


R1705 R1609 Multifamily Baseline and Weatherization Opportunity Study

prepared for

Connecticut Energy Efficiency Board

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CT EEB R1705 R1609 Multifamily Baseline and Weatherization Opportunity Study

The Connecticut Energy Efficiency Board (EEB) commissioned ERS to conduct a baseline and weatherization study of multifamily (MF) units in Connecticut. This research informs the EEB's and utilities' strategies to achieve the Public Act 11-80 mandate to weatherize 80% of residential units in Connecticut by 2030, building on prior and concurrent baseline and weatherization research on single-family (SF) homes.

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This study achieves three primary objectives: 1) estimating the quantity and key characteristics of MF units in Connecticut; 2) conducting on-site visits to validate tenant responses to the Residential Appliance Saturation Survey (RASS) and collect weatherization characteristics; and 3) estimating the statewide technical potential savings if all systems were converted to high-efficiency alternatives in MF units.

This study's field data collection focused on the apartments of 137 tenants that completed the RASS. While common area data collection was not a primary focus, ERS engineers collected key common area data when possible. After aggregating, cleaning, and reviewing unit-level data, in coordination with the concurrent SF study, ERS analysts developed tables and figures to characterize the typical apartment in CT by segments of interest (e.g., rent/own). This market data will be valuable for baseline assumptions in the PSD.

Results of the unit-level analysis are summarized in the graphic to the right.

REFRIGERATORS
- **41%** are ENERGY STAR qualified
- **17%** have exceeded EUL of 11 years
- **90%** have inefficient "top freezer" configuration

THERMOSTATS
- **68%** of units have basic dial thermostats
- Only **2%** have Wi-Fi-enabled smart thermostats

LIGHTING
- **35%** CFL
- **28%** LED
- **23%** Incandescent

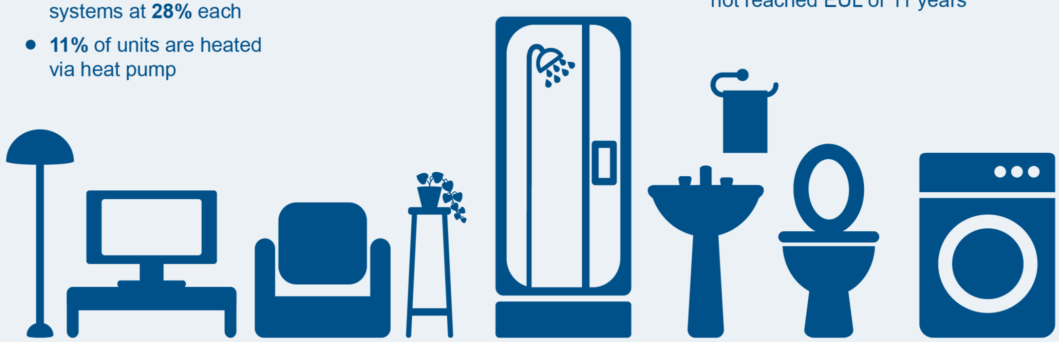
DISHWASHERS
- **72%** of units have a dishwasher
- **64%** are ENERGY STAR qualified
- **80%** have not reached EUL of 10 years

WEATHERIZATION
- **50%** of units are eligible for weatherization upgrades
- Old buildings are less likely to be air-sealed/insulated
- Inefficient windows are in **6%** of units

HEATING
- **54%** of units are primarily heated with natural gas
- Furnaces and electric baseboards comprise the highest shares of heating systems at **28%** each
- **11%** of units are heated via heat pump

COOLING
- **87%** of units have cooling
- **51%** of cooling is provided by room air conditioners
- Heat pumps comprise **12%**

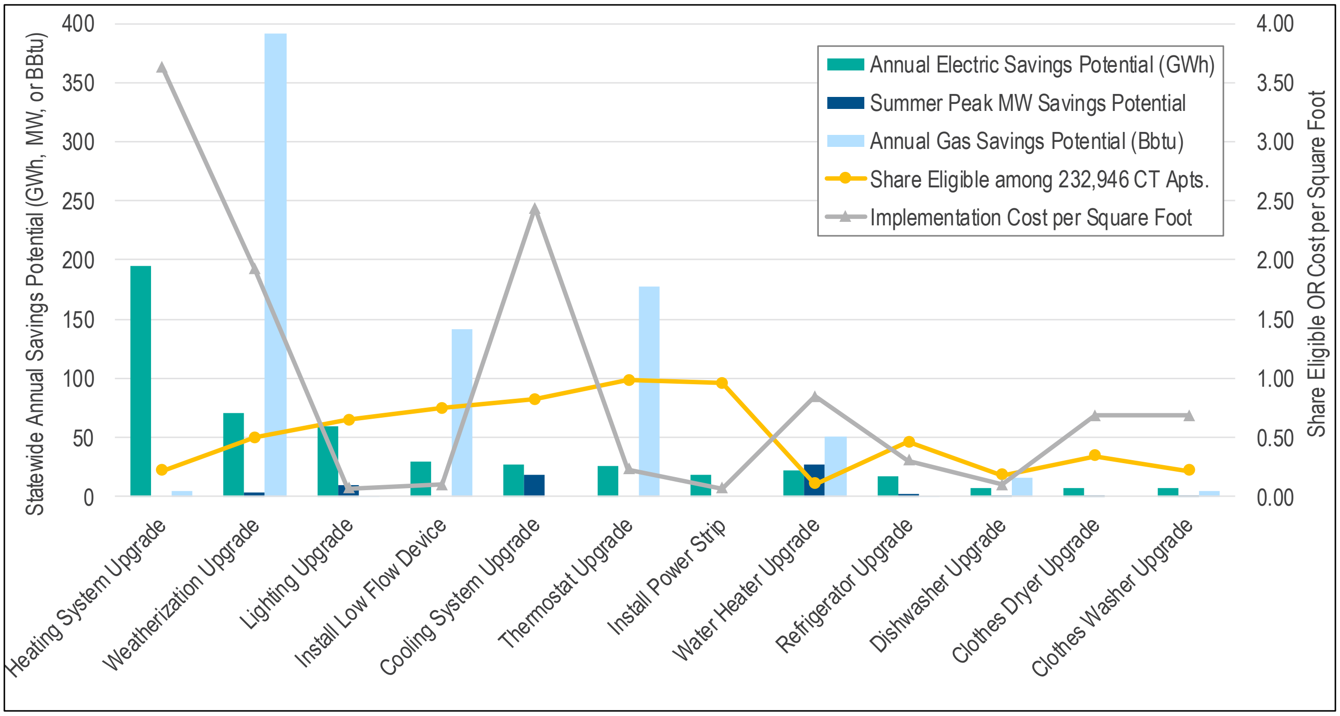
WASHERS & DRYERS
- **50%** of tenants have in-unit washers
- **50%** washers and **9%** dryers are ENERGY STAR qualified
- **70%** washers and **60%** dryers have not reached EUL of 11 years



ADVANCED POWER STRIPS (APS)
- **4%** of units have at least one APS
- **1.5** entertainment hubs and **0.6** IT hubs per unit would benefit from an APS

LOW-FLOW DEVICES
- The average unit has **3.7** faucets (sinks/showerheads)
- Showerheads are the least efficient, with an average flow rate approx. **0.5** gpm higher than an efficient alternative

Comparing existing conditions with high-efficiency alternatives for Connecticut's 232,946 occupied MF units shows significant technical savings potential statewide, as illustrated in the figure below for electric (GWh) and gas (BBtu).



Key Conclusions

1. Conversion to air-source heat pumps (ASHPs) presents the most promising savings opportunity of any measure considered in this study. We found that 28% of MF units are heated by electric resistance baseboards while only 8% are heated via ASHP, indicating significant potential for higher electric efficiency. Using ASHPs to replace existing non-electric heating would also result in significant carbon savings from fuel switching.
2. 50% of the state's MF units would benefit from at least one weatherization measure. This weatherized share is comparatively higher than that found in the 2014 SF study. Weatherization opportunities depend closely on building vintage for all measures studied, with older buildings offering greater savings potential.
3. There are significant savings opportunities from LED upgrades in tenant units. LEDs comprise only 27% of lighting sockets, while incandescents comprise 23% of sockets and 38% of stored bulbs.
4. Smart thermostats and advanced power strips offer significant savings opportunity because nearly the entire statewide MF population is eligible for upgrade.

Recommendations

1. Pursue deeper penetration of low-cost measures that offer significant savings potential, including LED lighting, smart thermostats, low-flow devices, and advanced power strips.
2. Electric heating system upgrades and weatherization measures should be further assessed for feasibility, achievable savings, barriers, and contractor training needs in Connecticut.
3. As key common spaces such as basements and rooftops were not always accessible, we recommend that this study be supplemented with a similar baseline study with MF common areas as the focus.
4. This study quantified technical savings potential, which does not consider measure cost-effectiveness, implementation barriers, or market adoption rates. We recommend that a follow-up, global economic or achievable potential study be conducted, using this study's research as a starting point for the MF sector.
5. Given Connecticut's focus on carbon emissions reduction as well as the preponderance of electric resistance and oil space-heating for MF units, we recommend that further research be conducted on strategic electrification opportunities.

Contents

Glossary of Terms

Adjusted – An objective of this study was to validate responses to the residential appliance saturation survey (RASS, see below). The term "adjusted" refers to true-up of self-reported RASS data with on-site findings.

Common area – A multifamily (MF) building's spaces that are accessible to all tenants. For the purposes of this study, common area also includes non-dwelling spaces such as basements and mechanical rooms.

Conditioned floor area (CFA) – The square footage conditioned by an HVAC system.

Effective useful life (EUL) – The median length of time (in years) that an energy efficiency measure is functional.[i]

Eligibility – In this study's technical savings potential analysis, the share of statewide multifamily tenants eligible for equipment upgrade. The value discounts two groups of tenants: 1) the share of tenants that already use high-efficiency equipment, and 2) the share of tenants without the equipment altogether.

In-unit – Dwelling spaces only within a multifamily building.

Low income – Per the eligibility requirements of the Home Energy Services (HES) Income Eligible program, low income describes Connecticut residents at or below 40% of the statewide median household income.

Per-unit – An individual apartment's savings from an upgrade to high-efficiency equipment. These results are later scaled statewide using the count of MF units in Connecticut.

RASS – The residential appliance saturation survey (RASS) was administered to Connecticut residents in 2018, gathering self-report information on demographics and equipment characteristics on appliances, electronics, and HVAC and DHW systems.

Source savings – Source savings take into account generation, transmission, and distribution losses for electricity as well as fossil fuels, providing an equitable quantification of savings among different energy sources.

Technical savings potential – Energy savings opportunity reflecting existing market conditions and business-as-usual program operations and assuming adoption of higher-efficiency

[i] Lawrence Berkeley National Laboratory, "Energy Savings Lifetimes and Persistence: Practices, Issues, and Data," May 2015, https://emp.lbl.gov/sites/all/files/savings-lifetime-persistence-brief.pdf

alternatives whenever possible. Technical savings potential does not consider economic, programmatic, or market-based barriers to efficiency adoption.

Weighted – As the sample of RASS respondents and on-site volunteers may not have been fully representative of statewide demographics, many results in this report are scaled to reflect statewide demographics on income, tenure (rent vs. own), and prior program participation. Weatherization results were also scaled to reflect the statewide distribution of MF buildings by construction vintage.

1 Executive Summary

This report provides results from the R1705 Multifamily Baseline and Weatherization Opportunity study conducted by ERS, commissioned by the Connecticut Energy Efficiency Board (EEB), and advised by its Evaluation Administration (EA) team. This research is intended to inform the EEB's and utilities' strategies to achieve the Public Act 11-80 mandate to weatherize 80% of residential units in Connecticut by 2030. While the EEB has previously sponsored similar research for single-family (SF) residences, this study exclusively addresses multifamily (MF) units. MF housing, defined for this study as buildings with at least five units, constitutes approximately 17% of the state's residential units.

This study builds on prior research. In 2014, the EEB funded a SF home weatherization characterization study.[1] In 2018, the EEB sponsored a residential appliance saturation survey (RASS), which targeted both SF and MF customers.[2] The RASS's self-report data provides valuable market information but warrants validation through a sample of on-site visits.

This study addresses the above research needs via three primary objectives:

1. Estimate the number of MF units in Connecticut, as well as their key characteristics – e.g., income assistance, primary heating fuel, building vintage, etc.
2. Collect detailed information on key energy-consuming systems and weatherization characteristics for a sample of MF apartment units, in order to validate the RASS response data and supplement the 2014 SF weatherization data with MF data.
3. Based on the above, estimate the statewide technical potential savings if all systems were converted to high-efficiency alternatives in MF units.

This report focuses on MF equipment characteristics and savings potential. When paired with the R1706 R1616 RASS and SF report, the studies provide a comprehensive overview of

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[1] Connecticut Energy Efficiency Board, "Single-Family Weatherization Baseline Assessment (R5)," June 2014, https://www.energizect.com/your-town/single-family-weatherization-baseline-assessment-r5, hereafter referred to as the 2014 CT SF study.

[2] The RASS and single-family characterization study, hereafter referred to as the RASS report or R1706 R1616 study, was completed by NMR in parallel with this MF research and contains additional details on weighting and comparison between survey and on-site data. The study can be found on the Energize CT website: [add link once public]

Connecticut residential customers and their equipment. To ensure alignment between the two studies, ERS and NMR coordinated closely on data collection instruments and weighting and adjustment of RASS and on-site results.

1.1 Summary of Methods

ERS's data collection and analysis methodology is summarized as follows:

- **Statewide statistics –** To achieve objective #1, analysts used data from the 2010 US Census, the 2016 American Communities Survey (ACS), and town-specific tax assessor records to calculate the number of MF units in the state and related statistics.
- **Recruitment of RASS respondents** – ERS contacted a selection of 677 MF tenants who completed the RASS to schedule a convenient date and time for on-site verification of RASS responses. Customers were offered a $200 gift card for hosting the approximately 90-minute site visit.
- **On-site data collection (objective #2)** – In order to verify tenant RASS responses, field engineers focused data collection within apartments, inventorying key energy-consuming systems within 137 tenant units. Weatherization data collection focused on three measures accessible within tenant units: wall insulation, fenestration, and air sealing. While common area data collection was not intended to be a focus of the study, field staff collected relevant common area data, such as central HVAC characteristics, whenever possible. To maximize consistency with the SF RASS verification study in parallel, ERS used identical, iPad-based data collection software.
- **Per-unit analysis** – After visits were completed, data was uploaded to a master database, cleaned, and reviewed by senior analysts. Upon establishing a final MF data set, ERS analysts examined key equipment characteristics (e.g., vintage, efficiency, location, ENERGY STAR qualification) among different segments of interest (e.g., low-income vs. non-low-income tenants). The per-unit data was weighted to represent statewide demographics and compared with RASS responses to validate or adjust the survey data.[3]
- **Statewide savings potential analysis (objective #3)** – By comparing per-unit characteristics with high-efficiency alternatives, analysts calculated statewide technical savings potential by end-use category. The energy savings per measure in the potential study presumes business-as-usual conditions for programs in that all measure efficiencies are based on equipment currently available to the market in 2019. The analysis does not discount for economic viability or the ability of a program to influence the market to make such a choice.

[3] Additional details on data weighting and adjustment can be found in Section 3.2.1 as well as in the R1706 R1616 report.

1.2 Results

The study's statewide and per-unit MF research is summarized below, followed by a summary of technical savings potential. These summaries are further expanded in Sections 4 and 5.

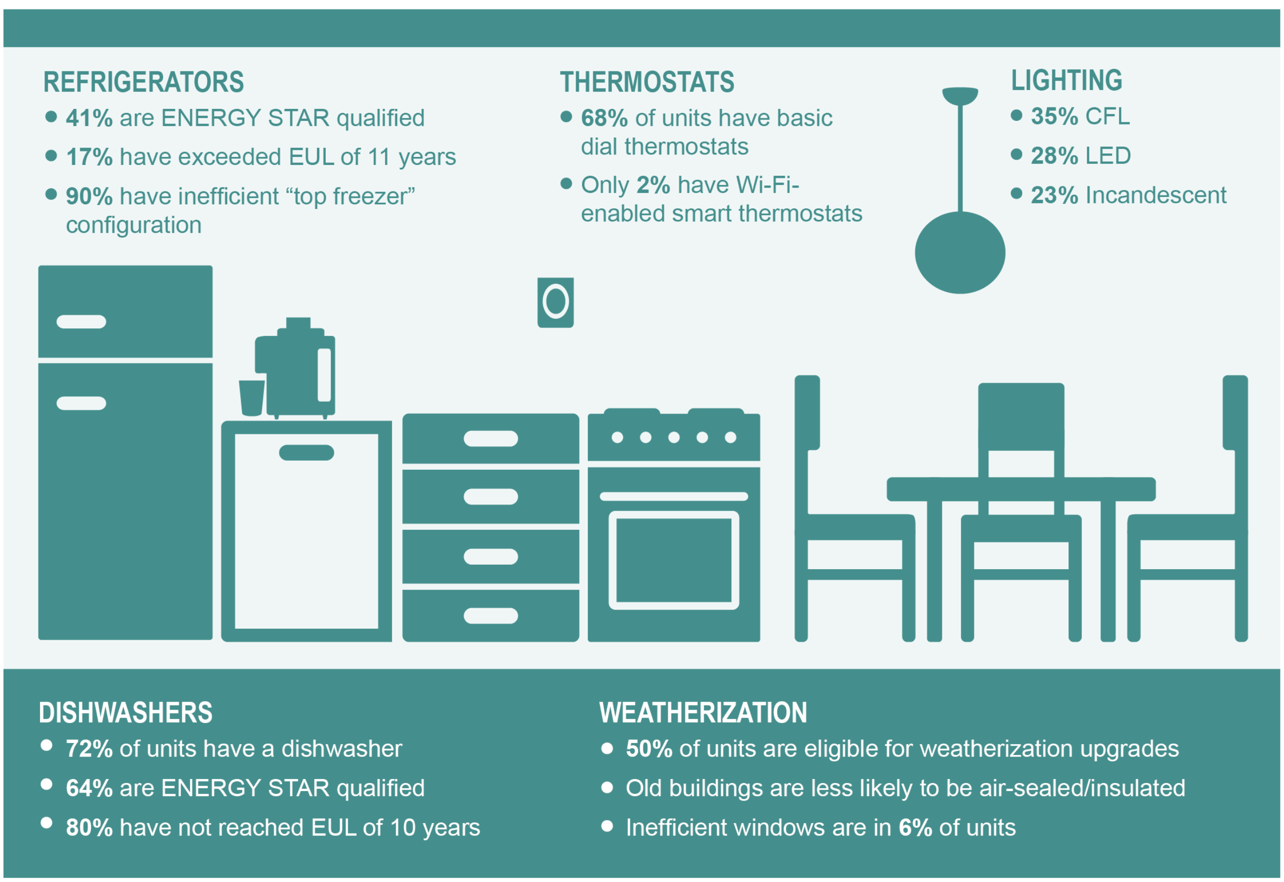
1.2.1 Statewide Statistics

According to our calculations, Connecticut has an estimated 232,946 occupied MF units.[4] They are overwhelmingly urban (89%) and almost two-thirds of them (63%) were built prior to 1980. Space-heating fuels and systems vary. Just over half are heated with gas (54%), 20% with electricity, and 26% with oil, propane, and other sources. Hot air furnaces and hot water boiler heating systems are most common.

1.2.2 Per-Unit Characteristics

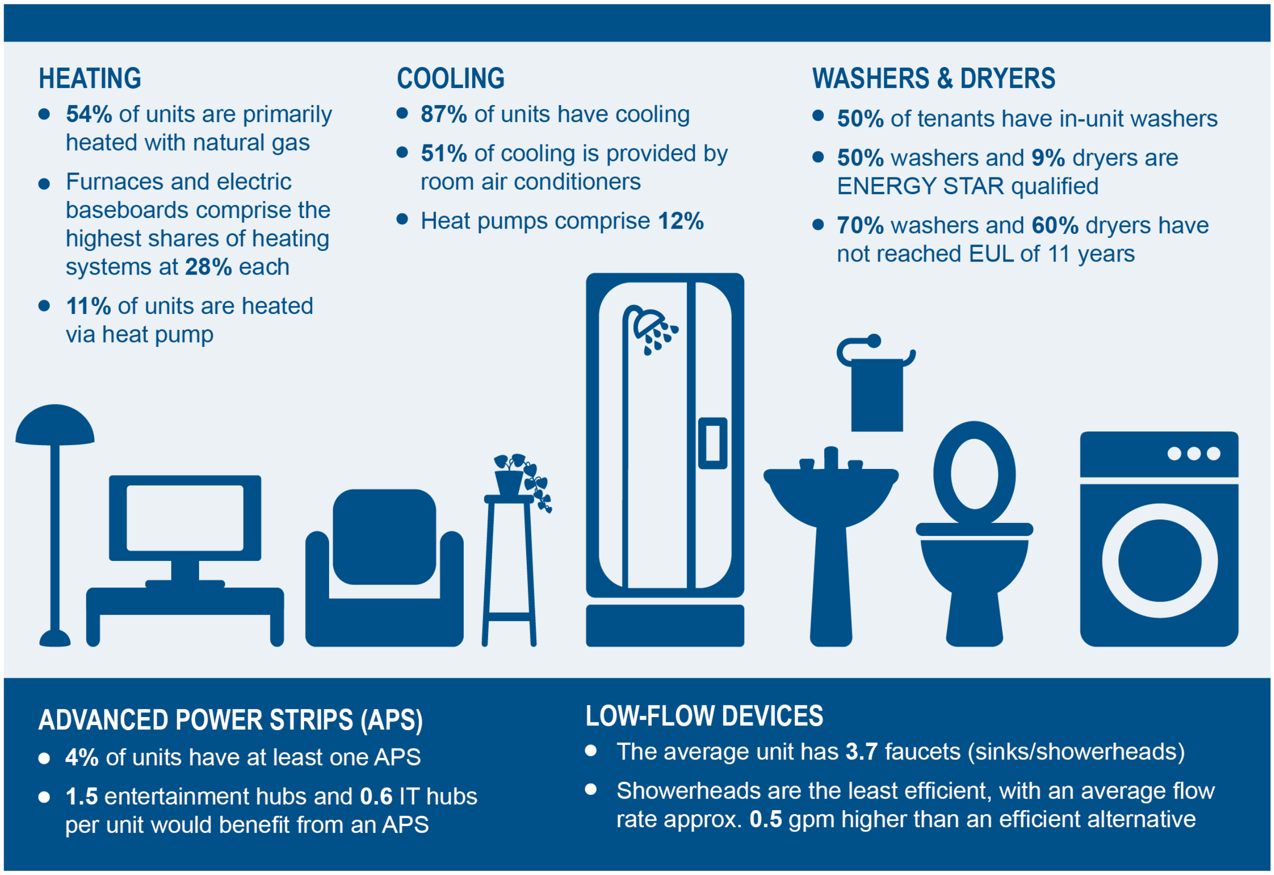
Figure 1-1, below and continued on the next page, summarizes key unit-level findings.

Figure 1-1. Summary of Key Findings from MF Unit Inventories and RASS Responses



[4] The 2016 ACS reports 265,197 total multifamily units and a residential occupancy rate of 88%.

