R1706 Residential Appliance Saturation Survey & R1616/R1708 Residential Lighting Impact Saturation Studies

Final Report

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Connecticut RASS (R1706) and Lighting (R1616/R1705) Studies

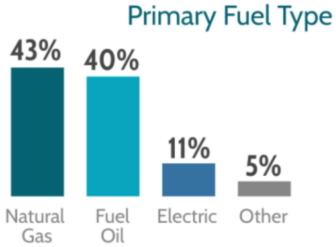
In late 2017 and early 2018, researchers fielded a Residential Appliance Saturation Survey (RASS) and lighting study with UI and Eversource electric customers. The study included web surveys and on-site verification visits. This report provides estimates of penetration and characterizes a variety of end uses among the customer population. The study also resulted in a comprehensive database.

Approach

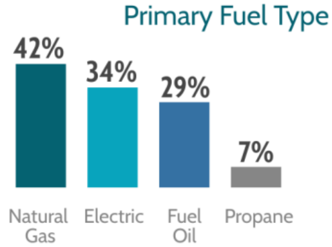
- 30,300 recruitment letters
- 2,426 web surveys
- 227 on-site verification visits

Select Key Findings

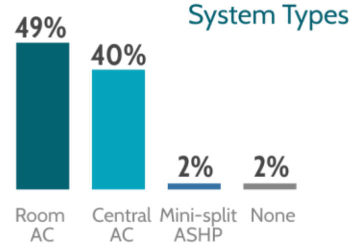
Heating



Water Heating



Cooling



Thermostats

Customers most often have standard thermostats (**61%**). Only **70%** of the customers with programmable thermostats use the programmable features.

Heat Pump Water Heaters

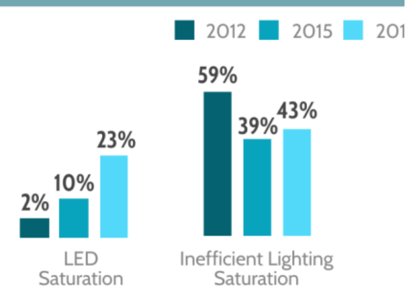
Only **1%** of customers had heat pump water heaters. Nearly one-half of single-family homes (**47%**) could have technically accommodated them – the limiting factor was most often insufficient space (**26%**).

Advanced Power Strips

More than three-fifths (**61%**) of survey respondents reported having APS installed, but on-site visits revealed that penetration was only **4%**. Nearly all on-site homes (**97%**) had peripheral devices based around a TV or computer, indicating a plethora of opportunities for APS.

Lighting

.ED saturation (the percentage of all sockets filled with LEDs) doubled between 2015 and 2018 – a tenfold ncrease from 2012. While inefficient (incandescent and halogen) saturation has decreased, substantial opportunity for savings still exist. Additionally, Connecticut LED saturation lags neighboring program states Rhode Island – 33% & Massachusetts – 31%). However, federal standards and naturally occurring market adoption present risk to continued program interventions. These competing factors mean Connecticut must carefully examine future program efforts related to residential lighting.



Average Equipment Age (years)

Furnaces	Boilers	Central ACs	Room ACs	Water Heaters	Fridges	Dishwashers	Washers	Dryers	Dehumidifiers
12	17	14	12	11	13	10	11	12	10

Abstract

The *R1706 Residential Appliance Saturation Survey (RASS)* and *R1616/R1708 Lighting Impact Saturation* studies were based on web surveys with 2,426 Eversource and United Illuminating (the Companies) electric customers and follow-up on-site verification visits with 227 of those customers.[1] With the goal of developing an inventory of residential end uses and building characteristics, the study produced an Excel database that contains all primary research data and detailed analyses. Analyses include adjustment factors that were calculated based on differences between self-reported data and on-site observations (to correct for self-reported data errors). As summarized in this report, results often reinforced current program offerings and directions outlined in Connecticut's 2019 to 2021 Plan or implied additional tactics to save energy:

1. The Plan notes strategies for exploring and pursuing decarbonization through electrification in Connecticut. Findings underscore the relevance for programs to support near-term strategic electrification. Most customers rely on natural gas/propane (48%) or fuel oil (40%) as their primary heating fuel. Similarly, over two-fifths of customers rely on natural gas/propane (49%) or fuel oil (34%) for water heating. Heat pump water heaters were uncommon, but nearly one-half of single-family homes could technically accommodated them.
2. Results emphasize the value of the Companies' current support of ENERGY STAR®-qualified smart learning thermostats, which are less reliant on consumer knowledge and behavior. Their penetration is low (5%), and customers demonstrated a general lack of understanding of thermostats and programmable features on programmable models.
3. Supporting ENERGY STAR-qualified appliances is still relevant. ENERGY STAR saturation was low among appliances manufactured in 2013 or more recently.
4. Secondary refrigerators were present in one in five homes, which may indicate a need to explore the cost-effectiveness of appliance recycling programs.
5. The Companies' support of advanced power strips (APS) through its E-Commerce Platform is likely worthwhile. It may be beneficial to explore including APS as a direct-install measure in Home Energy Solutions and Home Energy Solutions – Income Eligible programs. Despite ample opportunities for employing APS, relatively few customers (4%) had them. Nearly all homes had at least one set of electronics with peripherals devices based around a TV or PC, yet they were rarely plugged into an APS.
6. While LED saturation has increased substantially since 2012, the study reveals considerable opportunity for additional LED adoption: 43% of sockets have inefficient bulbs and 57% of bulbs in storage are inefficient. While these findings may indicate that continued promotion of ENERGY STAR LEDs is warranted, federal standards and naturally occurring market adoption may present risk to continued program interventions in the form of reduced baseline.

[1] In partnership with the *R1705/R1609 Multifamily Baseline and Weatherization Opportunity*.

This study also examined weatherization in single-family homes, but complications in comparability between a 2011 study and these 2018 results implied the need to commission a more comprehensive weatherization study to accurately assess the current and changing state of single-family home weatherization in Connecticut.

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Executive Summary

Executive Summary

The following report includes results from the *R1706 Residential Appliance Saturation Survey (RASS)* and *R1616/R1708 Lighting Impact Saturation* studies. The studies resulted in (1) an inventory of residential end-uses, including heating and cooling equipment, water heating, appliances, consumer electronics, and lighting; (2) a characterization of customer homes, including building characteristics; and (3) estimates of lighting saturation and retrospective upstream program net-to-gross (NTG).[2] In partnership with the *R1705/R1609 Multifamily Baseline and Weatherization Opportunity* study research, these studies leveraged results from 2,426 web surveys and 227 follow-up on-site verification visits with Eversource and United Illuminating (the Companies) residential electric customers. In addition to this report, which provides an overview of the study methodology and an analysis of results, the study produced an Excel database (RASS Database) that includes all primary research data points and detailed analyses, along with a database user guide.

Methodology

This section summarizes the research methodology described in Section 2.

Topics. The web survey asked about appliances, consumer electronics, HVAC, water heating, building characteristics, demographics, program participation, and attitudes towards environmental issues. The on-site visits took place for a subset of web survey respondent households to verify select self-reported data and collect additional information on various end uses, including lighting, shell characteristics, efficiency levels, and equipment ages.

Sampling and fielding. The sample frame consisted of 30,300 customers from the Companies' residential electric customer databases. Outreach through letters and emails yielded 2,426 completed web surveys (R1706) and 90 single-family (R1616/1708) and 137 multifamily (R1705/R1609) on-site verification visits at the homes of a subset of survey respondents.

Weighting. The analysis applied proportional weights that accounted for income, program participation, and dwelling type. However, results coming solely from single-family on-site visits used dwelling-age-based weights since the on-site sample overrepresented pre-1950s homes.

Adjustment factors. Using a comparison between self-reported (web-survey results) and observed (on-site results) end-use equipment, the analysis developed adjustment factors (ratios) to correct self-reported data among the full survey sample. Adjustment factors were applied in cases where on-site verified results differed statistically significantly from the web-survey results at the 90% confidence level.

Database development. Web-survey and on-site verification data were combined with anonymized respondent billing data in an Excel database to provide additional details and

[2] The retrospective NTG value for the upstream program has been provided as context for other, more robust, NTG estimates produced for Connecticut as part of the CT R1615 analysis and is not meant to supplant existing and planned NTG values.

breakdowns not presented in this report. Appendix G (provided separately) includes a database user guide.

Benchmarking. This study undertook benchmarking efforts where appropriate:

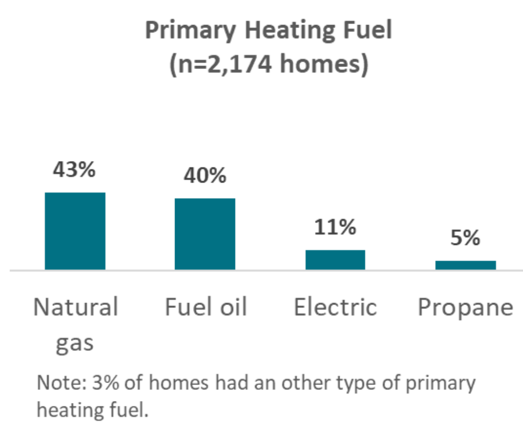
- **Non-lighting.** In 2011, the Connecticut Energy Efficiency Board (EEB) commissioned a comprehensive weatherization study to assess Connecticut's single-family homes. While the 2011 study relied solely on on-site visits, this 2018 study used a combination of web-survey and on-site visit results to develop adjustment factors to estimate penetration (the percentage of homes with the end use) and quantities for non-lighting end uses. In instances where data were collected only on site (primarily equipment efficiency levels, equipment ages, and building shell data points) – not through the web survey – this study compares results to those of 2011, where possible.
- **Lighting.** Massachusetts and National Grid Rhode Island have commissioned lighting market assessments in recent years. This study used those results – and results from the 2012 Connecticut lighting market assessment – to contextualize the effectiveness of Connecticut's lighting program, primarily in terms of saturation (the percentage of all sockets filled with a specific bulb type), and to estimate NTG.

The following sections present the key findings and offer some considerations for planning.

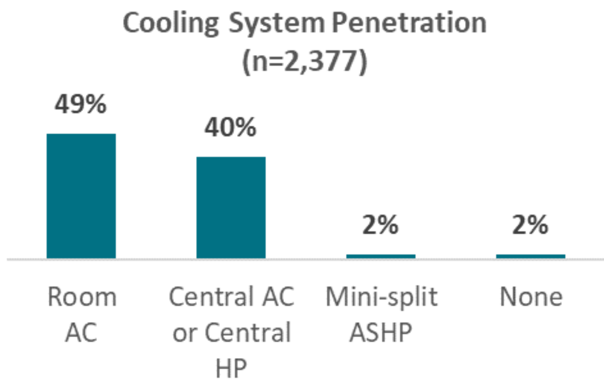
Heating and Cooling

Findings

Heating. Based on web-survey responses and on-site observations, the most common primary heating fuels were natural gas (43%) and fuel oil (40%). While single-family customers were most likely to use fuel oil as their primary heating fuel (45%), multifamily customers were most likely to use natural gas (54%). Heating systems were most often oil boilers (22%), gas furnaces (21%), and gas boilers (20%). On-site observations showed that, on average, in single-family homes, boilers were 17 years old and furnaces were 12 years old. The effective useful life (EUL) in the Connecticut Program Savings Document (PSD) for gas furnaces is noticeably longer than the median age observed in furnaces (all fuel types) in the sample (20 versus 11 years); in fact, it is also longer than that in the Massachusetts 2019-2021 Technical Reference Manual (15 years). There are similar, yet not as extreme, differences among boilers.



Cooling. Results from the web-survey and on-site visits show that nearly one-half of customers (49%) had room air conditioners for their cooling needs, while four in ten (40%) had central air



conditioners.[3] Only 2% of homes had no cooling equipment. On-site observations found that, among single-family homes, room air conditioners were 12 years old and central air conditioners were 14 years old, on average. Room air conditioner EUL in the Connecticut PSD is nine years, which is shorter than the median age of units in the sample (13 years), while central air conditioner EUL in the PSD is longer (18 years) than the median age in the sample (11 years).

Heat pumps. Heat pump penetration was low based on web-survey results and on-site visits. Only 4% of customers used central heat pumps and 3% used ductless mini-split heat pumps (DMSHP) for their heating needs; 2% had DMSHP for cooling.[4]

Efficiency. Among common heating systems assessed while on site in single-family homes, the most noticeable difference – where sample sizes were adequate – between observed efficiency and federal standards was for natural gas furnaces (AFUE of 88.4 versus 80.0).[5]

Section 3.1 provides additional details regarding heating and cooling end uses.

Considerations

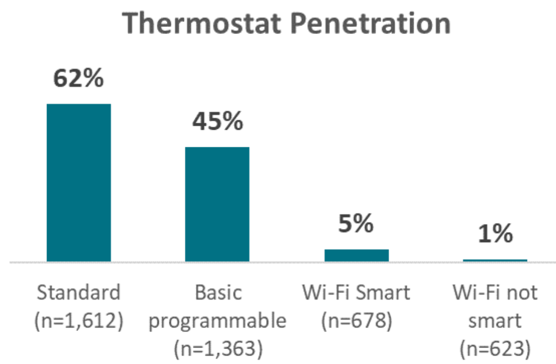
- The 2019 to 2021 Plan outlines the Companies' near-term plan to pilot heat pump incentives for customers with fuel oil or propane heating (and references the pursuit of strategic electrification). The low penetration of heat pumps and prevalence of fossil fuel-based heating presented here support the pilot's relevance. The EEB and the Companies can consider this, and the results from the recently released draft of the *R1617 Ductless Heat Pump Market Characterization* study and upcoming *R1965 HP/HPWH Baseline and Potential Assessment* study, as they assess the effectiveness of the pilot and determine their long-term approach to supporting heat pumps.
- Study *X1931 In-Depth PSD Review* should consider updating the EULs for furnaces, boilers, and room and central air conditioners based on these results.

[3] As confirmed by on-site data, some of these central air conditioners may be air source heat pumps, which are likely indistinguishable from central AC systems to most homeowners.
[4] It is surprising that heat pump usage for heating was slightly higher than for cooling, yet sample sizes (number of heat pumps) were too small to draw conclusions about heat pump usage behavior. Additionally, survey respondents were provided an option for "air source heat pump" under the heating question, but not for cooling; it is possible some air source heat pumps may have been captured in the central air conditioner response category. For a better assessment, see DNV GL's 2019 *R1617 Connecticut Residential Ductless Heat Pumps Market Characterization Study*.
[5] Sample sizes among other systems were too small to draw conclusions about differences in efficiency.

THERMOSTATS

Findings

Penetration. According to web-survey responses and on-site observations, more than two-fifths of customers (45%) had programmable thermostats, yet standard thermostats (62%) were still more common. Smart (5%) and not smart (1%) wireless (Wi-Fi) thermostats had barely penetrated the market. During the web survey, roughly three-quarters of respondents indicated that they did not know if they had either of these. On that note, thermostat types all required adjustment factors, implying a general lack of consumer understanding of thermostat features.



