation for this measure did not vary. The 2016-2019 PSDs used the same calculations as 2020. Consequently, there were no changes in energy or demand savings for the measures in the sample between prospective and retrospective savings.

Verification methodology: The research team:

1. Confirmed this measure was installed through file review. In a few cases, the facility manager confirmed measure installation by providing photos of a few example units.
2. Where input values were available for a project, the research team recalculated savings.

Verified Savings and Adjustments:

The research team found a very high realization rate for annual kWh, annual CCF, lifetime kWh, and summer demand (kW); the realization rate was lower but still high for winter demand (kW).

Table 23. Air Sealing. Ex Post Savings Results (Eversource only)

Annual kWh	Annual CCF	Lifetime kWh	Summer Demand	Winter Demand
98% (90-106%)	172% (54-289%)	108% (93-122%)	100% (80-120%)	86% (65-108%)

Note: Range in parenthesis show 90% confidence interval.

The research team's adjustments to **Eversource** measure-level savings included the following:

- Overcount of Measures:
  - Removed savings for 1 measure at a project which double-counted heating savings (i.e., awarded both CCF and kWh savings)
- Underclaimed Savings:
  - Increased gas savings for 1 project where 9 times more units were air sealed (from invoice) than planned (from the LOA Generator)
- Corrected fuel type: Added gas savings but removed oil saving for 2 projects that claimed the incorrect fuel for savings
- Adjustment for Prospective PSD: None

- Lifetime Adjustments: No lifetime-specific adjustments.
- Demand Adjustments:
  - Removed winter demand savings (kW) for 5 projects that incorrectly claimed the peak CCF savings as winter demand, and for 3 projects with gas heat.
  - Added winter demand savings for 2 projects with electric heat that had not claimed it.
  - Reduced demand savings for 8 projects by multiplying by the blower door factor (BF = 0.925), because the ex ante had only adjusted energy (but not demand) savings. The ex ante demand savings for these projects had assumed a BF equal to 1, which is for single-family homes only.

For the **UI** calculator review, the research team found that the calculator followed the PSD.

The research team's adjustment to UI measure-level savings included the following:

- Overcount of Measures: Reduced electric savings for 2 projects where less units were sealed (QA sheet/ invoice) than planned (LOA).
- Underclaimed Savings: Added electricity savings for 1 project with air conditioning where it was not claimed.

Measure-level Recommendations:

- Eversource should ensure that the CCF "peak demand" is not incorrectly applied to winter kW demand, and multiply demand by BF
- UI should label final files as "final" and old files with "archive" in file name or put in "archive" folder. Or include date in file name to show the most recent files.
- Other recommendations for this measure, related to verification, are included in Section 7 of this report.

6.5 ECM Pumps

Overview: This measure describes the retrofit installation of Electronically Commutated Motor circulation pumps (ECM pumps) to replace existing circulating pumps in multifamily projects.

Figure 10. Example of installed ECM pumps

Savings contribution in Eversource Database: This measure provides a small amount of savings: 3% of annual electric savings, and 1% of annual winter demand savings.

Number of Occurrences in Sample: This was a less common measure, with 10 total instances in the sampled projects (across both Eversource and UI). This represented 3% of total ex ante electric savings in the sample.

Table 24. ECM replacements: Instances in Sample and Ex Ante Savings in Sample (Both Eversource and UI)

Instances in Sample	Sampled kWh Savings from Measure (%)
10	3%

Savings calculation overview (2020 PSD Section 4.2.13):

The 2020 PSD calculates savings from this measure as follows:

- Electricity savings: Number of ECM pumps installed x 68 kWh/year (Annual Electric Energy Savings)
- Demand savings: Number of ECM pumps installed x 0.024 kW (Seasonal Winter Peak Savings)
- Lifetime savings are calculated by multiplying annual savings by the lifetime, which the PSD assumes as 15 years.

Changes in savings calculation from PSDs in evaluated years (2016-2019) and 2020 PSD

The energy savings calculation for this measure varied as shown in the previous PSDs:

- 2017: energy and demand multipliers were higher than the 2020 PSD:
  - Electricity Savings: Number of ECM pumps installed x 285 kWh/year
  - Demand Savings: Number of ECM pumps installed x 0.056 kW
- 2018: energy was the same as 2020 PSD, but demand was lower
  - Demand savings: Number of ECM pumps installed x 0.015 kW
- 2019: energy and demand were the same as 2020 PSD

Verification methodology: The research team:

1. Confirmed ECM pumps were installed in all projects
2. Recreated the calculation using prospective (2020) and retrospective (2017-2019) calculations where the number of ECM pumps were identified in the project files.

Verified Savings and Adjustments:

The research team found a moderately low realization rate for annual electricity savings and winter demand.

Table 25. ECM Pump: Ex Post Savings Results (Eversource only)

Annual kWh	Annual CCF	Lifetime kWh	Summer Demand	Winter Demand
59% (28-89%)		67% (31-103%)		68% (45-92%)

Note: Range in parenthesis show 90% confidence interval.

The research team's adjustments to **Eversource's** measure-level savings included the following:

- Undercount Measures: Added savings for 1 project (as documented in the file and from the post inspection report) that was not claimed in the database
- Adjustment for Prospective PSD: Reduced prospective savings for 2 projects from 2017, since the 2020 PSD awarded ~1/4 of savings compared to the 2017 PSD. See additional adjustments under Demand Adjustments
- Lifetime Adjustments: No lifetime-specific adjustments.
- Demand Adjustments: Reduced prospective savings for projects in 2017 and 2018, since the 2020 PSD awarded less savings. However, the adjustments were not as great for demand as for energy: the 2020 PSD awarded half the demand savings as the 2017 PSD, compared to one-fourth the energy savings as the 2017 PSD. Consequently, the demand savings adjustment was lower than the energy savings adjustment.

For the **UI** calculator review, the research team found that

- The PSD was followed. There was only 1 ECM pump project. The research team reduced the savings for this project because it was a 2017 project (per the PSD change)

Measure-level Recommendations for Eversource:

- Update the PSD to allow for use of the VFD calculator for central ECM Pumps.

6.6 Windows

Overview: This measure describes the installation of windows that are at least as efficient as ENERGY STAR standards in multifamily common areas and dwelling units. Most of the window replacements in the sample were in dwelling units.

Figure 11. Example of installed window and window label

Savings contribution in Eversource Database: This measure provides a small amount of savings: 3% of annual electric savings and 3% of annual gas savings.

Number of Occurrences in Sample: This was a less common measure, with 9 total instances in the sampled sites (across both Eversource and UI). This represented 2% of total ex ante electric savings and 4% of total ex ante gas savings in the sample.

Table 26. Windows: Instances in Sample and Ex Ante Savings in Sample (Both Eversource and UI)

Instances in Sample	Sampled kWh Savings from Measure (%)	Sampled CCF Savings from Measure (%)
10	2%	4%

Savings calculation overview (2020 PSD Section 4.4.3):

The 2020 PSD calculates savings from this measure as follows:

1. Energy savings = Area x factor that depends on the removed window, the type of heating and cooling equipment, the type of window installed and its u-factor
2. Example calculation for electric resistance heating (kWh) = (Annual electric heating usage of baseline windows - Annual electric heating usage of ENERGY STAR windows) x Area
3. Demand = Area x a multiplier that depends on the type of heating and cooling equipment. Winter demand savings are available only for projects with electric heat, and summer demand savings are available only for projects with air conditioning.
4. Lifetime savings are calculated by multiplying annual savings by the lifetime, which the PSD assumes as 25 years.

Changes in savings calculation from PSDs in evaluated years (2016-2019) and 2020 PSD

The energy savings calculation for this measure varied as shown in the previous PSD:

1. 2017: The 2020 PSD allowed a triple pane window installation, whereas the 2017 PSD only allowed ENERGY STAR window installations (similar to savings from double pane with low-e windows). The triple pane window generates more savings. Consequently, the 2020 PSD allows higher savings than the 2017 PSD.
2. 2018 and 2019: same calculations as 2020

Verification methodology: The research team:

1. Verified windows installed in all projects
2. Recalculated savings under the 2020 and (for 2017 projects) 2017 PSD calculations where enough information was available

Verified Savings and Adjustments:

The research team found a fairly high realization rate for annual electricity savings and winter demand.

Table 27. Windows: Ex Post Savings Results (Eversource only)

Annual kWh	Annual CCF	Lifetime kWh	Summer Demand	Winter Demand
83% (63-102%)		83% (63-102%)		79% (57-101%)

Note: Range in parenthesis show 90% confidence interval.

The research team's adjustments to **Eversource** measure-level savings included the following:

- Overclaimed Savings:
  - Reduced savings for two (2) projects. For one, the invoice showed a lower quantity of windows than claimed. For the second, the project file did not have a calculator, so the research team could not determine why the savings were overclaimed.
- Corrected Fuel Type:
  - Switched savings from oil to natural gas for one project. The facility manager interviewed reported the project has natural gas heat, but the project claimed oil savings.
- Adjustment for Prospective PSD:
  - Increased savings for one 2017 project, because the 2020 calculation allows higher savings for triple-pane windows[45].
- Lifetime Adjustments: No lifetime-specific adjustments.
- Demand Adjustments: Added summer demand (kW) for 1 project that had not claimed it even though it had air conditioning. For winter demand savings, the projects noted above with reductions in energy savings also had similar reductions to demand.

For the **UI** calculator review, the research team found that

- The PSD was followed. There was only 1 window project.

Measure-level Recommendations for Eversource:

- Improve the review of fuels to ensure the correct fuel type is claimed and review the prevalence of air conditioning in project applications to correctly claim summer demand.

6.7 HVAC Heat Pumps

Overview: This measure describes the installation of high-efficiency air-source heat pumps providing space heating and space cooling in dwelling units and common areas of multifamily projects. These heat pumps replace lower efficiency electric heating, such as electric resistance heating systems or older heat pumps. Note that the PSD does not currently allow fuel switching – i.e., incentives for heat pumps to replace fossil fuel-fired equipment. Of the verified heat pumps in the sample, two of the projects served dwelling units and two served common areas. Note there is another measure for DHW heat pumps, but the one DHW heat pump in the sample is discussed in the low-flow fixtures section, since the Eversource database categorizes low-flow fixtures and DHW heat pumps as "DHW."