Figure 1-1. Summary of Key Findings from MF Unit Inventories and RASS Responses (Continued)

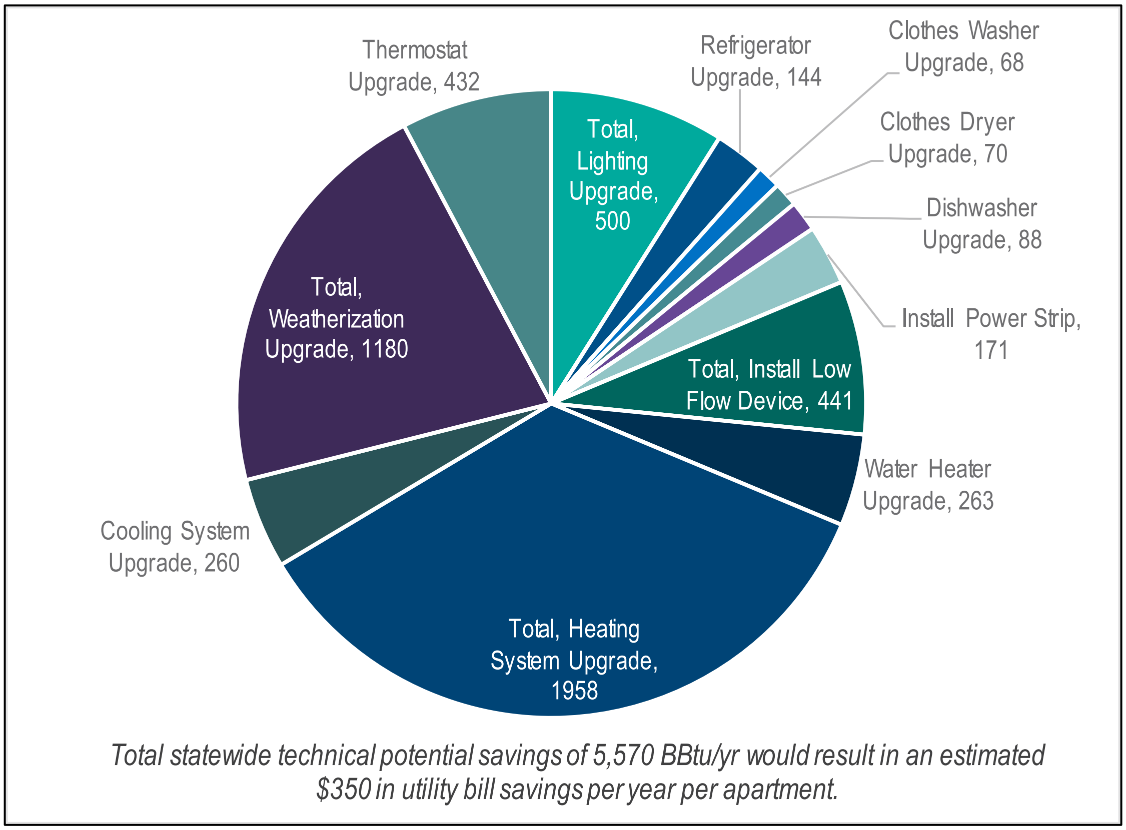


1.2.3 Statewide Savings Potential

Extrapolating the per-unit equipment characteristics statewide, ERS analysts calculated technical savings potential by measure category, as illustrated in Figure 1-2 for source BBtu (billion Btu) savings.[5]

[5] Source BBtu savings take into account generation, transmission, and distribution losses for electricity as well as fossil fuels, providing an equitable quantification of savings among different energy types. The following source-site ratios were incorporated into all source energy conversions in this study – electricity: 2.80; natural gas: 1.05; fuel oil: 1.01; and propane: 1.01. These factors were referenced from EPA and ENERGY STAR's 2018 recommendations found here: https://portfoliomanager.energystar.gov/pdf/reference/Source%20Energy.pdf

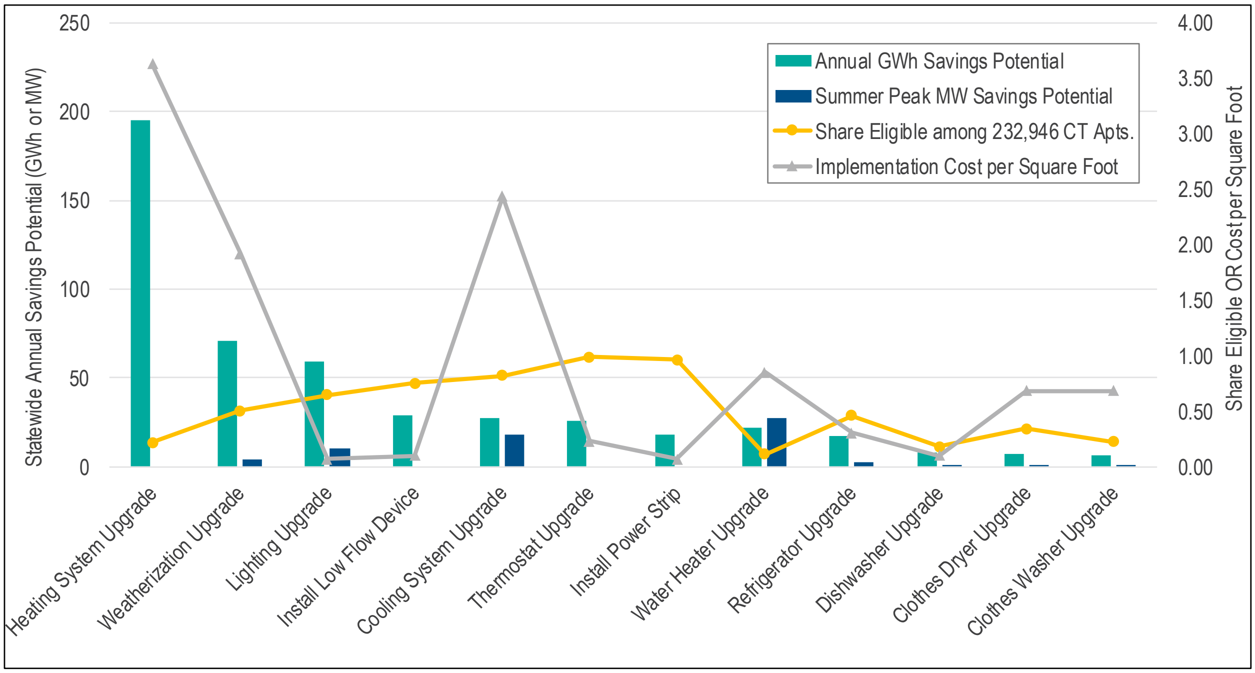
Figure 1-2. Annual Statewide Technical Savings Potential by Measure Category (Source BBtu/yr)



On the following page, Figures 1-3 and 1-4 further examine electric and natural gas technical savings potential, respectively, along with the share of customers eligible for high-efficiency upgrades.[6]

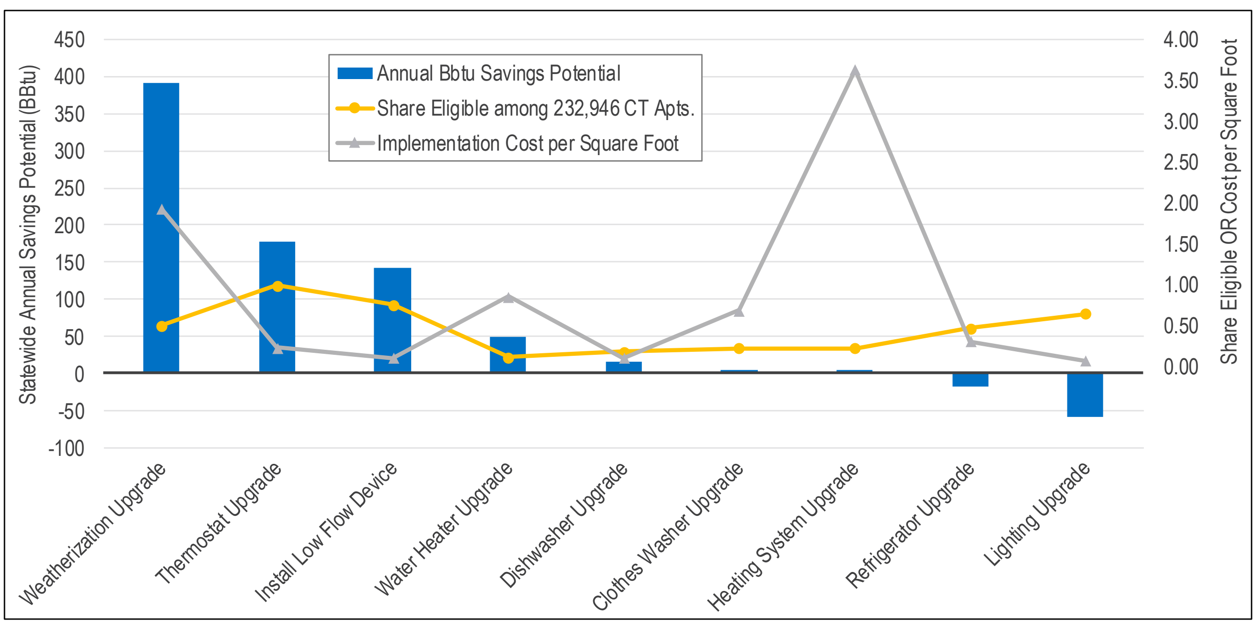
[6] These eligibility shares disregard customers who already have high-efficiency equipment as well as customers who do not have the equipment within their apartments.

Figure 1-3. Statewide Electric Savings Potential (Annual GWh and Peak MW) by Measure Category



Heating system upgrades – most prominently, conversion from electric baseboard heat to high-efficiency air-source heat pumps – offer the most significant GWh savings potential. Other high-opportunity electric measures include lighting and weatherization upgrades. Please note that the water heater upgrade savings include energy and demand savings from heat pump water heater cooling contributions. These categories are further explored in Section 5 and in Appendix C.

Figure 1-4. Statewide Natural Gas Savings Potential (Annual BBtu) by Measure Category



The most significant gas savings opportunities arise from weatherization upgrades and device replacements such as low-flow water fixtures or thermostats. Interestingly, gas-fired space-heating systems do not offer significant savings opportunity, as analysts found that existing systems on average do not markedly differ from high-efficiency alternatives.

1.3 Conclusions and Recommendations

Based on this study's per-unit and statewide research, ERS has developed the following conclusions and recommendations. All collected data from this study has been delivered to the EEB in an Excel-based database that includes RASS and SF study data as well. Such data will be valuable for program administrators in measure planning, baseline establishment, and savings quantification.

1.3.1 Conclusions

- Conversion from electric resistance heat to air-source heat pumps (ASHPs) presents the most promising savings opportunity of any measure considered in this study. Of the surveyed MF units, 28% are heated by electric resistance baseboards while only 8% are heated via ASHP, indicating significant potential for higher electric efficiency. Low-income apartments are statistically significantly more likely to be heated by electric baseboards. Converting electric baseboards to high-efficiency ASHPs would lead to approximately 30% reduction in per-unit heating consumption. Using ASHPs to replace existing non-electric heating, which accounts for nearly two-thirds of MF heating systems, is also promising and would result in considerable decarbonization from fuel switching.
- Significant savings opportunity remains for LED lighting within both tenant units and common areas. Only 27% of in-unit lighting sockets had LEDs, while only 17% of visited properties had predominantly LED lighting in common areas. Incandescents comprise 23% of sockets and 38% of stored bulbs.
- Smart thermostats offer significant savings opportunity because nearly the entire statewide MF population is eligible for upgrade.
- Half (50%) of the MF units are eligible for weatherization upgrades—in other words, half of MF units would benefit from at least one weatherization measure. This share is comparatively higher than the SF share found in the 2014 CT study. The weatherization measures that could be readily characterized within MF units – air sealing, wall insulation, and fenestration upgrades – offer significant potential savings for all fuel types. Weatherization opportunities depend closely on building vintage for all measures studied, with older buildings offering greater savings potential.

- For multiple equipment types, including laundry, HVAC, and DHW systems, inventoried vintage data showed that existing systems generally fall well below the effective useful lives (EULs) referenced in the PSD, indicating one of two conclusions: 1) existing systems offer limited opportunity for end-of-life savings, or 2) that the EULs referenced in the PSD are unrealistically high.
- Appliances and space-cooling equipment offer modest savings potential, as existing systems do not markedly differ from high-efficiency alternatives.
- Two mass-market measures could lead to significant energy savings with relatively low delivery costs:
  - Only 4% of visited units included a Tier 1 or Tier 2 APS.
  - In approximately half of units, low-flow showerheads and faucet aerators offer significant gas- and water-savings opportunities.

1.3.2 Recommendations for Program Administrators

- Pursue deeper penetration of low-cost and low-barrier measures that offer significant savings potential. Such opportunities include LED lighting, smart thermostats, low-flow devices, and APSs. Program administrators (PAs) currently offering these measures should consider multiple delivery methods (e.g., direct install, mailer kits, online marketplace) to accelerate adoption as much as possible. More complex devices like APSs and smart thermostats might require contractor training, installation assistance, customer education, and troubleshooting to maximize persistence and energy savings.
- High-impact measure categories – in particular, electric heating system upgrades and weatherization measures – should be further assessed for feasibility in Connecticut MF buildings. Heating system upgrades would be most impactful for low-income tenants, and weatherization upgrades are most needed in older buildings. Such high-impact opportunities require more disruptive retrofits, higher capital commitment, and a dedicated contractor base. We recommend deeper research on achievable savings, barriers to adoption, customer and contractor perceptions of the technologies, and appropriate incentive levels.

1.3.3 Recommendations for Further Research

- As one of this study’s primary objectives was to validate RASS responses, the research focused on equipment within tenant units. While visiting tenant units, ERS field staff collected as much common area information as possible; however, key common spaces such as basements and rooftops were not always accessible, limiting data collection on central systems and building envelope. We recommend that this study be supplemented with a similar baseline and savings opportunity study with MF common areas as the research focus.

- This study quantified ***technical*** savings potential based on existing characteristics and high-efficiency alternatives. By definition, technical savings potential does not consider measure cost-effectiveness, implementation barriers, or market adoption rates. To more comprehensively inform program plans, we recommend that a follow-up, global economic or achievable potential study be conducted in Connecticut. Such a study should address the MF sector distinctly using this study's research as a starting point.
- Given Connecticut's focus on carbon emissions reduction as well as the preponderance of electric resistance and oil space-heating for MF units, we recommend that further research be conducted on strategic electrification opportunities in Connecticut. Heating system upgrades comprise about 30% of statewide source BBtu savings potential and even greater carbon emissions reduction potential. This study's research on equipment-specific characteristics and statewide population data should be supplemented with additional research on barriers and costs to fuel switching and expanded to other sectors like SF residents and nonresidential customers. This additional research would provide a more realistic roadmap to transitioning Connecticut customers away from fossil fuels and electric resistance space-heating.

2 INTRODUCTION AND BACKGROUND

Public Act 11-80 mandates weatherizing 80% of Connecticut residential units by 2030,[7] as overseen by the Connecticut Department of Energy and Environmental Protection (DEEP), which set the state's existing weatherization standard in 2015.[8] In 2014, the Connecticut Energy Efficiency Board (EEB) sponsored a research study on the compliance of single-family (SF) residences to the Public Act 11-80.[9] That study was intended to develop a baseline of existing SF weatherization characteristics to inform the EEB's and utilities' strategies to achieve meet the 80% weatherization goal.

The 2014 weatherization study examined only SF residences. Approximately 17% of the state's 1,354,713 residential units are classified as multifamily (MF), defined in this report as residential units coexisting with five or more total dwelling units at the same address. Information on current weatherization compliance by MF units is therefore critical for the DEEP, EEB, utilities, and other stakeholders facing the 80% by 2030 weatherization mandate that encompasses both SF and MF residential units.

In 2017, the EEB sponsored a residential appliance saturation survey (RASS), in which a sample of residential utility customers completed an online survey examining the saturation and characteristics of typical energy-consuming equipment in their residential dwellings. While this self-report data is valuable for utilities to develop baseline characteristics of residential customers, it did not address weatherization components, as tenants are unlikely to be familiar with systems such as wall insulation and window glazing. Rather, the EEB commissioned this study to collect weatherization data and to validate the self-reported RASS data through physical inspection of apartment units and subsequent analysis.

This report addresses many of the MF research needs identified in the above paragraphs. The Connecticut EEB has commissioned ERS to achieve the following three research objectives through comprehensive on-site data collection and analysis among a statewide sample of MF units:

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[7] Connecticut General Assembly, Public Act No. 11-80, July 2011, https://www.cga.ct.gov/2011/ACT/PA/2011PA-00080-R00SB-01243-PA.htm

[8] Connecticut Department of Energy and Environmental Protection, "Definition of 'Weatherization' of Residential Units in Connecticut," August 2015, https://www.ct.gov/deep/lib/deep/energy/weatherization/definitionofweatherizationinconnecticutaugust32015.pdf

[9] Connecticut Energy Efficiency Board, "Single-Family Weatherization Baseline Assessment (R5)," June 2014, https://www.energizect.com/your-town/single-family-weatherization-baseline-assessment-r5

1. Estimate the number of MF units in Connecticut, as well as their key characteristics – e.g., income assistance, primary heating fuel, building vintage, etc.
2. Collect detailed information on key energy-consuming systems and weatherization characteristics in order to validate the RASS response data and supplement the 2014 SF weatherization data with MF data. To validate the tenants' RASS responses, this study emphasizes *in-unit* data collection and analysis.
3. Based on the above, estimate the technical potential savings if all systems were converted to high-efficiency alternatives in MF units statewide.

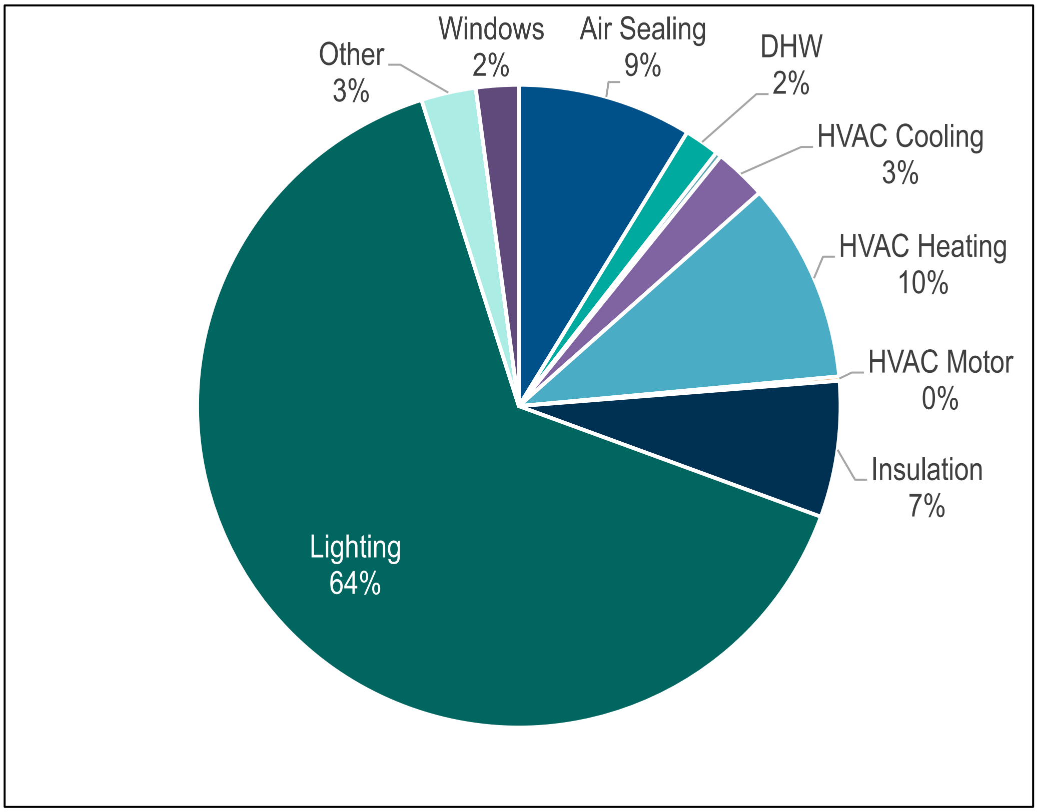
2.1 Multifamily Programs Background

The Connecticut Energy Efficiency Fund (CEEF) supports energy efficiency programs administered by the following two investor-owned utilities: 1) Connecticut Light & Power, doing business as Eversource Energy (Eversource), and 2) United Illuminating (UI) on their own behalf and that of Connecticut Natural Gas and Southern Connecticut Gas. Connecticut MF customers are primarily served by four energy efficiency programs: Home Energy Services (HES), Home Energy Services – Income Eligible (HES-IE), Small Business Energy Advantage (SBEA), and Commercial and Industrial (C&I) Retrofit. The latter two programs primarily sponsor efficiency measures in the common areas of participating MF buildings, including measures affecting central HVAC and water-heating systems that serve multiple dwelling units.

Of the programs identified in the above paragraph, HES and HES-IE achieved the highest levels of MF customer participation. In 2017, the HES programs sponsored residential efficiency projects claiming 57,153 MWh and 260,887 MMBtu of electric and natural gas energy savings, comprising 15% and 77% of total portfolio MWh and MMBtu savings, respectively. Based on tracking data for HES projects completed in program year (PY) 2017, projects classified as MF accounted for 30% of HES electric savings and 43% of HES natural gas savings, respectively. As illustrated in Figure 2-1, below, nearly two-thirds of 2017 HES MF source MMBtu[10] savings occurred from lighting upgrades, followed by heating system improvements, air sealing, and insulation measures.

[10] Source MMBtu savings incorporate power plant losses in the conversion of fossil fuels to electricity. Source-site factors were referenced from EPA and ENERGY STAR recommendations in 2018: https://portfoliomanager.energystar.gov/pdf/reference/Source%20Energy.pdf.

Figure 2-1. PY2017 HES Multifamily Measure Categories and Source MMBtu Savings Shares



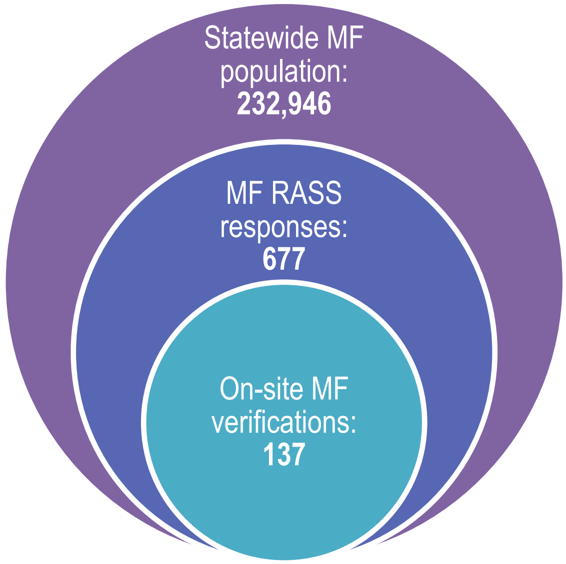
ERS's data collection and analysis addressed each of the measure categories identified in Figure 2-1, as well as several other potential or emerging measure opportunities.

2.2 Residential Appliance Saturation Survey

Shortly before this study's launch, the Connecticut EEB sponsored a RASS among a random sample of SF (1–4 units) and MF utility customers. The sample was enhanced with a MF-only supplement to ensure a sufficient MF response rate[11]. The RASS collected information on heating and cooling equipment, thermostats, water heating, appliances, consumer electronics, miscellaneous end uses, building characteristics, demographics, program participation, and attitudes towards environmental issues. As illustrated in Figure 2-2, the 677 MF customers completing the RASS were targeted for on-site verification, as described in the next sections.

[11] The RASS targeted 30,300 randomly sampled residential electric customers to achieve a goal of 2,000 completed web surveys. Ultimately, 2,426 web surveys were completed. MF customers were oversampled after the initial waves of recruitment to achieve sufficient MF response rate. Ultimately, 677 MF customers completed the RASS, 267 of which volunteered to participate in the on-site portion of the study. Further details behind the RASS design, recruitment, and fielding are addressed in the R1706 R1616 report.

Figure 2-2. MF Statewide Population, RASS Respondent, and On-Site Counts



2.3 Limitations with In-Unit Data Collection

Since validating RASS participant responses is a primary objective of the study, ERS focused the on-site data collection ***within tenant units***. RASS participants were offered gift cards to host a field engineer for an approximately 90-minute inventory of the dwelling unit's energy-consuming equipment, geometry, and envelope characteristics, as well as the resident's demographic information. Data collection in the MF buildings' common areas was limited, as full access to relevant common area spaces would have required separate recruitment and scheduling with the buildings' managers or landlords. During the planning of this study, the EEB's Evaluation Administration team and ERS decided that this additional recruitment was not in the scope of this study.

Nonetheless, field engineers collected as much common area information whenever accessible, including most prevalent lighting types, shared laundry characteristics, central HVAC and/or domestic hot water (DHW) nameplate data, and whole-building envelope characteristics. A description of the in-unit and common-area data collection scope is provided in Section 3.

2.4 Organization of Report

Section 3 describes the data collection and analysis methodologies supporting the study's results. Section 4 focuses on the characteristics of a typical Connecticut MF residential unit. Section 5 examines the statewide technical savings potential if all inventoried equipment were upgraded to high-efficiency alternatives. Section 6 concludes the study with a summary of key findings and recommendations to the EEB and utility program administrators moving forward.

3 METHODOLOGY

This section describes the sampling, recruitment, data collection, and analysis techniques implemented by ERS to achieve the study's objectives.

3.1 Data Collection Methods

Multifamily (MF) data collection was divided into three phases: sampling and recruitment, on-site data collection, and data QC and aggregation.

3.1.1 Sampling and Recruitment

At the conclusion of the RASS, multifamily respondents were asked to participate in an in-home visit in exchange for a $200 gift card.[12] Of the 677 multifamily tenants completing the survey, 267 volunteered for in-home visits. To achieve a goal of 145 site visits, ERS contacted the interested tenants via phone and/or email to schedule the most convenient date and time for the visits. After exhausting the full list of volunteers with eight contact attempts at different times of day and days of the week,[13] ERS successfully recruited and visited 137 tenants.[14] Section 3.2 addresses sample demographics and weighting to correct for representativeness of respondents by income and program participation. The RASS report also contains some informative comparisons between the RASS respondent pool and statewide demographics.[15]

ERS's and the EEB's original intention was to recruit a large sample to achieve statistical significance for at least one primary segment of interest (e.g., low-income versus non-low-income[16]). However, due to the limited number of RASS MF respondents and a lower-than-expected volunteer rate for on-sites, ERS simply exhausted the full list of RASS volunteers to achieve 137 site visits. As Table 3-1 illustrates, below, the on-site participant demographics slightly vary between the RASS respondent demographics. To account for these potential

[12] Recruitment started with a $50 incentive offer, but due to a lower-than-expected volunteer rate, the incentive was increased to $200 per visit.

[13] To mitigate selection bias and diversify the on-site sample as much as possible, ERS incorporated evening and weekend telephone recruitment. Participants could also choose to host evening or weekend in-home visits when convenient.

[14] Of the 130 remaining tenants that had previously volunteered, 67 were unreachable or could not schedule an available appointment, 40 were determined to be single-family units, and 23 declined to participate.

[15] Once published, the link for the RASS study will be shared.

[16] Low income is defined in this study to reflect the eligibility requirements for the HES-Income Eligible program in 2017: total household annual maximum income at or below 40% of the state's median household income.

differences, the RASS and on-site data were compared and adjusted when statistically significant, as addressed in Section 3.2.1 and in the R1706 R1616 report.

Table 3-1. Multifamily RASS Respondent and On-Site Participant Counts by Segment

Segment		RASS Respondents	On-Site Participants
Income	Low-Income	158	40
	Non-Low-Income	519	97
Tenure	Own	166	40
	Rent	511	97
Utility	Eversource	531	122
	UI	146	15
Totals		**677**	**137**

3.1.2 On-Site Data Collection

ERS field engineers conducted 137 MF site visits between May and August 2018. The site visits typically required 1–2 hours and primarily involved comprehensive inventory of energy-using equipment and assessment of customer demographics and behaviors.