Habits. From December through February, depending on the time of day, web-survey respondents said they set their thermostats to between 66°F and 68°F, on average. Those who had cooling systems, set their thermostats, on average, to between 70°F and 71°F from June through August. Comparing maximum settings with minimum settings, the typical respondent varied their temperature set points by 2°F or 3°F on a given day. In the web survey, nearly one-third of respondents with programmable thermostats (30%) reported that they did not actually program them.[6]

Section 3.2 presents more information on this topic.

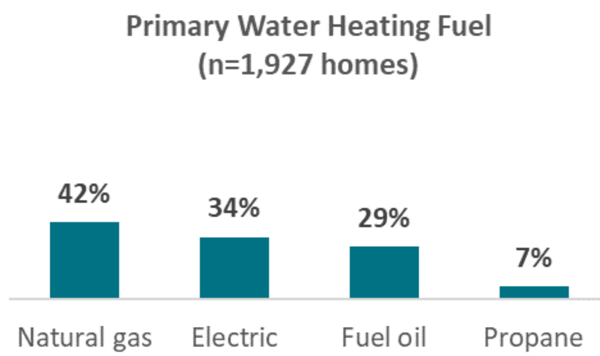
Considerations

- Lack of understanding regarding thermostat features and setup observed as part of this study underlines the potential importance of smart learning thermostats being included as part of the Companies 2019 to 2021 plans because expected savings from smart thermostats are less dependent on customer setup and understanding. However, the decision to carry thermostat efforts forward should be based on evaluation results that demonstrate that properly setup thermostats produce energy savings – which this study did not address.

[6] This is somewhat lower than in Rhode Island, where 40% of customers with programmable thermostats did not program them. Source: NMR. "National Grid Rhode Island Residential Appliance Saturation Survey (Study RI2311 Report." October 11, 2018. http://www.ripuc.org/eventsactions/docket/6.%20National%20Grid%20RI2311%20RASS%20Final%20Report%2011OCT2018.pdf.

Water Heating

Findings



As detailed in Section 3.3, customers most often had natural gas water heaters (42%), and about one-third of customers (34%) had fuel oil water heaters (according to web-survey responses and on-site visit results). Fuel oil water heaters were considerably more common among single-family customers (58%) than multifamily customers (2%). Regardless of fuel type, tankless and combination water heaters were uncommon, and storage tank water heaters were more common. While 29% of customers had electric water heaters, heat pump water heaters (HPWHs) were very uncommon: only 1% of customers had them. Based on on-site observations, nearly one-half of single-family homes (47%) could have technically accommodated them – the limiting factor was most often insufficient space (26%).

The average water heater Energy Factor (EF) observed on site in single-family homes was 0.67 among gas systems and 0.66 among oil systems. Water heaters observed on site in single-family homes were 11 years old, on average.

Considerations

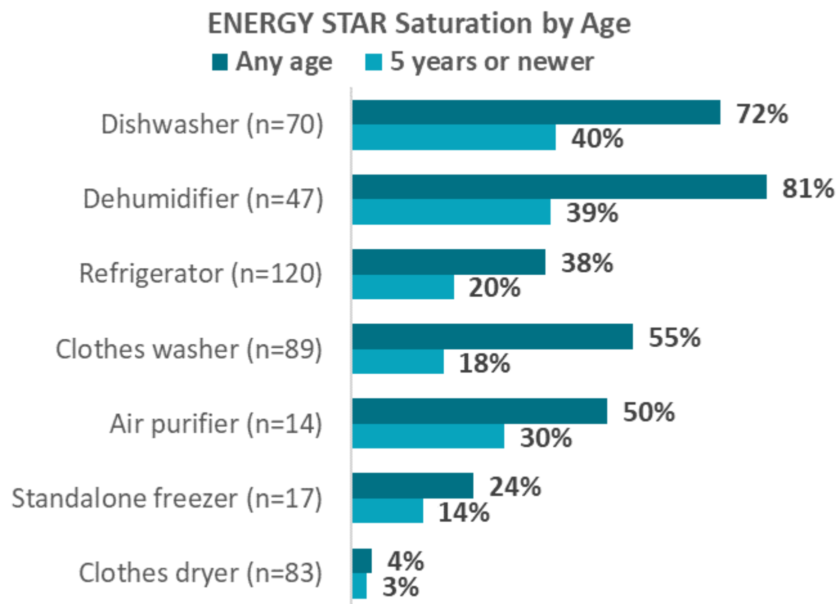
- The high-technical feasibility of HPWHs and their low penetration supports the relevance of the Companies' current incentives for them.

Appliances

Findings

Laundry. Based on web survey and on-site results, more than three-quarters of homes had clothes washers (79%) and dryers (77%) in their units. This differed by dwelling type. For example, only one-half of multifamily customers had in-unit clothes washers, while nearly all single-family customers (97%) did. According to survey responses, the average customer used warm or hot water for more than one-half (52%) of their loads of laundry. On average, web-survey respondents reported running 4.5 loads of laundry per week, but this was not verified through on-site data collection. In contrast, the 2018 PSD specifies 295 loads per year, aligning with the default value that the ENERGY STAR appliance calculator uses – 5.7 loads per week.

Dishwasher. Without differentiation between single- and multifamily, nearly three-quarters (73%) of homes had a dishwasher according to web-survey responses and on-site observations. Web-survey respondents reported running 3.3 dishwasher cycles per week, but this was not verified on site. The PSD specifies 215 cycles per year, equivalent to the ENERGY STAR assumption of 4.1 cycles per week. Compared to other appliances inspected on-site in single-family homes, dishwashers had high ENERGY STAR saturation: more than two-thirds were ENERGY STAR-labeled (72%) and two-fifths (40%) were both ENERGY STAR-labeled and manufactured in the last six years.[7]



Refrigerator. According to web-survey and on-site results, one in five customers had more than one refrigerator. Refrigerators inspected on site in single-family homes were 13 years old, on average.

For more details on appliances, see Section 3.4.

Considerations

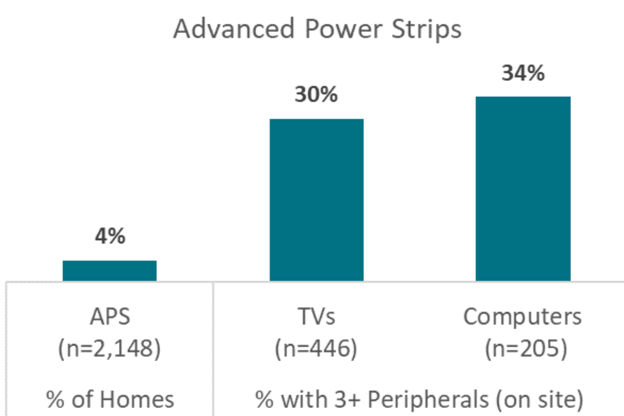
- Given the proportion of homes with more than one refrigerator, the Companies may wish to explore the cost-effectiveness of an appliance recycling program.
- Study *X1931 In-Depth PSD Review* should consider updating PSD assumptions of the number of loads of laundry or dishwasher cycles that customers run. However, in that decision-making process, the study should weigh the reliability of self-reported values (versus metered values). Similarly, it should consider updating assumptions of dehumidifier EUL.
- The relatively low saturation of new ENERGY STAR models supports the relevance of the Companies' incentives for ENERGY STAR appliances.
- Educating customers about the benefits of using cold water for washing clothes could be worthwhile.

[7] ENERGY STAR shares shipment data, which readers can use for further comparisons: https://www.energystar.gov/index.cfm?c=partners.unit_shipment_data.

Consumer Electronics

Findings

Penetration. This study measured the *penetration* of consumer electronics solely through web surveys. Laptop computers (85%) and tablets (79%) surpassed desktop computers (59%) in terms of penetration. The average home had 1.45 laptop computers, 1.33 tablets, and 0.75 desktop computers. Almost two-fifths of customers (39%) had automation devices (e.g., Amazon Echo, Google Home, Apple Home Pod). As with most consumer electronics, penetration of automation devices was higher in single-family homes (41%) than in multifamily homes (29%). Customers with automation devices most often reported that they had thermostats (45%), audio or Bluetooth devices (27%), or lighting (23%) connected to them, but this was not verified on site.[8]



Advanced power strips (APS). The study assessed penetration of APS both on site and through the web surveys. Comparing the on-site results with the web-survey results implied customer confusion about APS. Roughly three-fifths (61%) of web-survey respondents reported having APS installed in their homes, but on-site visits revealed that penetration was only 4%. It may be that customers mistook surge protectors and simple power strips without advanced features for APS given their visual similarities. On-site visits revealed a plethora of opportunities for APS:

- Nearly all homes (97%) had at least one set of electronics with peripheral devices either based around a television or a computer.
- Most homes (94%) had televisions with peripheral devices (i.e., home entertainment centers [HECs]), with roughly two peripheral devices each. However, only 2% of HECs observed on site were connected to an APS. Excluding set-top-boxes (STBs), which are recommended to be plugged into the *always-on* outlet of APS, somewhat fewer homes (87%) had at least one HEC. Nearly one-third of televisions (30%) had three or more peripheral devices.
- Roughly one-half (51%) of homes had at least one computer with peripheral devices (i.e., computer hub). Only 5% of computer hubs were connected to an APS, yet the average home had 1.3 opportunities to use APS with their computers. About one-third of computers (34%) had three or more peripheral devices.

Section 3.5 presents all results.

[8] Analysis of the implied penetration of smart thermostats (13%) compared to verified smart thermostats (5%) suggests that self-reported home automation devices may not be entirely correct.

Considerations

- With such low penetration and awareness, as well as many opportunities for employing them in the average home, it appears that the Companies' support of APS through its E-Commerce Platform is worthwhile, and it may be beneficial to explore including them as a direct-install measure in Home Energy Solutions and Home Energy Solutions – Income Eligible programs. Greater education about what distinguishes them from surge protectors may also be needed.

Lighting

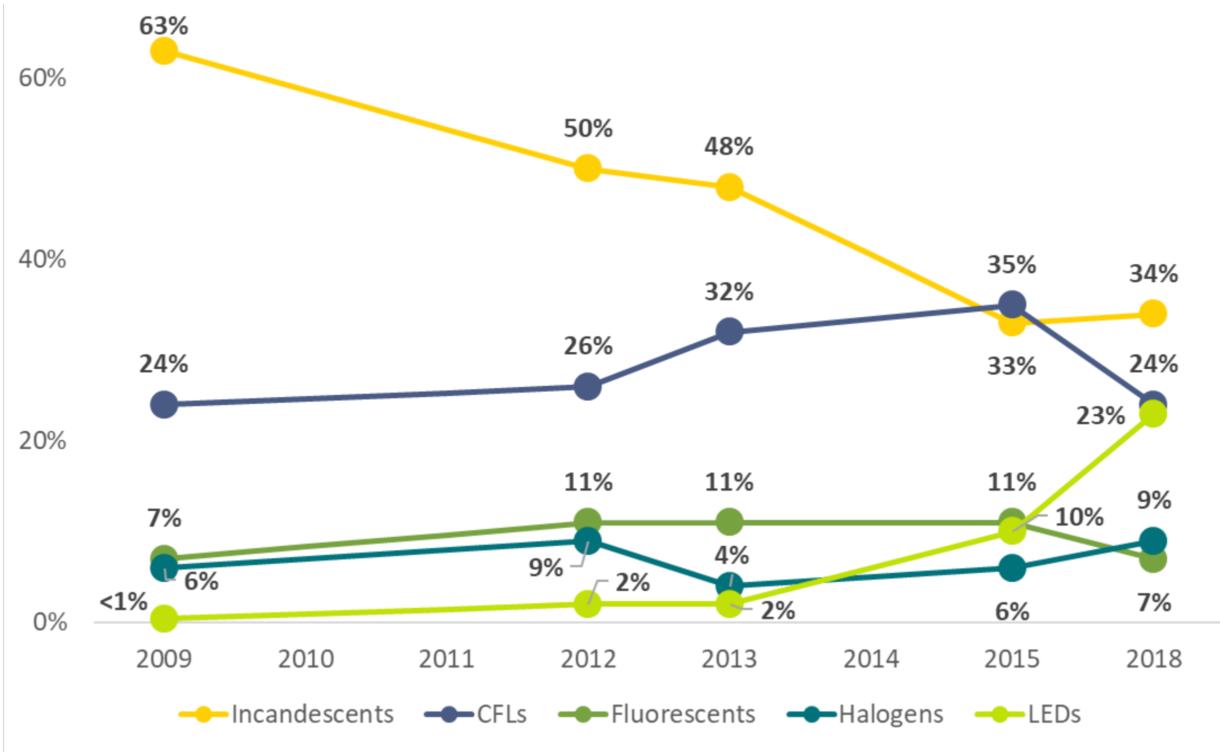
Findings

Cross-year comparison. Figure 1 illustrates lighting saturation trends in Connecticut from 2009 to 2018 based on on-site visits. The key trends were as follows:

- LED saturation (the percentage of all sockets filled with a specific bulb type) in Connecticut households has shown a dramatic increase. Between 2012 and 2018, LED saturation increased more than tenfold (2% to 23%), and more than doubled since 2015 (10%).
- CFL saturation decreased marginally from 26% in 2012 to 24% in 2018, after a slight bump in 2015 to 35%.
- Inefficient bulb (incandescent and halogen) saturation decreased from 59% in 2012 to 39% in 2015, but then increased slightly to 43% in 2018. From to 2015 to 2018, halogen saturation increased from 6% to 9% and incandescent saturation increased from 33% to 34%.
- Not shown below, the proportion of stored bulbs that were incandescent has steadily decreased from 63% in 2012 to 52% in 2015 to 46% in 2018. However, the proportion of incandescent bulbs in storage in 2018 was still more than double the shares represented by LEDs (20%) and CFLs (20%).

In Massachusetts, similar findings regarding bulbs in storage led to evaluators recommending that the Massachusetts PAs *carefully consider what program efforts can be made to encourage customers to replace inefficient bulbs before failure or remove inefficient bulbs from storage. The PAs may want to consider further educational efforts, as well as a bulb buyback program, to persuade people to change out inefficient bulbs before they burn out, fill sockets with LEDs, and remove inefficient bulbs from storage.* See the MA RLPNC 18-10 2018-19 Residential Lighting Market Assessment Study for more details.

Figure 1: Connecticut Saturation Trends, 2009-2018



Regional benchmarking. To help provide context to the changes in saturation observed in Connecticut, this report benchmarks against recent saturation studies in the Northeast that took place in and around the time that the Connecticut on-site visits were underway. Table 1 lists those comparable studies and their timing relative to Connecticut's effort. Essentially, Rhode Island visits took place concurrently with Connecticut's, and the Massachusetts and Upstate New York visits took place about six months before and six months after the Connecticut visits. For ease of comparison, this study reports the averages of the 2017 and 2018 visits for Massachusetts and New York.[9] Appendix D provides the saturation estimates for each visit separately.