[45] Because savings are deemed and based on the existing window type (e.g., double pane or single pane), the installed window (e.g., ENERGY STAR double pane or ENERGY STAR triple pane), and the heating fuel system, rather than the u-factor, the savings increased moving from an installed window that is ENERGY STAR triple pane compared with ENERGY STAR double pane.

Figure 12. Example of installed heat pump outdoor unit and nameplate

Savings contribution in Eversource Database: This measure provides 2% of annual electric savings, so is a low savings contributor.

Number of Occurrences in Sample: This was a less common measure, with 7 instances in the sampled projects (across both Eversource and UI). This represented 3% total an ex ante electric savings in the sample.

Table 28. Heat Pumps: Instances in Sample and Ex Ante Savings in Sample (Both Eversource and UI)

Instances in Sample	Sampled kWh Savings from Measure (%)
7	3%

Savings calculation overview (2020 PSD Section 4.2.2 ducted heat pumps serving dwelling units, 4.2.6 ductless heat pumps serving dwelling units, 2.2.2 heat pumps in common areas)

The 2020 PSD calculates savings from this measure as follows:

- Energy Savings has three potential components:
  - Lost Opportunity for heating season performance factor (HSPF) of installed equipment compared to baseline, and
  - Retrofit for HSPF of baseline compared to existing equipment, and
  - air conditioning savings (if project has cooling)
- Summer demand savings are only available if a project has air conditioning. Winter demand savings are awarded for ductless heat pumps in dwelling units. Ducted heat pumps and common area heat pumps do not have winter demand savings.
- Lifetime savings are calculated using a dual baseline approach, with 5 years for the remaining useful life (the baseline is assumed to be the existing equipment) and 18 years for the lost opportunity (a code baseline is assumed for the remainder of the lifetime, in this case for 18 minus 5 = 13 years)

Changes in savings calculation from PSDs in evaluated years (2016-2019) and 2020 PSD

The energy savings calculation for this measure did not vary. The 2016-2019 PSDs used the same calculations as 2020. Consequently, there were no changes in energy or demand savings for the measures in the sample between prospective and retrospective savings.

Verification methodology: The research team:

1. Confirmed that the measure was installed based on file review, and (where available) photos from facility manager or an onsite visit
2. Reviewed the calculator to verify that it followed the PSD

Verified Savings and Adjustments:

The research team found a high realization rate for annual electricity savings and demand, and a very low realization rate for winter demand savings.

Table 29. Heat Pumps. Ex Post Savings Results (Eversource only)

Annual kWh	Annual CCF	Lifetime kWh	Summer Demand	Winter Demand
100% (100-100%)		100% (100-100%)	100% (100-100%)	60% (20-100%)

Note: Range in parenthesis show 90% confidence interval.

The research team's adjustments to **Eversource** measure-level savings included the following:

- Overcount of Measures: None
- Adjustment for Prospective PSD: None
- Lifetime Adjustments: No lifetime-specific adjustments.
- Demand Adjustments: Removed winter demand (kW) savings for one project that was a common area heat pump since the PSD does not award winter demand savings for this measure. In addition, the adjustments to the annual savings affected the winter demand savings for three other projects. Two other heat pump projects correctly did not claim winter demand savings. So only one of the five projects that claimed winter demand savings was verified to have winter demand savings.

No **UI** sampled projects installed heat pumps.

Measure-level Recommendations:

- Improve documentation and add a check for agreement between the database entry and the project calculator.

6.8 Boilers

Overview: This measure describes the replacement of natural gas-fired, hydronic heating central boilers installed in multifamily projects.

Figure 13. Examples of installed condensing boilers

Savings contribution in Eversource Database: This measure provides 26% of annual gas savings. It is one of the three measures providing the bulk of natural gas saving along with air sealing (27%) and insulation (22%).

Number of Occurrences in Sample: This was a fairly common measure, with 12 total instances in the sampled projects (across both Eversource and UI). This represented 19% of total ex ante gas savings in the sample

Table 30. Boilers: Instances in Sample and Ex Ante Savings in Sample (Both Eversource and UI)

Instances in Sample	Sampled CCF Savings from Measure (%)
12	19%

Savings calculation overview (2020 PSD Section 2.2.6):

The 2020 PSD calculates savings from this measure as follows:

- Heating savings is a function of input capacity, boiler efficiency, baseline boiler, efficiency oversize factor[46], equivalent full load hours, and an adjustment factor (1.0 for noncondensing and 0.97 for condensing units).
- Lifetime savings are calculated using a dual baseline approach, with 5 years for the remaining useful life (the baseline is assumed to be the existing equipment) and 20 years for the lost opportunity (a code baseline is assumed for the remainder of the lifetime, in this case for 20 minus 5 = 15 years)

[46] From the PSD section 2.2.6: "The oversize factor ("OF") is assumed to be 1.15 for single boiler/furnace installations; reflecting the industry standard of installing equipment that has an output greater than estimated peak load. The OF for multiple boiler and furnace installations is 1.3 reflecting the industry practice of oversizing multiple pieces of equipment to allow for one piece of equipment to provide a higher percentage of load in emergency situations."

Changes in savings calculation from PSDs in evaluated years (2016-2019) and 2020 PSD

The energy savings calculation for this measure did not vary. The 2016-2019 PSDs used the same calculations as 2020.

Consequently, there were no changes in energy or demand savings for the measures in the sample between prospective and retrospective savings.

Verification methodology: The research team:

1. Verified that the boilers were installed in all cases, based on information collected from an onsite visit, facility manager photo, or files (invoice).
2. Confirmed the equipment nameplate and calculation where possible. For a few, nameplate information was not available and ex ante savings were awarded.

Verified Savings and Adjustments:

The research team found a fairly high realization rate for annual gas savings.

Table 31. Boilers: Ex Post Savings Results (Eversource only)

Annual kWh	Annual CCF	Lifetime kWh	Summer Demand	Winter Demand
-	80% (63%-97%)	-	-	-

Note: Range in parenthesis show 90% confidence interval.

The research team's adjustments to **Eversource** measure-level savings included the following:

- Corrected Calculation: Reduced savings for 3 projects that had an incorrect calculation. These adjustments included an incorrect oversize factor, used the input capacity instead of the output capacity, and used an incorrect efficiency
- Adjustment for Prospective PSD: None
- Demand Adjustments: Removed winter demand (kW) savings for 3 projects, which misapplied peak CCF savings to winter demand savings. The savings are not shown in the figure above since boilers should have zero demand savings. While there are some electrical needs for boilers, which would affect demand, this is a relatively small electrical load, and the PSD does not recognize it.

For the **UI** calculator review, the research team found that

- There was only 1 boiler project. No name plate information was provided to recalculate savings, so the research team could not check that the calculation was done correctly. Since there was documentation, it was installed, and the research team awarded the ex ante savings.

Measure-level Recommendations for Eversource:

- Increase the review of the boiler savings tab, or add more automated checks
- Ensure that CCF "peak demand" is not incorrectly applied to winter kW demand

6.9 Insulation

Overview: This measure describes attic, attic hatch, and basement ceiling insulation (referred to as "floor insulation" in the PSD) installed in multifamily common areas and dwelling units. Among the sampled projects, the majority of insulation measures were basement ceiling insulation, followed by attic insulation and attic hatch insulation.

Figure 14. Examples of installed attic insulation using cellulose (left) and fiberglass (right)

Savings contribution in Eversource Database:

This measure provides 22% of annual gas savings. It is third in terms of gas savings, behind air sealing and boiler replacement. It also provides a very small amount (1%) of electricity savings.

Number of Occurrences in Sample: This was a fairly common measure, with 18 total instances in the sampled projects (across both Eversource and UI). This represented 1% of the total ex ante electricity savings in the sample and 24% of total ex ante gas savings in the sample.

Table 32. Insulation: Instances in Sample and Ex Ante Savings in Sample (Both Eversource and UI)

Instances in Sample	Sampled kWh Savings from Measure (%)	Sampled CCF Savings from Measure (%)
18	1%	24%

Savings calculation overview (2020 PSD Section 4.4.9 Ceiling Insulation, 4.4.10 Floor Insulation, and 4.4.6 Insulate Attic Openings for attic hatch insulation):

The 2020 PSD calculates savings from this measure as follows:

- Energy savings = difference in effective R-value before and after upgrade (calculated) * heating degree days (HDD, assumed to be 5,885°F-day as the average value for Connecticut, which assumes a base temperature of 65°F) * 24 hr/d * ASHRAE adjustment factor (a multiplier adjustment to the HDD) * total area of insulation
- For ceiling insulation, the savings is adjusted for heating system type (i.e., electric resistance heat, heat pump) and cooling system type (i.e., central or room air conditioner). For floor insulation, the savings is only adjusted for the heating system type.

- Lifetime savings are calculated by multiplying annual savings by the lifetime, which the PSD assumes as 15 years.

Changes in savings calculation from PSDs in evaluated years (2016-2019) and 2020 PSD

The energy savings calculation for this measure did not vary. The 2016-2019 PSDs used the same calculations as 2020.

Consequently, there were no changes in energy or demand savings for the measures in the sample between prospective and retrospective savings.

Verification methodology: The research team:

1. Confirmed insulation was installed, typically through photos or facility manager interviews, otherwise through documentation.
2. Recalculated savings where enough information was available.
3. In all cases, savings were similar (ex post generally calculated slightly higher savings), so the research team awarded the ex ante savings to be conservative, since it was not possible to verify the condition of the installation.

Verified Savings and Adjustments:

The research team found a high realization rate for annual electricity and gas savings and demand.

Table 33. Insulation: Ex Post Savings Results (Eversource only)

Annual kWh	Annual CCF	Lifetime kWh	Summer Demand	Winter Demand
100% (100-100%)	100% (100-100%)	100% (100-100%)		100% (100-100%)

Note: Range in parenthesis show 90% confidence interval.