In a parallel single-family (SF) version of this study, the EEB contracted NMR to conduct in-home visits to validate RASS responses from SF customers. The RASS verification scope was nearly identical for SF and MF customers, though the MF scope also included weatherization characteristics. In the interest of data collection consistency, both NMR and ERS used identical, iPad-based data collection software during the site visits.

Due to the nature of MF buildings, some pertinent central HVAC/DHW and building shell data were difficult to collect within the participating tenant's unit. Often, the participating tenants could not provide access to the roof, basement, or mechanical room to gather information on central equipment or building envelope. During the planning of this study, the EEB's evaluation administrators and ERS decided that separate recruitment of building management or landlords was not in the scope of this study.

However, ERS field engineers were asked to make a concerted effort whenever possible to access common-area spaces through access authorized by building management. For approximately half of the visited MF buildings, field engineers successfully accessed the most relevant common-area spaces and inventoried key information. For the remaining share of buildings, field engineers could not gain full access to common areas and therefore attempted to ascertain basic system characteristics (e.g., heating system type) from within the participating unit or other accessible spaces. Any assumptions or conclusions drawn from incomplete information was noted during the site visit and accounted for in the analysis. Appendix A provides a detailed breakdown of common-area information typically available or unavailable within participating MF buildings.

Table 3-2 summarizes the typical data collected by ERS field staff at participating MF dwellings.

Table 3-2. MF On-Site Data Collection Scope by End-Use Category

End Use \ Parameter	Technology Type	Qualitative Notes	Fuel type	Location	Wattage / Size	Quantity	Vintage	Capacity	Efficiency / Rating	Make/Model	ENERGY STAR Qualification	Controls Method	Notes
Lighting	✓			✓	✓	✓						✓	Inventoried stored bulbs, marked bulbs for future study
Appliances	✓		✓		✓	✓	✓	✓	✓	✓	✓		Focus on ENERGY STAR-eligible equipment
Mechanical equipment	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	Central and in-unit HVAC systems, thermostats
Water heating	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	System characteristics, flow devices
Weatherization	✓	✓					✓		✓				Wall insulation, windows and doors, air sealing
Electronics	✓			✓									Entertainment/IT hubs for APS potential
Renewables / Transportation	✓	✓			✓								Solar on rooftop, EV charging stations

During all site visits, the field engineer conducted a brief interview with the tenant to confirm demographic and behavioral survey responses from the RASS survey, such as tenure (own vs. rent), income assistance status, program participation, and awareness of efficiency programs. These demographics were ultimately used to develop adjustment factors applied to results in Sections 4 and 5. Field engineers focused the site visit on inventorying characteristics of key energy-consuming systems to collect more detail than was self-reported via the RASS to inform the statewide savings potential analysis.

To support baseline weatherization characterization, field engineers attempted to collect building envelope information within the dwelling unit. Windows, doors, and above-grade walls were typically the envelope components most accessible from within the unit; on the other hand, components such as ceilings, floors, joists, and slabs were often not accessible from units or authorized common areas for detailed characterization. In lieu of blower door testing, which is costly and unreliable within MF buildings, field engineers inspected and measured air/duct gap geometry, surveyed the tenant on draftiness, and qualitatively graded each residential unit to estimate air leakage.

Upon completion of the site visit, the field engineer completed a final walk-through of the unit with the tenant to verify that all equipment and systems were functioning properly. The participant was given the $200 gift card after signing a closeout form.

3.1.3 Data QC and Aggregation

Upon completion of the site visit, field engineers uploaded the inventory data through individual iPads to a master online database. Through coordination between ERS and NMR, the iPad software and database were designed to align closely with SF data collection and analysis. Once uploaded, each site's data underwent a three-step QC and aggregation process before the analysis phase:

1. **Site-by-site field engineer review:** Field engineers reviewed notes and photos to ensure accuracy and comprehensiveness of inventoried characteristics. In addition, engineers referenced online resources, manufacturer data, and specification sheets to confirm ENERGY STAR status, efficiencies, and capacities. For the systems with verifiable key specifications (e.g., make, model, and size), analysts researched the manufacturer's specification data through a comprehensive web search to verify system characteristics.
2. **Site-by-site senior engineer QC review:** A senior engineer next reviewed each individual site's inventory, comparing inventoried characteristics with photos and online resources to confirm accuracy and completeness.
3. **Aggregate review:** Engineers from ERS and NMR reviewed data on an aggregate level to screen for outliers and data gaps.

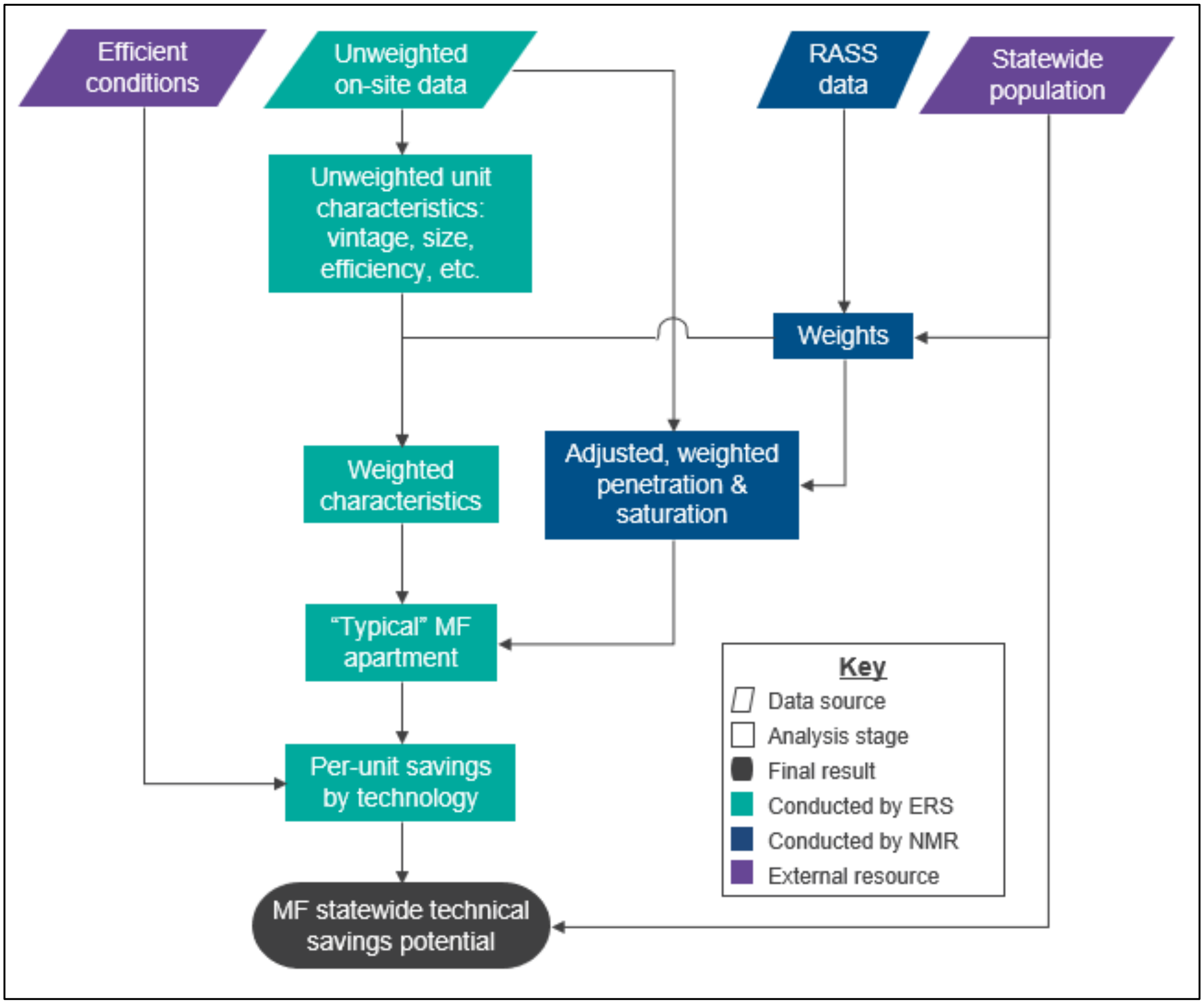
3.2 Analysis Methods

After field data review and aggregation, ERS analysts weighted and examined the data as illustrated in Figure 3-1 and described in the next paragraphs.

NMR administered the RASS survey in early 2018 among a random sample of residential customers based on electric utility account information. The RASS was completed by 677 multifamily tenants by May 2018, at which point the survey was closed. ERS collected field inventory data among 137 apartments of tenants that completed the RASS to validate their survey responses and collect additional weatherization details. As described in Section 3.2.1, all RASS and on-site results were *weighted* to reflect statewide demographics, and the RASS results were *adjusted* to reflect on-site conditions when statistically significant differences were found.

Weighted and adjusted MF results were ultimately used to define the "typical" MF apartment in Connecticut. After comparing existing characteristics with high-efficiency alternatives and extrapolating to the state's 232,946 occupied apartments, technical savings potential was calculated for the multifamily sector statewide.

Figure 3-1. Per-Unit and Statewide Analysis Flowchart



3.2.1 Weighting and Adjustment

The RASS was administered among a random selection of utility customers, a subset of which were MF and another subset of which volunteered for an on-site verification visit. Therefore, it was important to ensure that the demographics of the on-site participants were reflective of statewide demographics. Since NMR administered the RASS and faced a similar weighting requirement for the SF on-sites, NMR developed weighting factors for dwelling type (SF vs. MF), income status (low-income vs. non-low-income), and program participation (yes vs. no over the past decade). These weighting factors were chosen to ensure that RASS respondent characteristics were truly representative of statewide demographics. NMR also considered weighting factors for education and tenure (own vs. rent); however, these alternate weighting variables resulted in poorer representation or more volatile results. ERS analysts applied the MF-specific weights to the MF on-site data set; MF weights are reflected in all results in this report unless otherwise noted.

An objective of the MF site visits was to validate or adjust the information self-reported through the RASS. This validation occurred through adjustment factors.[17] Adjustment factors leveraged three statistics: (1) self-reported values from the full web-survey sample, (2) self-reported values among on-site sample respondents, and (3) verified values from the on-site visits. The adjustment factors are the ratio between self-reported values from the on-site sample and verified values from the on-site sample. These ratios are applied to the full web-survey sample values only when the self-reported results differed statistically significantly from the web-survey results at the 90% confidence level. The adjustment factors developed by NMR informed the statewide penetration and saturation data examined in Sections 4 and 5.

3.2.2 Technical Potential

The potential study estimates the energy savings available to measures associated with each type of equipment inventoried in the market assessment. The energy savings per measure in the potential study presumes business-as-usual conditions for programs in that all measure efficiencies are based on equipment currently available to the market in 2019. New program measures are not required. Where possible, analysts used algorithms and assumptions in Connecticut's existing PSD or impact evaluation reports of savings completed in the last three years to estimate unit energy savings. Unit savings are not based on aggressive assumption scenarios and do not rely on new innovation; rather, unit savings generally reflect current program offerings at efficiency levels available on the market.

Regarding market penetration, the potential analysis adjusts for the likelihood that MF units can technically accommodate each energy efficiency measure. There is no discount for economic viability or for the ability of a program to influence the market to make such a choice. Because the technical potential study is based on already-available goods and services and does not include economic or achievable potential, adoption curves and related time-based trajectory analysis are not relevant.

[17] The sentences following are extracted from the R1706 R1616 RASS and SF report's Appendix B.

4 Unit-Level Results

The following sections examine unit-level characteristics and savings potential among lighting, appliance, HVAC, hot water, and weatherization categories. First, we characterize the units and buildings housing the participating multifamily (MF) customers.

4.1 Unit and Building Characteristics

Table 4-1 illustrates differences in per-unit occupancy and square footage among the 137 visited MF units for two segments of interest: income status and tenure. Generally, low-income and rented units had more occupants but less square footage than non-low-income and owned units. As expected, occupancy and square footage are lower in MF units than single-family (SF) homes.[18]

Table 4-1. Per-Unit Occupancy and Square Footage Data by Segments of Interest

(Source: 137 on-site observations and demographic data, weighted)

Segment		*n*	Number of Occupants	Number of Bedrooms	Square Footage
Income	Low-Income	40	1.89*	1.63	834
	Non-Low-Income	97	1.61*	1.52	949
Tenure	Own	40	1.45*	1.49	941
	Rent	97	1.88*	1.62	860
Statewide		**137**	**1.79**	**1.59**	**876**

* Denotes statistically significant difference at the 90% confidence interval

Table 4-2 examines key building characteristics by vintage and by layout (campus versus single-structure buildings). Please note that Tables 4-1 and 4-2 represent statistics for the MF on-site participant population only, not the statewide population. At five visited properties, field staff could not determine a credible vintage estimate from tenants or property staff.

[18] All comparisons to Connecticut SF homes are derived from the RASS and SF study preceding this report; public link will be inserted once published.

Table 4-2. Building Vintage and Characteristics among Visited Properties

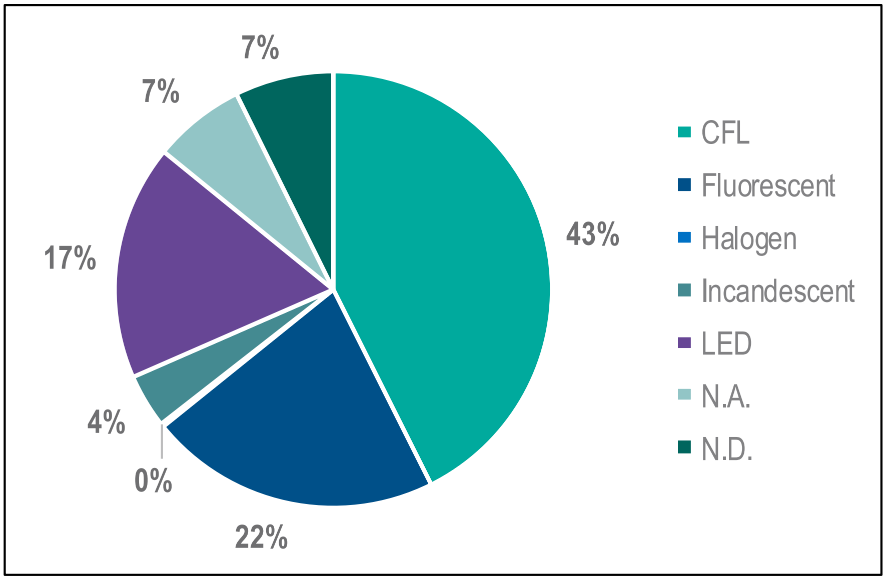
(Source: On-site observations, weighted)

Building Vintage	Campus			Single Building		
	n	Average Floors	Average Count of Units	*n*	Average Floors	Average Count of Units
Pre-1939	1	1.0	16.0	13	2.8	22.2
1940-1979	14	2.0	19.0	15	3.8	44.1
1980-1999	10	2.9	38.3	2	4.0	39.1
2000-2009	8	1.6	64.3	5	4.4	27.6
2010 or later	24	4.1	75.4	40	4.4	69.1
Indeterminate	2	1.2	20.9	3	2.6	20.8

Figure 4-1 illustrates the most prevalent lighting type found within common-area spaces.

Figure 4-1. Most Prevalent Lighting Type within MF Common Areas

(Source: On-site observations, weighted)



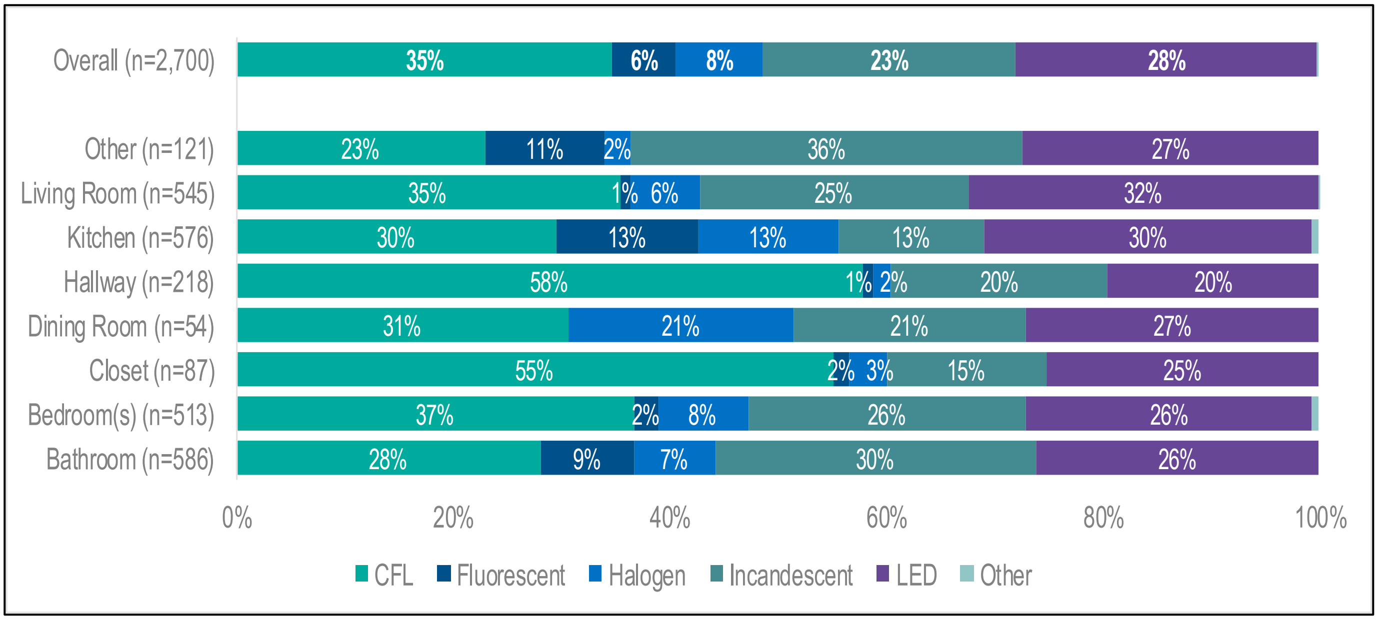
Compact fluorescent lamps (CFLs) and fluorescent fixtures comprise nearly two-thirds of the common-area lighting systems in MF buildings. LEDs comprise only 17%, indicating broad savings potential from common-area lighting upgrades.

4.2 Lighting

This section presents socket saturation and other lighting characteristics verified from ERS's field inventories. Figure 4-2 illustrates the shares of bulbs by type and by location, with the total count of inventoried bulbs indicated for each room type.

Figure 4-2. Shares of Inventoried In-Unit Bulbs by Type and Location

(Source: Field inventories among 137 tenant units, weighted)



Field auditors were able to characterize over 99% of observed bulbs. In a few isolated cases, the bulbs were inaccessible or deemed too fragile to inspect; those bulbs are not reflected in the figure above or the tables that follow.

Figure 4-2 indicates that CFLs (35% of sockets overall) and LEDs (28%) together occupy a majority of sockets in Connecticut apartments, particularly in high-use areas such as kitchens and hallways. While incandescents are the most common lamp type in bathrooms, where "warm" or specialty instant-on lighting is most desired, they have no more than a 36% share for any room type.[19] As 23% of sockets overall are occupied by incandescents, significant opportunity still remains for lighting upgrades in Connecticut apartments. Appendix D compares socket shares in CT apartments with results from recent studies in the Northeast.

ERS analysts explored variation in socket saturation among income-assisted and market rate classifications, as presented in Table 4-3. Non-low-income tenants were more likely to use LEDs and also, surprisingly, incandescents.

[19] Other spaces include basements, attics, offices, foyers/mudrooms, and utility/laundry rooms.

Table 4-3. In-Unit Socket Shares of Lighting Technologies by Income Status

(Source: Field inventories among 137 tenant units, weighted)

Technology	Low-Income	Non-Low-Income	Statewide
n	40	97	137
CFL*	40%	27%	34%
Fluorescent*	7%	4%	6%
Halogen	7%	9%	8%
Incandescent*	19%	28%	23%
LED	26%	30%	27%
Other	1%	2%	2%

* Denotes statistically significant difference at the 90% confidence interval

Per the RASS and SF study, these socket shares generally align with SF lighting. SF homes were slightly more likely to have incandescents (27%), less likely to have CFLs (29%), and nearly the same for LEDs (26%).

Next, we examined the average wattage of each lamp type, in order to establish baseline conditions on which technical savings potential can be calculated. Table 4-4 provides average rated wattage for the most prevalent lamp types. The analysts did not find significant variation in wattage by location (e.g., an LED bulb in a kitchen generally had a similar average wattage compared to an LED in a bedroom) or by income status, tenure, or utility.

Table 4-4. Average Rated Wattage by Lighting Technology within Units

(Source: Field inventories among 137 tenant units, weighted)

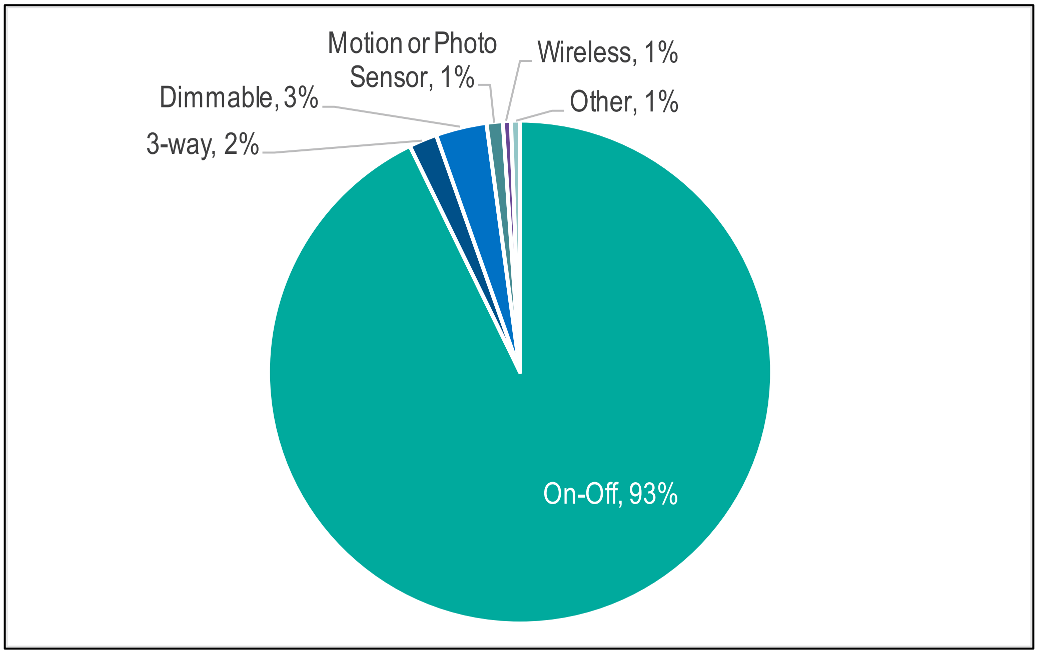
Lighting Technology	*n*	Average Rated Wattage
CFL	934	16.4
Fluorescent	159	26.0
Halogen	213	47.1
Incandescent	618	57.9
LED	742	9.8
Other	8	23.2
Statewide	**2,674**	**27.2**

As expected, incandescent and halogen lamps feature the highest average wattages, while LED bulbs draw approximately 80% less power on average than less-efficient alternatives.

We next examine the distribution of lighting control types in Figure 4-3.

Figure 4-3. Shares of In-Unit Lighting Control Methods

(Source: Field inventories among 137 tenant units, weighted)

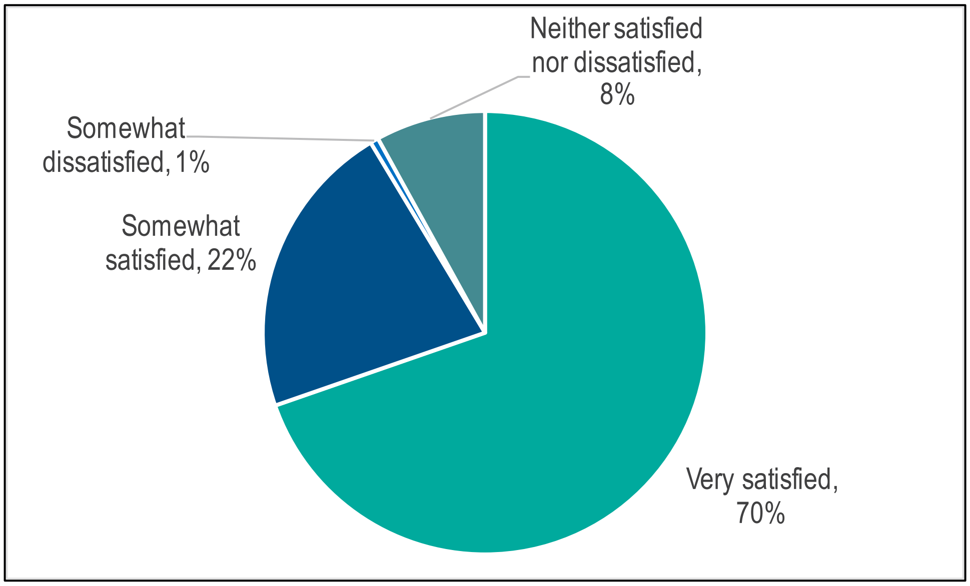


On/off switches comprise the significant majority of lighting control statewide, while dimmable switches account for only 3%. Other control methods, such as 3-way switches or motion-based control, account for the remaining 5% when combined.