Table 1: Lighting Saturation On-Site Visit Timing

(Conducted by NMR)

Area	October – December 2017	April – May 2018	October – December 2018
Connecticut		✓	
Rhode Island		✓	
Massachusetts	✓		✓
Upstate New York	✓		✓

[9] Simple average of 2017 and 2018 estimates – rounded to nearest whole percent.

LED saturation in Connecticut (23%) compared to neighboring states in the following ways:

- It was lower than in Rhode Island (33%)
- It was lower than in Massachusetts (31% average of 2017 and 2018 visits)
- It was higher than in New York (18% average of 2017 and 2018 visits)

CFL saturation in Connecticut (24% in 2018) was relatively similar to all other areas visited, regardless of the timing of the data collection.

Like Massachusetts and Rhode Island, Connecticut programs provide incentives only for ENERGY STAR-qualified LEDs (New York does not provide any incentives for lighting). ENERGY STAR-qualified LED saturation was statistically significantly higher in Rhode Island (24%) and Massachusetts (20%) than in Connecticut (14%). ENERGY STAR-qualified LED saturation in New York averaged 8% across the two visits, but it is worth noting that that percentage doubled from 5% to 10% between the 2017 and 2018 visits. LED storage patterns were fairly similar across states.

Additional Findings. Other interesting findings are as follows:

- This 2018 study leveraged a panel effort to visit 81 homes, which were visited in 2015 as part of R154 Lighting Study.[10] Fifteen of those homes engaged in on site visits again in 2018. The LED saturation in those homes more than tripled, increasing from 9% to 29% over the three-year period, but the sample size is too small to draw conclusions.
- In 2018, low-income households in Connecticut had significantly[11] higher saturation levels (than their non-low-income counterparts) of CFLs (34% versus 20%) and slightly higher saturation of LEDs (26% versus 22%).
- Similarly, CFL saturation was statistically significantly higher among multifamily than single-family homes (34% versus 21%), but LED saturation was fairly similar (28% versus 22%) regardless of dwelling type.
- More than one-third of sockets (36%) had specialty bulbs, but they were rarely efficient bulbs – 6% of sockets had specialty LEDs. Most commonly, specialty bulbs were reflectors/floods. While nearly one-third of those bulbs were LEDs (32%), slightly more were incandescent (36%).

Appendix D provides the full on-site results of lighting saturation, penetration, and storage, as well as comparisons across time and territories.

Considerations

- Comparisons to other states imply that the Connecticut program may not have as much impact on LED sales as programs in Massachusetts and Rhode Island. While LED saturation has increased considerably in a fairly short period, more than two-fifths of

[10] The *R154 LED Lighting Study* assessed the residential market for LEDs in Connecticut and consisted of telephone surveys of a random sample of homes throughout Connecticut and 81 on-site lighting inventories conducted with a subset of those telephone survey respondents.

[11] Significance was tested using a t-test equality of means and were considered significant at a 90% confidence level (p-value less than 0.1).

sockets still have inefficient lighting installed and only 14% qualify as ENERGY STAR (the program only supports ENERGY STAR products). Moreover, a notable number of inefficient bulbs were in storage despite a dramatic decrease from 2012. Together, these findings indicate that continued promotion of ENERGY STAR-qualified LEDs may be warranted. However, it is important to note that federal standards and naturally occurring market adoption may present risk to continued program interventions in the form of reduced baseline wattages, which would reduce savings.

Miscellaneous End Uses

Findings

According to web-survey responses, photovoltaic (PV) solar panels remain an uncommon end use: only 2% of homes had them installed. With an average installed capacity of 7 kW, 14% had energy-storage batteries to accompany their panels. As shown in Section 3.7, most miscellaneous end-uses, such as whole-home generators (6%) – often fueled by propane – also had limited penetration. Respondents listed other equipment in their homes that they estimated used a great deal of energy; most frequently, they mentioned power tools and/or air compressors (2%) and medical equipment (1%).

Considerations

- There is a great deal of space in the market to support solar and energy-storage measures (which the Companies do not currently support).

Building Characteristics

Findings

Cross-year comparisons. As noted, in 2011, the EEB commissioned a comprehensive weatherization study (referred to as *R5*) to assess Connecticut's single-family homes.[12] In contrast, the 2018 study's primary goal was to measure end-use saturation, while weatherization assessments were a secondary priority. As such, the designated budget meant a less comprehensive approach in assessing building shell and duct characteristics, so making direct comparisons between the studies is challenging. Specifically, the 2011 study used equipment (such as infrared cameras, blower doors, and duct blasters) and assessed all walls, ceilings, windows, and ducts to measure and characterize area, efficiency level, and material. In contrast, the 2018 study – with a different budget and scope – was limited to assessing *predominant* walls, windows, and ducts. Moreover, the 2011 single-family on-site sample size (n=180) was twice that of 2018 (n=90). Lastly, in 2011, NMR assigned Home Energy Rating System (HERS) index values for all homes visited. With a lower budget in 2018, NMR did not collect all of the data necessary, nor use certified HERS raters, which would have been necessary to assign HERS values to homes.

[12] NMR. "R5 Single-Family Weatherization Baseline Assessment." June 3, 2014. Accessed at https://www.energizect.com/sites/default/files/R5-Connecticut%20Weatherization%20Baseline%20Assessment-FINAL%2006-04-14.pdf.

Insulation rates were the most questionable attribute when assessing differences. After reviewing 2011 raw data, it appeared that 14% of predominant walls had little-to-no insulation, yet, in 2018, 23% of predominant walls appeared to have little-to-no insulation. It is unlikely that insulation rates would have decreased; some of this difference may be due to sampling error or differences in methodological approaches.[13]

Building shell, windows, and ducts. In 2018, on-site results indicated that predominant walls in single-family homes were most often insulated with fiberglass batts (FGB) (66%), and predominant flat and vaulted ceilings were most often insulated with FGB or rockwool (64% and 78%, respectively) – this was not markedly different in 2011. The predominant window type (most common window type in a given home) in most single-family homes was double-pane (85%). About two-fifths of predominant windows (43%) had low-emissivity (low-E) coatings. Predominant windows' frames were most often made of vinyl (64%). Basement ducts were uninsulated in roughly one-half of homes. Attic ducts were uninsulated in about one-third of homes. This varied slightly between supply and return ducts.

Section 4 provides more results.

Considerations

- Some unlikely differences over a seven-year period imply the need to commission a more comprehensive weatherization study to accurately assess the current and changing state of home weatherization in Connecticut. The 2018 study included budgetary restrictions that necessitated methodological differences from the 2011 study, limiting the reliability of comparisons.
- Existing housing stock still shows substantial opportunities for savings in terms of improving homes' envelopes and mechanical systems.

Upstream Lighting NTG

Findings

Program support. As noted, LED saturation in Connecticut increased exponentially between 2012 and 2018. The increase corresponds with the Companies' increasing levels of support for LEDs: according to program data, they supported roughly 430,000 LEDs in 2013 (upstream and direct install), while they supported 1.8 million LEDs in 2018 (through July). It should be noted that program activity in 2018 was impacted by a legislative budget diversion.[14]

Exploratory Exercise – NTG Estimates. In 2017, the R1615 study recommended prospective NTG values for LEDs for 2019 and 2020. It is important to note that this analysis (R1616/R1708) is meant to help provide context for other, more robust, NTG estimates produced for Connecticut

[13] As previously mentioned, the 2011 study took a more comprehensive approach to assessing all walls, including using HERS raters to assess all portions of the building shell, and, with advanced diagnostics, may have been able to identify instances of degraded insulation that felt like no insulation to technicians probing walls in the 2018 study.
[14] Note that the Connecticut energy-efficiency programs were impacted by a budget sweep in 2018, which reduced funding for energy-efficiency programs in the first half of 2018 – likely resulting in lower program performance and fewer LEDs being distributed. https://www.courant.com/politics/hc-pol-energy-efficiency-warning-20180308-story.html

in the R1615 analysis and is not meant to supplant existing and planned NTG values.[15] This study estimated an overall upstream lighting NTG ratio of 63% (excluding stored bulbs) and 86% (including stored bulbs) for Connecticut for the program period of 2013 through 2018. As shown in the formula below, the NTG algorithm relied on using the number of LEDs installed, in storage, and supported by the Connecticut upstream program, as well as comparable installation and storage data for New York (which was used as the basis for these counterfactual calculation because it does not have an upstream LED program), to estimate net gains in LEDs in Connecticut homes. The net gain is equal to the change in installed and stored bulbs found in Connecticut homes minus those found in New York homes divided by Connecticut program sales.

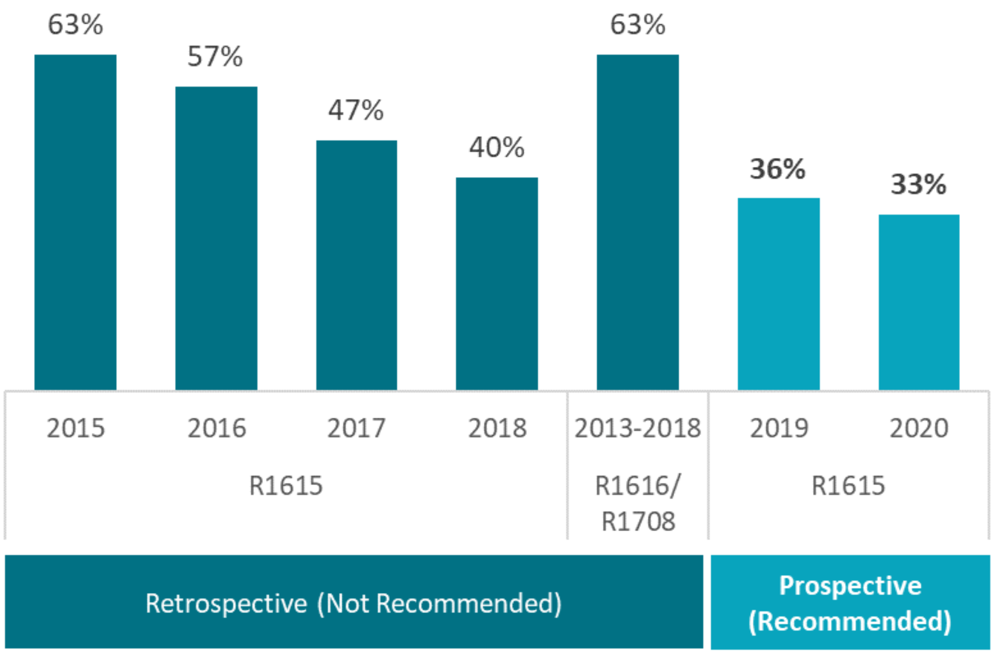
NTG = [(CT installed bulbs + CT stored bulbs) – (NY installed bulbs + NY stored bulbs)] / CT Upstream Program Bulbs

Specifically, the estimated net gain in Connecticut was 9.4 million installed LEDs and 2.7 million stored LEDs cumulatively from 2013 through July 2018. Dividing these by the 14.9 million upstream program-supported LEDs resulted in the NTG ratios of 63% for installed LEDs only, and 86% when taking storage into account. As shown in Figure 2, this study does not recommend supplanting the current PSD LED NTG values for 2019 and 2020 (Connecticut does not revise NTG retrospectively).

[15] NMR Group Inc., DNV GL, and Cadmus, *R1615 Light Emitting Diode (LED) Net-to- Gross Evaluation*. Submitted on August 7, 2017. Available at https://www.energizect.com/sites/default/files/R1615_CT%20LED%20Net-To-Gross%20Evaluation%20Report_Final_8.5.17.pdf.

Figure 2: Comparison of Estimated and Recommended NTG Values by Study

(Sources: R1615 and R1616/R1708)



Note: R1615 values represent recommendations for non-hard to-reach markets. NTG estimates for hard-to-reach markets were higher. Additionally, the R1616/R1708 value excludes stored bulbs.

All results, including annual NTG estimates, are included in Appendix E.

Considerations

- Because on-site lighting data collection did not occur annually in Connecticut, and New York data collection also experienced gaps, the analysts interpolated annual saturation and storage estimates from its comparable neighboring state, Massachusetts – which had commissioned annual studies during that time and offered a similar LED program (referenced above). This raises questions about the validity of the NTG results (i.e., whether they truly reflect the NTG in Connecticut). For this reason, the analysts urge caution when interpreting the results. In addition, the NTG results are entirely retrospective and are not meant to supplant prospective values already adopted by Connecticut.

Program Participation and Attitudes

Findings

Participation. Sixteen percent of web-survey respondents self-reported or confirmed they had participated in one of the Companies' downstream energy-efficiency programs at some point in the past two years. Nearly two-thirds (64%) of respondents reported that they made some type of energy upgrade in the past two years. Most commonly, they reported installing energy-efficient lighting; in fact, more than one-half of respondents said they did so (54%). More than one-third (35%) of respondents planned on making energy upgrades in the next two years; however, only 4% of that subset of respondents planned to upgrade their lighting in the next two years. Note that while evaluators cannot confirm participation in upstream programs, it is likely that some of the respondents that reported making an energy upgrade in the past two years did so as a result of upstream programs efforts, including lighting, products, and appliance incentives.[16] Respondents were very unfamiliar with rebates and financing programs available through Energize CT. When asked to rate their familiarity with *utility rebates* on a scale of 1 to 5, where 1 is *not at all familiar* and 5 is *extremely familiar*, they rated their familiarity 1.7, on average. Almost four-fifths (78%) of those who had made upgrades did not use rebates or financing, and those who had used their credit card(s) (15%).

Attitudes. Respondents often considered themselves *moderate environmentalists* (45%). When asked about their level of activity in environmental movements, most frequently they thought of themselves as *sympathetic towards the movement, but not active* (42%).

Appendix F presents more findings and context.

Considerations

- Customers' lack of awareness of rebates and financing options and common lack of plans to improve their homes' energy efficiency suggests that stronger promotion of rebates and financing and benefits of upgrading equipment would be worthwhile.

[16] Under Priority Five, the Plan states that "the Companies will encourage energy efficiency to occur organically through market actions such as… moving incentives upstream."