The research team's adjustments to **Eversource** measure-level savings included the following:

- Overcount of Measures: None.
- Corrected Fuel Type: For 1 project, the LOA Generator had oil as the fuel type, but the facility manager reported the units use natural gas, so the research team changed the fuel for savings.
- Adjustment for Prospective PSD: None
- Lifetime Adjustments: No lifetime-specific adjustments.
- Demand Adjustments: No demand-specific adjustments. The projects with an overcount of measures did not claim demand savings, so the realization rate for summer and winter demand was 100%.

For the **UI** calculator review, the research team found that

- The PSD was followed. For 1 of the 2 projects that included an insulation calculator, no documentation measure was installed, so the research team awarded no savings.

Measure-level Recommendations:

- Improve the review of fuels and measure count in project application compared to what is actually installed.

6.10 Low Flow Fixtures

Overview: This measure describes the installation of low-flow faucet aerators and showerheads in multifamily dwelling units. In the sample of projects reviewed, most projects installed both showerheads and aerators in the dwelling units that received this measure.

Figure 15. Example of installed low flow showerhead (left) and faucet aerator (right)

Savings contribution in Eversource Database: This measure provides 2% of annual electric savings and 5% of annual gas savings, so is a fairly low contributor to savings.

Number of Occurrences in Sample: This was a common measure, with 39 total instances in the sampled projects (across both Eversource and UI). This represented 3% of total ex ante electric savings and 5% of total ex ante gas savings in the sample. The savings per measure is low, as illustrated by the high number of occurrences but the low percent of savings that it contributes.

Table 34. Low Flow Fixtures: Instances in Sample and Ex Ante Savings in Sample (Both Eversource and UI)

Instances in Sample	Sampled kWh Savings from Measure (%)	Sampled CCF Savings from Measure (%)
39	3%	5%

Savings calculation overview (2020 PSD Section 4.5.1 and 4.5.2)

The 2020 PSD calculates savings from this measure as follows:

- Energy savings (kWh) = 151 x sqrt(number of showerheads)
- Energy savings (therms) = 6.28 x sqrt(number of showerheads)
- Energy savings (kWh) = 61.2 x sqrt(number of aerators)
- Energy savings (therms) = 2.55 x sqrt(number of aerators)
- No demand savings
- Lifetime savings are calculated by multiplying annual savings by the lifetime, which the PSD assumes as 5 years for aerators and 10 years for showerheads.

Changes in savings calculation from PSDs in evaluated years (2016-2019) and 2020 PSD

- The 2017, 2018, 2019 PSDs are all the same as the 2020 PSD

While the research team used the 2020 PSD for all other measures in this impact evaluation, we made an exception for low-flow fixtures and used the proposed calculations for the 2021 PSD. This is because the 2021 PSD removes the square root function from the equation, which significantly increases the savings, and there is a strong rationale for removing the square root function. As part of the research team's review the 2020 PSD, we found that the source cited for the square root function, KEMA (2010), assumes that one shower may be used more often the other. However, in the water savings equation, the average number of shower events in a unit is being divided by the number of fixtures. Since the water savings already reflect an average across showerheads, the square root function is redundant. Other TRMs, including the Midatlantic TRM, NY TRM, and Wisconsin TRM, do not use the square root value. For the 2021 PSD update, the research team proposed a multiplier that is multifamily specific, because it assumes a lower number of occupants per dwelling unit (compared to single-family). The Connecticut utilities reported they will adopt those values, so they are used for the ex post calculations, as shown below:

- Energy savings (kWh) = 155.2 x Number of showerheads
- Energy savings (therms) = 6.47 x Number of showerheads
- Energy savings (kWh) = 55.93 x Number of aerators
- Energy savings (therms) = 2.33 x Number of aerators
- No demand savings

Verification methodology: The research team:

1. Verified the fixtures were installed in all projects using file review and facility manager photos in some instances
2. Recalculated savings under the 2020 PSD (Retrospective) and 2021 PSD (Prospective) calculations where enough information was available

Verified Savings and Adjustments:

The ex ante calculators did *not* assume a square foot function. However, the upfront multipliers for showerheads and aerators were slightly different from the values proposed for the 2021 PSD. The ex ante calculators did not show a source for their calculation. Adjustments to the ex ante savings were relatively minor, since neither the ex ante nor ex post calculations used a square roof function.

The research team found a high realization rate for annual electricity and CCF savings, but a low realization rate for winter demand.

Note that the Eversource database categorizes low-flow fixtures as "DHW;" in addition to the low-flow fixtures, one DHW heat pump was also categorized as DHW, so is included in the realization rates in the figure below.

Table 35. Low flow fixtures. Ex Post Savings Results (Eversource only)

Annual kWh	Annual CCF	Lifetime kWh	Summer Demand	Winter Demand
88%	107%	130%		14%
(78-98%)	(73-142%)	(110-150%)		(-9-38%)

Note: Range in parenthesis show 90% confidence interval.

- Both Eversource and UI used a calculation that deviated from PSD

- 2017 thru 2020 PSDs used a square root factor, while ex ante calculation did not
- 2021 PSD also removes square root factor. However, the 2021 PSD used different multipliers than the ex ante calculation, so the prospective realization rate is close to 100%

The research team's adjustments to **Eversource** measure-level savings included the following:

- Overcount of Measures:
  - Reduced energy savings for 3 Eversource projects (electric) that claimed more fixtures than installed
- Adjustment for Prospective PSD: Changed savings to align with the 2021 PSD, described in the Verified Savings and Adjustments section above. Note that, while the Adjustment for Prospective PSD typically uses the 2020 PSD, the research team used the 2021 PSD for this measure because we found that the 2020 PSD calculation was technically incorrect.
- Lifetime Adjustments: Lifecycle savings increased for 11 projects that assumed 5 years for the EUL of both aerators and showerheads, whereas the 2020 PSD assumes 5 years for aerators and 10 years for showerheads.
- Demand Adjustments: Removed winter demand (kW) for 6 Eversource measures at 4 sites and summer kW for 1 site since the PSD assumes zero demand (kW) savings. The winter demand savings are greater than zero, because the winter demand savings includes the DHW heat pump, which had a 100% realization rate.

Measure-level Recommendations:

- Update calculator to reflect the 2021 PSD.
- Eversource should ensure the calculators show zero kW savings for this measure.
- Create a separate category for low-flow fixtures and for all other DHW measures (e.g., heat pump water heaters or natural gas-fired water heaters47), since they are very different measures.

6.11 Other Measures

In addition to the measures described above, the sampled projects included various other measures. These included:

- Duct sealing
- Central air conditioner
- Variable Frequency Drives (VFD)
- Wifi thermostats

The instances of these measures were low, and the savings were low. While they were included in the evaluation and affected the overall program realization rates, the research team does not present measure-specific findings for these measures. (In other words, this report does not include a section on

[47] Based on the sample of projects reviewed, low-flow fixtures were labeled as "DHW" and were far more common than water heating appliance measures. The research team identified only one natural gas fired water heater in the sample of projects reviewed, which was an Eversource project. The sample also included one heat pump water heater. It is possible that some of the small gas-only projects from UI that were excluded from the sample included water heating appliances. If the UI database clearly differentiated between low-flow fixtures and water heating appliances, a future study could identify the prevalence of water heating appliance measures.

measures that were only occasionally installed and that generated small savings.) If these measures become more common or contribute a larger fraction of savings in the future, future evaluations should determine measure-level realization rates if possible.

While the research team did not find systematic issues with the few instances of duct sealing, central air conditioning, or VFDs installed, the research team did make changes to the few instances of WiFi thermostats installed. This is because the 2020 PSD assumes half the savings in multifamily units from WiFi thermostats as for single-family homes, because of the reduction in heating and cooling in multifamily units. The 2017 and 2018 versions of the PSD did not reduce savings in half for this measure in multifamily units, so the research team reduced savings for the prospective savings[48].

[48] The research team did not apply this adjustment to retrospective savings for these WiFi thermostat projects, but only the prospective savings were used to calculate realization rates at the program and utility-wide level. WiFi thermostats were one of the few measures where there was a significant difference in results between prospective and retrospective savings.

7 Air Sealing Measure Investigation

7.1 Purpose and Background

The purpose of the air sealing investigation was to gain a better understanding of how this measure is currently implemented, and how savings are calculated to inform recommendations to improve the robustness of savings.

As background: Air sealing dwelling units involves identifying and sealing accessible leaks, such as around windows, doors, plumbing and HVAC equipment penetrations, electrical outlets on exterior walls, and other areas of the dwelling unit envelope area. Air sealing reduces air changes with the exterior, which provides heating and cooling savings. It can also improve comfort through reduced drafts. Table 36 shows the usual goals for an air sealing program, based on the research team's experience, and challenges with achieving these goals in multifamily units.

Table 36. Air Sealing Measure Objectives vs. Challenges with Achieving These Goals in Multifamily Units

Goal for Air Sealing Program Offering	Challenge with Achieving Goal in Multifamily Dwelling Units
Maximize air sealing savings	Some leaks are not accessible (e.g., blocked by large furniture, soffits, or other objects that are difficult to move), and any project must pass a cost-effectiveness test, which focuses work on larger leaks. More extensive sealing is more invasive to building occupants.
Accurately confirm that the claimed air sealing was accomplished	Measuring changes in air sealing typically involves a blower door test and conducting a test pre- and post-retrofit on every unit within a multifamily building would be a large cost. As explained in the next subsection, the program allows sampling for this reason.
Calculate the savings that occurred	Some air leakage will come from the exterior (which would reduce heating and cooling needs), but some air leakage will come from adjacent units or common corridors. The leakage from adjacent spaces is typically conditioned, so reducing this leakage would not provide heating and cooling savings. A blower door test shows total air leakage but does not show where this leakage comes from (i.e., fraction from adjacent spaces vs. the exterior)[49]. As explained below and discussed in more detail in section 7.3, the PSD requires that the projects de-rate savings using a multiplier (called the "blower door factor": BF) so that only a fraction of measured air leakage is claimed, to account for the leakage from adjacent (conditioned) spaces.