ERS field staff gathered additional data on LED bulbs specifically. Of the inventoried LED bulbs, 82% had been purchased prior to the last twelve months, while 15% had been purchased within the last twelve months (respondents could not recall purchase date for the remaining 3%). Two out of every three LED users were "very satisfied" with the technology, as illustrated in Figure 4-4. Of the 1% "somewhat dissatisfied" with LEDs, prevalent reasons were that the LEDs were too bright, a different color than expected, or required too much time to warm up.

Figure 4-4. Distribution of LED Customer Satisfaction

(Source: Field surveys among 107 LED users, weighted)



4.2.1 Stored Bulbs

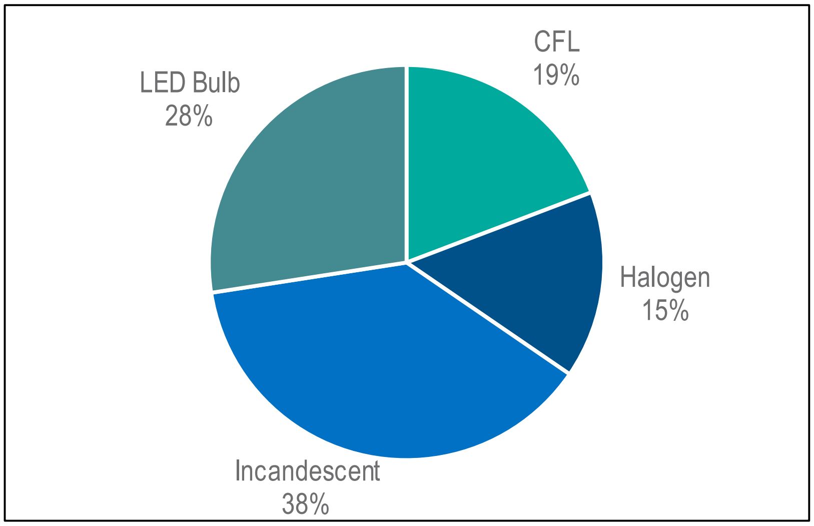
ERS field staff also inventoried all stored bulbs and found that 37% of the 137 visited MF units featured stored bulbs; this share is considerably lower than that of Connecticut SF customers.[20] We attribute the difference to a higher-than-typical share of visited apartments with at least one lighting fixture maintained by building management (approximately 40%).

Tenants with stored bulbs had 5.9 bulbs in storage on average, with a distribution by technology illustrated in Figure 4-5. We found no significant differences in bulb storage likelihood or stored bulb technology between low-income and non-low-income apartments.

[20] Per the R1706 R1616 RASS report, visited SF homes (n = 90) had 10.2 bulbs in storage on average, whereas MF units (n = 137) had 2.2 bulbs in storage on average.

Figure 4-5. Shares of Stored Bulbs by Lighting Technology

(Source: Field inventories among 51 tenant units with stored bulbs, weighted)

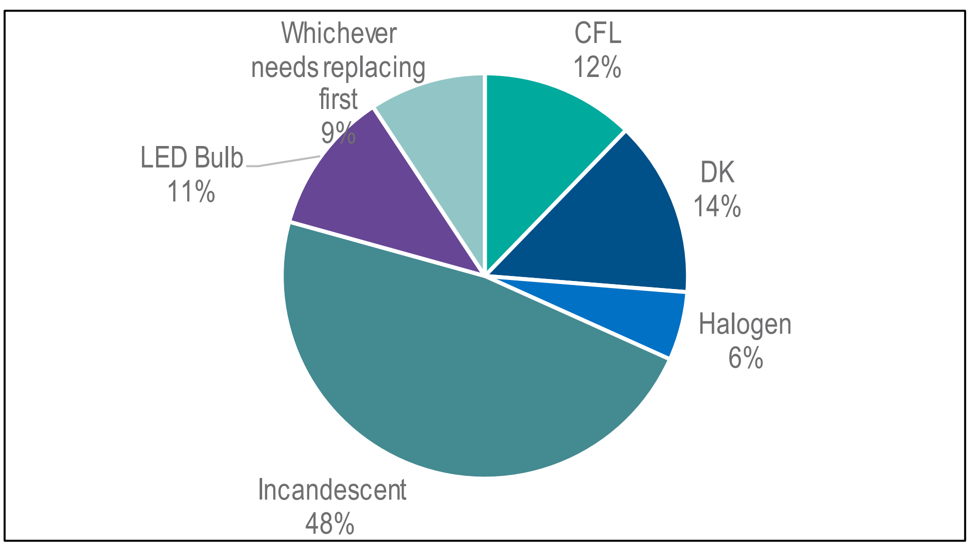


ERS field staff surveyed tenants with stored bulbs to characterize if and how they would replace existing bulbs within the apartment. Overall, tenants indicated that they planned to install 94% of the stored bulbs in the future, with small shares of stored bulbs to be unused, given to a friend, or thrown out.

Figure 4-6 illustrates which lighting technologies the tenants expected would be replaced next with the stored bulbs. While this data suggests that incandescents are gradually departing the MF market, the high share of stored incandescents (38%) indicates savings opportunity from intervention with LED bulbs.

Figure 4-6. Shares of Bulb Technologies Expected to Be Replaced Next

(Source: Field surveys among 51 tenants with stored bulbs, weighted)



Tenants generally expected less-efficient lighting technologies to be replaced next, while 9% of tenants indicated that the stored bulbs would be used in whichever fixture needed it first.

ERS field staff marked each stored bulb using a different color ink than that used for active bulbs in order to potentially measure the lighting replacement practices of tenants over time, should a follow-up study be undertaken.

Per-Unit Savings Potential

Immediate savings opportunity exists from upgrading less-efficient lighting technologies with LEDs. Based on the saturation characteristics presented in the above sections, we estimate annual energy savings of 289 kWh per apartment from converting screw-in incandescents, CFLs, and halogens to LED-equivalent bulbs. Supporting information on this calculation can be found in Appendix C, and the contribution of lighting to statewide savings potential is examined in Section 5.2.

Energy savings are also achievable through more optimized control of lighting operation. From our review of 2017 program tracking data, lighting control measures are not prevalent among MF tenant customers. As the lighting market continuously evolves toward a higher saturation of LEDs, lighting control measures will present savings opportunities past that of a one-for-one bulb upgrade. Residential lighting control systems now feature photocell-based dimming, app-based control, and circadian rhythm lighting. The energy impact of these control systems is somewhat unproven, and the maturing technologies are cost-prohibitive; therefore, we have not estimated technical savings potential from these measures.

4.3 Appliances and Electronics

The next sections examine unit-level characteristics and savings potential for refrigerators and freezers, clothes washers, clothes dryers, dishwashers, and advanced power strips. Appendix D compares CT MF appliance characteristics with results from relevant RASS and market characterization studies.

4.3.1 Refrigerators and Freezers

All surveyed MF dwellings included one full-size refrigerator. In addition, 4% of dwellings featured a standalone freezer, 2% featured a mini-refrigerator, and 1% a wine refrigerator. Due to the low saturation of non-full-size refrigerators and freezers, this section focuses on saturation and characteristics of full-size refrigerators only.

Non-low-income tenants were slightly more likely to use an ENERGY STAR–qualified refrigerator than low-income tenants, as indicated in Table 4-5.

Table 4-5. Refrigerator ENERGY STAR Qualification by Income Segment

(Source: Field inventories among 137 tenant units, weighted)

ENERGY STAR Status	Low-Income	Non-Low-Income	Statewide
n	40	97	137
Qualified	37%	46%	41%
Not Qualified	32%	33%	32%
Indeterminate	31%	22%	27%

Table 4-6 examines the distribution of refrigerator vintages by income status, illustrating that non-low-income tenants are slightly more likely to use a newer refrigerator than low-income tenants. At least 65% of the current MF refrigerator stock has not reached the effective useful life (EUL) of 11 years as referenced in the CT PSD.

Table 4-6. Refrigerator Vintage by Income Segment

(Source: Field inventories among 137 tenant units, weighted)

Vintage Range (EUL = 11)	Low-Income	Non-Low-Income	Statewide
n	40	97	137
Pre-2000	3%	2%	2%
2000–2005	8%	3%	6%
2006–2010	14%	25%	18%
2011–2015	38%	36%	38%
2016–Present	26%	28%	27%
Indeterminate	11%	7%	9%

Table 4-7 compares full-size refrigerator rated energy consumption and size among segments of interest, indicating statistically significant differences in kWh (utility) and size (tenure).

Table 4-7. Refrigerator Rated kWh and Size among Segments of Interest

(Source: Field inventories among 137 tenant units, weighted)

Segment		*n*	Rated Annual kWh	Volume (cubic feet)
Income Assistance	Low-Income	40	466	17.5
	Non-Low-Income	97	459	17.8
Tenure	Own	40	485	18.9*
	Rent	97	458	17.3*
Utility	Eversource	122	446*	17.7
	UI	15	585*	16.9
Statewide		**137**	**464**	**17.6**

* Denotes statistically significant difference at the 90% confidence interval

Per-Unit Savings Potential

Refrigerator energy use varies by configuration and icemaker presence. Table 4-8 compares existing conditions with current ENERGY STAR–qualified equivalent units to calculate per-unit technical savings potential from refrigerator upgrade.

Table 4-8. Refrigerator Consumption and Savings Potential by Configuration

(Source: Field inventories among 124 tenant units, weighted)

Refrigerator Characteristic		*n*	Weighted Shares	Existing Rated kWh	High-Efficiency Alternative	
					Rated kWh	Annual kWh Savings
Configuration	Bottom Freezer	6	2%	478	455	23
	Side-by-Side	9	7%	660	556	104
	Single Door	2	1%	406	336	70
	Top Freezer	107	90%	444	374	71
Statewide		**124**	**100%**	**464**	**388**	**76**

Per-unit refrigerator savings are revisited in Section 5's statewide savings potential analysis as well as in Appendix C.

4.3.2 Dishwashers

Dishwashers were found in 72% of MF dwellings: 80% in non-low-income dwellings and 63% in low-income dwellings. The field staff found that 64% of all inventoried dishwashers were confirmed to be ENERGY STAR–qualified. As Table 4-9 shows, approximately 80% of the MF dishwasher stock has not reached the EUL of 10 years as referenced in the CT PSD.

Table 4-9. Share of Dishwashers by Vintage and Income Status

(Source: Field inventories among 113 tenant units, weighted)

Vintage (EUL = 10)	Low-Income	Non-Low-Income	Statewide
n	**26**	**87**	**113**
Pre-2000	4%	3%	3%
2000–2005	0%	6%	3%
2006–2010	7%	20%	13%
2011–2015	67%	44%	57%
2016–Present	22%	25%	23%
Indeterminate	0%	1%	1%

Table 4-10 examines dishwasher energy consumption among key segments of interest, indicating higher-consuming units for low-income tenants and renters.

Table 4-10. Dishwasher Energy Consumption by Segment

(Source: Field inventories among 98 tenant units, weighted)

Segment		*n*	Rated kWh
Income Assistance	Low-Income	24	317*
	Non-Low-Income	74	290*
Tenure	Own	30	280*
	Rent	68	314*
Company	Eversource	95	307
	UI	3	290
Statewide		**98**	**306**

* Denotes statistically significant difference at the 90% confidence interval

Per-Unit Savings Potential

Current ENERGY STAR standards require annual energy consumption no greater than 270 kWh for full-size dishwashers,[21] indicating technical savings potential of 36 kWh per dishwasher upgrade.

4.3.3 Clothes Washers

Per RASS responses confirmed with on-site information, 50% of MF dwellings include in-unit clothes washers, while 44% of tenants have access to clothes washers within the MF building's common areas. The likelihood of in-unit clothes washers is statistically significantly different between low-income and non-low-income tenants, as illustrated in Table 4-11.

Table 4-11. Clothes Washer Penetration by Location and Income Assistance

(Source: Field inventories among 137 tenant units, weighted and adjusted to RASS results)

Segment		*n*	In Unit	Common Area	None in Building
Income Assistance*	Market Rate	97	61%	31%	8%
	Low-Income	40	37%	57%	6%
Tenure	Own	40	52%	41%	7%
	Rent	97	45%	49%	6%
Company*	Eversource	122	50%	42%	7%
	UI	15	20%	78%	2%
Statewide		**137**	**50%**	**44%**	**6%**

* Denotes statistically significant difference at the 90% confidence interval

[21] ENERGY STAR, "Dishwashers Key Product Criteria," 2016, https://www.energystar.gov/products/appliances/dishwashers/key_product_criteria

To explore the potential savings from upgrading existing clothes washers, analysts next examined the vintages and ENERGY STAR qualifications of inventoried clothes washers, as outlined in the next tables.

Table 4-12. Shares of Clothes Washers by Vintage Range and Income Status

(Source: Field inventories among 127 tenant units, weighted)

Vintage Range (EUL = 11)	Low-Income	Non-Low-Income	Statewide
n	37	90	127
Pre-2000	1%	3%	2%
2000–2005	2%	4%	3%
2006–2010	15%	22%	17%
2011–2015	53%	35%	47%
2016–Present	18%	30%	22%
Indeterminate	11%	8%	10%

Table 4-12 illustrates that at least 70% of MF clothes washers have not reached their EUL of 11 years.[22]

The prevalence of ENERGY STAR–qualified clothes washers is examined in Table 4-13 for the 127 inventoried washers with accessible nameplate information.

Table 4-13. Shares of Clothes Washers by ENERGY STAR Status and Income Status

(Source: Field inventories among 127 tenant units, weighted)

ENERGY STAR Status	Low-Income	Non-Low-Income	Statewide
n	37	90	127
Qualified	53%	43%	50%
Unqualified	34%	46%	38%
Indeterminate	13%	11%	12%

Overall, 50% of inventoried clothes washers are ENERGY STAR–qualified. To assess potential savings from upgrading existing clothes washers to ENERGY STAR–qualified units, we next examine the rated efficiency of existing washers, as characterized by the modified energy factor[23] (MEF) in Table 4-14.

[22] EUL referenced from Connecticut 2018 Program Savings Document, page 314, https://www.energizect.com/sites/default/files/2018-PSD-FINAL-121217.pdf

[23] The MEF is defined as the ratio of the washer's capacity (in cubic feet) to the total washer energy consumption per cycle, including energy use related to machine dynamics, water heating, and moisture removal. The higher the MEF, the more efficient the clothes washer.

Table 4-14. MF Clothes Washer Efficiency by Segment

(Source: Field inventories among 111 tenant units, weighted)

Segment		*n*	MEF
Income Assistance*	Low-Income	35	2.35
	Non-Low-Income	76	2.13
Tenure*	Own	29	1.95
	Rent	82	2.35
Company	Eversource	105	2.28
	UI	6	2.23
Statewide		**111**	**2.28**

* Denotes statistically significant difference at the 90% confidence interval

Per-Unit Savings Potential

Clothes washer MEF varies by configuration, with front-load washers significantly more efficient than top-load equivalents.[24] Table 4-15 examines the existing MEFs and estimated annual energy consumptions by location and configuration.

Table 4-15. Comparison of Existing and High-Efficiency Clothes Washers by Location

(Source: Field inventories among 110 tenant units, weighted)

			Existing Conditions		High-Efficiency Alternative		
Location	Configuration	*n*	MEF	Annual kWh	MEF or IMEF	Annual kWh	Savings
In Unit	Front-load	27	2.66	99	2.92	41	58
	Top-load	31	1.62	119	2.17	55	64
In Unit		**58**	**2.08**	**110**	**2.50**	**49**	**61**
Common Area	Front-load	35	2.72	230	2.23	230	0
	Top-load	17	1.62	500	2.23	215	285
Common Area		**52**	**2.41**	**306**	**2.23**	**61**	**81**
Statewide		**110**	**2.28**	**230**	**2.33**	**56**	**73**

Per-unit clothes washer savings are extrapolated statewide in Section 5.

4.3.4 Clothes Dryers

Per RASS responses confirmed with on-site information, 48% of MF dwellings feature in-unit clothes dryers, while 46% of tenants have access to common-area clothes dryers within the MF building. The comparison of in-unit and common-area dryers by income segment is similar to

[24] While recent RASS research on clothes washers is limited, the share of front-load (horizontal axis) washers appears higher than other jurisdictions: CA (30%, 2014), PA (28%, 2014), and MA (25%, 2009).

that of clothes washers illustrated in Table 4-16. The field staff confirmed that 96% of all inventoried clothes dryers are primarily electrically heated.

In order to explore the potential savings from upgrading existing clothes dryers, we examine vintages and ENERGY STAR qualifications in the next tables.

Table 4-16. Shares of Clothes Dryers by Vintage and Income Status

(Source: Field inventories among 126 tenant units, weighted)

Vintage Range (EUL = 11)	Low-Income	Non-Low-Income	Statewide
n	36	90	126
Pre-2000	0%	1%	0%
2000–2005	26%	7%	12%
2006–2010	7%	18%	15%
2011–2015	35%	39%	38%
2016–Present	12%	29%	24%
Indeterminate	21%	7%	10%

At least 60% of MF clothes dryers have not reached their EUL of 11 years,[25] indicating one of two possible findings: 1) the current opportunity to improve efficiency through replace-on-burnout intervention is limited, or 2) the PSD's clothes dryer EUL is unrealistically high.

From an ENERGY STAR qualification perspective, clothes dryers in Connecticut offer significant potential for efficiency upgrade. Only 9% of clothes dryers were confirmed to be ENERGY STAR–qualified, as illustrated in Table 4-17.

Table 4-17. Clothes Dryer ENERGY STAR Qualification by Income Status

(Source: Field inventories among 126 tenant units, weighted)

ENERGY STAR Status	Low-Income	Non-Low-Income	Statewide
n	36	90	126
Qualified	8%	9%	9%
Unqualified	85%	80%	83%
Indeterminate	7%	11%	8%

Next, we examined the rated efficiency of existing models, as characterized by the energy factor[26] (EF), in Table 4-18. Please note that EF data was only available for 47 clothes dryer models.

[25] EUL derived from Connecticut 2018 Program Savings Document, page 314, https://www.energizect.com/sites/default/files/2018-PSD-FINAL-121217.pdf

[26] The energy factor is defined as the ratio of the laundry load (in pounds) and the dryer's per-cycle electric energy consumption (sum of standby and operational kWh). Therefore, the higher the EF, the more efficient the dryer.

Table 4-18. Clothes Dryer Efficiency among Segments of Interest

(Source: Field inventories among 47 tenant units, weighted)

Segment		*n*	Energy Factor
Income Assistance	Low-Income	8	3.73
	Market Rate	39	3.50
Tenure	Own	17	3.53
	Rent	30	3.64
Company	Eversource	43	3.65
	UI	4	3.32
Statewide		**47**	**3.61**

Per-Unit Savings Potential

ENERGY STAR's current minimum qualified EF for electric clothes dryers is 3.93, resulting in potential annual kWh savings of 52 kWh per clothes dryer. Section 5 contains additional details on in-unit and common-area clothes dryer savings potential extrapolated statewide.

4.3.5 Advanced Power Strips

ERS field auditors characterized the saturation and type of electronics at participating MF dwellings. The objective of this assessment was twofold: 1) to assess the penetration of advanced power strips (APSs) among MF units in Connecticut, and 2) to estimate the technical savings potential from installing an APS in a typical MF dwelling. Field auditors identified and characterized electronics within entertainment and information technology (IT) "hubs," defined as a collection of proximate electronic devices that could be supported by a single APS. Electronics not related to entertainment or IT, or not grouped within a hub, were not characterized in this study.

Statewide, 4% of visited MF units contained at least one Tier 1 APS, indicating significant opportunity for deeper penetration of APSs within the MF market. Interestingly, 63% of MF RASS respondents reporting having an APS installed in their apartments,[27] but penetration was significantly reduced to 4% after adjustment from in-field data. Such a difference indicates that residential customers often mistake an APS for a standard surge protector.

ERS analysts next examined the entertainment and IT hubs not currently supported by an APS, as outlined in Table 4-19.

[27] Further comparisons between RASS and on-site data can be found in the R1706 R1616 report.

Table 4-19. Visited MF Dwellings without Tier 1 APSs – Saturation and Savings Potential

(Source: Field inventories among 132 tenant units, weighted)

Metric	Entertainment	IT
A – Average hubs per MF dwelling	1.55	0.64
B – Average devices per hub	3.11	3.19
C – Estimated annual consumption per hub (kWh)	351	345
D – Total annual consumption per MF dwelling (kWh) (A × C)	544	222
E – High-end Tier 1 APS annual savings[a]	12.5%	15.8%
F – High-end Tier 1 APS annual savings per MF unit (kWh) (D × E)	68	35
G – Low-end Tier 1 APS annual savings in MF apartments (kWh)[b]	77	

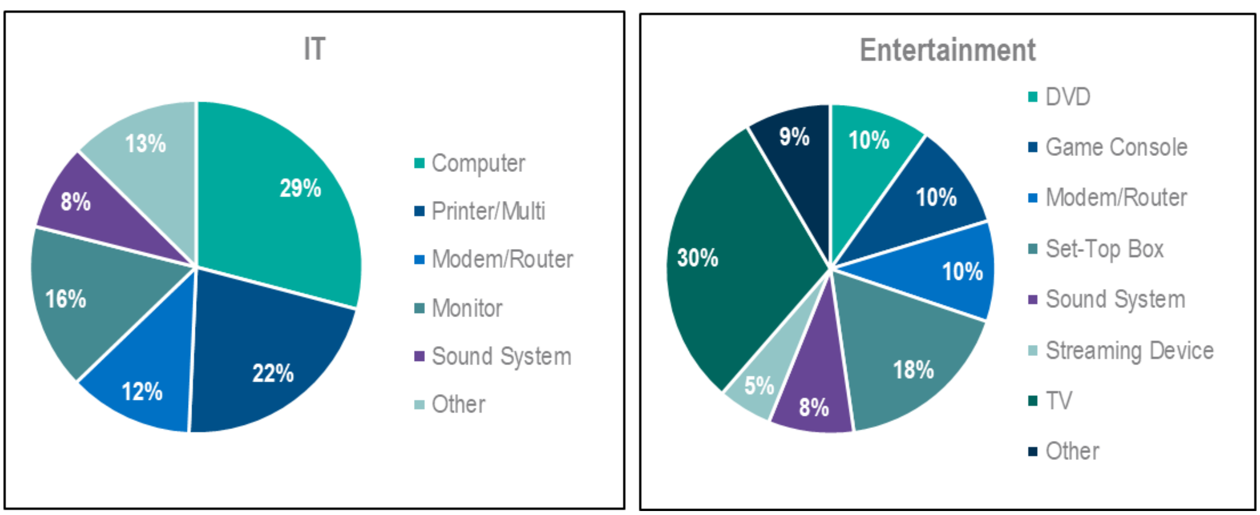
[a] Per NYSERDA's "Advanced Power Strip Research Report," https://www.nyserda.ny.gov/-/media/Files/EERP/Residential/Power-Management-Research-Report.pdf

[b] From Energy Trust of Oregon's "Pilot Study of Tier 1 Advanced Power Strips in Multifamily," https://www.energytrust.org/wp-content/uploads/2018/03/Tier-1-APS-ETO-MF-Pilot-Evaluation-Report_FINAL_wSR.pdf. This pilot study involved independent metering among 125 MF units at 10 properties. However, the analysis did not differentiate between entertainment and IT loads.

The estimated APS kWh savings per MF dwelling, as indicated in the last row of the table, were derived from an analysis of device prevalence among the entertainment and IT hubs not currently supported by an APS. The penetration shares among devices within each hub type are illustrated in Figure 4-7.

Figure 4-7 - Device Shares among Entertainment and IT Hubs

(Source: Field inventories among 126 tenant units, weighted)



The body of independent research on APS savings is continually growing. While Tier 2 APSs offer higher energy reduction potential (ERP) than Tier 1, recent research shows that Tier 2

APSs suffer from high removal and override rates.[28] The persistence rate is particularly low for infrared-only (IR) Tier 2 APSs, with 58% of Tier 2 IR APS users indicating plans to remove the strip in a recent Massachusetts study.[29] Comparatively, Tier 1 APSs have shown higher persistence[30] and customer satisfaction.[31] For these reasons, this report considers Tier 1 APS savings potential only, using the most conservative savings estimate found from our research.

The statewide technical savings potential for the APS measure is further examined in Section 5.

4.4 Mechanical Equipment

The next subsections examine statewide characteristics and per-unit savings potential among cooling, heating, and hot water categories.

4.4.1 Cooling

Based on RASS responses validated through on-site inventories, 99% of MF units feature some form of mechanical cooling. Field staff observed a total of 194 cooling systems among the sample of 137 units visited. Field staff collected as much central cooling information as possible; however, equipment access and nameplate specifications were limited for some central systems.

Statewide, room air conditioners comprise the highest share of cooling systems (46%), while central air systems and air-source heat pumps (ASHPs) were also prevalent with a combined share of 38%, as indicated in Table 4-20.

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[28] Massachusetts Program Administrators and EEAC, “Advanced Power Strip Metering Study,” prepared by NMR, March 2019, http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC_173_APSMeteringReport_Revised_18March2019.pdf (page 72)

[29] Ibid, page 72

[30] Ibid, page 71

[31] Energy Trust of Oregon, “Pilot Study of Tier 1 Advanced Power Strips in Multifamily,” March 2018, https://www.energytrust.org/wp-content/uploads/2018/03/Tier-1-APS-ETO-MF-Pilot-Evaluation-Report_FINAL_wSR.pdf (Section 6.2)

Table 4-20. Cooling System Penetration by Detailed System Type[a]

(Source: 137 on-site observations and 677 survey responses, weighted)

RASS Category	On-Site Inventoried Cooling System Type	System Type Penetration
AC - Room Air Conditioner	Room Air Conditioner	46.0%
AC - Central Air/ASHP	ASHP	7.0%
	Central Air-packaged	4.4%
	Central Air-split	26.7%
AC - MSHP	Ductless mini split	0.5%
AC - No cooling	None	0.8%
Not addressed in RASS[b]	Chiller	3.0%
	Cooling tower	2.6%
	GSHP-closed loop	0.4%
	GSHP-open loop	0.1%
	Packaged roof-top unit	0.3%
	PTAC	3.1%
	PTHP	1.0%
	WSHP	4.0%
Total		**100.0%**

N.D. = No data

[a] System penetrations have been scaled to 100% because the RASS did not collect data on quantity of systems. On-site inventories showed 28 units with more than one cooling system identified and 1.33 cooling systems per unit on average.