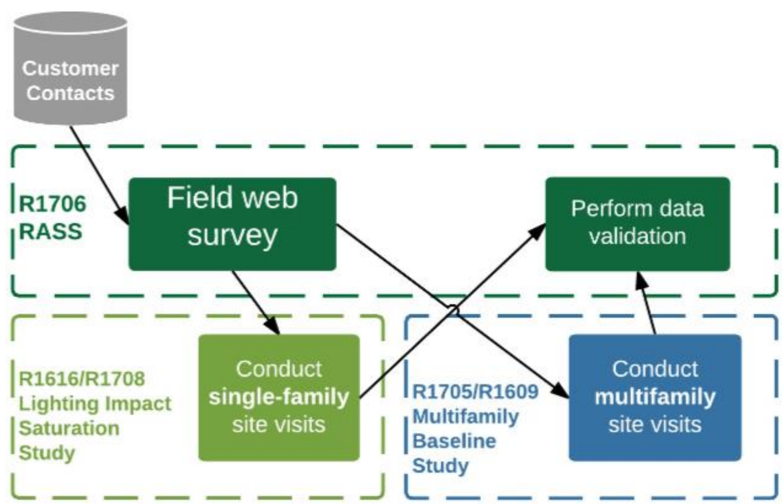
1

Section 1 Introduction

This report presents the results from the *R1706 Residential Appliance Saturation Survey (RASS)* and *R1616/R1708 Lighting Impact Saturation* studies. The studies resulted in (1) an inventory of residential end uses, including heating and cooling equipment, thermostats, water heating, appliances, consumer electronics, lighting, and miscellaneous end uses; (2) a characterization of customer homes, including building characteristics; and (3) estimates of lighting saturation and upstream program net-to-gross (NTG). In partnership with the *R1705/R1609 Multifamily Baseline and Weatherization Opportunity* study research, these studies fielded web surveys and follow-up on-site verification visits with Eversource and United Illuminating (the Companies) residential electric customers. In addition to this report, which provides an overview of the study methodology and an analysis of results, the study produced an Excel database (RASS Database) that includes all primary research data points and detailed analyses, along with a database-user guide.

While NMR fielded the web surveys and conducted 90 on-site verification visits with single-family (one to four units) respondents as part of R1706 and R1616/R1708, ERS conducted an additional 137 on-site verification visits with multifamily (five or more units) respondents. ERS reports multifamily on-site results in its R1705/R1609 report; however, this report leverages those results to develop adjustment factors for estimating end-use penetration, lighting penetration and saturation, and advanced power strip (APS) usage. This report only analyzes *on-site-only* results, such as efficiency levels and age of non-lighting end-uses, for single-family homes. Figure 3 illustrates the relationships between the three studies.

Figure 3: Relationships Between Studies



Note: This report only uses the R1705/R1609 results for estimating end-use penetration, lighting penetration and saturation, and APS usage. The R1705/R1609 report includes detailed analyses on weatherization and other details (e.g., equipment age, efficiency) for multifamily homes.

1.1 Study Objectives

Using web-based surveys with 2,426 residential customers and follow-up on-site verification visits with 227 of those customers, the studies accomplished several goals:

Household characterization. The results established a sector-wide characterization of Connecticut households by researching a select set of end uses, building characteristics, and demographics.

Database. Analyses produced a comprehensive database housing all survey and on-site data appended with respondents' billing data. The RASS Database was delivered to the Companies for stakeholders to conduct any additional analyses to meet their varied needs. In other words, it offers anyone the ability to drill down as needed – a more efficient and user-friendly alternative to a report with innumerable tables.

Lighting market assessment. The study estimated lighting saturation, other lighting elements (e.g., storage behavior and LED satisfaction), and NTG estimates for upstream lighting.

1.2 Report Organization

This report includes findings from both the web surveys and on-site verification visits. Table 2 outlines the structure of the report.

Table 2: Report Organization

Section	Purpose/Contents
Methodology	
Section 2	Recounts the methodology undertaken to design the web survey, field and sample for the web-survey and on-site verification visits, analyze data, and develop the database.
Appendix A	Offers more fielding and sampling details and lists end uses and attributes studied.
Appendix B	Gives further insight into analytical methods, including weighting, adjustment factors, and weatherization benchmarking.
Appendix C	Summarizes the approach for cleaning primary data and attaching billing data to develop the database.
Results	
Section 3	Analyzes penetration and other key characteristics of the end uses.
Section 4	Presents building characteristics, building shell, and ductwork results.
Section 5	Characterizes the sample demographics.
Appendix D	Summarizes lighting saturation and penetration results.
Appendix E	Summarizes upstream lighting NTG results.
Appendix F	Summarizes program participation and attitudes towards environmental issues.
Reference Materials	**(Provided in separate documents)**
Appendix G	Consists of the RASS Database user guide.
Appendix H	Includes the web-survey instrument.

Section 2 Methodology

This section details the study methodology, including survey design, fielding, sampling, on-site verification, analysis, and database development.

2.1 Data Collection Instruments

The web survey asked about heating and cooling equipment, thermostats, water heating, appliances, consumer electronics, miscellaneous end uses, building characteristics, demographics, program participation, and attitudes towards environmental issues. The on-site visits, performed for a sample of web survey respondents, verified much of this self-reported data and collected additional information on various end uses, including lighting, shell characteristics, efficiency levels, and ages. Appendix A.2 lists the end-uses and attributes that the web survey and on-site verification visits examined, and Appendix H (in a separate document) includes the web-survey instrument itself.

2.2 Fielding and Sampling

The Companies provided random samples of residential electric customers pulled from their customer databases, totaling 51,164 customers. The study selected a subset of 30,300 customers for the RASS sample frame.[17] Between December 15, 2017 and April 20, 2018, those customers received letters inviting them to respond to the web survey. In support of the lighting portion of the study, 81 *panel* customers who had participated in the 2016 *R154 LED Lighting study* were also invited to respond.[18]

The study mailed letters in three waves. To monitor the demographic spread of survey responses, response rates for certain sample strata were estimated approximately two weeks after the release of each wave.[19] This allowed the study to selectively sample wave two and three to target any underrepresented strata. Non-responsive customers received email reminders (where email was available). Respondents received a $10 Amazon gift card for completing the survey. In addition to asking questions about their household, the web survey asked respondents if they were willing to participate in on-site verification visits. Nearly one-half (49%) of the 2,426 web-survey respondents agreed to on-site verification visits in exchange for a $150 gift card.

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[17] The planned sample frame expected 20,000 customers. However, after lower than expected response rates from multifamily homes, the approach added 10,300 homes with a higher likelihood of being multifamily to the sample frame.

[18] The *R154 LED Lighting Study* assessed the residential market for LEDs in Connecticut and consisted of telephone surveys of a random sample of homes throughout Connecticut and 81 on-site lighting inventories conducted with a subset of those telephone survey respondents.

[19] The study identified three population parameters to assess representativeness of responses: location, dwelling type, and income level.

The RASS study sought to complete 2,000 web surveys and exceeded this goal, resulting in 2,426 completed web surveys (an 8% response rate) (Table 3). Ninety single-family (one to four units) and 137 multifamily (five or more units) homes/units took part in on-site verification visits.

Table 3: Completed Surveys and On-Site Verification Visits

(Housing Units)

Dwelling Type	Population Size[1]	Web Survey		On-Site Verification Visits	
		Completed	Sampling Error	Completed	Sampling Error
Single-family, 1-4 units	1,121,767	1,749	1.8%	90	8.5%
Multifamily, 5+ units	232,946	677	2.8%	137	6.9%
Total	**1,354,713**	**2,426**		**227**	

[1] Because the Companies do not comprehensively track dwelling type, the sampling errors rely on U.S. Census Bureau, ACS 2012-2016 data. Proportions are based on occupied housing units.

The Companies' participation data indicated that roughly 7% of all residential customers (weighted by Company) had participated in a downstream program between 2015 and 2017.[20] Participation rates were strongly skewed by Company, which is likely due to differences in calculation methodologies – evaluators reviewed Eversource data and estimated participation rates, while United Illuminating (UI) staff estimated participation rates themselves. According to the data, UI web-survey respondents were three times as likely to have participated in a program compared to Eversource respondents (24% versus 8%).

Compared to the general population of customers, customers who participated in a downstream program were slightly more likely to respond to the survey and agree to site visits: 12% of web-survey respondents and 11% of on-site homes (unweighted) participated in the Companies' programs.

Appendix A.1 provides additional fielding and sampling steps and considerations.

2.3 Analysis

This section discusses (1) how the analysis applied weights to the results and (2) the development and application of adjustment factors.

2.3.1 Weighting

As referenced above, sampling addressed three separate studies with unique goals. To support the R1705/R1609 multifamily study, the RASS oversampled multifamily homes so there would be adequate sample for multifamily on-site visits (a larger-scale effort than the *R1616/R1708* single-family on-site visit study). In addition to adjusting for differences in dwelling types, the weighting scheme adjusted for differences in income and program participation between the web-survey

[20] UI could not provide raw customer data for their population, so they provided an estimated participation rate for their population of electric customers. To estimate an overall participation rate among both service territories, the analysis calculated a weighted average by using a 70/30 Eversource/UI split.

sample and the Census[21] or the Companies' customers. Appendix B.1 presents these weights and details the process of segmenting the population and developing the weights.

As shown in Section 4.3, the single-family on-site sample somewhat overrepresented older homes (pre-1950) as compared to the Connecticut population (42% and 30%, respectively) in Census results; therefore, results drawn solely from on-site visits (versus web-sample-related results), such as equipment age and efficiency level, were weighted by home age.

2.3.2 Adjustment Factors

As described above, on-site visits yielded the opportunity to verify web-survey results. Comparing self-reported and observed end-use equipment, the study developed adjustment factors to correct for erroneous self-reported data. For example, if 12% of on-site customers reported an end use in the web-survey, and on-site observations found that 21% of homes had the end use, the analysis would adjust web-survey results by a factor of 1.75 (21% divided by 12%). Adjustment factors were applied only if on-site verified results differed statistically significantly from the web-survey results at the 90% confidence level. For cases where fewer than five on-site homes reported having the end use, adjustment factors were not applied. Note, sometimes when adjustment factors are applied, the penetration and average units per home statistics appear incongruous, because one (e.g., penetration) showed a significant difference but the other (e.g., average units per home) did not. The analysis estimated separate adjustment factors for single-family and multifamily homes.

The Adjustment Factor tab in the database reports adjustment factors by measure and indicates if adjustment factors were applied for the measure-level analysis. Table 4 lists the end uses with adjustment factors applied; generally, respondents overreported end uses – the table highlights if they underreported them with a designation of "✓ **(under)**." The table footnotes in this report also indicate if the analysis applied adjustment factors. For additional details on adjustment factor calculations and the penetration adjustment factors applied to the analysis, please see Appendix B.2.

[21] U.S. Census Bureau. ACS 2012-2016.

Table 4: End Uses with Adjustment Factors Applied
(Source: NMR comparison between web-survey and on-site visits)

End Use	Single-Family, 1-4 units (n=1,724)	Multifamily, 5+ units (n=653)	Overall (n=2,377)
Appliances			
Clothes washer		✓	✓
Clothes dryer		✓	✓
Clothes dryer - electric		✓	✓
Clothes dryer - gas		✓	✓
Dishwasher	✓	✓	✓
Stand-alone freezer (chest & upright)		✓	✓
Upright freezer		✓	✓
Chest freezer		✓	✓
Dehumidifier	✓	✓	✓
Air Purifier		✓	
Stovetop		✓ (under)	✓ (under)
Stovetop – natural gas	✓		✓
Oven – natural gas	✓		
Primary Heating Fuel			
Natural gas		✓ (under)	✓ (under)
Electric		✓	✓
Heating System			
Natural gas furnace	✓		✓
Propane furnace			✓
Oil furnace	✓		✓
Oil boiler	✓ (under)		
Electric furnace		✓	✓
Electric boiler		✓	✓
Central (ducted) air source heat pump	✓	✓	✓
Electric baseboard	✓	✓	✓
Electric space heater	✓ (under)	✓	✓ (under)
Electric wall heater		✓	✓
Cooling System			
None	✓	✓	✓
Central Air		✓	
MSHP/ASHP		✓	✓
Thermostat			
Standard	✓	✓	✓
Basic programmable	✓	✓	✓
Wi-Fi smart	✓	✓	✓
Wi-Fi not smart	✓	✓	✓

End Use	Single-Family, 1-4 units (n=1,724)	Multifamily, 5+ units (n=653)	Overall (n=2,377)
All		✓ (under)	
Water Heater Fuel			
Electric	✓	✓	✓
Natural gas		✓ (under)	
Fuel oil	✓ (under)	✓	✓ (under)
Water Heater System			
Natural gas standard		✓	✓
Natural gas tankless		✓ (under)	✓ (under)
Electric heat pump		✓	✓
Electric tankless			✓
Fuel oil standard			✓
Electronics			
APS	✓	✓	✓

✓ = End uses adjusted

2.4 Database Development and Purpose

The RASS Database includes all primary research data points and detailed analysis, such as penetration (with precision) by dwelling type, income, tenure, primary heating fuel, participation, and electric company.

The Database combines web-survey and on-site verification data, as well as anonymized respondent billing data, and was designed to provide additional details and breakdowns not presented in this report. The Database should allow the Companies, or other interested stakeholders, to conduct additional analyses to meet their varied needs, offering users the ability to drill down as desired. The available raw data could facilitate innumerable possibilities for analyses and could answer questions such as the proportion of multifamily units with residential sized and central boilers or furnaces, share of predominant windows with low-E coating by home vintage, and other similar detailed analyses.

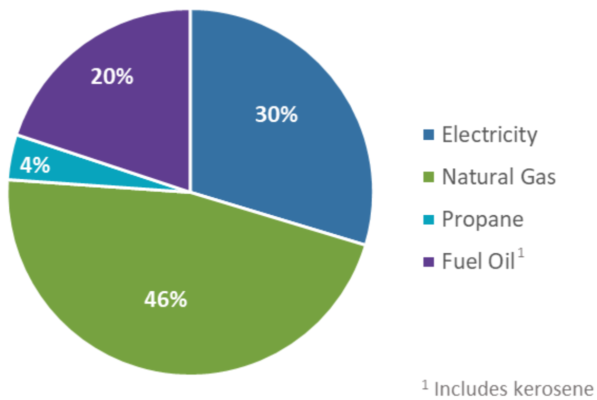
Appendix C describes the data processing and Appendix G (provided separately) includes a database-user guide.

Section 3 End-Use Results

In the Northeast, the majority of annual household energy consumption is from natural gas (46%) and electricity (30%) (Figure 4). Space heating, water heating, and air conditioning consume the largest shares of annual household energy.

Figure 4: Annual Household Consumption in the Northeast by Fuel Type

(Source: U.S. Energy Information Administration)[1]

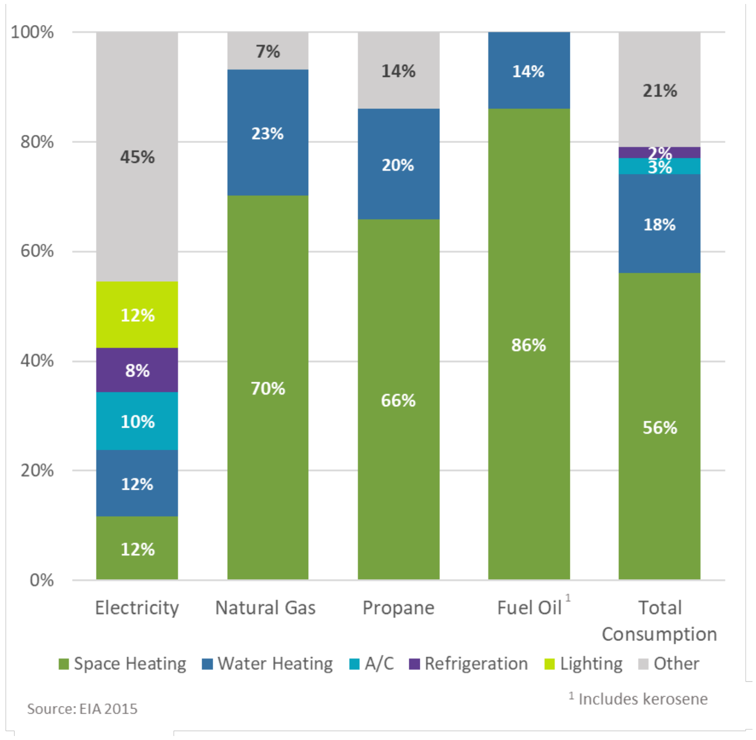


[1] Table CE2.2 released May 2018. For more details, see https://www.eia.gov/consumption/residential/data/2015/c&e/pdf/ce2.2.pdf.