[49] A more complicated blower door test called a "guarded" test involves pressurizing adjacent spaces through multiple blower door fans, so they are neutral with the test unit and so that the leakage measured from the blower door fan in the test unit comes from the exterior. However, this uses much more equipment and time than a standard blower door test so is used for research purposes only. The research team is not aware of any program or building code that requires a guarded blower door test.

The PSD includes two paths for energy savings from air sealing:

1. Infiltration Reduction Testing (Blower Door Test). This is a performance-based path, which awards savings based on the difference in air leakage pre and post air-sealing, based on blower door testing. As described in the Calculator Reviews section, the PSD includes a "blower door" (BF) – a multiplier between 0 and 1 – to reduce savings in multifamily units to account for leakage from adjacent (conditioned) spaces.
2. Prescriptive Infiltration Reduction (Prescriptive). This awards savings based on number of air sealing materials installed, such as number of gaskets, door kits, or door sweeps; or per linear feet of weatherstripping or caulking.

Both methods have pros and cons. The first (performance-based) method is based on an actual measurement, but results must be adjusted to account for leakage to adjacent spaces. It can be more disruptive since the testing adds to the time needed to access each unit. The second (prescriptive) method is easier to implement but could miss significant sealing opportunities because there is no testing component. As described in the next subsection, almost all projects pursue the first (performance-based) method.

7.2 Contractor Interview Findings

All contractors interviewed said they prefer the first (performance-based) method, for reasons that include: more savings are available, the results are more accurate, and the blower door testing helps identify where to seal. Due to COVID-19 restricting access to units, for the 2020 program year, the contractors have shifted to a semi-prescriptive approach, which includes visual inspections instead of the blower door test. The utilities are paying the air sealing incentives based on person-hours. One contractor expressed that they like the hourly pay system, in part because it allows them to seal attics and basements, which they reported would otherwise not be covered by the blower door test method. Another contractor reported this system does not the cover costs of materials and did not seem to be aware of the additional incentive for attic and basement air sealing.[50] The research team did not investigate projects submitted under this alternative approach, because this evaluation covered program years 2017-2019. In addition, contractors reported they plan to return to the performance-based method once COVID-19 restrictions have lifted. The research team infers that contractors will therefore no longer seal dwelling units from the attics or crawlspaces, because the current incentive payment does not incentivize or compensate contractors for this work.

The remainder of this section only describes findings for the first (performance-based) method, since that was the method that contractors typically use. This aligns with the research team's findings from our project review: All projects in the sample used the performance-based method; none used the second (prescriptive) approach.

7.2.1 Contractors' process for air sealing

Contractors reported that they use the following process at each project for the air sealing measure:

1. The contractor conducts blower door tests on a representative sample of units to estimate savings. Each sampled unit receives a pre-sealing test, air sealing (referred to as "production"),

[50] It was beyond the scope of this study to compare the cost of air sealing with incentive amounts, although Section 7.4 provides a recommendation for utilities to gather data to conduct such a comparison.

and a post-sealing test. For most projects, 10% of units are sampled (per utility requirements), and includes a mix of units by orientation, size, and floor. In projects with more than 200 units, contractors can test a sample of 5% of units. Utility third party quality assurance (QA) inspectors are present for this testing. There is no testing or QA inspection after this step. Section 7.2.2 provides more discussion of this process.

2. The contractor submits airflow reduction results and dimensions of the building and typical units (needed to do the BF calculation) to the utility using the MF Fill Out Form.
3. The utility enters the sample results into a separate air sealing calculator. If the measure is cost effective, the utility approves the measure and determines the incentive for the project. Note that this determination that the air sealing measure is approved (i.e., is cost-effective) occurs *after* a sample of units have been sealed and tested, but *before* the bulk of the units have been sealed and tested. While contractors would ideally determine that the measure is approved before any units have been sealed, the utilities and contractors need some assurance that air sealing will be cost-effective at the project to move forward.[51]
4. Once approved, the contractor conducts sealing on the remaining units.
    - The contractors primarily seal exterior walls, but also seal common areas where appropriate (i.e., weather strip common area doors as needed when the hallway is heated).
    - Typically, contractors air seal all units in the project. Due to access issues, a few units may not be air sealed. But contractors reported they are typically able to seal 90-95% of units in a building.
    - Some contractors will typically air seal the same locations in all units. Others will change the work scope depending on the need as identified during the initial blower door testing based on unit type and, at times, the presence of health and safety concerns. One contractor conducts blower door tests of all units as part of an iterative approach to air sealing (i.e., test, seal, test again to identify improvements). The research team notes that, while the iterative approach would likely provide more energy savings, it also takes more time (labor costs); consequently, we do not recommend that the utilities require one approach over another.
5. The contractor's site supervisor conducts visual inspections after air sealing work is done. Some contractors will occasionally do a post-sealing test if they think something was missed.

The research team's file review confirmed that the above steps were followed in 2017-19. This includes the sampling rate identified above: Project documentation showed that 10% of units were sampled for blower door testing.

Generally, all contractors reported using use the following materials: caulk, spray foam, door sweeps/ door kits, backer rod and ROXUL for larger gaps, weatherstripping, and fireproof products where required. Some mentioned that they use rigid insulation, as well. A CT Department of Energy and Environmental Protection (DEEP) staff member reported that contractors may apply V-seal or other glued-on weatherstripping to exterior doors to reduce drafts. This type of product is not durable and

[51] The research team did not investigate the percent of air sealing projects that do not move forward because they are not found to be cost effective. However, this study found that air sealing is a very common measure, and at least one contractor described it as a "core" measure, which indicates it is cost effective for many projects.

may last for only a few months after installation. Most contractors reported they only sealed around the door if it is connected to the exterior or to an unconditioned corridor. None called out V-seal specifically. Project invoices do not show the materials, so the research team could not investigate whether glued on materials were used.

Several contractors stated that one motivation of conducting air sealing is to get the "comprehensive bonus". The comprehensive bonus is a kicker that the utilities provide if the project achieves significant savings from in-unit measures, which can be used to incentivize other (more costly) in-unit measures. Air sealing is inexpensive, but disruptive to the tenants, so owners can install this measure to buy down another measure. Contractors provided the example that the owner is motivated to get new LED lighting, so they will agree to do air sealing to get free LEDs; the same process could work to buy down heating and cooling measures.

7.2.2 Inspection Process

As described by contractors and utility staff, the contractor conducts pre-retrofit blower door testing, then air sealing, then post-retrofit blower door testing on a sample of projects *before* the measure has been approved by the utility. A third party-inspector observes this testing. Once the measure is approved, no additional blower door testing is conducted.

The research team identifies several potential problems with this approach:

- Since the incentive payment calculation is based on results of the sampled units only, there is an inherent motivation for contractors to do a more careful job of sealing the sampled units.
- There is a natural tendency for contractors to do a more careful job on the sampled units because they are being observed by the inspector (known as the "Hawthorne effect"). Consequently, results from the sampled units may not be representative of all units.
- Inspectors observe the blower door testing, but results could alternatively be verified from the blower door software, which logs results. While slightly less rigorous than visual observations, it is significantly less expensive.
- There is *no* inspection of blower door testing of non-sampled units. Consequently, contractors may not seal these units as carefully, and the inspector would not identify these oversights.

In summary, the results for the sampled units may not represent results for all units. In addition, there is more oversight than necessary on the testing of the sample, but not enough oversight on the units outside of the sample. Section 7.4 provides recommendations related to these findings.

7.3 Calculator Reviews

The research team reviewed the air sealing calculators for each utility to see how they were used for each of the 60 sampled projects with air sealing. This review revealed the following findings.

The utilities are reducing savings to account for infiltration from conditioned spaces but using different methods. It is not clear why the utilities use different methods, but as described in Section 7.4, the research team recommends that they both use the approach taken by Eversource, for reasons discussed below.

Table 37. Infiltration Reduction Calculation Methods by Utility

Utility	Blower Door Factor (BF)	Air leakage reduction claimed compared to measured
UI	Per the 2020 PSD methodology, based on project-specific data from the contractor, UI **calculates a project-specific BF** based on building dimensions, age, and other data. The BF in UI projects ranged from 0.46 to 0.84, with an average value of 0.61. Because of the multiple variables in the BF calculation, it is appropriate for the BF to vary as widely as it does in these UI projects. In two multifamily projects, UI erroneously claimed a BF of 1, which should only be used for single-family homes (since all infiltrating air comes from the exterior in single-family homes).	**Claimed all measured** reductions multiplied by the BF
Eversource	Assumes **0.925 for all projects.** The research team did not have enough information to recalculate an ex post adjustment, but 0.925 is higher than warranted given most building geometries.	Many calculators claimed lower leakage reductions ("CFM Reduction - Remaining Units") than measured through testing ("CFM Reduction - Test Units"). As explained below, Eversource calculates the "CFM Reduction - Remaining Units" using a calculation developed by Steven Winter and Associates

The Eversource calculator showed the adjustment to measured leakage as illustrated in the example below. For this example, 429 cfm was measured, but the savings calculation assumed 118 cfm.

Figure 16. Example reduction to measured air leakage (cfm) in Eversource air sealing calculator

Average Blower Door CFM reduction (TEST UNITS)	429
Average Blower Door CFM reduction (REMAINING UNITS)	118

Some Eversource projects did claim all measured savings – i.e., the "CFM reduction for Remaining units" was the same as the "CFM reduction for Test units." For others (as shown in the example in Figure 16), the "CFM reduction for Remaining units" was less than the "CFM reduction for Test units", but the calculator included in the project files did not document how the value in "CFM reduction for Remaining units" calculated – it was a hard-coded number.

The research team asked utility staff how the "CFM reduction for Remaining units" is calculated and requested a copy of the calculator. The Eversource staff reported in interviews and follow-up emails the following chronology of an adjustment factor to account for leakage from conditioned space:

- Through 2018 (including Program Years 2017 and 2018): Eversource was conducting custom billing analysis on every project to determine the claimed CFM reduction for energy savings, using a billing analysis calculator developed by Steven Winter and Associates (SWA).