[b] The RASS was limited in its ability to characterize detailed cooling system types, as a tenant often cannot differentiate among different systems.

For low-income tenants, room air conditioners are more prevalent than for non-low-income tenants, while non-low-income units are more likely to feature central conditioning or ASHP systems. Table 4-21 illustrates cooling system market penetration by income category; please note that Table 4-21 compares weighted results among the three RASS cooling categories scaled to reflect the penetrations in Table 4-20 as confirmed on-site.

Table 4-21. Penetration of Cooling System Types by Income Assistance
(Source: 137 on-site observations and 677 survey responses, weighted)

Cooling System Type	Low-Income	Non-Low-Income	Statewide
AC - Room Air Conditioner*	57%	33%	46%
AC - Central Air/ASHP*	28%	50%	38%
AC - MSHP	0%	1%	1%
Total	**86%**	**83%**	**85%**

* Denotes statistically significant difference at the 90% confidence interval.

Analysts found no correlation between cooling system capacity and unit square footage. The average capacity of a cooling system serving a single unit is approximately 15,177 Btu/hr, leading to a normalized capacity of approximately 17.3 Btu/sq ft, which is within the range of typical capacities in MF buildings.

Cooling system efficiency ratings exist in multiple formats (EER, SEER, CEER, COP), depending on system type and manufacturer. For the purposes of reporting, all efficiencies have been converted to SEER.[32] Table 4-22 illustrates the average cooling system efficiency for all systems that could be characterized, and Figure 4-8 shows the efficiency distribution. Table 4-24 provides high-efficiency SEERs for prevalent system types. Generally, central systems were more likely to be located in basements or on rooftops and were therefore more challenging to fully inspect and characterize.

[32] Most efficiency rating types correlate closely and can be easily converted. SEER is an average ratio of cooling capacity to input power over the cooling season. The SEER rating can be approximately expressed as $EER = (1.12*SEER) – (0.02*SEER^2)$. RACs were typically expressed in EER, but they are now expressed in CEER. CEER can be expressed as EER multiplied by 1.01. By definition, COP can be converted to EER by multiplying by 3.412.

Table 4-22. Cooling System Efficiencies (Normalized to SEER) by Type

(Source: Field inventories among 84 tenant units, weighted)

Cooling System Type	*n*	Average SEER or SEER-Equivalent
ASHP	10	12.3
Central air-packaged	5	10.7
Central air-split	22	12.9
Chiller	1	11.4
Ductless mini split	2	19.0
GSHP-closed loop	3	14.4
Packaged roof-top unit	1	13.0
PTAC	11	14.8
PTHP	8	9.4
Room air conditioner	31	11.8
WSHP	22	14.2
Total	**116**	**12.8**

Figure 4-8 is a box and whisker plot illustrating the distribution of cooling system efficiencies. The rectangle for each category represents the first through the fourth quartile. The line dividing the box represents the median, and the X represents the average. The whiskers, or the line extending from each box, represent the minimum and maximum values, excluding outliers, which are represented as individual dots.

Figure 4-8. Cooling System Efficiency Distribution

(Source: Field inventories among 84 tenant units)

Next, we examined cooling system vintages to determine the shares exceeding EUL and identify possible end-of-life savings opportunities. Central air and heat pump cooling systems have an EUL of 18 years, and room air conditioners have an EUL of 9 years.[33] The field auditors were able to verify system vintages for 76% of systems either through nameplate verification or serial number research. Table 4-23 indicates approximately 30% of cooling systems have exceeded their EULs, indicating either 1) limited opportunity for end-of-life efficiency improvements, or 2) that the PSD's cooling system EULs are unrealistically high.

[33] EUL derived from Connecticut 2018 Program Savings Document, page 314, https://www.energizect.com/sites/default/files/2018-PSD-FINAL-121217.pdf

Table 4-23. Cooling System Vintage Compared with Effective Useful Life

(Source: Field inventories among 102 tenant units, weighted)

System Type	EUL	% Beyond EUL
ASHP	18	7%
CAC	18	16%
GSHP	18	56%[a]
RAC	9	52%
WSHP	18	0%
Total		**30%**

[a] Please note that five of eight observed GSHPs had exceeded EUL but were located in the same MF building.

Figure 4-9 illustrates cooling system vintage distribution by type.

Figure 4-9. Cooling System Vintage Distribution

(Source: Field inventories among 102 tenant units)

Per-Unit Savings Potential

To determine the potential savings for replacement of each cooling system type, analysts referenced CT PSD algorithms along with typical performance ratings of high-efficiency units by type. Table 4-24 compares existing conditions with current high-efficiency equivalent units based on market trends to calculate per-unit technical savings potential from cooling system upgrade. Appendix C contains additional details and references on savings calculation assumptions.

Table 4-24. Per-Unit Cooling Savings Potential by System Type

(Source: Field inventories among 137 tenant units, weighted)

Cooling System Type	Adj. Pen.	CFA (sf)	Btu/hr/sf	Annual Hours	Baseline Efficiency		Proposed Efficiency		Annual Energy Savings[a]	Peak Demand Savings
					Value	Unit	Value	Unit	kWh	kW
RAC	46%	876	13.05	364	11.00	CEER	11.92	CEER	29.1	0.02
Central Air/ASHP	38%	876	23.43	718	12.67	SEER	16.18	SEER	269.9	0.17
MSHP	0.5%	876	23.43	718	19.00	SEER	20.21	SEER	70.2	0.04
None	0.8%	-	-	-	-	-	-	-	-	-
Other[b]	15%	-	-	-	-	-	-	-	-	-
	100%		**17.32**						**116.6[c]**	**0.08**

[a] Annual energy savings are based on the difference between the average efficiency observed on-site and a market-based efficient replacement. Some savings values are low because the difference between the two efficiencies is minimal.

[b] Due to the small shares represented in the Other category, additional savings potential measures were not considered.

[c] The total annual energy savings do not directly sum because it includes adjusted penetration values, which are not applied to the individual rows.

4.4.2 Space Heating

All MF dwellings feature at least one type of space-heating system based on the RASS survey and on-site data collection. Field staff observed a total of 187 heating systems among the sample of 137 units visited. Field staff collected as much information as possible; however, equipment access and nameplate specifications were limited for some systems.

Statewide, natural gas is the most common space-heating fuel (54% of units). Low-income units are more likely to be electrically heated, whereas non-low-income units are much more likely to be heated with natural gas. Table 4-25 details the distribution of heating fuel by income category.

Table 4-25. Space-Heating Fuel Distribution by Income Category

(Source: 137 on-site observations and 677 survey responses, weighted, adjusted)

Heating System Fuel	Low Income	Non-Low Income	Statewide
Electric*	35%	28%	32%
Fuel Oil	6%	5%	6%
Natural Gas*	45%	65%	54%
Propane	5%	4%	4%
Total[a]	**90%**	**103%**	**97%**

* Denotes statistically significant difference at the 90% confidence interval.

[a] Percentages do not sum to 100% due to statewide weighting and adjustment of RASS data from on-site verifications.

Statewide, gas-fired furnaces and electric baseboards comprise the highest shares of heating systems at 28% each. Units with low-income tenants are much more likely to feature electric baseboards, whereas non-low-income units are much more likely to feature furnaces. Connecticut MF tenants are significantly more likely (28%) to have electric baseboard heating than SF residents (8%). Table 4-26 illustrates heating system distribution by income category.

Table 4-26. Space-Heating System Distribution by Income Category

(Source: 137 on-site observations and 677 survey responses, weighted)

Heating System Type	Low Income	Non-Low Income	Statewide
Natural gas - furnace	21%	37%	28%
Electric baseboard*	35%	19%	28%
Natural gas - boiler	19%	14%	17%
Central (ducted) air source heat pump*	7%	8%	8%
Fuel oil - boiler	5%	3%	4%
Other[a]	17%	24%	20%
Total[b]	**103%**	**106%**	**104%**

* Denotes statistically significant difference at the 90% confidence interval.

[a] No individual share is greater than 4%.

[b] Percentages do not sum to 100% due to statewide weighting, adjustment of RASS data from on-site verifications, and the possibility that customers had more than one type of heating system.

Similar to cooling systems, we found no correlation between heating system capacity and unit square footage. The average capacity of a heating system serving a single unit is approximately 41,098 Btu/hr, resulting in an average normalized capacity of approximately 46.9 Btu/sq ft.

Heating system efficiency ratings exist in multiple formats (AFUE, HSPF, COP), depending on system type. Table 4-27 illustrates the average cooling system efficiency for the 78 tenant units' systems that could be characterized.

Table 4-27. Space-Heating Efficiencies by System Type and Service[a]

(Source: Field inventories among 78 tenant units, weighted)

Heating System Type	*n*	Average Efficiency	Efficiency Unit
Multi-Unit Systems			
Boiler (forced hot water)	15	0.92	AFUE
Boiler (hydro-air)	3	0.94	AFUE
Single-Unit Systems			
ASHP	8	7.40	HSPF
Combination DHW and space heat	7	0.95	AFUE
Electric baseboard	14	1.00	COP
Furnace	21	0.88	AFUE
GSHP	8	4.34	COP
WSHP	22	4.91	COP

[a] An additional 71 systems were identified that could not be fully characterized for efficiency.

For MF heating systems, heat pumps have an EUL of 18 years, and boilers and furnaces have an EUL of 20 years.[34] Table 4-28 illustrates that approximately 11% of heating systems have exceeded their EUL, indicating limited opportunity for end-of-life efficiency improvements.

Table 4-28. Space-Heating System Vintages Compared with Effective Useful Life

(Source: Field inventories among 83 tenant units, weighted)

System Type	EUL	% Beyond EUL
ASHP	18	7%
Boiler (forced hot water)	20	18%
Combination DHW and space heat	20	0%
Furnace	20	11%
GSHP	18	56%[a]
WSHP	18	0%
Total		**11%**

[a] Please note that five of eight observed GSHPs had exceeded EUL but were located in the same MF building.

ERS field auditors were able to verify system vintages for 65% of systems either through nameplate verification or serial number research. Figure 4-10 illustrates the heating system vintage distribution by type.

[34] EUL derived from Connecticut 2018 Program Savings Document, page 314. https://www.energizect.com/sites/default/files/2018-PSD-FINAL-121217.pdf

Figure 4-10. Space-Heating System Vintage Distribution

(Source: Field inventories among 83 tenant units, unweighted)

Per-Unit Savings Potential

To determine the potential savings from heating system upgrades, the analysts referenced CT PSD algorithms along with typical performance ratings of high-efficiency units by type. Table 4-29 compares existing conditions with current high-efficiency equivalent units available on the market to calculate per-unit technical savings potential from a heating system upgrade.

Table 4-29. Per-Unit Space-Heating Savings Potential by System Type

(Source: Field inventories among 137 tenant units, weighted)

Heating System Type	Fuel	Penetration	Annual Hours	Baseline Efficiency	Proposed Efficiency	Unit	Annual MMBtu Savings[a]
Furnace	Natural Gas	28%	496.4	0.87	0.96	AFUE	2.0
	Propane	3%	496.4	0.78	0.96	AFUE	4.8
	Oil	3%	496.4	0.76	0.86	AFUE	3.1
	Electric	2%	496.4	0.80	9.43	HSPF	18.1
Boiler	Natural Gas	17%	496.4	0.94	0.94	AFUE	0.1
	Propane	2%	496.4	0.82	0.94	AFUE	3.2
	Oil	4%	496.4	0.80	0.88	AFUE	2.2
Central (ducted) ASHP	Electric	8%	496.4	7.40	9.43	HSPF	2.0
Ductless MSHP	Electric	2%	442.0	10.00	9.57	HSPF	0.0
GSHP	Electric	1%	496.4	4.34	4.15	COP	0.0
Electric baseboard	Electric	28%	442.0	1.00	2.8	COP	8.5
Not eligible for upgrade	Misc.	8%	-	-	-	-	-
Total		**104%**					**3.81[b]**

[a] Annual energy savings are based on the difference between the average efficiency observed on-site and a market-based efficient replacement. Some savings values are low because the difference between the two efficiencies is minimal.

[b] The total annual energy savings do not directly sum because it includes adjusted penetration values, which are not applied to the individual rows.

4.4.3 Thermostats

Based on a combination of findings from the RASS survey and on-site verification, field auditors determined that 99% of MF tenants have at least one thermostat in their unit. Field auditors inventoried 188 thermostats as part of the on-site verifications and found no significant difference in thermostat type between income categories, as shown in Table 4-30. Smart thermostats comprise only 2% of MF thermostats statewide, indicating promising savings potential.

Table 4-30. Distribution of Thermostat Types by Income Category

(Source: 137 on-site observations and 677 survey responses, weighted)

Thermostat Type	Low-Income	Non-Low-Income	Statewide
Standard	68%	68%	68%
Basic Programmable	26%	40%	32%
Wi-Fi, Not Smart	1%	1%	1%
Wi-Fi, Smart	1%	2%	2%
Total[a]	**96%**	**110%**	**102%**

[a] Percentages do not sum to 100% due to statewide weighting and adjustment of RASS data from on-site verifications.

Per-Unit Savings Potential

As shown in Table 4-31, ERS analysts calculated energy savings potential for upgrading standard and basic programmable thermostats to smart thermostats based on ENERGY STAR's key product criteria,[35] which estimates that smart thermostats result in energy savings factors (ESFs) of 4% to 8% for heating and 5% to 10% for cooling. ERS analysts acknowledge that smart thermostats are an emerging technology with a limited body of research on savings. After reviewing five studies[36] with savings estimates ranging from 0% to 12%, ERS used ENERGY STAR's reasonably conservative and independently researched estimates.

Table 4-31. Per-Unit Smart Thermostat Savings Potential

(Source: Field inventories among 137 tenant units, weighted)

HVAC System	Pene-tration	Annual Energy Use[a]	Unit	Annual MMBtu Use	Max ESF	Max Savings[b]		
						kWh	Therm	MMBtu
Heat - Natural gas - Furnace	28%	213	therm	21.3	0.08	0.0	17.05	1.71
Heat - Propane - Furnace	3%	233	gallons propane	21.3	0.08	0.0	0.00	1.71
Heat - Oil - Furnace	3%	171	gallons oil	23.7	0.08	0.0	0.00	1.90
Heat - Electric - Furnace	2%	634	kWh	2.2	0.08	50.7	0.00	0.17
Heat - Natural Gas - Boiler	17%	216	therm	21.6	0.08	0.0	17.31	1.73
Heat - Propane - Boiler	2%	237	gallons propane	21.6	0.08	0.0	0.00	1.73
Heat - Fuel Oil - Boiler	4%	168	gallons oil	23.3	0.08	0.0	0.00	1.87
Heat - Central (ducted) air source heat pump	8%	2,163	kWh	7.4	0.08	173.1	0.00	0.59
Heat - Ductless mini-split air source heat pump	2%	1,898	kWh	6.5	0.08	151.9	0.00	0.52
Heat - Ground source heat pump	1%	17,287	kWh	59.0	0.08	1383.0	0.00	4.72
Heat - Electric baseboard	28%	1,898	kWh	6.5	0.08	151.8	0.00	0.52
AC - Central Air-split	35%	911	kWh	3.1	0.10	91.1	0.00	0.31
AC - MSHP/ASHP	1%	729	kWh	2.5	0.10	72.9	0.00	0.25
Total				**214.4**		**108.1**	**7.63**	**1.34**

[a] Annual energy use based on proposed HVAC upgrades as discussed in Sections 4.4.1 and 4.4.2 to avoid double-counting savings.

[b] The total annual energy savings do not directly sum because it includes adjusted penetration values, which are not applied to the individual rows.

[35] https://www.energystar.gov/products/heating_cooling/smart_thermostats/key_product_criteria

[36] SMUD's Smart Thermostat Pilot (2014), Xcel Energy Colorado Smart Thermostat Pilot (2017), Energy Trust of Oregon Smart Thermostat Pilot (2016), ComEd Advanced Thermostat Evaluation (2018), ACEEE's Smart Thermostats and the Triple Bottom Line (2016)

4.4.4 Domestic Hot Water

Field staff observed a total of 137 DHW systems installed across the sample of 137 apartment units visited. For sites at which the DHW system was inaccessible, field auditors were able to assess the equipment type from afar, even if detailed system characteristics could not be confirmed. Table 4-32 provides the distribution of DHW system types, segmented by income category, which are relatively similar. Standard storage tank water heaters are the most prevalent, representing 70% of the population.

Table 4-32. DHW System Distribution by Income Category

(Source: 137 on-site observations and 677 survey responses, weighted)

DHW System Type	Low-Income	Non-Low-Income	Statewide
Electric - Standard	51%	43%	46%
Natural Gas - Standard	19%	22%	21%
Natural Gas - Tankless	8%	24%	17%
Natural Gas - Indirect	9%	5%	7%
Electric - Tankless	3%	3%	3%
Fuel Oil - Standard	2%	3%	3%
Other[a]	10%	7%	9%
Total[b]	**100%**	**107%**	**105%**

[a] No individual share >2%.

[b] Percentages do not sum to 100% due to statewide weighting, adjustment of RASS data from on-site verifications, and the possibility of more than one DHW system per apartment.

Field auditors collected DHW nameplate data while on-site, including capacity, efficiency, vintage, and single-unit vs. multiple-unit service. The average capacity for DHW units that serve a single apartment is 48.7 gallons. Table 4-33 provides DHW system capacities by equipment type and unit-service configuration for those systems with verifiable characteristics.

Table 4-33. DHW System Storage Capacity by Type and Service[a]

(Source: Field inventories among 64 tenant units, weighted)

DHW System Type	*n*	Capacity (Gallons)
Multiple Units	**14**	**261.7**
Indirect w/storage tank	4	595.0
Storage, stand alone	10	89.6
Single Unit	**54**	**48.7**
Indirect w/storage tank	2	44.6
Storage, stand alone	52	48.8
Total	**68**	**100.2**

[a] An additional 30 systems surveyed, whose capacities were unable to be verified.

Figure 4-11 provides the vintage distribution of DHW systems. Field auditors determined that 13% of all DHW systems have exceeded EUL, indicating either: 1) limited present opportunity for replace-on-failure efficiency improvements, or 2) that the PSD's DHW system EULs are unrealistically high.

Figure 4-11. DHW System Vintage Distribution

(Source: Field inventories among 91 tenant units, weighted)

Table 4-34 provides the average efficiency of DHW systems segmented by system type and service configuration for those systems with verifiable characteristics. The systems serving multiple units were notably less efficient than the systems serving individual units. Due to their location in basements or mechanical rooms, systems serving multiple units were generally more difficult to fully characterize than single-unit systems.

Table 4-34. DHW System Efficiency by Type and Service

(Source: Field inventories among 77 tenant units, weighted)

DHW System Type	*n*	Average Efficiency
Multiple Units	**12**	**71.3%**
Indirect w/storage tank	4	88.4%
Storage, stand alone	7	66.0%
Single Unit	**69**	**91.2%**
Combination appliance	13	93.7%
Indirect w/storage tank	2	82.1%
Instantaneous	6	94.4%
Storage, stand alone	48	90.7%
Total	**81**	**87.6%**

To support analysis of potential savings from a temperature turndown measure, field auditors also took at least one DHW temperature reading from a faucet within each visited unit. Figure 4-12 illustrates the DHW temperature reading results. On average, we found a DHW temperature of 124°F; since the recommended minimum DHW temperature is 122°F to prevent Legionella bacteria, savings potential from DHW temperature turndown is limited.

Figure 4-12. DHW Temperature Reading Distribution

(Source: Field inventories among 137 tenant units, weighted)

Per-Unit Savings Potential

To calculate potential savings for upgrading DHW systems, analysts referenced CT PSD algorithms along with typical performance ratings of ENERGY STAR high-efficiency units by type. Analysts used the NY Technical Reference Manual (Version 7)[37] method for estimating annual hot water volume, as it incorporates a per-capita input and can therefore be customized to this MF population rather than a typical SF household. The average visited MF apartment houses 1.79 residents.

Table 4-35 compares existing DHW systems with high-efficiency equivalent units available on the market to calculate per-unit technical savings potential. Note that the electric upgrades are based on a proposed heat pump water heater (HPWH) technology, which field auditors determined are only feasible in approximately 17% of units based on space constraints, ambient

[37] http://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/72c23decff52920a85257f1 10 0671bdd/$FILE/TRM%20Version%207%20-%20April%202019.pdf

space temperature, and the presence of nearby drainage. This value was considerably lower than the 47% estimated for SF residents.

Table 4-35. Per-Unit Annual DHW Savings Potential by System Type

(Source: Field inventories among 137 tenant units, weighted, adjusted)

DHW System	Adj. Penetr.	Percent Eligible	DHW Load (MMBtu/yr)	Baseline Efficiency	Proposed Efficiency	Energy Savings	Unit
Natural Gas Standard Upgrade	24%	66%	6.22	0.64	0.70	0.2147	MMBtu
Electric Standard to HPWH	37%	17%	6.22	0.92	3.16	88.79	kWh
Electric Tankless to HPWH	2%	17%	6.22	0.91	3.16	6.04	kWh
Total Annual Gas Savings						**0.215**	**MMBtu**
Total Annual Electric Savings						**94.82**	**kWh**

DHW savings can also be achieved by reducing hot water consumption through the installation of low-flow devices. Field auditors characterized DHW fixtures in every unit visited. Table 4-36 illustrates the existing conditions, high-efficiency alternatives, and potential savings per unit from installing low-flow faucet aerators and showerheads.

Table 4-36. Per-Unit Annual DHW Fixture Savings Potential by Fixture Type

(Source: Field inventories among 137 tenant units, weighted)

DHW Outlet	Avg. Count/ Unit	Baseline Flow Rate	Efficient Flow Rate	Water Savings (gal)	Electric Savings (kWh)	Gas Savings (Therm)	Oil/Propane Savings (MMBtu)
Bathroom sink	1.4	1.27	1.00	625.3	18.1	1.2	0.012
Kitchen sink	1.0	1.52	1.50	51.4	1.3	0.1	0.001
Showerhead	1.3	2.01	1.52	1864.7	105.3	4.8	0.049
Total					**124.7**	**6.1**	**0.062**

4.5 Weatherization

ERS field auditors assessed weatherization compliance at 137 MF units through physical inspection and qualitative assessments. Due to complexities with blower door testing at MF structures, blower door tests were not included in the scope of this study. Nonetheless, the field staff inventoried physical characteristics through noninvasive inspection methods whenever possible. ERS compared the collected weatherization data with the Connecticut Department of

Energy and Environmental Protection's Definition of Weatherization[38] using the prescriptive approach; the results of this comparison are presented in this section.

Due to limited access to MF common-area spaces, ERS field auditors could not collect sufficient data to assess weatherization for certain building components: roofs, ceilings, frame floors, and foundations. However, the field staff collected comprehensive data on windows and above grade wall (AGW) insulation to compare their characteristics with the current weatherization standard. In lieu of blower door testing, the auditors visually inspected any air sealing gaps, interviewed tenants on apartment tightness and comfort, and qualitatively graded each apartment. Therefore, we use windows, wall insulation, and air sealing characteristics as the three primary variables for assessing weatherization compliance.

Table 4-37 presents the prescriptive levels defined by Connecticut's weatherization standard. To maintain consistency and allow comparison with SF results, we also reference realistic weatherization upgrade levels in the rightmost column, derived from the 2014 Single-Family Weatherization and Baseline Study.[39]

Table 4-37. Weatherization Standard Compared with Typical Upgrade

Measure	Weatherization Standard	Typical Weatherization Upgrade
Above grade walls	R-11	2x4 framing - R-12 2x6 framing - R-19 Other - R-20
Air leakage	9 ACH @ 50 Pa	7 ACH @ 50 Pa
Windows	U-0.50 (Double pane or single pane with storm windows)	U-0.20

Table 4-38 presents the breakdown of units passing the measure-level weatherization standard by building vintage.

Table 4-38. MF Units Meeting Weatherization Standard by Building Vintage

(Source: Field inventories among 132 tenant units, weighted, adjusted)

Building Vintage	*n*	Meets Air Sealing Standard	Meets Window Standard	Meets AGW Standard
Pre-1939	15	45%	92%	47%
1940–1979	29	80%	90%	56%

[38] "DRAFT Definition of 'Weatherization' of Residential Units in Connecticut," Connecticut Department of Energy and Environmental Protection, August 2015. https://www.ct.gov/deep/lib/deep/energy/weatherization/definitionofweatherizationinconnecticutaugust32015.pdf

[39] Connecticut EEB: "R5 Single-Family Weatherization Baseline Assessment," prepared by NMR Group, June 2014, https://www.energizect.com/your-town/single-family-weatherization-baseline-assessment-r5

Building Vintage	*n*	Meets Air Sealing Standard	Meets Window Standard	Meets AGW Standard
1980–1999	12	100%	100%	84%
2000–2009	13	100%	100%	73%
2010 or later	64	100%	99%	82%
Total	**133**	**82%**	**95%**	**70%**

Building vintage correlates closely with air sealing and wall insulation compliance. Newer buildings are more likely to feature sufficiently insulated walls and are more likely to be tightly sealed. Newer buildings were prominently featured in the 137 units visited; as a result, the analysts scaled the weatherization savings potential analysis to reflect statewide vintage demographics, in addition to the overall weighting factors' adjustment for income, tenure, and prior program participation.