As shown in Figure 5, more than two-thirds of natural gas consumption is used for space heating (70%) and nearly one-quarter is for water heating (23%). End uses, such as consumer electronics, refrigeration, lighting, combined account for two-thirds (66%) of electricity consumption.

Figure 5: Annual Household Energy Consumption in the Northeast by End Use

(Source: U.S. Energy Information Administration)[1]



[1] 2015 RECS Survey Data Tables CE3.2 and CE4.2: https://www.eia.gov/consumption/residential/data/2015/index.php?view=consumption.

This section presents key web-survey and on-site results for heating and cooling, thermostats, water heating, appliances, consumer electronics, lighting, and miscellaneous end-uses. The Database provides comprehensive data points, standard errors, and analyses. The reader should note a few details when reviewing these results:

- **Adjustment factors.** Data are unadjusted unless noted otherwise. **Blue text** indicates that an adjustment factor was applied.
- **Weighting.** Data are unweighted only where specified or if sample sizes are less than 20.
- **Sample sizes.** These vary because invalid responses such as, "don't know," were removed from the denominator (*i.e.*, base).
- **Dwelling type.** The analyses categorize respondents as multifamily if they live in buildings with five or more units.
- **Dashes.** Dashes in penetration tables indicate that penetration or average units per home are equal to zero.
- **Penetration and saturation.** The report analyzes the penetration of end uses and the saturation of energy-efficient appliances, products, and lighting.
    - **Penetration** is the percentage of homes with one or more of a particular end use.

- **Saturation** is the percentage of a particular end use that share a specific characteristic (e.g., the share of refrigerators that are ENERGY STAR labeled).

3.1 Heating and Cooling

- **Primary Heating Fuels:** Natural gas (43%) and fuel oil (40%) were most common.
- **Heating Systems:** Oil boilers (22%), gas furnaces (21%), and gas boilers (20%) had the highest penetration. Oil furnaces were uncommon (9%).
- **Heating System Ages:** In single-family homes, boilers were 17 years old and furnaces were 12 years old, on average. These are newer than they were in 2011 (at that time).
- **Cooling Systems:** Room air conditioners (49%) were more common than central air conditioners (40%). Most homes (98%) had at least one cooling system.
- **Cooling System Ages:** In single-family homes, room air conditioners were 12 years old and central air conditioners were 14 years old, on average. These were older than they were in 2011 (at that time).
- **Heat Pumps:** Heat pump usage was rare for heating and cooling, with penetration levels ranging from 2% to 4%.
- **Efficiency:** All efficiency levels of common heating and cooling systems in single-family homes have improved since 2011.

3.1.1 Penetration

Penetration estimates of primary heating fuels and heating and cooling systems are based on a combination of web-survey results and on-site visits.

Just over two-fifths (43%) of customers' primary heating fuel was natural gas, followed closely by fuel oil (40%) (Table 5). While single-family customers were most likely to use fuel oil as their primary heating fuel (45%), multifamily customers were most likely to use natural gas (54%). Nearly one-third (32%) of multifamily homes used electricity as the primary heating fuel, while only one-tenth (11%) of single-family homes used electric heat for their primary heating fuel.

Table 5: Primary Heating Fuel

(Source: web-survey and on-site visits)

Heating Fuel	Single-Family, 1-4 units (n=1,640)	Multifamily, 5+ units[1] (n=534)	Overall[1] (n= 2,174)
Natural gas	35%	**54%**	**43%**
Fuel oil	45%	6%	40%
Electric	11%	**32%**	**11%**
Propane	5%	4%	5%
Other	4%	<1%	3%

[1] Percentages do not sum to 100% due to the application of adjustment factors. **Blue text** indicates that an adjustment factor was applied.

Based on the on-site verification visits, it was clear that some web-survey respondents struggled to accurately identify their heating fuel and system types. For example, a respondent may have correctly identified that his/her heating system used natural gas, but may not have known that it was a boiler (or vice versa). The differences in knowledge meant adjustment factors should be estimated separately for fuel types and system types. As such, proportions across end-use attributes do not always align given that adjustment factors are applied to proportions, not individuals. This type of scenario also occurred with water heating.

Overall, customers reported heating their homes most often with fuel oil boilers (22%), natural gas furnaces (21%), and boilers (20%). Table 6 presents the penetration of heating system types. Single-family customers were most likely to report heating their homes with oil (38%) and natural gas (21%) boilers – nearly one-third (30%) also used electric space heaters. Multifamily customers most often reported using natural gas furnaces (28%) and electric baseboards (28%) for heating. Customers rarely had central heat pumps (4%) and ductless mini-split heat pumps (DMSHP) (3%) for heating. Approximately 10% of survey respondents reported having radiant floor heating in their bathrooms (not reported in table).

Table 6: Primary and Non-Primary Heating System Penetration

(Source: web-survey and on-site visits)[1]

Heating System	Single-Family, 1-4 units (n=1,665)		Multifamily, 5+ units (n=549)		Overall (n= 2,214)	
	Customers	Fuel Type	Customers	Fuel Type	Customers	Fuel Type
Natural Gas[2]						
Furnace	**18%**	39%	28%	58%	**21%**	45%
Boiler	21%	46%	17%	35%	20%	43%
Fireplace	7%	15%	3%	6%	6%	13%
Fuel Oil						
Boiler	**38%**	76%	4%	57%	22%	71%
Furnace	**12%**	24%	3%	43%	**9%**	29%
Electric[2]						
Space heater	**30%**	71%	**2%**	5%	**16%**	46%
Electric baseboard	**8%**	19%	28%	70%	**12%**	34%
Central heat pump	**1%**	2%	**8%**	20%	**4%**	11%
DMSHP	3%	7%	2%	5%	3%	9%
Propane						
Boiler	3%	43%	2%	40%	3%	75%
Furnace	4%	57%	3%	60%	**1%**	25%
Other						
Fireplace (Wood)	16%	100%	1%	100%	14%	100%

[1] Surveys did not ask for heating system quantities. Percentages do not sum to 100% because of adjustment factors and customers had more than one type of heating system. **Blue text** indicates that an adjustment factor was applied.

[2] Natural gas system types (47%) and electric system types (35%) sum to greater than the primary heating fuels (43% and 11%, respectively) shown in Table 5 due to adjustment factors and the fact that some homes do not use these as their primary systems.

Customers most often cooled their homes using room air conditioners (49%) (Table 7). Two-fifths of homes (40%) had central air conditioning.[22] DMSHPs were rare, as only 2% of customers used them for cooling.[23] Only a small number of respondents (2%) reported having no cooling system.[24] Among respondents with a cooling system, 53% had at least one other type of cooling mechanism, such as a secondary air conditioning system, a portable fan, or a ceiling fan.

Table 7: Cooling System Penetration

(Source: web-survey and on-site visits)[1]

Cooling System	Single-Family, 1-4 units (n=1,724)	Multifamily, 5+ units (n=653)	Overall (n=2,377)
Room air conditioner	50%	46%	49%
Central air conditioner or central heat pump	39%	**38%**	40%
Mini-split heat pump	4%	**<1%**	**2%**
No cooling system[2]	**3%**	**1%**	**2%**

[1] Surveys did not ask about quantities for these systems. Some homes had more than one cooling system. Percentages sum to less than 100% because of adjustment factors. **Blue text** indicates that an adjustment factor was applied.
[2] This also includes respondents who reported having only ceiling or portable fans.

3.1.2 Efficiency and Age

Efficiency and age assessments come solely from on-site visit results. This report assesses those data from single-family on-site visits (the R1705/R1609 report assesses similar parameters for the multifamily on-site visits).

Table 8 summarizes the efficiency level of heating and cooling systems. For each of the following, higher values represent higher efficiency levels:

- Annual fuel utilization efficiency (**AFUE**)[25] measures the efficiency of furnaces and boilers on a zero to 100 scale.
- Seasonal energy-efficiency ratio (**SEER**) measures the efficiency of central air conditioners, ductless MSHPs, and ducted ASHPs over an assumed cooling season.
- The energy-efficiency ratio (**EER**) measures the efficiency of room air conditioners based on cooling capacity per wattage.

[22] The team calculated adjustment factors that included air source heat pumps found on-site. Air source heat pumps are likely indistinguishable from central air systems to the average homeowner.
[23] Other types of heat pumps were observed on-site, particularly in multifamily homes, but DMSHPs were the only type of heat pump included in the survey.
[24] Survey respondents could specify portable fans and ceiling fans as cooling systems. On site, the team collected data on room and central air conditioners and heat pumps only. In order to make accurate comparisons with on-site data, we consider respondents that cool their homes exclusively with a portable or ceiling fan as having no cooling system. Overall, 6% of respondents reported they exclusively cool their home with a portable or ceiling fan. (This is higher than the percent of homes reported to have no cooling system because that value was adjusted, while we did not verify the presence of fans on-site.)
[25] On-site technicians recorded the efficiency ratings shown on units' energy labels. Technicians did not test actual performance.

- Heating seasonal performance factor (**HSPF**) measures heat pump efficiency, representing the heat delivered to a space given an amount of electricity consumed.

Federal standards are included in the far-right column for comparison; though, with comparisons, one should note the small sample sizes for many equipment types. Among common systems, the most noticeable difference between observed efficiency and federal standards was for natural gas furnaces (AFUE of 88.4 versus 80.0).

Table 8: Heating and Cooling System – Efficiency Levels[1]

(Source: single-family on-site visits; n = 90)

End-Use		Quantity (n)	Average	Minimum	Median	Maximum	Standard Dev.	Federal Standards[2]
Furnace (AFUE)	Natural gas	*26*	**88.4**	68.0[1]	92.3	96.7	8.59	80
	Oil	*9*	**82.7**	80.0	82.8	86.0	2.17	83
Hot water boiler (AFUE)	Natural gas	*25*	**83.0**	65.0	82.0	95.5	8.18	82
	Oil	*19*	**83.1**	80.0	83.2	87.0	2.58	84
	Propane	*2*	**94.0**	91.2	94.0	96.8	-	82
Steam boiler (AFUE)	Natural gas	*4*	**76.9**	65.0	80.0	82.4	7.98	80
	Oil	*1*	**83.8**	-	-	-	-	82
All boilers (AFUE)	*Natural gas*	*29*	***82.5***	*65.0*	*81.8*	*95.5*	*8.29*	*See above*
	Oil	*20*	***83.1***	*80.0*	*83.5*	*87.0*	*2.51*	
	Propane	*2*	***94.0***	*91.2*	*94.0*	*96.8*	-	
Air conditioners	Central (SEER)	*39*	**13.1**	10.0	13.0	16.0	1.80	13
	Room (EER)	*109*	**10.2**	6.7	10.0	12.2	0.93	9 to 11[3]
Ductless mini-split systems	HSPF[4]	*3*	**9.9**	8.6	10.6	10.6	1.15	8.2
	SEER	*5*	**16.3**	13.5	15.3	20.0	3.07	14
Ducted air-source heat pump	HSPF	*2*	**8.6**	8.2	8.6	9.0	-	8.2
	SEER	*2*	**16.0**	15.0	16.0	17.0	-	14

[1] The efficiency values in this table include age-based default values provided by NEHERS and RESNET in limited instances where an efficiency could not be identified for older equipment. This matches the methodology used in the R5 Weatherization study.

[2] Natural gas furnace standards went into effect in 2015, while oil furnace standards went into effect in 2013 and boiler standards went into effect in 2012. Central air conditioner and heat pump standards went into effect in 2015, while room air conditioner standards went into effect in 2014. *Source*: Electronic Code of Federal Regulations. https://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8. March 14, 2019.

[3] Values range by size and other features. Federal standards began using combined EER (CEER) in 2014, but the team did not collect CEER data. However, using the U.S. Department of Energy's Compliance Certification Database, we ran a regression model suggesting that CEER is equal to 99% of EER.

[4] Two ductless MSHPs were only used for cooling, so they did not have HSPF ratings.

All efficiency levels of common heating and cooling systems have improved to some extent since 2011 (Table 9).

Table 9: Common Heating and Cooling System – Efficiency Levels by Year[1,2]

(Sources: single-family on-site visits)

End-Use	2011		2018	
	Quantity (n)	Average	Quantity (n)	Average
Natural gas furnace (AFUE)	28	85.1	26	88.4
Natural gas boiler (AFUE)	25	79.7	29	82.5
Oil boiler (AFUE)	84	82.1	20	83.1
Central air conditioner (SEER)	94	11.3	39	13.1
Room air conditioner (EER)	172	9.7	109	10.2

[1] Values not tested for statistical differences across years.

[2] Average values for both reports include the use of age-based defaults where data were unavailable.

Table 10 displays ages for common heating and cooling equipment in single-family homes. Boilers averaged 17 years old; one-half (50%) were 14 years old or older. Furnaces averaged 12 years and the majority were between four and 13 years old (67%). Compared to the 2011 study results, heating systems were newer in 2018 – furnaces had been 16 years old and boilers had been 18 years old, on average, at that time (not shown). The effective useful life (EUL) of gas furnaces in the PSD is noticeably longer than the median age of furnaces (all fuel types) observed in the sample (20 versus 11 years); in fact, it is also longer than that in the Massachusetts 2019-2021 Technical Reference Manual (15 years). There are similar, yet not as extreme, differences among boilers.

Nearly four-fifths of room air conditioners (79%) and central air conditioners (77%) were manufactured after 2000; on average, they were 12 and 14 years old, respectively (with median ages of 13 and 11). Room air conditioner EUL in the PSD is shorter (nine years) than the sample, while central air conditioner EUL in the PSD is longer (18 years) than the sample.[26] Systems in 2018 were newer compared to the 2011 results – room air conditioners were nine years old and central air conditioners were 11 years old, on average, at that time.

[26] EUL is the median length of time that a measure is functional, so it is generally shorter than the average age. For more details, see https://emp.lbl.gov/sites/all/files/savings-lifetime-persistence-brief.pdf.