- 2019 thru March 2020 (when Covid-19 shelter-in-place policies started): Eversource switched from using billing analysis and instead used a SWA prescriptive calculation method, based on a tool provided by SWA that was calibrated based on guarded blower door test values. Similar to the PSD BF method, this Eversource calculator reduces the measured leakage based on unit and building geometry. The calculator output is "CFM reduction for Remaining units".
- March 2020 through present: Eversource returned to using a billing analysis method, because blower door measurements were prohibited due to concerns of transferring contaminated air from (or to) neighboring units. Eversource staff reported it is onerous to conduct billing analysis for every project.

Based on the research team's review of air sealing projects installed in the 2017 through 2019 program years, Eversource's practice of reducing tested leakage through the SWA prescriptive calculation method appeared random. For some projects, "CFM Reduction for Remaining Units" was the same as measured (the "CFM Reduction for Test Units"), while for others it differed, and there were no trends by year. (In other words, there were 2017 and 2018 projects where the CFM Reduction for Remaining Units and CFM Reduction for Test Units were the same, and others where they differed; it was the same for 2019 projects.)

Eversource also provided an example calculator for the SWA prescriptive calculation method (used from 2019 through March 2020). The research team reviewed this calculator and found it determines the "CFM reduction for Remaining units" based on:

- Number of units in the building,
- Number of floors in the building,
- Dwelling unit ceiling height,
- Square footage of the dwelling unit, and
- Measured CFM reduction

In contrast, the PSD calculation is based on:

- Shared Surface Area (ft2) between conditioned spaces for each unit, and
- Envelope Perimeter (ft) (the sum of all the lengths of the edges of the unit, common and exterior surfaces) for each unit, and
- Measured CFM reduction

The research team tested a few example scenarios (i.e., dwelling units with different sizes, in buildings with different numbers of stories,) with the SWA prescriptive calculator and found that the **prescriptive calculator method** resulted in a reduction to cfm leakage (compared to measured leakage) ranging from **0.18 to 0.61**, while the **PSD method (as applied by UI)** resulted in a reduction to cfm leakage (compared to measured) ranging from **0.46 to 0.84.**

The research team views the SWA calculation method based on the SWA prescriptive calculator (used 2019 through March 2020) as preferred because it is based on a method that used guarded blower door data for calibration, and it requires inputs that are easier to determine (e.g., ceiling height, square footage, number of stories) than the PSD calculation inputs (shared surface area and envelope perimeter). In addition, it is simpler (less labor intensive) compared to billing analysis. However, because some Eversource projects claim the same "CFM reduction for Remaining units" as for "CFM reduction for Test units", Eversource appears to be applying its method inconsistently. In addition, because

Eversource applies a multiplier of 0.925 for all projects and has a lower value for "CFM reduction for Remaining units" compared to "CFM reduction for Test units" for many projects, the utility is reducing savings twice (i.e., double-penalizing itself), which is not accurate.

Note that other jurisdictions reviewed, including the New York and Massachusetts TRMs, do ***not*** reduce savings for infiltration from conditioned space in multifamily air sealing, so essentially assume a BF equal to one (1). Consequently, the CT PSD is more rigorous in this regard.

7.4 Recommendations

The following figure summarizes findings and recommendations for the air sealing measure.

Table 38. Air sealing findings and recommendations

Finding	Recommendation
Utilities are reducing savings to account for infiltration from conditioned spaces, using different methods.	Utilities should continue to reduce savings to account for this. But (once shelter-in-place lifts) both utilities should move to the Eversource calculation method (based on a SWA prescriptive calculator and used 2019 through March 2020) for calculating "CFM reduction for Remaining units", instead of the PSD blower door factor for estimating the reduction in leakage due to infiltration from conditioned spaces. Eversource should apply its calculation method consistently across projects and drop the 0.925 multiplier, since this double-penalizing savings.
The utility 3rd party inspectors shadow the contractor during blower door testing of a sample of units observing both before and after tests. They do no independent verification.	3rd party inspectors should test (or do visual inspections of) a sample of units separate from contractor's sample[52] to check that the contractor's sampled work represents remainder. • Inspectors should do some independent blower door testing instead of just shadowing contractor for blower door testing, and inspectors should spot check sample of "logged data" from blower door software. • The inspector's "pre" testing could be done the same days as the contractor's sample testing, and the "post" could be done while contractor is sealing the remaining units to reduce disruption to tenants.

[52] The research team did not gather field data, so cannot provide accurate information on whether a sample size of 10% is adequate, particularly in the case of buildings with small numbers of units (e.g., a sample size of two for a 20-unit building). Some sampling protocols require a minimum number for testing (e.g., at least seven), but this would incur additional costs for small projects, so they may not pass cost-effectiveness requirements.

Attics and basements can be leakage paths for dwelling units and be easier to seal than some dwelling unit areas. The current process gives no incentive nor measures any savings from these measures. One contractor reported the "person-hour" incentive mechanism (due to COVID-19) allowed for sealing attics and basements, but another was not aware that incentivized labor could be applied in these spaces and reported person-hour incentives did not cover costs.	Utilities should consider providing an option in the performance path to incentivize air sealing of common areas adjacent to dwelling units (e.g., attics, basements) to reduce dwelling unit leakage[53], and highlight offering in training. • Require invoices to show materials and their costs. • After one year, investigate costs of labor and materials (from invoices) compared to incentive, and readjust offering as needed.
CT DEEP staff reported that contractors may use V-seal (glued-on) around doorways, but that this product lasts for only a few months. Invoices reviewed for this study do not show sealing materials, so this could not be verified.	Prohibit use of glued-on sealing materials (such as V-seal for doorways) and require door kits that are nailed or screwed to the door frame, preferably with a rubber gasket that butts up against the door when it is closed. Per above, require invoices to show materials, and check that prohibited materials are not used.

[53] Based on our interviews, under current practices, contractors typically conduct all air sealing work on one unit before moving onto the next unit. For example, contractors conduct pre-sealing blower door testing, seal the unit, and then conduct post-sealing blower door testing of the unit; and then move to the next unit. This reduces blower door set up time, and the pressurization from the blower door fan can help identify leaks for sealing. The downside of this approach is that if the contractor seals the crawlspace or attic later, the effects of that sealing would not be captured. The utilities should create a mechanism to encourage sealing of attics, basements, and crawlspaces adjacent to units (e.g., prescriptive savings based on per linear foot of attic or crawlspace sealed).

8 Program Level Findings and Recommendations

8.1 Eversource Findings and Recommendations for Data Improvement

For Eversource projects in the sample, the research team adjusted savings for approximately one-fifth of the projects. Some projects had no documentation in the file. Others had multiple entries in the database for the same measure – in these cases, the second entry often had zero or low realization rate. Table 39 and Table 40 summarize the adjustments that the research team made to Eversource projects in the verified sample for energy savings, and for summer and demand savings, respectively.

Table 39. Summary of energy savings adjustments for Eversource projects

Adjustments to Annual Energy Savings (% of total: n=283)							
Under-claimed Savings	**Overclaimed Savings**			**Mix of under and overclaimed savings**			**No utility error**
Did not claim measure at all	Claimed but not documented	Wrong Calculation	Claimed more than installed	Incorrectly claimed Interactive Effects	Unclear why claim was incorrect	Wrong fuel claimed	Retrospective PSD used different calculation
2 (1%)	13 (5%)*	47 (20%)**	9 (4%)	9 (4%)	7 (3%)	5 (2%)	2 (1%)

* Of those 34 measures, 7 were the 2nd instance of the measure at same project

** Includes the 29 Eversource low-flow fixtures that all had the incorrect calculation. Without that adjustment, 8% used an incorrect calculation. Does not include the 70 dwelling unit lighting projects for which the research team applied an adjustment for an EISA-compliant baseline

Table 40. Summary of demand savings adjustments for Eversource projects

Additional Adjustments to Summer and Winter Demand (% of total: n=148 for summer, n=185 for winter)			
Under-claimed Savings	**Overclaimed Savings**		**Mix of under and overclaimed savings**
Did not claim kW, but had electric heat or A/C	Claimed winter kW when should be 0	Wrong calculation	Incorrect coincidence factor (CF)
3 (2%)	9 (6%)	2 (1%)	20 (14%)

To reduce or eliminate these issues, the research team recommends that the Eversource program staff make the following process changes:

1. Develop a final review process for each project to verify the following:
    - All measure installations are documented,
    - The number of measure installations align with the correct PSD calculations,
    - The correct heating fuel is identified,

    - Winter demand is claimed only for electric measures, and
    - The presence of air conditioning is captured correctly.
2. Correct measure-level program calculators as noted in Section 6, including:
    - Correct coincidence factors for demand calculations
    - Ensure that ECM Pump projects follow calculation for that measure
    - Update the low-flow fixture calculation to align with the 2021 PSD
3. Consider "rolling up" the savings for measures listed twice for the same site. As noted above, several projects had the same measure listed twice in the databased, and the second entry often had a zero or low realization rate.

8.2 UI Findings and Recommendations for Data Improvement

For UI projects, the research team adjusted approximately one-third of UI project savings.

Table 41. Summary of energy savings adjustments for UI projects

Adjustments to Annual Energy Savings (% of total: n=48)						
Under-claimed Savings	**Overclaimed Savings**				**Mix of under and overclaimed savings**	**No utility error**
Did not claim kW, but had A/C	Claimed more than installed	Claimed but not documented	Wrong Calculation*	Incorrectly claimed interactive Effects	Wrong fuel claimed	Retroactive PSD used different calculation
2 (4%)	3 (6%)	2 (4%)	2 (4%)	2 (4%)	2 (4%)	2 (4%)

In terms of demand adjustments, of the 17 measured with summer kW and 18 measured with winter kW, the only additional adjustment made for demand (kW) was for 1 measure with an incorrect coincidence factor.

For most UI projects in the sample, the "bottoms up" savings in the measure calculators did not sum to the project savings in the database. This made it very difficult for the research team to identify the source of the discrepancies between the ex post and ex ante project-level savings. In addition, many projects also had numerous files with conflicting information, including different values for the same installed measures. To find the ex post savings, the research team used the values in invoices or post-inspection reports wherever possible, but they often differed from the LoA Generator.