Table 4-39 compares weatherization compliance as a function of income assistance. Only slight variation was determined between low-income and non-low-income units. Income category is not a reliable indicator of weatherization compliance.

Table 4-39. MF Dwellings Meeting Weatherization Standard by Income Assistance

(Source: Field inventories among 137 tenant units, weighted)

Building Vintage	*n*	Meets Air Sealing Standard	Meeting Window Standard	Meets AGW Standard
Income assisted	16	98%	100%	75%
Market rate	121	78%	94%	68%
Total	**137**	**82%**	**95%**	**70%**

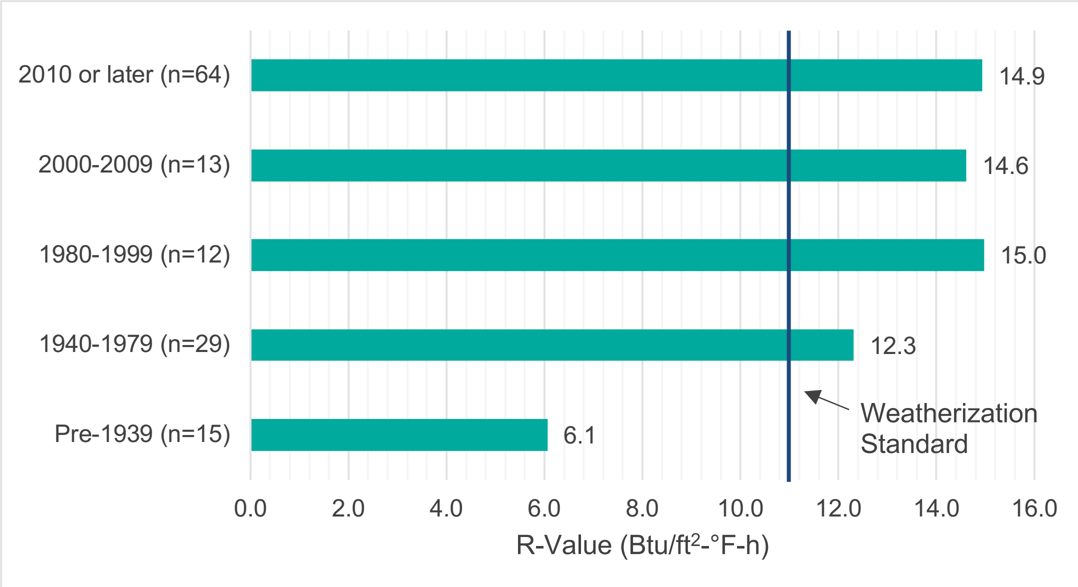
4.5.1 Above-Grade Wall Insulation

ERS field auditors collected data on framing material and configuration and above-grade wall insulation material, depth, and quality for 91% of units visited. The remaining 9% of units could not be characterized noninvasively. Statewide, 85% of surveyed units featured fiberglass batt insulation. The analysts investigated possible correlations between insulation type or framing type and building vintage, building size, income assistance, heating fuel, and utility. However, no reliable correlations were found.

Figure 4-13 presents the average above-grade wall insulation R-value by building vintage. The data shows that newer buildings are generally better insulated than older buildings.

Figure 4-13. Above Grade Wall Insulation R-Value by Building Vintage

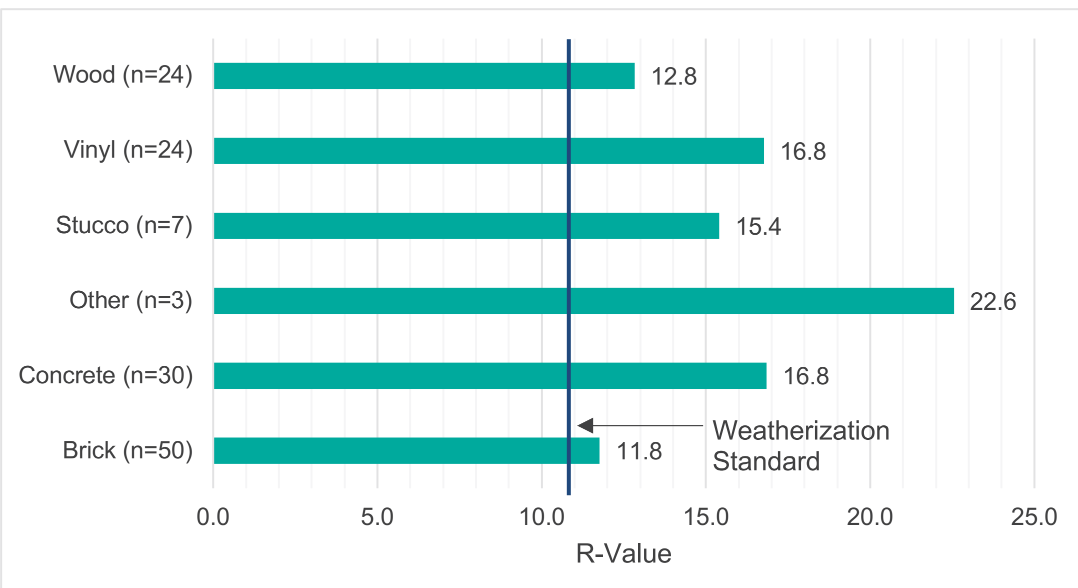
(Source: Field inventories among 130 tenant units, weighted)



The analysts investigated wall insulation R-values as functions of income assistance, building size, heating fuel, and utility; however, no statistically valid correlations were found among these segments. Building construction material, however, correlated with average AGW R-value, as illustrated in Figure 4-14. On average, brick and wood-framed buildings barely exceeded the weatherization standard.

Figure 4-14. Above Grade Wall R-Value by Building Construction Material

(Source: Field inventories among 135 tenant units, weighted)



4.5.2 Windows

ERS field auditors collected size, frame material, and pane characteristics for all windows in each of the 137 visited MF units. Sliding glass doors were included in the analysis because of their similarity to windows; in fact, two visited units did not have any windows but only a sliding glass door. Table 4-40 provides the makeup of glazing and framing types. Double-paned, low-emissivity (lo-E) glazing accounts for almost half of the fenestration.

Table 4-40. Fenestration Glazing and Framing Distributions

(Source: Field inventories among 137 tenant units, weighted)

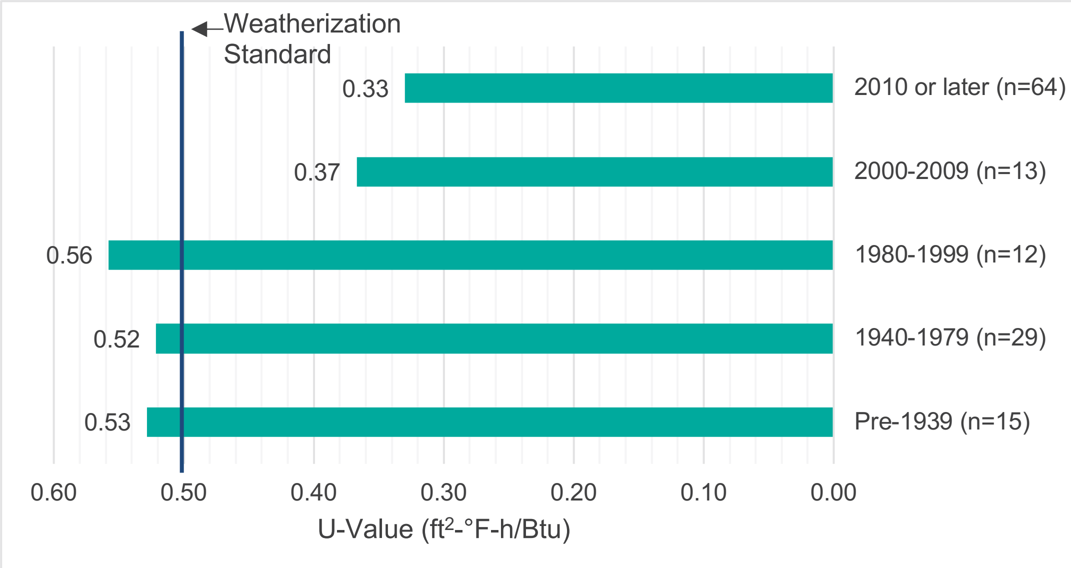
Material	Proportion of Units
Glazing	
Double pane, lo-E	46%
Double pane	35%
Single pane	5%
Double pane, lo-E, argon	7%
Double pane, lo-E + storm	2%
Double pane, lo-E, argon + storm	2%
Single pane + storm	2%
Double pane + storm	1%
Frame	
Vinyl	59%
Metal	25%
Wood	15%
Fiberglass	1%

Because the vast majority of windows do not bear specification data, ERS estimated U-values based on inventoried frame material and pane configuration data using the median value of the Efficient Window Collaborative's recommended ranges.[40] Figure 4-15 shows the average U-value by building vintage; please note that the perspective is inversed to emphasize that lower U-values are more efficient. Again, building vintage appears to correlate with weatherization compliance, as newer buildings feature more efficient windows. The analysts also investigated possible correlation of window U-value and income assistance, building size, heating fuel, and utility; however, no statistically significant correlations were determined among those segments.

[40] https://www.efficientwindows.org/

Figure 4-15. Window and Glass Door U-Value by Building Vintage

(Source: Field inventories among 130 tenant units, weighted)

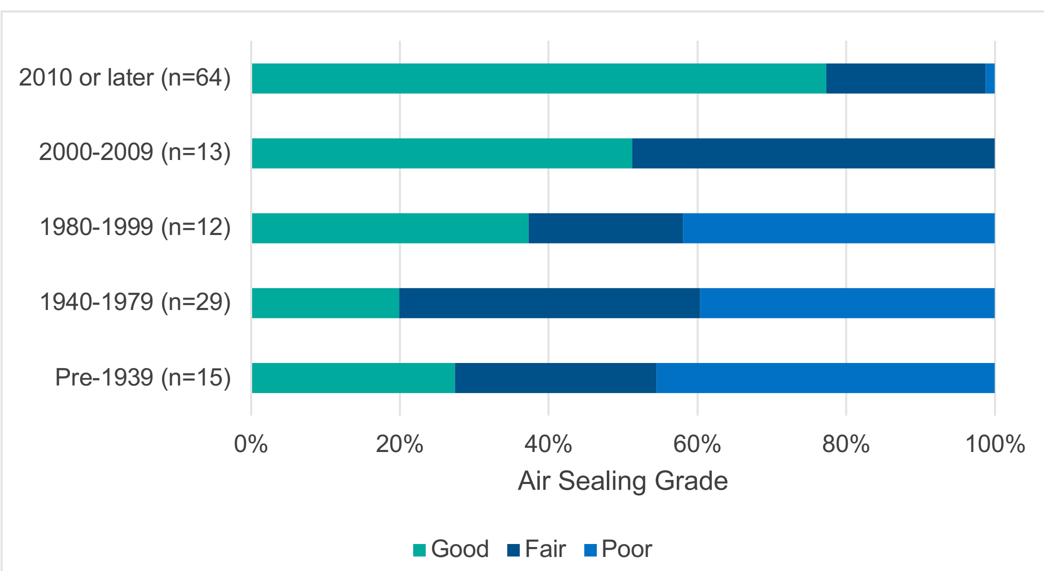


4.5.3 Air Leakage

In lieu of blower door testing, ERS field auditors visually inspected any air sealing gaps, interviewed tenants and management on building tightness and thermal comfort, and graded each unit's air sealing on a good/fair/poor scale. Figure 4-16 shows the distribution of apartments in each air sealing grade based on building vintage.

Figure 4-16. Air Sealing Grade by Building Vintage

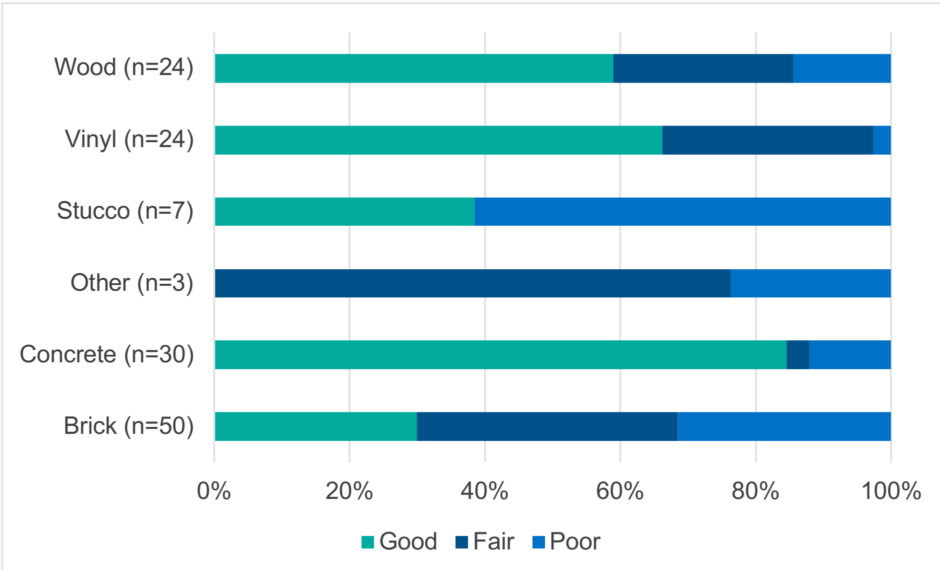
(Source: Field inventories among 124 tenant units, weighted)



Examining air leakage by building construction material, we found that vinyl and concrete buildings are more air-sealed than stucco and brick buildings. This finding corroborates with the vintage analysis in Figure 4-16, as brick buildings tend to be older. Figure 4-17 shows the breakdown of air sealing grade by building construction material.

Figure 4-17. Air Sealing Grade by Building Construction Material

(Source: Field inventories among 129 tenant units, weighted)



4.5.4 Weatherization Compliance and Savings Potential

Ten equipment categories comprise Connecticut's current prescriptive weatherization standard[41]; if a residence complies with at least five such categories, it is considered weatherized. Due to this study's emphasis on in-unit data collection, and limitations on supplementary common area data collection, this study characterized three of those categories: wall insulation, fenestration, and air sealing. It is therefore not possible in this study to define a multifamily unit as "weatherized" by the prescriptive standard. Instead, we assume that, if any of the three categories discussed in Sections 4.5.1 through 4.5.3 were not in compliance with the current weatherization standard, the unit is *eligible for weatherization upgrade*.

[41] Connecticut Department of Energy and Environmental Protection, "Definition of 'Weatherization' of Residential Units in Connecticut," August 2015, https://www.ct.gov/deep/lib/deep/energy/weatherization/definitionofweatherizationinconnecticutaugust32015.pdf

As the 137 MF units visited were predominantly in newer buildings, the analysts scaled the weatherization eligibility results to the statewide building vintage distribution. This true-up revealed that 50% of Connecticut apartments are eligible for weatherization upgrade.

Analysts applied deemed savings algorithms from the CT PSD to calculate savings for all fuels, as illustrated in Table 4-41. Savings for each measure were calculated independently. The statewide technical savings potential for the weatherization measures is contextualized with other measures in Section 5.

Table 4-41. Per-Unit Weatherization Savings Potential

(Source: Field inventories among 137 tenant units, weighted)

Building Vintage	Pre-1939	1940–1979	1980–1999	2000–2009	2010 or later	Total[a]
Population Share	**20%**	**43%**	**25%**	**6%**	**6%**	**100%**
Above Grade Wall Savings						
Electric Energy Savings (kWh)	448.24	78.46	18.24	11.55	45.66	**130.10**
Summer Peak Demand Savings (kW)	0.02	0.00	0.00	0.00	0.00	**0.01**
Gas Savings (MMBtu)	2.47	0.43	0.10	0.06	0.25	**0.72**
Oil Savings (MMBtu)	0.36	0.06	0.01	0.01	0.04	**0.10**
Propane Savings (MMBtu)	0.23	0.04	0.01	0.01	0.02	**0.07**
Fenestration Savings						
Electric Energy Savings (kWh)	89.79	67.59	0.00	0.00	4.34	**46.79**
Summer Peak Demand Savings (kW)	0.01	0.01	0.00	0.00	0.00	**0.00**
Gas Savings (MMBtu)	0.51	0.39	0.00	0.00	0.02	**0.27**
Oil Savings (MMBtu)	0.07	0.06	0.00	0.00	0.00	**0.04**
Propane Savings (MMBtu)	0.05	0.04	0.00	0.00	0.00	**0.02**
Air Sealing Savings						
Electric Energy Savings (kWh)	439.46	92.56	0.00	0.00	0.00	**126.23**
Summer Peak Demand Savings (kW)	0.02	0.00	0.00	0.00	0.00	**0.01**
Gas Savings (MMBtu)	2.41	0.51	0.00	0.00	0.00	**0.69**
Oil Savings (MMBtu)	0.35	0.07	0.00	0.00	0.00	**0.10**
Propane Savings (MMBtu)	0.22	0.05	0.00	0.00	0.00	**0.06**

[a] The total annual energy savings do not directly sum because it includes adjusted penetration values, which are not applied to the individual rows.

The average MF unit could save 303 kWh and 2.1 MMBtu annually if all possible weatherization opportunities are implemented among the three studied categories. Following the algorithms recommended in the 2019 CT PSD, the analysts considered the HVAC system distributions shown in Tables 4-20 and 4-26, along with the weatherization characteristics for non-complying units (weighted for vintage), in the calculation of per-unit savings potential. Appendix C contains additional detail and supporting references for all savings potential calculations.

5 Statewide Savings Potential

ERS analysts next paired the characteristics of a typical multifamily (MF) apartment in Connecticut with statewide statistics and adjustment factors to calculate technical savings potential, defined as the savings that could be achieved if all existing systems were upgraded to high-efficiency alternatives, regardless of barriers such as cost-effectiveness and program limitations.

5.1 Statewide Statistics

In order to extrapolate per-unit characteristics throughout Connecticut, ERS analysts gathered information on the statewide population of MF tenants using publicly available data sources. The analysts used the 2010 US Census and 2016 American Communities Survey (ACS) to develop a statewide MF unit count, segmented by county, town, development level, and building size. Table 5-1 details the total count of all residential units, broken down by county and building size.

Table 5-1. Multifamily Unit Breakdown by County and Building Size

Development	Multifamily Housing Units	5–9 Building Units	10–19 Building Units	20+ Building Units
Fairfield County	25,782	6,432	3,540	15,811
Hartford County	45,676	16,676	10,309	18,691
Litchfield County	17,991	5,252	4,216	8,523
Middlesex County	22,798	7,971	5,481	9,345
New Haven County	50,701	14,322	10,798	25,580
New London County	16,430	5,961	4,030	6,439
Tolland County	28,440	8,277	5,978	14,184
Windham County	25,128	7,647	5,591	11,890
Total	**232,946**	**72,538**	**49,943**	**110,464**

ERS analysts also collected town-specific tax assessor (TA) records for 75 towns across the state, accounting for approximately 60% of the MF population. TA records were used to inform building vintage and HVAC system characteristics for fair extrapolation of unit characteristics statewide. ERS categorized towns by level of development (rural/suburban/urban) based on population density to inform statewide averages when not all towns were represented. Table 5-2 provides development-level characteristics.

Table 5-2. CT Multifamily Population Characteristics by Development Level

Development	Total Towns	Tax Assessor Towns	MF Population Density (Units/sq mile)	MF Units	% of MF Population
Rural	57	25	62	4,190	2%
Suburban	56	26	204	25,944	10%
Urban	56	24	933	235,063	89%
Total	**169**	**75**	**398**	**265,197**	**100%**

Table 5-3 provides the estimated count of statewide MF buildings by size category, based on ACS data. For buildings with fewer than 20 units, ERS analysts estimated the building count based on the average number of units per building size category. To estimate the number of buildings in the 20+ unit category, the analysts developed a distribution of large buildings using the 2001 Residential Finance Survey (RFS)[42], which provides unit counts for 321 large buildings in the Northeast. The large building distribution was then applied to each town's large building unit count to estimate total number of large buildings.

Table 5-3. Building Count by Building Size and Development Level

Development	5–9 Unit Buildings	10–19 Unit Buildings	20+ Unit Buildings	Total Buildings
Rural	287	59	18	363
Suburban	1,616	395	72	2,082
Urban	9,895	3,468	815	14,178
Total	**11,797**	**3,921**	**905**	**16,624**

Table 5-4 provides the distribution of MF units by building vintage, which were applied to weatherization characteristics to adjust the makeup of visited sites to represent the statewide vintage distribution.

Table 5-4. Statewide Buildings Vintage Distribution via Tax Assessor Data

Development	Pre-1939	1940–1979	1980–1999	2000–2009	Post-2010
Rural	19%	30%	39%	6%	5%
Suburban	10%	32%	42%	10%	7%
Urban	21%	44%	23%	6%	6%
Total	**20%**	**43%**	**25%**	**6%**	**6%**

[42] https://www.census.gov/data/datasets/2001/demo/rfs/rfs-pums-data.html

Tables 5-5 and 5-6 provide breakdowns of heating fuel and heating system distributions based on tax assessor records. While this data was not directly used to inform the savings potential calculation, the data supports the heating fuel and system distributions as characterized by the RASS and on-site verifications.

Table 5-5. MF Heating Fuel Distribution via Tax Assessor Data

Development	Natural Gas	Electric	Other
Rural	18%	40%	43%
Suburban	44%	33%	23%
Urban	56%	18%	26%
Total	**54%**	**20%**	**26%**

Table 5-6. Tax Assessed Buildings Heating System Breakdown

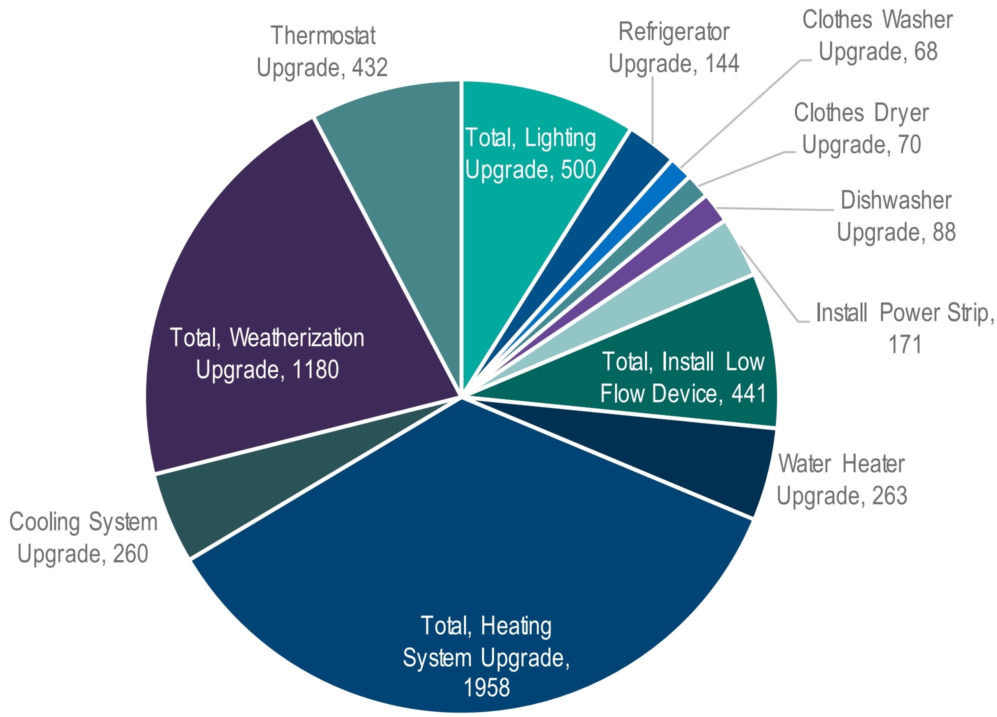
Development	Forced Hot Air	Hydronic	Electric Baseboard	Heat Pump	Other	Unknown
Rural	35%	31%	32%	0%	1%	1%
Suburban	45%	21%	26%	1%	1%	7%
Urban	36%	33%	11%	0%	0%	19%
Total	**37%**	**32%**	**13%**	**0%**	**0%**	**17%**

5.2 Statewide Technical Potential by Measure

Figure 5-1 illustrates annual source BBtu (billion Btu) technical savings potential[43] by measure category.

[43] Source BBtu savings take into account generation, transmission, and distribution losses for electricity as well as fossil fuels, providing an equitable quantification of savings among different energy types. The following source-site ratios were incorporated into all source energy conversions in this study: electricity: 2.80; natural gas: 1.05; fuel oil: 1.01; and propane: 1.01. Per EPA and ENERGY STAR recommendations found here: https://portfoliomanager.energystar.gov/pdf/reference/Source%20Energy.pdf.