Table 10: Common Heating and Cooling System – Ages

(Source: single-family on-site visits; n = 90)

Year Manufactured[1]	Heating		Cooling[2]		Heat Pumps[2]
	Furnace (n=32)	Boiler (n=41)[2]	Room (n=86)	CAC (n=41)	(n=6)
2016 or newer	2%	9%	13%	7%	17%
2011 to 2015	28%	17%	33%	24%	17%
2006 to 2010	39%	24%	11%	21%	67%
2001 to 2005	15%	12%	22%	25%	-
1991 to 2000	11%	26%	20%	23%	-
1981 to 1990	5%	8%	2%	-	-
1980 or earlier	-	4%	-	-	-
Age in Years					
Average	12	17	12	14	9
Median	11	14	13	11	10
CT EUL[3]	20 (gas)	20 (gas)	9	18	18
MA EUL[4]	15 (gas)	19 (gas)	8	18	18

[1] Age was indecipherable for some units.
[2] Percentages do not sum to 100% due to rounding.
[3] Source: *2019 CT Program Savings Document*: https://www.energizect.com/sites/default/files/2019%20PSD%20%283-1-19%29.pdf
[4] Source: Massachusetts 2019-2021 Technical Reference Manual: https://etrm.anbetrack.com/dms/api/v1/documents/5be42a1cc1c0ab7b64b2db65/view#page=39

3.2 THERMOSTATS

- **Type:** Standard thermostats (62%) were more common than programmable thermostats (45%). Wi-Fi thermostats (1% to 5%) had not penetrated the market at all. Customers were generally unfamiliar with the type of thermostats they had.
- **Programming:** Nearly one-third of customers with programmable thermostats (30%) did not actually program them.
- **Usage:** The typical customer reported that their thermostat setpoints changed by two or three degrees over the course of the day.

As shown in Table 11, according to web-survey and on-site visit results, customers most often had standard thermostats (62%), followed by basic programmable thermostats (45%). Customers rarely had smart (5%) or not smart (1%) Wi-Fi thermostats; however, readers will note the particularly small sample sizes for Wi-Fi thermostat: the majority of respondents did not know if they had these – an indication of lack of awareness of this technology. On that note, thermostat types all required adjustment factors, implying a general lack of understanding of thermostat functions and features. Of the homes with basic programmable thermostats, 70% of web-survey respondents reported using the programmable features.[27] Of the 132 respondents who reported having a smart Wi-Fi thermostat, Nest was the most popular brand (36%), followed by Honeywell (31%) and Ecobee (14%).

Table 11: Thermostat – Penetration and Average Units per Household

(Source: web-survey and on-site visits)[1]

Thermostat	Single-Family, 1-4 units			Multifamily, 5+ units			Overall		
	n	Pen.	Units	n	Pen.	Units	n	Pen.	Units
Standard	1,151	56%	1.05	461	68%	1.04	1,612	62%	1.10
Basic programmable	1,000	50%	0.94	353	32%	0.36	1,353	45%	0.81
Wi-Fi smart	455	6%	0.08	223	2%	0.02	678	5%	0.07
Wi-Fi not smart	419	2%	0.05	204	1%	0.01	623	1%	0.03
Overall	**1,721**	**99%**	**2.28**	**647**	**99%**	**1.39**	**2,368**	**98%**	**2.20**

Note: n = number of respondents; Pen. = penetration; Units = Average units per household.
[1] Percentages do not sum to 100% because customers can have more than one thermostat. **Blue text** indicates that an adjustment factor was applied.

As shown in Table 12, web-survey respondents reported that, during the heating season,[28] depending on the time of day, they set their thermostats to between 66°F and 68°F, on average. Standard deviations were roughly 4°F to 5°F, yet averages and medians were nearly identical. Comparing their maximum settings with their minimum settings, the typical respondent varied their temperature set points by 3°F on a given winter day.

On average, respondents who had cooling systems reported that they set their thermostats to between 70°F and 71°F during the cooling season. Standard deviations were about 4°F, yet averages and medians were nearly identical. Their cooling thermostat set points generally did not vary by time of day. However, the variation for each respondent's average high and low temperature indicates they changed their set points by 2°F on a typical summer day.

[27] This is somewhat higher than in Rhode Island, where 60% of customers with programmable thermostats used programmable features. Source: NMR. "National Grid Rhode Island Residential Appliance Saturation Survey (Study RI2311 Report." October 11, 2018. http://www.ripuc.org/eventsactions/docket/6.%20National%20Grid%20RI2311%20RASS%20Final%20Report%2011OCT2018.pdf.
[28] Heating season refers to December through February and cooling season refers to June through August.

Table 12: Temperature Setting Habits (°F)
(Source: web-survey only)

Time of Day[1]	Single-Family, 1-4 units			Multifamily, 5+ units			Overall		
	Avg.	Median	Std. Dev.	Avg.	Median	Std. Dev.	Avg.	Median	Std. Dev.
Heating Season		(n=1,659)			(n=586)			(n=2,245)	
Morning (6 to 9am)	67	68	3.88	69	70	4.02	67	68	3.98
Day (9am to 5pm)	66	67	4.23	68	70	4.54	67	68	4.34
Evening (5 to 9pm)	68	68	3.40	69	70	3.69	68	68	3.50
Night (9pm to 6am)	65	65	4.46	68	68	4.48	66	66	4.58
Setpoint change	**3**	**2**	**3.30**	**2**	**0**	**3.08**	**3**	**2**	**3.28**
Cooling Season		(n=1,315)			(n=515)			(n=1,830)	
Morning (6 to 9am)	71	70	4.10	70	70	4.11	71	70	4.13
Day (9am to 5pm)	71	70	4.45	70	70	4.62	71	70	4.49
Evening (5 to 9pm)	70	70	4.05	69	70	4.14	70	70	4.09
Night (9pm to 6am)	70	70	4.46	69	70	4.07	70	70	4.40
Setpoint change	**2**	**0**	**2.47**	**1**	**0**	**2.16**	**2**	**0**	**2.42**

[1] Values exclude outliers three standard deviations from the mean. Cooling sample sizes exclude respondents who did not have cooling systems. The table shows the sample sizes from the time of day with the most responses; sample sizes vary throughout the table because the survey question did not force a response.

3.3 Water Heating

- **Fuel Types:** Customers were most likely to have natural gas water heaters (42%).
- **Systems Types:** Storage tank water heaters had the highest penetration. HPWHs had not penetrated the market (1%), but on-site results show technical feasibility was high – nearly one-half of single-family homes (47%) could have technically accommodated them.
- **Ages:** As they were in 2011, water heaters in single-family homes were 11 years old, on average – a sign of nearing the end of useful life.

3.3.1 Penetration

Penetration estimates of water heating fuels and water heater systems are based on a combination of web-survey results and on-site visits.

Customers were more likely to have natural gas water heaters (42%) than fuel oil (34%) and electric (29%) units (Table 13). Single-family customers (58%) were considerably more likely than multifamily customers (2%) to have fuel-oil fired water heaters. Five percent of customers had a secondary water heater.

Table 13: Water Heating Fuel

(Source: web-survey and on-site visits)[1]

Fuel Type	Single-Family, 1-4 units (n=1,521)	Multifamily, 5+ units (n=406)	Overall[1] (n=1,927)
Natural gas	41%	**54%**	42%
Fuel oil	**58%**	**2%**	**34%**
Electricity	**24%**	**40%**	**29%**
Propane	8%	4%	7%

[1] Percentages do not sum to 100% due to the application of adjustment factors and households that reported multiple water heaters. **Blue text** indicates that an adjustment factor was applied. Sample sizes reflect households, not water heater units.

While natural gas and fuel oil water heaters were common, electric standard (i.e., storage) tank units (30%) had the highest penetration of any water heater type. They are closely followed by natural gas storage tank units (23%). Similar to heating systems, it was clear that some web-survey respondents struggled to accurately identify their water heaters' fuel *and* system types. As such, some results in Table 14 are difficult to reconcile with results in Table 13. Less than 1% of homes had HPWHs.

Table 14: Water Heating System Penetration

(Source: web-survey and on-site visits)[1]

Water Heater	Single-Family, 1-4 units (n=1,521)	Multifamily, 5+ units (n=406)	Overall (n=1,927)
Natural Gas			
Storage tank	32%	**21%**	**23%**
Indirect storage	6%	7%	6%
Tankless[2]	3%	**17%**	**7%**
Electric			
Storage tank	28%	46%	30%
Fuel oil			
Indirect storage	7%	1%	6%
Storage tank	10%	3%	**5%**
Tankless[2]	4%	1%	3%
Combination	3%	-	3%
Propane			
Storage tank	5%	1%	4%

[1] Percentages do not sum to 100% due to the application of adjustment factors and households that reported multiple water heaters. **Blue text** indicates that an adjustment factor was applied. Table excludes systems where overall penetration was less than 3% (e.g., electric tankless, heat pump, and pellet water heaters).

[2] Includes tankless coils and instantaneous, on-demand systems. Though, fuel oil systems are likely only tankless coils.

3.3.2 Efficiency and Age

Efficiency and age assessments come solely from on-site visit results. This report assesses those data from single-family on-site visits (the R1705/R1609 report assesses similar parameters for the multifamily on-site visits).

Table 15 shows the Energy Factors (EFs) of water heaters observed on site in single-family homes. EF is a measure of hot water produced per unit of fuel over a typical day (higher values equal greater efficiency). Readers should note small sample sizes for many system types. Looking at average EF by fuel type, the average EF among fossil-fuel based units ranged from 0.65 to 0.76. The average EF among electric units was 1.04 – the one HPWH had an EF of 3.25.

Not shown, EF values were not noticeably different than those reported in *R5*. For example, in 2011, electric storage water heater EF was 0.89, on average (versus 0.91 in 2018).

Table 15: Water Heaters – Energy Factors[1]

(Source: single-family on-site visits; n = 90)

End-Use		Quantity (n)	Average	Minimum	Median	Maximum	Standard Dev.
Standalone storage	Natural gas	*34*	**0.61**	0.50	0.60	0.79	0.06
	Electric	*16*	**0.91**	0.86	0.92	0.93	0.02
	Oil	*3*	**0.58**	0.56	0.56	0.63	0.04
	Propane	*1*	**0.69**	-	-	-	-
Indirect with storage	Oil	*11*	**0.76**	0.74	0.77	0.80	0.03
	Natural gas	*7*	**0.79**	0.74	0.80	0.84	0.04
	Propane	*1*	**0.84**	-	-	-	-
Tankless coil	Oil	*7*	**0.53**	0.45	0.50	0.60	0.06
	Natural gas	*1*	**0.50**	-	-	-	-
Combination appliance	Natural gas	*2*	**0.94**	0.94	0.94	0.95	-
Instantaneous	Natural gas	*2*	**0.96**	0.96	0.96	0.97	-
Heat pump water heater	Electric	*1*	**3.25**	-	-	-	-
Overall by Fuel Type							
Natural gas		*46*	**0.67**	0.50	0.62	0.97	0.12
Oil		*21*	**0.66**	0.45	0.74	0.80	0.12
Electric		*17*	**1.04**	0.86	0.92	3.25	0.57
Propane		*2*	**0.76**	0.69	0.76	0.84	-

[1] Federal standards for water heaters depend on tank volume and/or draw patterns. For more details, see: https://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=se10.3.430_132&rgn=div8. The exact value depends on tank volume and/or the draw pattern of the equipment (not reported here).

As shown in Table 16, considering the standard lifetime of water heaters,[29] the average water heater in single-family homes was nearing the end of its useful life. Most often they were manufactured between 2006 and 2015 (64%). As in 2011 (not shown), they were 11 years old, on average.

Table 16: Water Heaters – Ages

(Source: single-family on-site visits; n = 90)

Year Manufactured[1]	Indirect w/ Storage Tank (n=15)	Storage, Stand Alone (n=56)	Tankless Coil (n=7)	Other (n=5)[2]	Overall (n=83)
2016 or newer	7%	10%	-	20%	9%
2011 to 2015	40%	33%	29%	80%	34%
2006 to 2010	27%	34%	29%	-	30%
2001 to 2005	7%	14%	14%	-	13%
1991 to 2000	13%	9%	29%	-	13%
1981 to 1990	7%	-	-	-	1%
Age in Years					
Average	13	10	14	5	11
Median	11	10	12	5	10
CT EUL[3]	N/A	11 (high-efficiency gas)	N/A	13 (HPWH) 20 (tankless)	N/A
MA EUL[4]	20	13 (high-efficiency gas)	N/A	13 (HPWH) 20 (Tankless)	N/A

[1] Age was indecipherable for some units.
[2] The "Other" category includes two combination appliances, one HPWH, one solar hot water heater, and one instantaneous water heater.
[3] Source: *2019 CT Program Savings Document*.
[4] Source: *Massachusetts 2019-2021 Technical Reference Manual*

3.3.3 Heat Pump Water Heater Technical Feasibility

As shown in Table 17, nearly one-half (47%) of single-family on-site homes had water heaters installed in locations that could technically readily accommodate a HPWH because they were sufficiently large, warm, and had a drain to handle condensate.[30] The biggest limiting factor observed on site was insufficient space (26%). Nonetheless, this technical feasibility assessment does not account for the cost-effectiveness of installing HPWHs.

[29] The 2018 Connecticut Program Savings Document assumes an 11-year EUL for a high-efficiency gas water heater.
[30] Examples of programs providing these criteria as general requirements for HPWH installation: https://www.masssave.com/en/shop/equipment/electric-water-heaters/

Table 17: Heat Pump Water Heater Feasibility

(Source: single-family on-site visits; n=86)[1]

Conditions	Percentage of Homes
All conditions met	**47%**
Room likely kept at ≥ 50°F, year-round	90%
Ceiling height ≥ 6.5 feet	87%
Drain present	82%
Volume > 750 cubic feet	74%
HPWH already installed	1%

[1] Not all criteria could be assessed in four of the homes.

3.4 Appliances

- **Refrigerators:** One in five homes had more than one refrigerator.
- **Common Appliances:** Roughly three-quarters of homes had clothes washers (79%) and dryers (77%), and dishwashers (73%).
- **ENERGY STAR Saturation:** Among appliances in single-family homes, dishwashers had high ENERGY STAR saturation (73%) – an increase from 2011 (63%). While dehumidifiers had somewhat low penetration (33%), they had relatively high ENERGY STAR saturation (75%).
- **Appliance Ages:** On average, appliances in single-family homes were between nine and 16 years old.
- **Habits:** Customers used warm or hot water for more than one-half (52%) of their loads of laundry, on average.

3.4.1 Penetration

Penetration estimates of appliances are based on a combination of web-survey results and on-site visits. Table 18 presents the penetration and average number of units per household for kitchen and other appliances. As expected, refrigerator (100%), oven (99%), and stove (99%) penetration were high. On average, households reported having 1.23 refrigerators, with 20% of the sample having more than one refrigerator.

In-unit clothes washers (79%) and dryers (77%) were somewhat less common. Yet, this differed by dwelling type. For example, only one-half of multifamily customers had in-unit clothes washers, while nearly all single-family customers (97%) did. Without differentiation by dwelling type, nearly three-quarters (73%) of homes reported having a dishwasher.