On a positive note, UI's calculators typically followed the PSD.

To reduce these issues, the research team recommends that the UI program staff make the following process changes:

1. Most importantly, track savings in the database at the measure level
2. Add a comparison of measure-level roll-up savings to the project-level claimed savings for each project
3. Provide some sort of clarification in files to distinguish outdated files from files with updated (correct) information. For example, label final files as "final" and old files with "archive" in the

file name, put out-of-date files in an “archive” folder, or include dates in file names to show the most recent files.

4. As described for Eversource, develop a final review process for each project to verify the following:
    - All measure installations are documented,
    - The number of measure installations align with the correct PSD calculations,
    - The correct heating fuel is identified,
    - Winter demand is claimed only for electric measures, and
    - The presence of air conditioning is captured correctly.

In addition, the research team recommends that UI staff review a sample of projects for which the database indicates gas-savings-only measures. This strikes the research team as surprising, since the Multifamily Initiative strives to be comprehensive, and because there were no case of gas-savings only projects in the Eversource database (based on the sample reviewed). UI staff should review a sample of projects shown as gas-savings-only to determine if these are

- Small, single-end-use projects – in which case UI should consider program design changes to encourage more comprehensive scopes, or
- Projects that are partially tracked - i.e., have other electricity measures at the same site that are tracked separately, possibly by other utilities – in which case UI should improve data tracking, or
- Other challenges and develop a solution accordingly.

To support this investigation and others, the research team recommends that UI add a field in its program database for “Service Address” that reflects the postal code of the project.

8.3 Recommendations for both Utilities to Diversify Savings

Based on results, the research team provides the following recommendations. These recommendations are aimed at reducing the reliance of program savings on lighting, for which opportunities are dwindling as the market naturally adopts LEDs. Note that the research team found that – for both UI and Eversource – most sites had several measures installed. However, lighting was typically the primary driver of savings. Other measures were frequently installed, such as air sealing and/or low-flow fixtures, but these were lower savings measures so contributed less savings.

Table 42. Findings and recommendations for both utilities to diversify future savings

Finding(s)	Recommendation
Lighting contributes 80% of ex ante electric savings in the Eversource database, but these measures are sunsetting as most customers are choosing LEDs without the program. In addition, the measure that contributed the most electricity savings to HES-IE, which serves buildings with low-income households, was common area / exterior lighting, which does not directly impact the energy bills of low-income residents.	Sunset dwelling unit lighting measures as soon as possible, and sunset common area and exterior lighting in the next few years. • Continue to incentivize common area and exterior lighting short term, since this serves retrofits and incumbent technologies (fluorescent indoors, and HID outdoors) which have long measure lives. But as natural market adoption replaces these incumbent technologies with LEDs, phase out this measure. • Consider removing the dwelling unit lighting measure offering, since LEDs are standard practice and incumbent technologies (incandescent) have short measure lives. Eversource reports they are discontinuing the dwelling unit lighting measure offering except for low-income customers. If the utilities continue to offer these measures for low-income customers, change the baseline wattage to an EISA-compliant lamp, and require photo documentation for a sample (10%) of removed lamps to show they are incandescent/halogen[54] or CFL.

[54] Per the discussion in Section 6.2, since EISA regulations phased out traditional incandescent light bulbs in 2014, incandescent light bulbs have a lifetime of 1000 hours, and the PSD assumes 2.5 hours of use per day, all bulbs removed (even through early retirement) should be compliant with the regulations OR in areas with such low hours of use that the PSD would overestimate their energy savings. Also as explained in that section, incandescent and halogen bulbs are both filament-based lamp and difficult to distinguish once removed from the package, so the program should assume any removed filament-based bulb is halogen.

Finding(s)	Recommendation
Contractors reported the comprehensive bonus allows them to install deeper savings measures, such as boilers and extensive lighting. Other MF programs are struggling to move away from lighting. One requires ≤ 50% savings from lighting, one provides kicker for heat pumps, and two require ≥ 15% whole building savings from electric, gas, and other fuels on a BTU-basis which necessitates other end uses. Other frequently installed measures in these programs include some that are installed often in the Multifamily Initiative (HVAC and attic insulation) and others that are rarely installed in the Multifamily Initiative (DHW replacement, duct insulation). The in-unit measures would also reduce energy bills and improve comfort for occupants, which could help improve equity and inclusion for low-income households.	Encourage installation of non-lighting measures and discourage reliance on lighting. • Continue to offer the comprehensive bonus and potentially increase it, or provide an additional kicker for non-lighting measures, like HVAC or DHW replacements, duct insulation, or for ≥ 15% whole building savings on a BTU-basis. • Consider requiring < 50% savings max from lighting. • Highlight case studies of HVAC or DHW measures at annual meeting and/ or provide annual awards for projects with diverse scopes of work or that installed a less commonly installed measure. • Investigate measures with future savings opportunities. This should include an investigation of electrification measures (e.g., estimates of energy and carbon impacts from moving from fossil-fueled based HVAC and DHW measures to electric sources such as heat pumps) to inform policy discussions that could consider allowing fuel switching in the program. Also investigate the impact of different measures on both energy and demand savings, since winter and summer demand are important for statewide goals. • Ensure that a diversity of in-unit measures are provided for HES-IE participants, particularly HVAC and envelope measures which can reduce energy bills and provide better comfort, to improve equity and inclusion[55].

[55] It was beyond the scope of this project to determine why a more diverse measure mix is not provided to more projects in the HES-IE program. A process evaluation could potentially explore issues such as how often contractors recommend multiple in-unit measure types to HES-IE projects, conversion rates of HES-IE multifamily participants moving forward with these recommendations, and other potential obstacles.

9 Conclusions

Overall, this evaluation found moderately high **realization rates** for annual energy (kWh and CCF) and lifetime savings. Summer demand savings were lower primarily due to the use of an incorrect coincidence factor. Winter demand savings were lower primarily because the program database incorrectly applied winter peak natural gas (CCF) savings to winter demand (kW) savings for several projects. The incorrect winter demand savings appeared to be a clerical error (e.g., someone copied the winter CCF savings to the peak winter demand savings), since the PSD clearly provides different calculations for the two metrics, and the erroneous winter demand (i.e., kW) savings were claimed for measures that affected natural gas (not electric) equipment.

For the HES and HES-IE programs, the realization rates of all metrics evaluated were between 56% and 93%, so were moderate to high for all metrics. Realization rates did not vary much between utilities for annual electricity, lifetime savings, and summer demand savings. UI had a higher realization rate than Eversource for winter demand, while Eversource had a higher realization rate than UI for annual natural gas (CCF) savings. For both utilities, the realization rates of all metrics evaluated were between 58% and 102%, so were moderate to high for all metrics.

The research team identified various **opportunities for improving data tracking and correcting calculations**. The Eversource database tracks savings at the measure level, and this utility's files typically documented measure installation. However, the research team found that some measures were not documented, a few measures did not follow the PSD calculations, and claimed savings were sometimes based on the original plans (for number of measures or efficiency of equipment) instead of what was actually installed (based on invoices or post-inspection reports). The research team recommends that Eversource staff conduct a final review before project savings are entered in the database to catch these and other errors, and that Eversource corrects calculators for several measures as described in this report. The UI database does not track savings at the measure level, and the sum of measure-level savings that the research team found in project files often did not equal the database claim for that site. This made it more difficult to identify discrepancies between ex ante and ex post savings. The research team highly recommends that the UI database track savings at the measure level. UI calculators did almost always follow the PSD calculations. However, UI files had many of the same issues as Eversource (some undocumented measures, some savings claims that matched the initial plans but not invoices), so the research team recommends the same final review for each project for UI as we do for Eversource.

With almost one thousand sites enrolled across the two utilities for program years 2016-2019 (872 from Eversource and 121 from UI[56]), **the Multifamily Initiative appears to be successful in reaching many multifamily projects**. In addition, approximately two-thirds of participating sites participated in the HES-IE program, indicating that the Initiative is impacting many income eligible customers. However, note that the measure providing the most electricity savings is common area or exterior lighting, so residents would not enjoy energy bill reductions from this measure. Even though HES-IE is serving multifamily projects, it has a larger proportion of projects that are common area and exterior lighting compared to HES, which do not directly serve the residents.

[56] In addition, there were approximately 300 projects from UI that had gas-savings-only measures.

The Multifamily Initiative is achieving its goal of providing a variety of measures in both dwelling units and common areas. Lighting provides the most savings, but most sites had at least one other measure that was not lighting, including low-flow fixtures, air sealing, insulation, or refrigerators. HVAC measures (e.g., central boilers for heating or HVAC heat pumps) were less common but were installed in a handful of projects.

However, **80% of ex ante electricity savings is from lighting**. This is problematic since the market is naturally adopting LEDs. The initiative should phase out savings from lighting and actively work with contractors to increase the diversity of measure types installed. As discussed in more detail in Section 8.3, this could be done through both a carrot and a stick approach of additional incentives and awards for non-lighting measures, and requirements that no greater than a certain fraction of savings come from lighting or that multiple measure types be installed.

In general, the programs are successfully recruiting projects from this sector, which typically requires proactive engagement. But the programs should increase savings from non-lighting measures if they are to continue to provide similar savings in the future and so that they can best serve the needs of multifamily building occupants.

10 Appendix A. PSD Multifamily Measure Review and Recommendations

Please view this attached file by clicking the paperclip icon on the left-hand side of your PDF browser, then open the file named "CT-X1941-AppendixA-PSD MF Measure Review_Recommendations.