Figure 5-1. Annual Source Technical Savings Potential by Measure Category (BBtu/yr)

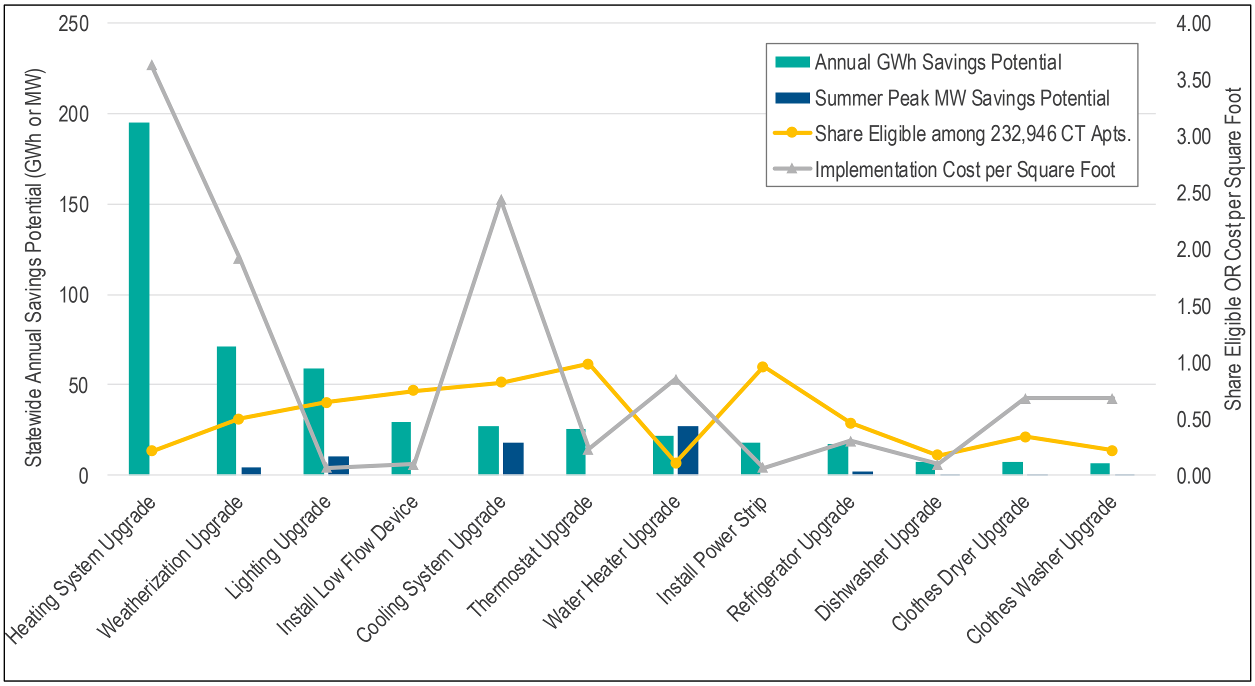


Total statewide technical potential savings of 5,570 BBtu/yr would result in an estimated $350 in utility bill savings per year per apartment.

Overall, we found that approximately 86% of source savings potential is electric, with the heating system upgrade category contributing to 35% of statewide savings potential. Electric savings comprise such a significant share of source BBtu savings due to the high remaining share of electric resistance heat that could be upgraded to considerably higher-efficiency ASHPs, as discussed in following paragraphs.

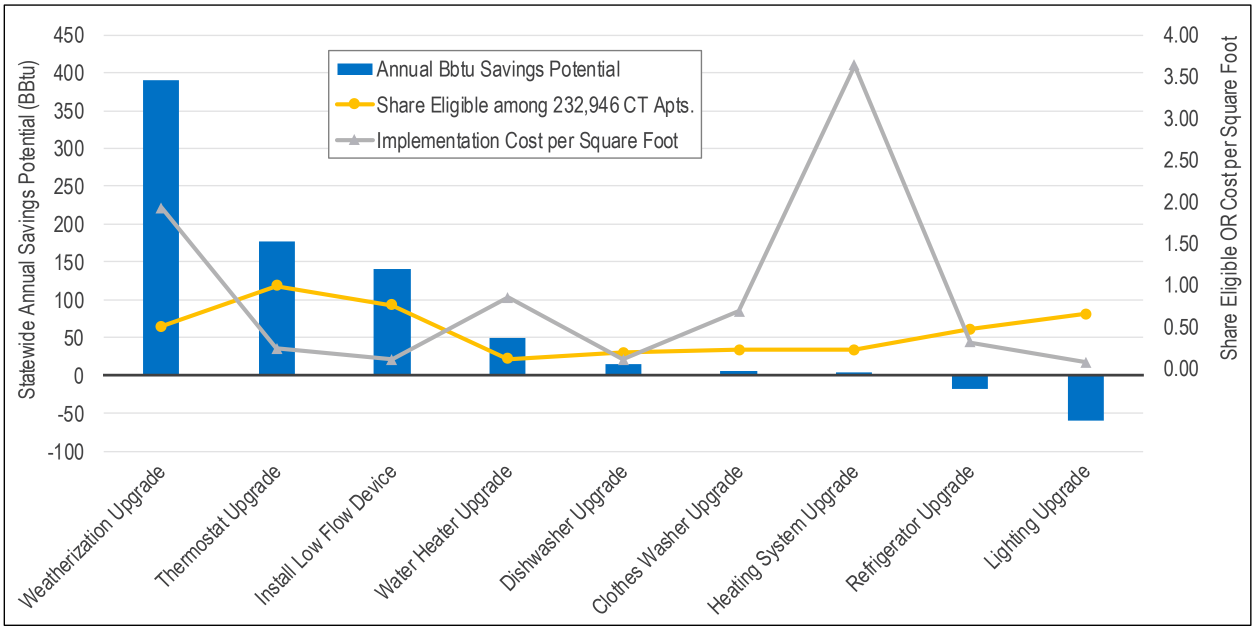
Figures 5-2 and 5-3 further examine electric and natural gas technical savings potential, respectively. Not all MF units are necessarily eligible for upgrade to higher-efficiency alternatives – some already contain high-efficiency equipment (e.g., a low-flow showerhead) or do not contain the equipment at all (e.g., units with common-area laundry). Figures 5-2 and 5-3 also indicate the share of customers that would benefit from upgrade to high-efficiency technology as well as estimated implementation costs normalized per square foot, based on recent installation data from multifamily programs in the Northeast.

Figure 5-2. Statewide Electric Savings Potential (Annual GWh and Peak MW) by Measure Category



Heating system upgrades – most prominently, conversion from electric baseboard heat to high-efficiency air-source heat pumps (ASHPs) – offers the most significant GWh savings potential. ERS found that 28% of MF units statewide are heated by electric baseboards. ASHPs operate over three times as efficiently as resistance heat, leading to substantial savings potential. Other high-opportunity electric measures include lighting upgrades, weatherization, and cooling system upgrades. Please note that the water heater upgrade savings include energy and demand savings from heat pump water heater (HPWH) cooling contributions.

Figure 5-3. Statewide Natural Gas Savings Potential (Annual BBtu) by Measure Category



The most significant gas savings opportunities arise from weatherization upgrades or device replacements like low-flow water fixtures or thermostats. Interestingly, gas-fired space-heating systems do not offer significant savings opportunity, indicating only incremental differences in efficiency between existing systems and high-efficiency alternatives. While only half of Connecticut MF units would benefit from a weatherization upgrade, resulting savings are significant enough to comprise over half of gas savings potential overall.

Some electric upgrades, such as refrigerator replacements or lighting upgrades, actually result in gas penalties due to reduced heating load; these impacts are identified for informational purposes and are considered in the calculation of overall source BBtu savings in Figure 5-1.

Table 5-7 identifies all measures researched in this study, along with the share of MF tenants eligible for upgrade and associated per-unit and statewide electric, gas, and source BBtu impacts. Additional savings potential results are examined in Appendix C. Key findings and recommendations from the statewide savings potential results are explored in the next section.

Table 5-7. Detailed Per-Unit and Statewide Technical Savings Potential by Measure

Measure Category	Measure Type	Detailed Measure Description	Share Eligible	Per-Unit Annual Savings Potential			Statewide Savings		
				kWh	Peak kW	therm	Electric (GWh/yr)	Gas (BBtu/yr)	Source Bbtu/yr Impacts
Lighting	Lighting Upgrade	CFL-to-LED Upgrade	77%	14	0.002	-0.1	3.3	-3.3	28
	Lighting Upgrade	Halogen-to-LED Upgrade	34%	39	0.007	-0.4	9.1	-9.2	77
	Lighting Upgrade	Incandescent-to-LED Upgrade	69%	199	0.034	-2.0	46.4	-46.7	394
Appliances	Refrigerator Upgrade	Full-Size Refrigerator Upgrade	46%	73	0.010	-0.7	17.0	-17.1	144
	Clothes Washer Upgrade	Clothes Washer - In Unit	22%	27	0.003	0.2	6.2	4.6	64
	Clothes Washer Upgrade	Clothes Washer - Common Area	22%	1	0.000	0.0	0.3	0.3	4
	Clothes Dryer Upgrade	Clothes Dryer - In-Unit Electric	34%	30	0.004	0.0	7.0		67
	Clothes Dryer Upgrade	Clothes Dryer - In-Unit Gas	34%	-	-	0.0		0.0	0
	Clothes Dryer Upgrade	Clothes Dryer - Common Area Electric	34%	1	0.000	0.0	0.3		3
	Clothes Dryer Upgrade	Clothes Dryer - Common Area Gas	34%	-	-	0.0		0.0	0
	Dishwasher Upgrade	Dishwasher Upgrade	18%	32	0.003	0.7	7.5	15.2	88
	Install Power Strip	Tier 1 APS - Entertainment	96%	51	0.000	0.0	11.9		113
	Install Power Strip	Tier 1 APS - IT	96%	26	0.000	0.0	6.1		58
DHW	Install Low Flow Device	Bathroom Faucet Aerator	79%	18	0.000	1.2	4.2	28.5	73
	Install Low Flow Device	Kitchen Sink Aerator	46%	1	0.000	0.1	0.3	2.0	5
	Install Low Flow Device	Low Flow Showerhead	95%	105	0.000	4.8	24.5	110.9	362
	Water Heater Upgrade	Storage Tank Water Heater Upgrade	17%	0	0.000	2.1		50.0	52
	Water Heater Upgrade	Storage Tank to HPWH Upgrade	6%	89	0.110	0.0	20.7		198
	Water Heater Upgrade	Tankless to HPWH Upgrade	0%	6	0.007	0.0	1.4		13
HVAC	Heating System Upgrade	Furnace Upgrade	31%	105	0.000	0.0	24.5		284
	Heating System Upgrade	Boiler Upgrade	5%	0	0.000	0.2		4.3	40
	Heating System Upgrade	Air Source Heat Pump Upgrade	8%	46	0.000	0.0	10.8		103
	Heating System Upgrade	Ductless Mini-Split Upgrade	0%	0	0.000	0.0			0
	Heating System Upgrade	Ground Source Heat Pump Upgrade	0%	0	0.000	0.0			0
	Heating System Upgrade	Electric Baseboard Upgrade	28%	688	0.000	0.0	160.2		1531
	Cooling System Upgrade	Room Air Conditioner Upgrade	43%	13	0.011	0.0	3.1		30
	Cooling System Upgrade	ASHP Upgrade	38%	103	0.064	0.0	24.0		229
	Cooling System Upgrade	MSHP Upgrade	0%	0	0.000	0.0	0.1		1
	Thermostat Upgrade	Smart Thermostat Upgrade	98%	111	0.000	7.6	25.8	177.7	432
Weather-ization	Weatherization Upgrade	Above Grade Walls Insulation Upgrade	36%	130	0.007	7.2	30.4	167.4	505
	Weatherization Upgrade	Fenestration Upgrade	6%	48	0.004	2.7	11.1	62.5	186
	Weatherization Upgrade	Air Sealing Upgrade	19%	127	0.006	6.9	29.6	161.2	489

6 Conclusions and Recommendations

Based on the per-unit and statewide results in Sections 4 and 5, respectively, ERS has developed the following conclusions and recommendations. All collected data from this study has been delivered to the EEB in an Excel-based database that includes RASS and SF study data as well. Such data will be valuable for program administrators in measure planning, baseline establishment, and savings quantification.

6.1 Summary of Key Findings

- Conversion from electric resistance heat to air-source heat pumps (ASHPs) presents the most promising savings opportunity of any measure considered in this study. Statewide, 28% of surveyed multifamily (MF) units are heated by electric resistance baseboards, while only 8% of units are heated via ASHP, indicating significant potential for higher electric efficiency. Low-income apartments are statistically significantly more likely to be heated by electric baseboards. Converting electric baseboards to high-efficiency ASHPs would lead to approximately 30% reduction in per-unit heating consumption. Using ASHPs to replace existing non-electric heating, which accounts for nearly two-thirds of MF heating systems, is also promising and would result in considerable decarbonization from fuel switching.
- Significant savings opportunity remains for LED lighting within both MF tenant units and common areas. Only 27% of in-unit lighting sockets had LEDs, while only 17% of visited properties had predominantly LED lighting in common areas. Incandescents comprise 23% of sockets and 38% of stored bulbs. Low-income tenants were slightly less likely to use LEDs but had a significantly higher share of CFLs than non-low-income tenants.
- Smart thermostats offer significant savings opportunity because nearly the entire statewide MF population is eligible for upgrade. We observed minimal differences in thermostat distribution among segments of interest, including income classification. Though the body of independent research on smart thermostat savings is continually growing, studies show that they save approximately 4–8 therms and 54–108 kWh per year per unit based on Connecticut's distribution of heating systems by fuel.
- Statewide, 50% of MF units are eligible for weatherization upgrades—in other words, half of MF units would benefit from at least one weatherization measure. This share is comparatively higher than the SF share found in the 2014 CT study. The weatherization measures that could be readily characterized within MF units – air sealing, wall insulation, and fenestration upgrades – offer significant potential savings for all fuel types. Weatherization opportunities depend closely on building vintage for all measures studied,

with older buildings offering greater savings potential. Income classification was not a reliable predictor of weatherization status or potential. Due to limitations in data collection within MF units and buildings, not all weatherization opportunities could be fully characterized in this study.

- While research on advanced power strip (APS) performance is limited, we estimate that Tier 1 APSs could save 77–103 kWh annually per MF unit based on independent research. Given that only 4% of visited units included an APS, this measure offers significant savings opportunity.
- In approximately half of units, low-flow showerheads and faucet aerators offer significant gas and water savings opportunities. MF tenants currently use showerheads rated at 2.0 gpm on average, while showerheads rated as low as 1.5 gpm are currently available on the market.
- For multiple equipment types, including laundry, HVAC, and DHW systems, inventoried vintage data showed that existing systems generally fall well below the effective useful lives (EULs) referenced in the PSD. This result indicates one of two conclusions: 1) existing systems offer limited opportunity for end-of-life savings, or 2) that the EULs referenced in the PSD are unrealistically high.
- Appliance upgrades offer modest savings potential. While most appliances in MF apartments are not ENERGY STAR–rated, high-efficiency alternatives offer approximately 10% to 20% savings compared to existing stock. Only half of inventoried clothes washers and dryers are located within tenant units.
- Cooling system upgrades offer moderate savings potential, mostly from central cooling system upgrades. Although 46% of MF cooling is provided by room air conditioners (57% for low-income tenants), the existing MF stock has generally reached the market's high-efficiency qualification. Heat pumps offer promising savings potential, but system type conversion (e.g., central air conditioning to heat pump conversion) were not explored as part of this study.

6.2 Recommendations for Program Administrators

Based on the above conclusions, we recommend the following to program administrators serving MF tenants in Connecticut:

- Pursue deeper penetration of low-cost and low-barrier measures that offer significant savings potential. Such opportunities include LED lighting, smart thermostats, low-flow devices, and advanced power strips. Administrators of programs currently offering these measures should consider multiple delivery methods (e.g., direct install, mailer kits, online marketplace) to accelerate adoption as much as possible. More complex devices like APSs and smart thermostats might require contractor training, installation assistance, customer education, and troubleshooting to maximize persistence and energy savings.

- High-impact measure categories – in particular, electric heating system upgrades and weatherization measures – should be further assessed for feasibility in Connecticut MF buildings. Heating system upgrades would be most impactful for low-income tenants, and weatherization upgrades are most needed in older buildings. Such high-impact opportunities require more disruptive retrofits, higher capital commitment, and a dedicated contractor base. We recommend deeper research on achievable savings, barriers to adoption, customer and contractor perceptions of the technologies, and appropriate incentive levels.

6.3 Recommendations for Further Research

This study provides a foundation for deeper examination of existing characteristics and savings opportunities within the Connecticut MF sector. We recommend the following further research:

- As one of this study's primary objectives was to validate RASS responses, the research focused on equipment within tenant units. While visiting tenant units, ERS field staff collected as much common-area information as possible, but key common spaces such as basements and rooftops were not always accessible, limiting data collection on central systems and building envelope. We recommend that a similar baseline and savings opportunity study be conducted among MF properties with common areas as the research focus. Since the HES and HES-IE programs often work with property managers on savings applications, a sample of such property representatives should be targeted for participation in a supplementary study.
- This study quantified ***technical*** savings potential based on existing characteristics and high-efficiency alternatives. By definition, technical savings potential does not consider measure cost-effectiveness, implementation barriers, or market adoption rates. To more comprehensively inform program plans, we recommend that a follow-up, global economic or achievable potential study be conducted in Connecticut. Such a study should address the MF sector distinctly using this study's research as a starting point.
- In 2008, the State of Connecticut passed the Global Warming Solutions Act (GWSA), mandating that the state reduce greenhouse gas emissions to 80% below 2001 levels by January 2050.[44] Given this legislation's focus on carbon emissions reduction and the preponderance of electric resistance and oil space-heating for MF units, we recommend

[44] https://www.cga.ct.gov/2008/ACT/PA/2008PA-00098-R00HB-05600-PA.htm

that further research be conducted on strategic electrification opportunities in Connecticut. As results in Section 5.2 indicate, heating system upgrades comprise about 30% of statewide source BBtu savings potential. Fuel switching was not a focus of this study, but conversion from fossil fuel-fired heating to ASHPs offers even more promising carbon emissions reduction potential. This study's research on equipment-specific characteristics and statewide population data should be supplemented with additional research on barriers and costs to fuel switching and expanded to other customer sectors like SF residents and nonresidential customers. This additional research would provide a more realistic roadmap to transitioning Connecticut customers away from fossil fuels and electric resistance space heating.

APPENDIX A:
Common-Area Data Collection

This appendix summarizes the scope of common-area data collection during ERS's on-site verifications among 137 multifamily (MF) units. While the study primarily focused on individual tenant units, the ERS team targeted key common area data to inform the statewide savings potential analysis. As some single-family (SF) weatherization categories may not be relevant for MF buildings, we have classified various data categories into one of four groups:

4. **Data collected**: The information was relevant for MF buildings and was generally available for collection.
5. **Data attempted to be collected**: The information was relevant for MF buildings but may not have been accessible without access to key common-area spaces. Field staff relied on building management or landlords during the site visits for this access.
6. **Data not collected (not applicable to MF)**: ERS did not collect this information, as it was not collected in the preceding RASS survey and does not materially inform the savings potential analysis.
7. **Data not collected (other reason)**: ERS did not collect this information for the reasons specified in italics.

Please note that Table A-1 addresses only the common-area data related to weatherization and HVAC. Details on in-unit data collection scope can be found in Section 3 of the report.

Table A-1. Multifamily Common Area Data Collection Scope

Category	Collected	Attempted to Collect	Did Not Collect (Not Applicable to MF)	Did Not Collect (Other Reason)
General building information	• Building type • Construction type • Primary heating fuel • Number of stories	• Building vintage • Total building heated sq ft • Total building cooled sq ft • Foundation type • Number of units *(requires common-area access and discussions with building management)*	• Conditioned volume	
General unit information	• Number of bedrooms • Thermostat type • Ownership status • Other non-weatherization information			
Building shell measures	• Exterior walls: construction, insulation location, area, type, R-value, grade	• Ceilings: insulation location, area, type, R-value, grade • Ground floor: insulation location, area type, R-value, grade • Basement: conditioned vs. unconditioned *(requires common-area access)*	• Intermediate floors: insulation location, area, type, R-value, grade *(not exposed to exterior)*	• Slabs: insulation location, area, type, R-value, grade *(2014 SF study recommended not using slab findings for weatherization scoring)* • Joist characteristics *(out of scope and potentially time-consuming)*
Windows	• Unit windows: type, location, area, U-value, SHGC value			• Common-area windows *(out of scope and potentially time-consuming)*
Doors	• Unit exterior door(s): type, location, area, insulation			• Unit interior doors • Common-area doors *(out of scope and potentially time-consuming)*

Category	Collected	Attempted to Collect	Did Not Collect (Not Applicable to MF)	Did Not Collect (Other Reason)
Mechanical equipment	• HVAC in-unit: system type, make, model age, efficiency, capacity • HVAC central: system type, primary fuel • DHW: central vs. in-unit	• HVAC central: system make, model, age, efficiency, capacity • DHW: type, make, model, primary fuel, age, efficiency, capacity *(requires common-area access)*		
Air leakage	• Unit-level inventory of exterior air gaps: location, size • Unit-level air sealing grade	•	• Diagnostic blower-door testing *(complex for MF buildings)*	• Common-area air leakage data *(out of scope and potentially time-consuming)*
Duct information	• Unit-level ducts: type of duct, insulating material, R-value • Unit-level duct sealing grade	•		• Common-area ducts *(out of scope and potentially time-consuming)*
Ventilation	• Unit-level bathroom fans: quantity, control type • Other unit-level ventilation systems	• Energy recovery and heat recovery ventilation (ERV/HRV) systems *(requires common-area access)*		

APPENDIX B:
Statewide Statistics Research

This appendix details the methodology and supplemental results from ERS's research on statewide multifamily (MF) unit count and characteristics.

6.4 Methodology

ERS analysts collected municipal tax assessor (TA) records for 75 towns across Connecticut, accounting for approximately 60% of the state's MF population. The TA records were primarily collected through the Vision Government Solutions online database,[46] with some supplemental downloading of individual towns' data, such as Hartford, as it accounts for a 9% of the state's total MF population. After collecting over 680,000 TA records for all property types, ERS analysts merged, cleaned, and categorized the data by property type.

To filter the data for the MF population of interest, analysts first removed commercial and industry properties based on building style and model. With only residential properties remaining, analysts identified single-family (SF) versus MF using three separate indicators, including occupancy-to-residential unit ratio, building style, and building occupancy as determined from the assessed total occupancy at a given parcel ID.

Though the TA records provided a sufficient cross-section to determine demographics of interest throughout Connecticut—including building size, square footage, heating fuels, and HVAC systems—ERS used census data to estimate the total number of MF units in the state. Only occupied units were considered in this study's savings potential analysis. TA demographics were applied to the statewide MF population assuming uniform representation from the 60% of Connecticut towns with downloadable data.

6.5 Supplemental Results

The following tables provide breakdowns of heating fuel and heating system distributions based on TA records. While this data was not used to inform the savings potential analysis, the findings generally support the results determined through on-site visits and the RASS survey, providing confidence in extrapolating such results statewide.

[46] http://www.vgsi.com/index.php/connecticut-online-database/

Table B-1. Tax Assessor Data on MF Heating Fuel Distribution

Development	Natural Gas	Electric	Other
Rural	18%	40%	43%
Suburban	44%	33%	23%
Urban	56%	18%	26%
Total	**54%**	**20%**	**26%**

Table B-1's data is nearly identical to the weighted RASS response data verified through on-site visits, providing confidence in survey results.

Table B-2. Tax Assessor Data on MF Heating System Type

Development	Forced Hot Air	Hydronic	Electric Baseboard	Heat Pump	Other	Unknown
Rural	35%	31%	32%	0%	1%	1%
Suburban	45%	21%	26%	1%	1%	7%
Urban	36%	33%	11%	0%	0%	19%
Total	**37%**	**32%**	**13%**	**0%**	**0%**	**17%**

Table B-2 mostly correlates with verified RASS data. Overall, analysts found that 31% of surveyed MF units were primarily heated via forced hot air. The electric baseboard and heat pump shares are low as compared to the survey and on-site results. The unknown category, particularly for urban properties which comprised most of the on-site sample, likely includes mixed-mode heating and less classifiable system types.

Table B-3. Tax Assessor Data on MF Cooling Penetration

Development	AC	No AC
Rural	37%	63%
Suburban	61%	39%
Urban	50%	50%
Total	**51%**	**49%**

Table B-3 contradicts the findings from the RASS and on-site verifications. We believe that a significant portion of MF units cooled by room air conditioners are categorized as "No AC" in tax records, as such systems do not require municipal permitting for installation.

APPENDIX C:
Technical Savings Potential

Figure C-1, on the following page, provides measure-by-measure site and source energy and demand savings, along with key sources of savings algorithms and assumptions paired with the multifamily (MF) per-unit characteristics detailed in Section 4 of the report.