Overall, one-third (33%) of homes reported having a dehumidifier, but penetration was much higher among single-family homes (46%) than multifamily homes (1%). Nearly one-half of homes (45%) reported having a humidifier.

Table 18: Appliances – Penetration and Average Units per Household

(Source: web-survey and on-site visits)[1]

End-Use	Single-Family, 1-4 units			Multifamily, 5+ units			Overall		
	n	Pen.	Units	n	Pen.	Units	n	Pen.	Units
Kitchen									
Refrigerator	1,729	99%	1.27	671	100%	1.03	2400	100%	1.23
Microwave[2]	1,689	96%	N/A	650	96%	N/A	2,339	96%	N/A
Dishwasher	1,588	**73%**	**0.75**	605	**72%**	**0.72**	2,193	**73%**	**0.74**
Standalone freezer	1,349	37%	0.40	416	**4%**	**0.04**	1,765	**20%**	**0.21**
Oven[3]	1,749	99%	N/A	677	98%	N/A	2,426	99%	N/A
Electric	1,749	71%	N/A	677	77%	N/A	2,426	72%	N/A
Natural gas[4]	1,749	**23%**	N/A	677	24%	N/A	2,426	30%	N/A
Stovetop	1,749	99%	N/A	677	**99%**	N/A	2,426	**99%**	N/A
Electric	1,749	62%	N/A	677	69%	N/A	2,426	63%	N/A
Natural gas[4]	1,749	**30%**	N/A	677	28%	N/A	2,426	**29%**	N/A
Clothes									
Clothes washer	1,683	97%	0.99	552	**50%**	**0.51**	2,235	**79%**	**0.81**
Clothes dryer	1,660	96%	0.97	544	**48%**	**0.50**	2,204	**77%**	**0.79**
Electric	*1,660*	*84%*	*0.85*	*544*	***46%***	***0.47***	*2,204*	***71%***	***0.72***
Natural gas	*1,660*	*11%*	*0.11*	*544*	***2%***	***0.02***	*2,204*	***7%***	***0.07***
Environmental Control									
Humidifier[2]	970	47%	0.62	427	37%	0.42	1,397	45%	0.59
Dehumidifier	1,257	**46%**	**0.62**	392	**1%**	**0.01**	1,649	**33%**	**0.44**
Air purifier	1,749	6%	N/A	677	**3%**	N/A	2,426	6%	N/A

Note: n = number of respondents; Pen. = penetration; Units = Average units per household.

[1] Percentages do not sum to 100% because homes had more than one end use. **Blue text** indicates that an adjustment factor was applied.

[2] Not verified on site.

[3] Penetration of electric and natural gas ovens may sum to greater than 100% because the respondent reported having two ovens with different fuel types.

[4] If respondents indicated they had "both" fuel types, the analysis assumed they had a gas stove or oven with an electric component and counted them as natural gas. Very few customers reported/had propane units, so those are excluded from this table.

3.4.2 Efficiency and Age

ENERGY STAR saturation and age estimates come solely from on-site visit results. This report assesses those data from single-family on-site visits (the R1705/R1609 report assesses similar parameters for the multifamily on-site visits).Table 19: Appliances – ENERGY STAR Saturation

(Source: single-family on-site visits; n = 90)

Appliance	Year of First ENERGY STAR Specification1	On-Site Quantity	ENERGY STAR Certified			
			ENERGY STAR Certified, Any Age		ENERGY STAR and Manufactured in or After 2013	
		n	Percentage	Count	Percentage	Count
Dishwasher	*1996*	*70*	72%	*49*	40%	*25*
Dehumidifier	*2001*	*47*	81%	*37*	39%	*17*
Refrigerator	*1996*	*120*	38%	*47*	20%	*23*
Clothes washer	*1997*	*89*	55%	*46*	18%	*15*
Standalone freezer	*1996*	*17*	24%	*4*	14%	*2*
Clothes dryer	*2014*	*83*	4%	*4*	3%	*3*
Air Purifier	*2004*	*14*	50%	*7*	30%	*3*

Table 19 shows ENERGY STAR saturation (percentage of the particular appliance currently found in homes in Connecticut that were labeled as ENERGY STAR at the time of sale) among on-site appliances by age. It is important not to confuse ENERGY STAR saturation with market share that is tracked nationally by ENERGY STAR.[31] The national ENERGY STAR market share tracking represents shipments of new products and does not account for existing products in consumers' homes.

ENERGY STAR saturation among dehumidifiers (81%) and dishwashers (72%) were fairly high. In the 2011 study, a smaller share of dishwashers (63%) were ENERGY STAR. However, ENERGY STAR specifications advance over time, so the label among older appliances loses significance. It is useful therefore to estimate the share that are both ENERGY STAR and recently manufactured appliances (2013 or later). Dishwashers (40%) and dehumidifiers (39%) still showed the highest levels of ENERGY STAR saturation. Saturation among clothes dryers was lowest (4%), but this is likely because ENERGY STAR did not develop specifications for clothes dryers until 2014.

[31] https://www.energystar.gov/index.cfm?c=partners.unit_shipment_data_archives

Table 19: Appliances – ENERGY STAR Saturation

(Source: single-family on-site visits; n = 90)

Appliance	Year of First ENERGY STAR Specification[1]	On-Site Quantity	ENERGY STAR Certified			
			ENERGY STAR Certified, Any Age		ENERGY STAR and Manufactured in or After 2013	
		n	Percentage	Count	Percentage	Count
Dishwasher	*1996*	*70*	72%	*49*	40%	*25*
Dehumidifier	*2001*	*47*	81%	*37*	39%	*17*
Refrigerator	*1996*	*120*	38%	*47*	20%	*23*
Clothes washer	*1997*	*89*	55%	*46*	18%	*15*
Standalone freezer	*1996*	*17*	24%	*4*	14%	*2*
Clothes dryer	*2014*	*83*	4%	*4*	3%	*3*
Air Purifier	*2004*	*14*	50%	*7*	30%	*3*

Regardless of type, appliances on site were most often manufactured between 2006 and 2015 (Table 20). Average ages ranged from ten years for dehumidifiers, air purifiers, and dishwashers to 15 years among the small sample of freezers. The PSD EUL of dehumidifiers (12 years) is somewhat longer than that of the average and median dehumidifier ages in the on-site sample (nine and seven years, respectively).

Table 20: Appliances – Ages

(Source: single-family on-site visits; n = 90)

Year Manufactured[1]	Refrigerator (n=127)[2]	Freezer (n=16)[2]	Clothes Washer (n=87)	Clothes Dryer (n=85)	Dishwasher (n=70)	Dehumidifier (n=45)	Air Purifier (n=10)
2016 or newer	10%	6%	12%	8%	17%	11%	20%
2011 to 2015	29%	19%	27%	23%	41%	59%	20%
2006 to 2010	23%	38%	42%	38%	21%	9%	50%
2001 to 2005	14%	13%	9%	16%	10%	11%	10%
1991 to 2000	19%	13%	6%	14%	7%	7%	-
1981 to 1990	4%	6%	4%	-	3%	3%	-
1980 or earlier	2%	6%	-	1%	1%	-	-
Age in Years							
Average	13	15	11	12	10	10	10
Median	11	12	10	11	8	7	10
CT EUL[3]	12	11	11	11	10	12	9

[1] Age was indecipherable for some units.
[2] Percentages do not sum to 100% due to rounding.
[3] Source: *2019 CT Program Savings Document*.

3.4.3 Habits

Web-survey respondents most often washed their clothing in cold water, but cumulatively they used warm or hot water more than one-half of the time. On average, they reported that they used cold water for 48% of loads, warm water for 37% of loads, and hot water for 15% of loads (Table 21). Other habits reported during the web survey included the following (none of these were confirmed through metered data or on-site inspection):

- On average, respondents reported running 4.5 loads of laundry per week. In contrast, the 2018 Connecticut PSD specifies 295 loads per year. This equates to the default value the ENERGY STAR appliance calculator uses (5.7 loads per week).[32]
- Respondents reported running 3.3 dishwasher cycles per week. The PSD specifies 215 cycles per year, equivalent to the ENERGY STAR assumption of 4.1 cycles per week.
- Respondents estimated that they used their microwave 3.1 times per day.[33]
- Just over three quarters (77%) of respondents who had them, said they leave their dehumidifier on an automatic setting, so that it turns on only when the environment calls for it.

[32] Accessed April 16, 2019: https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx.
[33] Laundry and microwave usage estimates included outlier values that might normally be excluded given that they were more than three standard deviations from the mean, but the analysis included them because they were associated with large households.

Table 21: Appliance Habits

(Source: web-survey)

Habit	Single-Family, 1-4 units	Multifamily, 5+ units	Overall
Laundry	**(n=1,749)**	**(n=677)**	**(n=2,426)**
About what percent of the time do you wash with hot, warm, or cold water?			
Average % of time using cold	49%	42%	48%
Average % of time using warm	38%	35%	37%
Average % of time using hot	13%	23%	15%
Loads per week[1]			
Average	4.8	2.7	4.5
Median	4.0	2.0	4.0
Standard deviation	2.1	3.5	3.4
Dishwasher (loads per week)	**(n=1,362)**	**(n=540)**	**(n=1,902)**
Average	3.3	2.9	3.3
Median	3.0	2.0	3.0
Standard deviation	2.5	2.2	2.3
Microwave (uses per day)	**(n=1,689)**	**(n=650)**	**(n=2,339)**
Average	3.2	2.4	3.1
Median	3.0	2.0	3.0
Standard deviation	2.3	3.1	3.0
Dehumidifier Setting (yes/no)	**(n=779)**	**(n=74)**	**(n=853)**
% of respondents using automatic setting	79%	50%	77%

[1] Responses excluded if homeowner did not report having a clothes washer. Analysis also removed zero and “don’t know” responses from the base.

3.5 Consumer Electronics

- **Computers:** Laptops (85%) surpassed desktops in penetration (39%).
- **Automation Devices:** Automation devices (39%) were somewhat common; typically, they were most often connected to thermostats (45%), audio equipment (27%), and lighting (23%).
- **APS:** Few customers had APS (4%). Examination of television and computer scenarios observed on site, it was clear that opportunities abounded.

3.5.1 Penetration

Estimates of penetration of consumer electronics come solely from web-survey results.

When asked about their consumer electronics, web-survey respondents most frequently reported having cell phones (98%), televisions (98%), and laptop computers (85%). As shown in Table 22, the average home had 2.13 cell phones, 2.39 televisions, and 1.45 laptop computers (excluding tablets). Desktop computers were much less common than laptop computers, with penetration reported at only 59% and an average of 0.75 desktop computers per home. Tablet penetration (79%) also surpassed that of desktop computers – the average home had 1.33 tablets.[34]

While the majority of homes reported having modems (80%), routers (77%), and printers (76%), smaller shares had automation devices (39%) (e.g., Amazon Echo, Google Home, Apple Home Pod) and stand-alone sound equipment (24%). As shown in Table 22, penetration of most devices was higher among single-family homes than multifamily homes, particularly for automation devices and printers.

[34] Customers estimated how often they left their computers and monitors plugged in, but standard deviations were too wide to draw conclusions.

Table 22: Consumer Electronics – Penetration and Average Units per Household

(Source: web-survey)[1]

Device	Single-Family, 1-4 units			Multifamily, 5+ units			Overall		
	n	Pen.	Units	n	Pen.	Units	n	Pen.	Units
Communication									
Cell phone	1,727	98%	2.22	667	99%	1.70	2,394	98%	2.13
Entertainment									
Television	1,722	98%	2.52	660	97%	1.72	2,382	98%	2.39
Tablet	1,556	79%	1.38	572	76%	1.07	2,128	79%	1.33
Game console	1,427	47%	0.74	496	45%	0.71	1,923	46%	0.74
TV sound system	1,433	45%	0.53	507	36%	0.41	1,940	43%	0.51
Office									
Laptop	1,599	85%	1.48	609	85%	1.29	2,207	85%	1.45
Monitor	1,450	62%	0.95	498	45%	0.55	1,948	59%	0.89
Desktop computer	1,474	61%	0.80	510	44%	0.49	1,984	59%	0.75
Modem	1,749	81%	N/A	677	74%	N/A	2,426	80%	N/A
Router	1,749	79%	N/A	677	67%	N/A	2,426	77%	N/A
Printer	1,749	80%	N/A	677	61%	N/A	2,426	76%	N/A
Other									
Automation device(s)	1,749	41%	N/A	677	29%	N/A	2,426	39%	N/A
Stand-alone sound equipment	1,749	25%	N/A	677	22%	N/A	2,426	24%	N/A

Note: n = number of respondents; Pen. = penetration; Units = Average units per household.
[1] Percentages do not sum to 100% because homes had more than one device. Average units per home estimates include outlier values because including them had no impact.

Customers with automation devices most often reported that they had thermostats (45%), audio or Bluetooth devices (27%), and lighting (23%) connected to them (Table 23).

Table 23: Consumer Electronics Connected to Automation Devices

(Source: web-survey)[1]

Device	Single-Family, 1-4 units (n=706)	Multifamily, 5+ units (n=225)	Overall (n=931)
Thermostat	47%	32%	45%
Audio or Bluetooth devices	26%	36%	27%
Lights	24%	21%	23%
Televisions	14%	26%	16%
Alarm system	17%	4%	15%
Security camera or baby monitor	12%	7%	11%
Garage door	11%	2%	10%
Water heater	4%	4%	4%
Kitchen appliances	2%	5%	3%
Portable heating/cooling equipment	2%	7%	3%
Clothes washer or dryer	1%	1%	1%
Other appliances	10%	12%	10%
Other electronics	3%	2%	2%

[1] Percentages do not sum to 100% because homes had more than one device.

3.5.2 Advanced Power Strips

Comparing on-site observations with web-survey responses implied that customers may have mistaken surge protectors or ordinary power strips for APS given that they have some visual similarities. While roughly three-fifths (61%) of respondents reported having APS installed in their homes, penetration was only 4% after being adjusted by on-site data. In contrast, Rhode Island residents – where APS are aggressively supported – had a penetration level of 27% at the same time; this is likely an indication that APS programs can be influential.[35]

As Table 24 shows, customers have 0.07 APS per home, on average, after applying adjustment factors. However, web-survey respondents reported having 1.73 APS per home, on average (not shown in table).

[35] NMR. "National Grid Rhode Island Residential Appliance Saturation Survey (Study RI2311 Report." October 11, 2018. http://www.ripuc.org/eventsactions/docket/6.%20National%20Grid%20RI2311%20RASS%20Final%20Report%2011OCT2018.pdf.

Table 24: Advanced Power Strips – Penetration and Average Units per Household

(Source: web-survey and on-site visits)

End-Use	Single-Family, 1-4 units			Multifamily, 5+ units			Overall		
	n	Pen.	Units	n	Pen.	Units	n	Pen.	Units
Advanced power strip	1,556	**4%**	**0.05**	592	**4%**	**0.07**	2,148	**4%**	**0.07**

Note: n = number of respondents; Pen. = penetration; Units = Average units per household. **Blue text** indicates that an adjustment factor was applied.