11 Appendix B. Adjustments to Projects

The CT-X1941 Analysis Workbook Summary contains the adjustments the research team made to the annual energy savings and the summer and winter demand for both utilities. That workbook is available at the following link [*we will add link to posting on Energize CT website*]

The following tables show the fields included this workbook. Note that:

- The "Measure Name" column shows how the measure was listed by the utility. The "Measure name if unclear" column shows how the measure was categorized by the research team. For many measures, the entries are identical. For others, the research team measure name was more specific. For example, if the "Measure Name" was lighting, the "Measure name if unclear" entry clarifies if it is dwelling unit lighting or common area / exterior lighting.
- The "Prospective" savings columns show savings that the research team calculated using the 2020 PSD.[57] These are the "forward looking" realization rates that the research team reported.
- The "Retrospective" savings columns show savings that the research team calculated using the PSD under which the project participated (so the 2017, 2018, or 2019 PSD). The purpose of this calculation was to illustrate the adjustments that were only caused due to updates in the PSD. For most measures, the savings calculations were not significantly different.

Column	Column Section Heading	Column Heading
A		Project Number
B		Program
C		Program Year
D		Measure Name
E		Measure Name if unclear
F		Eversource database measure category
G		Heating Fuel (electricity, oil, gas, propane)
H		Cooling (Yes/ No/ Don't know)
I	Ex Ante (Claimed)	kWh
J		Lifecycle kWh

[57] As described in Section 6, for two measures: low-flow fixtures, and dwelling unit lighting, the research team calculated savings using a recommended approach for the 2021 PSD. This was because the 2020 PSD calculation did not appear accurate for those measures.

Column	Column Section Heading	Column Heading
K		Summer Demand (kW)
L		Winter Demand (kW)
M		Gas (CCF)
N		Gas Lifetime Savings (CCF)
O		total_oil_annual_savings (gal)
P		total_oil_life_time_savings (gal)
Q		Measure verified as installed?
R	Prospective: Ex Post (Verified)	kWh
S		Lifecycle kWh
T		Summer Demand (kW)
U		Winter Demand (kW)
V		Gas (CCF)
W		Gas Lifetime Savings (CCF)
X		total_oil_annual_savings (gal)
Y		total_oil_life_time_savings (gal)
Z	Retrospective: Ex Post (Verified)	kWh
AA		Lifecycle kWh
AB		Summer Demand (kW)
AC		Winter Demand (kW)
AD		Gas (CCF)
AE		Gas Lifetime Savings (CCF)
AF		total_oil_annual_savings (gal)
AG		total_oil_life_time_savings (gal)

Column	Column Section Heading	Column Heading
AH		Verification Method
AI		Main finding from data collected from facility manager or onsite
AJ		Comments

Please view the attached file by clicking the paperclip icon on the left-hand side of your PDF browser, then open the file named "CT X1941-AppendixB-Adjustments_to_Projects_6.29.21".

12 Appendix C. Air Sealing Contractor Interview Guide

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Air Sealing Contractor Interview Guide

BACKGROUND

Project X1941 includes conducting an impact evaluation of Eversource and United Illuminating's programs with high savings from multifamily retrofit projects. In-field verification of measures has been challenging due to Covid. A commonly installed in-unit measure within the Home Energy Solutions (HES) and HES-Income Eligible (HES-IE) programs is air sealing. However, several factors are unknown regarding this measure, including what building elements are sealed, the fraction of units that contractors test to verify savings, and whether they consistently follow the Program Savings Document (PSD) savings calculation. Another commonly installed measure is in-unit lighting, which will likely be de-emphasized in future program years as the market naturally shifts to LEDs. Consequently, TRC has proposed that we conduct desktop verification of in-units measures, and divert funding to conducting interviews with air sealing contractors to gain a better understanding of how this measure is currently implemented, to inform recommendations to improve the robustness of savings.

RESEARCH QUESTIONS

The following research questions would be addressed through the interview questions:

Research Question	Interview question(s)
How do contractors develop a scope of work for air sealing?	4, 5
What processes do contractors follow for air sealing units?	9, 10, 11, 15
How rigorous and consistent is their air sealing process?	12, 13, 14
What is the process that contractors follow for measuring the improvement of air sealing?	16, 17, 18, 19, 21, 23, 24
How rigorous and consistent is their air sealing measurement process?	20, 22, 25, 26, 27
What process do contractors follow for determining energy savings from air sealing units?	28
Does their energy savings calculation process align with the Program Savings Document (PSD)? If not, why not?	29

For each research question above, how much variation exists among contractors?	Compare results from each question across contractors
What are drivers and barriers to air sealing?	6, 7, 8, 30, 31

CONTRACTORS FOR INTERVIEW AND RECRUITMENT PROCESS

TRC will review at least 24 project files (16 from Eversource, 8 from UI) to identify air sealing contractors for interview. To date, TRC has reviewed six files and identified that the following contractors performed air sealing in the following number of projects:

TRC will continue to build out this table based on additional file reviews. The goal is to interview staff from at least six air sealing contractors (assuming there are at least twelve active contractors). To recruit contractors for interviews, TRC will:

- Request that the utilities send an advance notice to the contractor, notifying them that TRC will be conducting the interview
- Email the contractor requesting an interview time.
- Follow up with a phone request for an interview.
- Contact the contractor at least four times requesting an interview.

Based on TRC's experience, contractors are reluctant to provide phone interviews so a high incentive will be required. TRC will offer the contractor $200 for the interview, which should last approximately 45 minutes.

GUIDE

Introduction

This is [NAME] from TRC, on behalf of [Eversource, UI or both], as part of their periodic evaluation of their EnergizeCT's energy programs. Thank you for taking time for this interview. We are interviewing contractors about air sealing processes, testing, and savings calculations in multifamily units for the HES and HES-IE programs. We will be looking for improvements for air sealing savings estimates and recommendations for documentation. Your responses will be combined with those of other contractors so will be anonymous. You will receive a $200 electronic gift card for completing this survey, which takes approximately 45 minutes.

Do you have any questions before we get started?

Role and background

1. First off, what is your title and role please?
2. Besides air sealing, what other types of services for existing multifamily buildings does your company provide?

Level of activity, drivers, and barriers

3. For approximately how many multifamily buildings has your company conducted air sealing in the past year? Since current events may have impacted your business, about how many multifamily buildings does your company air seal in a typical year?
4. How do you decide whether air sealing is needed in a building?
5. Do you seal all units in a building? If not, ow do you decide which units to seal?
6. What is an owner's typical reasons to conduct air sealing?
7. What are the owners' challenges with conducting air sealing?
8. What are your main challenges from an implementation perspective with conducting air sealing?

Air Sealing Process

Now let's discuss your process for air sealing multifamily units.

9. What elements of the unit do you seal? [if needed, probe: for example, around windows, around outlets, around plumbing penetrations, corner trim, etc.]
    a. Do you weather-strip doors?
    b. Do you improve windows with weather-stripping or new hardware?
    c. Do you always seal the same elements in a unit? If not, what does it depend on?
10. Do you always air seal from the interior or do you ever air seal from the exterior?
    a. How do you decide whether interior or exterior air sealing will work best for a building? (i.e., Are you limited by the number of stories?)
11. What materials do you use to seal those building elements?
12. Do you also seal common areas, or only the units?

Testing and savings documentation

Thanks for that information. Let's shift to discussing how you determine improvement.

13. Do the utilities provide training on the procedures for recording information in the Fill Out Forms for HES and HES-IE (Energize CT, Multifamily Initiative)?
    a. Are there other forms that you submit to the program (aside from the Fill Out Form)?
14. The Connecticut Program Savings Document (PSD) includes two paths for air sealing: Infiltration Reduction Testing (Blower Door Test), and a Prescriptive Infiltration Reduction (Prescriptive). Does your company follow either or both of those paths?
15. [If both]: How do you decide which path a particular project should follow?
16. [If they only follow one]: Why do you follow that path and not the other?

[If they ever conduct the infiltration reduction testing] For the Infiltration Reduction Testing (Blower Door Test),

17. Do you conduct blower door testing prior to sealing?
18. If so, on how many units? [Probe on whether this is a percentage basis, minimum number of units, or some combination thereof]
19. Do you conduct blower door testing after sealing?
20. If so, on what percent of units?

21. Do you conduct the pre blower door test on your sample, seal, and post test results on the sample on the same day?
22. If so, about how many units do you test and seal each day?
23. Do you have any in-house quality assurance to make sure the unsampled units get same level of sealing?
24. Do you ever use a whole building approach to testing where you test all units in the building?
25. Do you ever conduct blower door testing on common areas?
26. How do you document the results of this testing?
27. Do you submit all test results to each utility? If not, what is the reason?

[If they ever follow the prescriptive infiltration reduction path]

28. Do you conduct any quality assurance or checks on air sealing, such as a visual verification or use a smoke pencil to check for leaks?

Savings Claimed and Calculations

We're almost finished. I'd like to close with some questions about savings calculations.

29. When calculating savings for the Infiltration Reduction Testing path, do you calculate savings yourself or submit inputs for the utility to calculate savings?
30. [if needed, based on response to prior question]: The PSD has a "blower door factor (BF)" to account for infiltration from adjacent spaces. It is a multiplier to discount savings, and is approximately ~70-90% depending on the unit configuration.
    a. Are you aware of this factor?
    b. To calculate the factor, the utility needs inputs such as unit dimensions. Do you submit this information to the utilities?
    c. If you were aware of it but do not apply it, please explain your rationale.
31. Do you have any recommendations to the program to streamline the air sealing documentation process?
32. Those were all of my questions. Do you have any final comments?

Thank you again for your time. I'm planning to send the gift card to the following email address: [read contractor's email address]. Is that correct?

Thank you.

CONTACT INFORMATION FOR COMMENTS:

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510-400-5374

CC: Marian Goebes

13 Appendix D. Air Sealing Utility Interview Guide

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Interview Guide for Utilities Regarding Air Sealing Calculations

BACKGROUND

Project X1941 includes conducting an impact evaluation of Eversource and United Illuminating's programs with high savings from multifamily retrofit projects. In-field verification of measures has been challenging due to Covid. A commonly installed in-unit measure within the Home Energy Solutions (HES) and HES-Income Eligible (HES-IE) programs is air sealing. However, several factors are unknown regarding this measure. Many of these factors are controlled by contractors, including what building elements are sealed, how they are sealed, and testing procedures; TRC is exploring these issues through contractor interviews. TRC's interviews with air sealing contractors are finding that the utilities calculate air sealing savings based on information provided from the contractors.