Figure C-1. Statewide Technical Savings Potential by Measure with References

Measure Category	Measure Type	Detailed Measure Description	Share Eligible	Per-Unit Annual Savings Potential			Statewide Savings			Source(s) Paired with CT MF Baseline Data
				kWh	Peak kW	therm	Electric (GWh/yr)	Gas (BBtu/yr)	Source Bbtu/yr Impacts	
Lighting	Lighting Upgrade	CFL-to-LED Upgrade	77%	14	0.002	-0.1	3.3	-3.3	28	a
	Lighting Upgrade	Halogen-to-LED Upgrade	34%	39	0.007	-0.4	9.1	-9.2	77	a
	Lighting Upgrade	Incandescent-to-LED Upgrade	69%	199	0.034	-2.0	46.4	-46.7	394	a
Appliances	Refrigerator Upgrade	Full-Size Refrigerator Upgrade	46%	73	0.010	-0.7	17.0	-17.1	144	b, c
	Clothes Washer Upgrade	Clothes Washer - In Unit	22%	27	0.003	0.2	6.2	4.6	64	b, c
	Clothes Washer Upgrade	Clothes Washer - Common Area	22%	1	0.000	0.0	0.3	0.3	4	b, d
	Clothes Dryer Upgrade	Clothes Dryer - In-Unit Electric	34%	30	0.004	0.0	7.0		67	b, c
	Clothes Dryer Upgrade	Clothes Dryer - In-Unit Gas	34%	-	-	0.0		0.0	0	b, c
	Clothes Dryer Upgrade	Clothes Dryer - Common Area Electric	34%	1	0.000	0.0	0.3		3	b, d
	Clothes Dryer Upgrade	Clothes Dryer - Common Area Gas	34%	-	-	0.0		0.0	0	b, d
	Dishwasher Upgrade	Dishwasher Upgrade	18%	32	0.003	0.7	7.5	15.2	88	b, c
	Install Power Strip	Tier 1 APS - Entertainment	96%	51	0.000	0.0	11.9		113	e, f
	Install Power Strip	Tier 1 APS - IT	96%	26	0.000	0.0	6.1		58	e, f
DHW	Install Low Flow Device	Bathroom Faucet Aerator	79%	18	0.000	1.2	4.2	28.5	73	c, g, h
	Install Low Flow Device	Kitchen Sink Aerator	46%	1	0.000	0.1	0.3	2.0	5	c, g, h
	Install Low Flow Device	Low Flow Showerhead	95%	105	0.000	4.8	24.5	110.9	362	c, g, h
	Water Heater Upgrade	Storage Tank Water Heater Upgrade	17%	0	0.000	2.1		50.0	52	g, h
	Water Heater Upgrade	Storage Tank to HPWH Upgrade	6%	89	0.110	0.0	20.7		198	g, h
	Water Heater Upgrade	Tankless to HPWH Upgrade	0%	6	0.007	0.0	1.4		13	g, h
HVAC	Heating System Upgrade	Furnace Upgrade	31%	105	0.000	0.0	24.5		284	g, i
	Heating System Upgrade	Boiler Upgrade	5%	0	0.000	0.2		4.3	40	g, i
	Heating System Upgrade	Air Source Heat Pump Upgrade	8%	46	0.000	0.0	10.8		103	g, i
	Heating System Upgrade	Ductless Mini-Split Upgrade	0%	0	0.000	0.0			0	g, i
	Heating System Upgrade	Ground Source Heat Pump Upgrade	0%	0	0.000	0.0			0	g, i
	Heating System Upgrade	Electric Baseboard Upgrade	28%	688	0.000	0.0	160.2		1531	g, i
	Cooling System Upgrade	Room Air Conditioner Upgrade	43%	13	0.011	0.0	3.1		30	c, h
	Cooling System Upgrade	ASHP Upgrade	38%	103	0.064	0.0	24.0		229	c, h
	Cooling System Upgrade	MSHP Upgrade	0%	0	0.000	0.0	0.1		1	c, h
	Thermostat Upgrade	Smart Thermostat Upgrade	98%	111	0.000	7.6	25.8	177.7	432	b, c, i
Weatherization	Weatherization Upgrade	Above Grade Walls Insulation Upgrade	36%	130	0.007	7.2	30.4	167.4	505	c, g
	Weatherization Upgrade	Fenestration Upgrade	6%	48	0.004	2.7	11.1	62.5	186	c, g
	Weatherization Upgrade	Air Sealing Upgrade	19%	127	0.006	6.9	29.6	161.2	489	c, g

References

a. Lumen vs. wattage crosswalk analysis among different bulb types, https://www.thelightbulb.co.uk/resources/lumens_watts/

b. ENERGY STAR key product criteria, available by technology at https://www.energystar.gov/products/spec

c. 2018 installation data from a portfolio of residential programs in a similar jurisdiction in the Northeast. Installation data was used to define high-efficiency levels currently available on the market.

d. Rule-of-thumb estimate of count of MF units per common-area washer or dryer, http://mla-online.com/MLAOnline/Resources/Laundry_Room_Guide/MLAOnline/Laundry_Room_Guide.aspx?hkey=1cc449e8-788f-4cdc-9ae2-4e4cd97f0204

e. NYSERDA, "Advanced Power Strip Research Report," https://www.nyserda.ny.gov/-/media/Files/EERP/Residential/Power-Management-Research-Report.pdf

f. Energy Trust of Oregon, "Pilot Study of Tier 1 Advanced Power Strips in Multifamily," https://www.energytrust.org/wp-content/uploads/2018/03/Tier-1-APS-ETO-MF-Pilot-Evaluation-Report_FINAL_wSR.pdf

g. 2019 Connecticut Program Savings Document, https://www.energizect.com/sites/default/files/2019%20PSD%20%283-1-19%29.pdf

h. New York Technical Reference Manual: Version 7, http://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/72c23decff52920a85257f1100671bdd/$FILE/TRM%20Version%207%20-%20April%202019.pdf

i. ENERGY STAR qualified products lists, available by technology at https://www.energystar.gov/productfinder/. Qualified products lists were used to define high-efficiency options currently available to consumers on the market.

6.6 Measure-Specific Per-Unit Savings

Tables supporting the measure-by-measure per-unit savings values are included below with citations to the above sources.

Table C-1. Detailed Lighting Per-Unit Savings Analysis

	Operation		Baseline Case							Efficient Case (Market)			Savings per Apartment		
Space Type	Hr per Day[g]	Summer CF[g]	Qty Bulbs	CFL Share	CFL W	Incan Share	Incan W	Halo Share	Halo W	CFL to LED W[a]	Incan to LED W[a]	Halo to LED W[a]	Conn. W	kWh	Peak kW
Bedroom	2.3	0.13	3.74	35%	16.4	25%	57.9	6%	47.1	14.37	9.58	11.39	55.9	47.0	0.007
Bathroom	2.0	0.13	4.28	23%	16.4	36%	57.9	2%	47.1	14.37	9.58	11.39	80.4	58.7	0.010
Hallway	1.9	0.13	1.59	31%	16.4	21%	57.9	21%	47.1	14.37	9.58	11.39	29.3	20.3	0.004
Kitchen	4.2	0.13	4.20	55%	16.4	15%	57.9	3%	47.1	14.37	9.58	11.39	39.6	60.6	0.005
Living Rm.	3.5	0.13	3.98	37%	16.4	26%	57.9	8%	47.1	14.37	9.58	11.39	64.2	82.0	0.008
Dining Rm.	3.0	0.13	0.39	58%	16.4	20%	57.9	2%	47.1	14.37	9.58	11.39	4.5	4.9	0.001
Closet	1.9	0.13	0.63	30%	16.4	13%	57.9	13%	47.1	14.37	9.58	11.39	7.4	5.1	0.001
Other	1.9	0.13	0.88	28%	16.4	30%	57.9	7%	47.1	14.37	9.58	11.39	15.5	10.7	0.002
Total					**16.4**		**57.9**		**47.1**	**14.4**	**9.6**	**11.4**	**296.7**	**289.4**	**0.039**

Table C-2. Detailed Refrigerator Per-Unit Savings Analysis

Refrigerator Characteristic	*n*	Weighted Shares	Statewide Weighted Ave kWh	Statewide Weighted Ave. Vol. (cf)	Statewide Adjusted Volume (cf)	Market High Efficiency Alternative	
						High-Efficiency kWh[c]	Annual kWh Savings
Bottom Freezer	6	2%	478	16.6	20.6	455	23
Side-by-Side	9	7%	660	23.5	29.1	556	104
Single Door	2	1%	406	16.8	20.8	336	70
Top Freezer	107	90%	444	17.3	21.4	374	71
Statewide	**124**	**100%**	**464**	**17.6**	**21.3**	**388**	**76**

Table C-3. Detailed Dishwasher Per-Unit Savings Analysis

Segment		*n*	Statewide Weighted Ave kWh	Minimum High-Efficiency Alternative		Market-Based High-Efficiency Alternative	
				High-Efficiency kWh[b]	Annual kWh Savings	High-Efficiency kWh[c]	Annual kWh Savings
Income Assistance*	Market Rate	74	317	270	47	238	79
	Low Income	24	290	270	20	238	52
Tenure*	Own	30	280	270	10	238	42
	Rent	68	314	270	44	238	76
Company	Eversource	95	307	270	37	238	69
	UI	3	290	270	20	238	52
Statewide		**98**	**306**	**270**	**36**	**238**	**68**

Table C-4. Detailed Clothes Washer Per-Unit Savings Analysis

Location	Config.	*n*	Weighted Shares	Existing Conditions				Market-Based High-Efficiency Alternative		
				MEF	Capacity (cf)	Estimated IMEF	Annual kWh	IMEF[c,i]	Annual kWh	Savings
In Unit	Front-load	27	17%	2.66	3.48	2.27	99	2.92	41	58
	Top-load	31	22%	1.62	3.11	1.19	119	2.17	55	64
In Unit		**58**	**39%**	**2.08**	**3.27**	**1.66**	**110**	**2.50**	**49**	**61**
Common Area	Front-load	35	44%	2.72	3.27		230	2.23	230	0
	Top-load	17	17%	1.62	3.14		500	2.23	215	285
Common Area		**52**	**61%**	**2.41**	**3.23**		**306**	**2.23**	**226**	**81**
Statewide		**110**	**100%**	**2.28**	**3.25**	**1.66**	**230**	**2.33**	**157**	**73**

Table C-5. Detailed Clothes Dryer Per-Unit Savings Analysis

Dryer Heating Fuel	*n*	Weighted Shares	Energy Factor	Estimated Annual kWh or Therm	Market-Based High-Efficiency Alternative		
					High-Efficiency EF[c,i]	High-Efficiency kWh	Savings (kWh or therm)
Electric	45	95%	3.62	660	3.96	599	62
Natural gas	2	4%	3.30	23	3.49	22	1
Statewide	**47**	**99%**	**3.61**	**660**	**3.90**		

Table C-6. Detailed APS Per-Unit Savings Analysis

Cluster Type	Total Device Count	# Apts. with Hub(s)	Ave Hubs Overall	Ave Devices per Hub	Total kWh per Hub	Total kWh per Apt.	APS Tier 1 Savings %[e]	Max Savings per Apt.	Min Savings per Apt.[f]
Computer	276	70	0.6	3.2	345	222	16%	35	26
Entertainment	647	125	1.6	3.1	351	544	12%	68	51

Table C-7. Detailed Cooling Per-Unit Savings Analysis

End Use	RASS Penetration	CFA	Btuh/sf	Hours[g,h]	Baseline Efficiency		Proposed Efficiency[c]		Energy Savings	Demand Savings
					Value	Unit	Value	Unit	kWh	kW
Room Air Conditioner	46.0%	876	13.05	364	11.00	CEER	11.92	CEER	29.1	0.02
Central Air / ASHP	38.1%	876	23.43	718	12.32	SEER	16.18	SEER	269.9	0.17
MSHP	0.5%	876	23.43	718	15.66	SEER	20.21	SEER	70.2	0.04
No Cooling	0.8%	-	-	-	-	-	-	-	-	-

Table C-8. Detailed Space Heating Per-Unit Savings Analysis

End Use	Penetr.	CFA	Btuh/sf	Hours[g,h]	Baseline Efficiency		Proposed Efficiency[c,i]		Energy Savings		
					Value	Unit	Value	Unit	Value	Unit	Site MMBtu Savings
Heat - Natural gas - Furnace	28%	876	46.9	496.4	0.87	AFUE	0.96	AFUE	20.3	therm	2.0
Heat - Propane - Furnace	3%	876	46.9	496.4	0.78	AFUE	0.96	AFUE	53.0	Gallons propane	4.8
Heat - Oil - Furnace	3%	876	46.9	496.4	0.76	AFUE	0.86	AFUE	22.7	Gallons oil	3.1
Heat - Electric - Furnace	2%	876	46.9	496.4	0.80	AFUE	9.43	HSPF	5309.8	kWh	18.1
Heat - Natural Gas - Boiler	17%	876	46.9	496.4	0.94	AFUE	0.94	AFUE	1.1	therm	0.1
Heat - Propane - Boiler	2%	876	46.9	496.4	0.82	AFUE	0.94	AFUE	35.5	Gallons propane	3.2
Heat - Fuel Oil - Boiler	4%	876	46.9	496.4	0.80	AFUE	0.88	AFUE	15.8	Gallons oil	2.2
Heat - Central (ducted) ASHP	8%	876	46.9	496.4	7.40	HSPF	9.43	HSPF	593.4	kWh	2.0
Heat - Ductless MSHP	2%	876	46.9	442.0	10.00	HSPF	9.57	HSPF	0.0	kWh	0.0
Heat - GSHP	1%	876	46.9	496.4	4.34	COP	4.15	COP	0.0	kWh	0.0
Heat - Electric baseboard	28%	876	34.1	442.0	1.00	COP	2.80	COP	2492.0	kWh	8.5
Heat - Not eligible for upgrade	8%										

Table C-9. Detailed Smart Thermostat Per-Unit Savings Analysis

HVAC System	Penetr.	CFA	Btuh/sf	Hours [g,h]	Value	Unit	Annual Energy Use	Unit	Site MMBtu Use	Market Savings			
										Market ESF[b]	kWh	Therm	MMBtu
Heat - Natural gas - Furnace	28%	876	46.9	496.4	0.96	AFUE	59.5	Therm	5.9	0.08	0.0	4.76	0.48
Heat - Propane - Furnace	3%	876	46.9	496.4	0.96	AFUE	6.3	Gallons propane	0.6	0.08	0.0	0.00	0.05
Heat - Oil - Furnace	3%	876	46.9	496.4	0.86	AFUE	4.6	Gallons oil	0.6	0.08	0.0	0.00	0.05
Heat - Electric - Furnace	2%	876	46.9	496.4	9.43	HSPF	12.5	kWh	0.0	0.08	1.0	0.00	0.00
Heat - Natural Gas - Boiler	17%	876	46.9	496.4	0.94	AFUE	35.9	Therm	3.6	0.08	0.0	2.87	0.29
Heat - Propane - Boiler	2%	876	46.9	496.4	0.94	AFUE	4.3	Gallons propane	0.4	0.08	0.0	0.00	0.03
Heat - Fuel Oil - Boiler	4%	876	46.9	496.4	0.88	AFUE	7.1	Gallons oil	1.0	0.08	0.0	0.00	0.08
Heat - Central (ducted) ASHP	8%	876	46.9	496.4	9.43	HSPF	168.3	kWh	0.6	0.08	13.5	0.00	0.05
Heat - Ductless MSHP	2%	876	46.9	442.0	9.57	HSPF	34.2	kWh	0.1	0.08	2.7	0.00	0.01
Heat - GSHP	1%	876	46.9	496.4	4.15	COP	207.4	kWh	0.7	0.08	16.6	0.00	0.06
Heat - Electric baseboard	28%	876	46.9	442.0	2.80	COP	523.9	kWh	1.8	0.08	41.9	0.00	0.14
AC - Central Air-split	35%	876	23.4	718.1	16.18	SEER	319.8	kWh	1.1	0.10	32.0	0.00	0.11
AC - MSHP/ASHP	1%	876	23.4	718.1	20.21	SEER	3.8	kWh	0.0	0.10	0.4	0.00	0.00

Table C-10. Detailed DHW System Upgrade Per-Unit Savings Analysis

DHW System Type	Adjusted Penetr.	Eligible for Upgrade?	DHW GPY[g]	DHW Temp	Main Temp[g]	DHW Load (Btu/yr)	Baseline Efficiency		Proposed Efficiency[i]		Annual Energy Savings		Demand Savings
							Value	Unit	Value	Unit	Value	Unit	kW
Natural gas - Standard	24%	TRUE	11,228	123.8	57	6,223,884	0.64	EF	0.70	UEF	9.0	Therm	-
Natural gas - Tankless	19%	TRUE	11,228	123.8	57	6,223,884	0.94	EF	0.93	UEF	-	Therm	-
Natural gas - Indirect	8%	TRUE	11,228	123.8	57	6,223,884	0.88	EF	0.81	UEF	-	-	-
Natural gas - Combined	3%	TRUE	11,228	123.8	57	6,223,884	0.94	EF	0.81	UEF	-	-	-
Electric - Standard	37%	17%	11,228	123.8	57	6,223,884	0.92	EF	3.16	UEF	238.4	kWh	0.296
Electric - Tankless	2%	17%	11,228	123.8	57	6,223,884	0.91	EF	3.16	UEF	241.6	kWh	0.296

Table C-11. Detailed DHW Fixture Per-Unit Savings Analysis

Outlet	Count/ Unit	Baseline Flow Rate	Efficient Flow Rate[c]	Uses/Day[h]	Use Duration[g,h]	Temp In[g]	Temp Out[g]	Water Savings (gal)	Electric Savings (kWh)	Gas Savings (Therm)
Bathroom sink	1.4	1.27	1.00	17.0	0.5	55	80	625.3	18.1	1.2
Kitchen sink	1.0	1.52	1.50	17.0	0.5	55	80	51.4	1.3	0.1
Showerhead	1.3	2.01	1.52	1.3	8.3	55	105	1864.7	105.3	4.8

APPENDIX D:
Results Comparison with Other Research

In this appendix, results from the 2018 CT MF study are compared with results from recent or relevant studies from other jurisdictions in the Northeast. Table D-1 identifies the data sources referenced in the comparison tables that follow (Tables D-2 through D-8).

Table D-1. References for Results Comparison with Other Jurisdictions

Study Name	Abbrev.	Year	SF	MF	Link
Residential Appliance Saturation Survey & Residential Lighting Impact Saturation Studies	CT SF + RASS	2018	✓		TBD once published
National Grid Rhode Island Lighting Market Assessment	RI SF Lighting		✓		http://www.ripuc.org/eventsactions/docket/5.%20RI2311%20RASS%20Lighting%20Report%20Final%2027July2018.pdf
2017-18 Residential Lighting Market Assessment Study	MA SF Lighting	2017-18	✓		http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC_179_LtgMarketAssessment_28March2018_FINAL-1.pdf
Massachusetts Multifamily High Rise Baseline Study	MA MF Highrise	2017		✓	http://ma-eeac.org/wordpress/wp-content/uploads/MA-Multifamily-High-Rise-Baseline-Study-Report.pdf
National Grid New York (Upstate) Lighting Market Assessment	NY SF Lighting	2017-18	✓		Unavailable
Residential Statewide Baseline Study of New York State - Volume 2: Multifamily	NY MF	2015		✓	https://www.nyserda.ny.gov/-/media/Files/Publications/building-stock-potential-studies/residential-baseline-study/Vol-2-Multifamily-Res-Baseline.pdf
Massachusetts Multifamily Market Characterization and Potential Study	MA MF	2012		✓	http://ma-eeac.org/wordpress/wp-content/uploads/Massachusetts-Multifamily-Market-Characterization-Potential-Study-Volume-I-2011-Energy-Efficiency-Annual-Report-Appenxid-C-Study-5.pdf
Massachusetts Residential Appliance Saturation Survey (RASS)	MA RASS	2009	✓	✓	http://ma-eeac.org/wordpress/wp-content/uploads/11_MA-Residential-Appliance-Saturation-Survey_Vol_1.pdf

Table D-2. Comparison of CT MF Lighting Socket Shares with Other Research

Lighting Type	CT MF	CT SF (2018)	RI SF (2018)	MA SF (2018)	MA SF (2017)	NY SF (2018)	NY SF (2017)
CFL	35%	29%	22%	23%	26%	18%	21%
Halogen	8%	9%	10%	7%	0%	9%	8%
Incandescent	23%	27%	24%	24%	28%	37%	42%
LED	28%	26%	33%	34%	27%	22%	14%

Table D-3. Comparison of CT MF Stored Lighting Results with Other Research

Parameter	Lighting Type	CT MF	CT SF (2018)	RI SF (2018)	MA SF (2018)	NY SF (2018)
Quantity stored bulbs	All	2.2	10.2	9.2	14.5	12.1
Stored bulbs share	CFL	19%	20%	17%	9%	8%
	Halogen	15%	11%	7%	2%	3%
	Incandescent	38%	46%	51%	51%	58%
	LED	28%	20%	25%	22%	19%

Table D-4. Comparison of CT MF Appliance Characteristics with Other Research

Equipment	Parameter	CT MF	CT SF (2018)	NY (2015)	MA MF (2012)	MA RASS (2009)
Refrigerator	Saturation (includes freezers)	1.03	1.27	n.d.	1.02	1.10
	Share ENERGY STAR qualified	37%	38%	39%	n.d.	n.d.
Dishwasher	Saturation	0.72	0.75	n.d.	n.d.	0.69
	Share ENERGY STAR qualified	64%	73%	45%	n.d.	n.d.
Clothes washer	Saturation	0.51	0.99	n.d.	n.d.	0.43
	Share ENERGY STAR qualified	50%	55%	69%	n.d.	n.d.
Clothes dryer	Saturation	0.50	0.97	n.d.	0.21	0.41
	Share ENERGY STAR qualified	9%	4%	5%	n.d.	n.d.
	Share electric	96%	n.d.	77%	88%	85%

n.d. = No data

Table D-5. Comparison of CT MF Space Heating Characteristics with Other Research

<table>
<tr><th>Parameter</th><th>Type</th><th>CT MF</th><th>CT SF (2018)</th><th>NY (2015) – Central Systems</th><th>NY (2015) – In-Unit Systems</th><th>MA MF (2012)</th><th>MA RASS (2009)</th></tr>
<tr><td rowspan="6">Fuel shares</td><td>Natural gas</td><td>54%</td><td>35%</td><td>62%</td><td>50%</td><td>n.d.</td><td>51%</td></tr>
<tr><td>Fuel oil</td><td>6%</td><td>45%</td><td>26%</td><td>2%</td><td>n.d.</td><td>2%</td></tr>
<tr><td>Electricity</td><td>32%</td><td>11%</td><td>8%</td><td>44%</td><td>n.d.</td><td>46%</td></tr>
<tr><td>Steam</td><td>0%</td><td>0%</td><td>2%</td><td>3%</td><td>n.d.</td><td>0%</td></tr>
<tr><td>Propane</td><td>4%</td><td>5%</td><td>n.d.</td><td>1%</td><td>n.d.</td><td>1%</td></tr>
<tr><td>Other</td><td>4%</td><td>4%</td><td>2%</td><td>0%</td><td>n.d.</td><td>0%</td></tr>
<tr><td rowspan="5">System types</td><td>Forced air</td><td>28%</td><td>34%</td><td>9%</td><td>47%</td><td>28%</td><td>26%</td></tr>
<tr><td>Hydronic</td><td>21%</td><td>62%</td><td>74%</td><td>19%</td><td>55%</td><td>56%</td></tr>
<tr><td>Electric baseboard</td><td>28%</td><td>8%</td><td>10%</td><td>15%</td><td rowspan="2">15%</td><td>6%</td></tr>
<tr><td>Heat pump</td><td>8%</td><td>11%</td><td>0%</td><td>12%</td><td>1%</td></tr>
<tr><td>Other</td><td>20%</td><td>16%</td><td>7%</td><td>4%</td><td>2%</td><td>11%</td></tr>
<tr><td rowspan="2">System location</td><td>Central</td><td>32%†</td><td>N/A</td><td>69%</td><td>N/A</td><td>65%</td><td>n.d.</td></tr>
<tr><td>In-Unit</td><td>68%†</td><td>N/A</td><td>N/A</td><td>31%</td><td>35%</td><td>n.d.</td></tr>
</table>

n.d. = No data

N/A = Not applicable

† Results are at the system level, not the apartment level, and therefore do not disregard multi-unit systems (e.g., a unit with two ductless HPs)

Table D-6. Comparison of CT MF Space Cooling Characteristics with Other Research

<table>
<tr><th>Type</th><th>CT MF</th><th>CT SF (2018)</th><th>NY (2015) – In-Unit Systems</th><th>MA MF (2012)</th><th>MA RASS (2009)</th></tr>
<tr><td>RAC</td><td>46%</td><td>50%</td><td>78%</td><td>35%</td><td>40%</td></tr>
<tr><td>Central AC</td><td>31%</td><td>39%</td><td>16%</td><td>26%</td><td>36%</td></tr>
<tr><td>Heat pump</td><td>13%</td><td rowspan="2">4%</td><td>0%</td><td>n.d.</td><td>12%</td></tr>
<tr><td>Ductless</td><td>1%</td><td>n.d.</td><td>n.d.</td><td>2%</td></tr>
<tr><td>Other</td><td>9%</td><td>n.d.</td><td>0%</td><td>n.d.</td><td>1%</td></tr>
<tr><td>No cooling</td><td>1%</td><td>4%</td><td>6%</td><td>n.d.</td><td>8%</td></tr>
</table>

n.d. = No data

Table D-7. Comparison of CT MF DHW System Characteristics with Other Research

Parameter	Type	CT MF	CT SF (2018)	NY (2015) – Central Systems	NY (2015) – In-Unit Systems	MA MF (2012)	MA RASS (2009)
Fuel shares	Natural gas	54%	41%	64%	63%	n.d.	43%
	Fuel oil	2%	58%	30%	37%	n.d.	4%
	Electricity	40%	24%	2%	0%	n.d.	53%
	Propane or other	4%	8%	4%	0%	n.d.	0%
System types	Standard (storage)	70%	75%	26%	85%	n.d.	94%
	Tankless	20%	7%	3%	2%	n.d.	4%
	Indirect	7%	13%	67%	8%	n.d.	n.d.
	Other	9%	3%	4%	5%	n.d.	n.d.
System location	Central	22%†	N/A	72%	N/A	60%	n.d.
	In-Unit	78%†	N/A	N/A	28%	40%	n.d.

n.d. = No data

N/A = Not applicable

† Results are at the system level, not the apartment level, and therefore do not disregard multi-unit systems

Table D-8. Comparison of CT MF Window Characteristics with Other Research

Category	Type	CT MF	MA 2012	MA 2009
Framing material	Vinyl	59%	49%	35%
	Wood	15%	12%	23%
	Metal	25%	40%	34%
	Fiberglass	1%	0%	0%
Pane	Single pane	7%	12%	39%
	Double pane	93%	86%	59%
	Triple pane	0%	2%	1%