RESEARCH QUESTIONS

The following research questions would be addressed through the interview questions:

Research Question	Interview question(s)
What process do the utilities follow for determining energy savings from air sealing units?	3 through 7
Does their energy savings calculation process align with the Program Savings Document (PSD)? If not, why not?	8 through 14

UTILITY STAFF FOR INTERVIEW

TRC proposes to interview at least one staff member from each utility, Eversource and UI, who calculates air sealing savings on behalf of the utility.

DRAFT GUIDE

Introduction

This is [NAME] from TRC, as part of the periodic evaluation of their EnergizeCT's energy programs. Thank you for taking time for this interview. We are interviewing contractors about air sealing processes, testing, and documentation of results in multifamily units for the HES and HES-IE programs. Because the utility staff (not contractors), are responsible for conducting the air sealing savings calculations, we are conducting this interview today to understand the utility's processes for the air sealing savings calculations. We will be looking for

improvements for air sealing savings estimates and recommendations for documentation. This interview should last 20 to 30 minutes.

Do you have any questions before we get started?

Role and background

1. First off, what is your title and role please?
2. What is your role specifically as it relates to supporting the Multifamily Initiative?

Savings documentation

The Connecticut Program Savings Document (PSD) includes two paths for air sealing: Infiltration Reduction Testing (Blower Door Test), and a Prescriptive Infiltration Reduction (Prescriptive).

3. What information do you typically receive from contractors for calculating air sealing savings for the Infiltration Reduction (Blower door) path? [Interviewer: probe for components, such as
    a. Leakage (CFM) pre and post; number of units in building; number of units tested;
    b. Heating and cooling system information: heating system fuel: natural gas, electricity, fuel oil; heating system type – electric resistance, heat pump, geothermal, natural gas; cooling system (if present)
    c. For Blower Door Factor (BF): shared surface area between conditioned spaces, and envelope perimeter, for each unit tested
4. Does this vary by contractor? If so, how?
5. If some of the calculation components are not provided, what deemed values or assumptions do they use, and what are the sources for these values?
6. What information do you typically receive from contractors for calculating air sealing savings for the Prescriptive Infiltration Reduction (Prescriptive) path? [Interviewer, probe for:
    a. Number of weatherization measures installed – length of caulking, number of gaskets, number of door kits, etc.
    b. Heating and cooling information: heating fuel, heating system type, if central air conditioning is present]
7. Does this vary by contractor? If so, how?
8. If some of the calculation components are not provided, what deemed values or assumptions do they use, and what are the sources for these values?
9. Do the utilities provide training on the procedures for recording information in the Fill Out Forms for this measure?
    a. Are there other forms that you submit to the program (aside from the Fill Out Form)?

Savings Claimed and Calculations

Now I'd like to ask some questions about savings calculations.

10. For the Infiltration Reduction Testing (Blower Door Test), please describe the process you take for calculating savings for a multifamily building.

11. The PSD has a "blower door factor (BF)" to account for infiltration from adjacent spaces. It is a multiplier to discount savings, and is approximately ~70-90% depending on the unit configuration. Are you aware of this factor?
    a. What process do you follow for calculating this factor?
    b. What inputs do you use?
    c. If the project does not provide those inputs, what deemed or assumed values do you use? What are your sources for those assumptions?
12. For the Prescriptive Infiltration Reduction (Prescriptive), please describe the process you take for calculating savings for a multifamily building.
    a. What inputs do you use?
    b. If the project does not provide those inputs, what deemed or assumed values do you use?
13. Do you think the processes for calculating air sealing savings for the Infiltration Reduction Testing (Blower Door Test) path is burdensome? Please explain.
14. Do you think the processes for calculating air sealing savings for the Prescriptive Infiltration Reduction path is burdensome? Please explain.
15. Do you have any recommendations to the program to streamline the air sealing documentation process?

Inspections and Closing

16. Based on interviews with the air sealing contractors, we understand that a 3rd party inspector is present for the air sealing testing. Is an inspector present for all projects with air sealing, or is there a minimum threshold of units or savings to trigger the inspection?
17. Based on interviews with the air sealing contractors, it sounds like most contractors do all of their work (pre-leakage test, air sealing, and post-leakage tests) for 10% of units before applying for the incentive; once the application is approved, they air seal remaining units without further testing.
    a. Does an inspector ever conduct quality assurance (QA) on the remaining 90% of units?
    b. If so, when is that triggered, and what QA do they perform
18. Those were all of my questions. Do you have any final comments?

Thank you again for your time.

Appendix: Blower Door Infiltration Calculation from PSD

The following are excerpts from the PSD showing the infiltration reduction calculations

4.4.2 Infiltration Reduction Testing (Blower Door Test)

Description of Measure Blower Door Test equipment is used to verify infiltration reduction.

Inputs

Table 4-EEE: Inputs

Symbol	Description
CFM_{Pre}	Infiltration Before Air Sealing @ 50 Pa
CFM_{Post}	Infiltration After Air Sealing @ 50 Pa
	Heating Fuel Type (e.g., electric resistive, heat pump, natural gas, oil, propane, etc.)
	Heating System Distribution Type (e.g., forced air with fan, heat pump, resistive, radiator, etc.)

For electric resistive, heat pump, or geothermal heating systems:

$$AKWH_H = REM_{Heating} \times (CFM_{Pre} - CFM_{Post}) \text{ x BF}$$

For Fossil Fuel heating with air handler unit:

$$AKWH_H = REM_{AH} \times (CFM_{Pre} - CFM_{Post}) \text{ x BF}$$

For homes with natural gas heating system:

$$ACCF_H = REM_{NG} \times (CFM_{Pre} - CFM_{Post}) \text{ x BF}$$

For homes with oil heating system:

$$AOG_H = REM_{Oil} \times (CFM_{Pre} - CFM_{Post}) \text{ x BF}$$

For homes with propane heating system:

$$APG_H = REM_{Propane} \times (CFM_{Pre} - CFM_{Post}) \text{ x BF}$$

For homes with cooling:

$$AKWH_C = REM_{Cooling} \times (CFM_{Pre} - CFM_{Post}) \text{ x BF}$$

For the blower door reduction factor (BF) for multifamily units:

$$Calculated\ blower\ door\ CFM\ reduction = BF \times Measured\ CFM\ (Unguarded\ Blower\ Door\ Test)$$

$$BF = 0.7818\ - .0002 \times D + 0.0012 \times F$$

Where:

- D = Shared Surface Area (ft^2) between conditioned spaces.
- F = Envelope Perimeter (ft) is used to describe the sum of all the lengths of the edges of the unit, common and exterior surfaces.

4.4.7 Infiltration Reduction (Prescriptive)

Description of Measure Prescriptive infiltration reduction measures not validated by Blower Door testing, including: electric outlet covers, door sweeps, door kits, caulking and sealing, polyethylene tape, weather-strip doors/windows, and window repairs.

Savings Methodology Savings from this measure shall only be claimed if a Blower Door Test (Measure 4.4.4) is not feasible. Savings estimates based on actual measured infiltration reduction (through blower door testing) are more precise.

Note: *Infiltration reduction measures must be located directly between conditioned space and unconditioned space to be eligible for energy savings. Savings may not be claimed for both a Door Sweep and a Door Kit for weatherization of a single door.*

Savings are calculated by multiplying the savings per unit by the number of units, and then adding all the different measure types together to get total savings. No summer demand savings may be claimed since cooling energy savings are not quantified.

Inputs

Table 4-DDDD: Inputs

Symbol	Description
n	Number of Each Air Sealing Unit Installed
length	Total Length Installed of Caulking and Sealing, including Polyethylene Tape (in linear feet)
	Heating System Type

Retrofit Gross Energy Savings, Electric

Table 4-FFFF: Electric Savings for Infiltration Reduction Measures

Savings	Units	Annual Savings for Electric Resistance Heating (kWh)	Annual Savings for Heat Pump (kWh)
$AKWH_{gasket}$	kWh per gasket	9	4.5
$AKWH_{door\ kit}$	kWh per sweep	173	86.5
$AKWH_{sealing}$	kWh per linear ft	9.9	4.95
$AKWH_{wx}$	kWh per linear ft	11.5	5.75

Retrofit Gross Energy Savings, Fossil Fuel

$$Annual\ Btu\ Savings = \frac{AKWH \times 3412\ ^{Btu}/_{kWh}}{75\%}$$

Table 4-GGGG: Fossil Fuel Savings for Infiltration Reduction Measures

Measure	Units	ACCF	AOG	APG
Gasket	fuel per gasket	0.41	0.29	0.45
Door Kit	fuel per sweep	7.87	5.62	8.59
Sealing	fuel per linear foot	0.451	0.322	0.492
Window & Door Weatherization	fuel per linear foot	0.524	0.374	0.571

Nomenclature

Table 4-EEEE: Nomenclature

Symbol	Description	Units	Values	Comments
…gasket	Installation of Air Sealing Gasket on an Electric Outlet	per gasket	Tables 4-FFFF, 4-GGGG	Ref [1], p. 1-11, Table ES 9
…door kit	Installation of Door Sweep or Door Kit	per sweep	Tables 4-FFFF, 4-GGGG	Ref [1], p. 1-11, Table ES 9
…sealing	Foot of Caulking, Sealing, or Polyethylene Tape	per foot	Tables 4-FFFF, 4-GGGG	Ref [1], p. 1-11, Table ES 9
…wx	Window Repaired, Window Weather-stripped, or Door Weather-stripped	per linear foot	Tables 4-FFFF, 4-GGGG	Ref [1], p. 1-11, Table ES 9
ACCF	Annual Natural Gas Savings	ccf/yr		
AOG	Annual Savings for Oil Heat	Gal/yr/unit		
APG	Annual Savings for Propane Heat	Gal/yr/unit		
EF	Fossil Fuel System Efficiency, Including Distribution Loss		0.75	
PDF_H	Peak Day Factor – Natural Gas Heating		0.00977	Appendix One
PF_W	Winter Peak Factor	W/kWh	0.570	Ref [1]
WKW	Winter Seasonal Peak Electric Demand Savings	kW		

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