Based on on-site observations, nearly all homes (97%) had at least one set of electronics with peripheral devices based either around a television or a computer.

The 227 on-site homes had 394 home entertainment centers (HECs), in total.[36]

- Most homes (94%) had at least one HEC, and roughly one-half (55%) had more than one. HECs had an average of 2.3 periphery devices.
- Only 2% of HECs (nine HECs at nine homes) were connected to an APS,[37] yet the average home had 2.0 opportunities to use an APS with HECs.
- APS manufacturers recommend plugging in set-top-boxes (STBs). When excluding STBs, fewer homes (87%) had at least one HEC and the average number of periphery devices decreased to 2.0 periphery devices per HEC.

Table 25 presents HEC sizes by showing the proportion of televisions and homes associated with the specified count of peripheral devices. The majority of televisions (88%) could benefit from an APS because they had at least one peripheral device, and nearly one-third of televisions (30%) had three or more peripheral devices. However, excluding STBs reduces these proportions to 71% and 20%, respectively.

[36] An HEC consists of a television connected to at least one periphery electronic, such as set-top boxes, DVD players, VCRs, or game consoles.

[37] Overall APS penetration is higher because this value is a measurement of penetration of APS among HECs (not homes), so the base is different.

Table 25: Home Entertainment Center Sizes

(Source: on-site visits)

Count of Peripheral Devices	Single-Family, 1-4 units			Multifamily, 5+ units			Overall		
	Count of TVs	% of TVs (n=250)	% of Homes[1] (n=90)	Count of TVs	% of TVs (n=196)	% of Homes[1] (n=137)	Count of TVs[1]	% of TVs (n=446)	% of Homes[1] (n=227)
Including STBs									
None	30	12%	30%	22	11%	15%	52	12%	23%
1	74	28%	55%	55	30%	38%	129	29%	47%
2	76	31%	56%	54	26%	35%	130	30%	46%
3	33	13%	34%	39	18%	25%	72	15%	30%
4	19	7%	20%	17	10%	15%	36	8%	18%
5	13	6%	18%	5	2%	3%	18	5%	11%
6 or more	5	2%	5%	4	2%	3%	9	2%	4%
Excluding STBs									
None	76	29%	57%	56	27%	32%	132	29%	45%
1	80	30%	56%	61	33%	44%	141	31%	50%
2	48	22%	48%	37	19%	27%	85	21%	38%
3	24	9%	23%	29	15%	22%	53	11%	22%
4	14	6%	18%	7	3%	4%	21	5%	11%
5	7	3%	9%	4	3%	4%	11	3%	7%
6 or more	1	<1%	1%	2	1%	1%	3	<1%	1%

[1] Sums to more than 100% because some homes had more than one television.

The 227 on-site homes had 142 computer hubs in total.[38]

- Roughly one-half (51%) of homes had at least one computer hub, with only a small share (13%) having more than one computer hub.
- Only 5% of computer hubs (seven hubs at six homes) were connected to an APS,[39] yet the average home had 1.3 opportunities to use APS with their computers.
- On average, homes had 2.7 peripheral devices per computer hub.

Table 26 shows the proportion of computers and homes associated with the specified count of peripheral devices. Slightly more than two-thirds of computers (69%) could benefit from an APS because they had at least one peripheral device, and about one-third of computers (34%) had three or more peripheral devices.

[38] A computer *hub* consists of a computer connected to at least one periphery electronic, such as printers/scanners, external hard drives, monitors, modems, or routers.

[39] Overall APS penetration is lower because this value is a measurement of penetration of APS among computer hubs (not homes), so the bases are different.

Table 26: Computer Hub Sizes

(Source: on-site visits)

Count of Peripheral Devices	Single-Family, 1-4 units			Multifamily, 5+ units			Overall		
	Count of PCs	% of PCs (n=121)	% of Homes[1] (n=90)	Count of PCs	% of PCs (n=84)	% of Homes[1] (n=137)	Count of PCs	% of PCs (n=205)	% of Homes[1] (n=227)
None	39	34%	44%	24	18%	9%	63	29%	27%
1	16	13%	18%	19	25%	15%	35	17%	16%
2	19	14%	20%	19	26%	15%	38	17%	17%
3	25	21%	27%	11	15%	9%	36	19%	18%
4	13	11%	16%	5	9%	6%	18	11%	11%
5	5	4%	5%	4	6%	4%	9	4%	4%
6 or more	4	3%	5%	2	1%	1%	6	3%	3%

[1] Sum to more than 100% because some homes had more than one computer or less than 100% because some homes had no computers.
Note: PC = computer.

3.6 Lighting

- **Efficiency:** In 2012, LEDs and CFLs filled 28% of all sockets; this increased greatly to 45% in 2015 and then marginally increased to 47% in 2018. At the same time, inefficient bulb (halogen and incandescent) saturation decreased from 59% to 43% from 2012 to 2018, yet this represents a slight increase from 2015 (39%).
- **LED Penetration and Saturation:** LED penetration in Connecticut homes increased dramatically from 2012 (19%) and 2015 (42%) to 2018 (83%). Similarly, LED saturation increased more than tenfold since 2012 (2% to 23%) and more than doubled since 2015 (10%).[40]
- **Regional Comparison:** In 2018, LED saturation in Connecticut (23%) was lower than in Rhode Island (33%) and Massachusetts (31% – average of 2017 and 2018), both of which have aggressive upstream and direct install LED programs.[41] In fact, ENERGY STAR-qualified LED saturation in Connecticut (14%) was similar to the New York comparison area (10%), which did not have an upstream LED program. The combined CFL and LED saturation in Connecticut of 47% is lower than in Rhode Island (55%) and Massachusetts (53%), yet well ahead of the 37% in New York.
- **Specialty bulbs:** Similarly, when looking at LED saturation by specialty features, LED saturation of candle and globe shaped bulbs in Connecticut (15% and 8%,

[40] The sample only included electric customers in the Companies' territory. For purposes of brevity in the lighting analysis, the Companies' territories are referred to as "Connecticut," despite the fact that the sample does not span the entire state. UI and Eversource serve 96% of electric customers in the state.
[41] As discussed more in Section 3.6.2, the Rhode Island study was conducted at the same time as Connecticut. The Massachusetts and New York studies were conducted in late 2017 and late 2018, approximately six months before and six months after the 2018 Connecticut and Rhode Island visits.

respectively) were in line with New York (17% and 4%, respectively), while Massachusetts was much higher (34% and 32%, respectively). LED saturation of reflector/flood bulbs in Connecticut (32%) was in between that of Massachusetts (46%) and New York (20%), though far behind Rhode Island (59%).

- **Storage:** Customers had an average of ten bulbs in storage. On average, two were LEDs.

3.6.1 Cross-Year Comparison

As shown in Table 27, on-site visit results from 2012, 2015, and 2018 showed several lighting trends in Connecticut homes:

- LED bulbs filled nearly one-quarter (23%) of sockets in 2018, which was more than double that of 2015 (10%) and ten times that of 2012 (2%).[42]
- Overall, efficient bulbs (LEDs and CFLs combined) filled more than two-fifths (43%) of sockets in 2018 – representing a slight increase from 2015 when 45% of sockets had efficient bulbs, though a considerable increase from 2012 when 28% did. CFL saturation decreased marginally from 26% in 2012 to 24% in 2018, after a slight bump in 2015 to 35%.
- Inefficient bulb (incandescent and halogen) saturation decreased from 59% in 2012 to 39% in 2015, but then it increased slightly to 43% in 2018. From to 2015 to 2018, halogen saturation increased 6% to 9% and incandescent saturation increased from 33% to 34%.
- In 2018, the average home had 10.2 lightbulbs in storage, with 2.1 of them being LEDs (not shown below) (see Appendix D.3 for more details on storage behavior).
- Nearly one-half (46%) of stored bulbs were incandescent – more than double the shares represented by LEDs (20%) and CFLs (20%). However, the current incandescent storage rate is a sizable decrease from 2012 when more than three-fifths (63%) of bulbs in storage were incandescent, and a subtle decrease from 2015 when roughly one-half were (52%).

[42] NMR. “Connecticut LED Lighting Study Report (R154).” January 28, 2016. Accessed at: https://www.energizect.com/sites/default/files/R154%20-%20CT%20LED%20Lighting%20Study_Final%20Report_1.28.16.pdf. NMR. “Connecticut Efficient Lighting Saturation and Market Assessment.” October 2, 2012. Accessed at: https://www.energizect.com/sites/default/files/FINAL%20EISA%20Lighting%20Saturation%20and%20Market%20Assessment%20Report%20100212_pdf.pdf.

Table 27: Lighting Saturation and Storage by Year and Bulb Type

(Source: NMR 2012, 2015, and 2018 on-site visits)

Bulb Type	Saturation (% of Sockets)			Storage (% of Bulbs)		
	2012 (n=6,202)	2015 (n=4,990)	2018 (n=10,350)	2012 (n=1,657)	2015 (n=1,214)	2018 (n=2,314)
Incandescent	50%	33%	34%	63%	52%	46%
CFL	26%	35%	24%	30%	35%	20%
LED	**2%**	**10%**	**23%**	**<1%**	**4%**	**20%**
Halogen	9%	6%	9%	4%	5%	11%
Fluorescent	11%	11%	7%	4%	4%	3%
Empty sockets[1]	-	5%	3%	-	-	-
Other/don't know	2%	<1%	<1%	-	-	-

[1] Empty sockets not recorded in 2012.

LED penetration increased from 19% in 2012 to 83% in 2018. In contrast, incandescent penetration dropped from 100% to meet the current LED penetration. Albeit less dramatically, CFL penetration also decreased (96% to 88%) after peaking in 2015 (99%).

3.6.2 Regional Comparison

Based on benchmarking with other recent saturation studies, it appears that the Connecticut lighting program may not have as much impact on LED sales as programs in neighboring states, though the analysis did not account for differences in program spending and/or mix of supported lamps. At roughly the same time the Connecticut on-site visits were underway (April and May 2018), NMR fielded a nearly identical data collection effort in Rhode Island.[43] Several months before that (October through December 2017), NMR collected the same data points in Upstate New York and Massachusetts.[44] Then, NMR visited New York and Massachusetts homes again at the end of 2018 (October through December 2018) and collected the same data. To ease comparison and provide an estimate of the Massachusetts and New York values at a time that coincides with the Connecticut and Rhode Island visits, the study averaged the results of the 2017 and 2018 visits in Massachusetts and New York.[45] Appendix D provides the separate saturation estimates for each visit.

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[43] NMR. "RI2311 National Grid Rhode Island Lighting Market Assessment." July 27, 2018. Accessed at: http://www.ripuc.org/eventsactions/docket/5.%20RI2311%20RASS%20Lighting%20Report%20Final%2027July2018.pdf

[44] NMR. "RLPNC Study 17-9 2017-2018 Residential Lighting Market Assessment Study." March 28, 2018. Accessed at: http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC_179_LtgMarketAssessment_28March2018_FINAL-1.pdf.

[45] There are two drawbacks of taking the average of the 2017 and 2018 Massachusetts and New York visits. First, this assumes a constant rate of lighting purchases over the year, rather than reflecting the seasonality of lighting purchases. Second, the averages downplay the rapid changes in saturation between 2017 and 2018 seen in both states, which could present lessons for the Connecticut experience. Reporting the 2017 and 2018 values separately in Appendix D helps to address these two shortcomings.

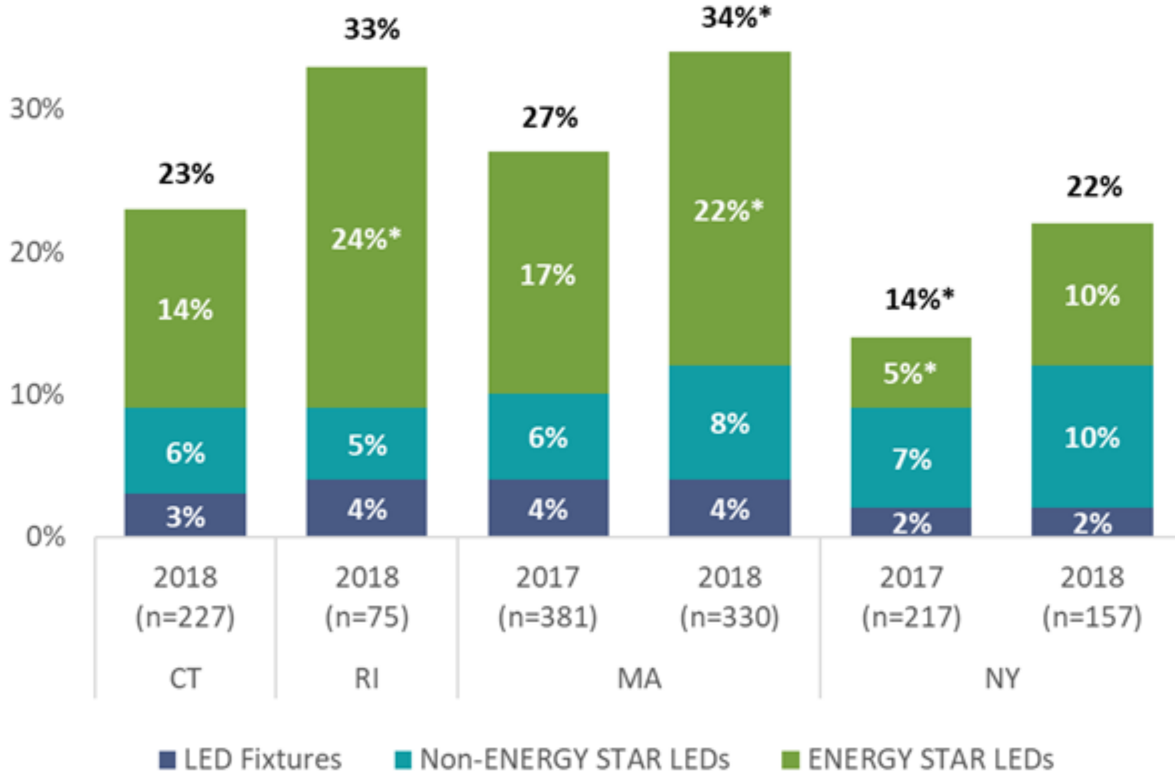
As shown in Figure 6, LED saturation in Connecticut (23%) was lower than in Rhode Island (33%) or Massachusetts (31%), but higher than in New York (18%). CFL saturation in Connecticut (24%) (not shown in Figure 6) was relatively similar to all other areas visited. CFL saturation was 22% in Rhode Island, 25% in Massachusetts, and 20% in New York. However, the combined CFL and LED saturation of 47% is lower in Connecticut than Rhode Island (55%) and Massachusetts (55%), yet ahead of the 37% in New York. This topic will likely be explored in the forthcoming *R1963 Short-term Residential Lighting Analysis*.

Like Massachusetts and Rhode Island, Connecticut programs provide incentives only for ENERGY STAR-qualified LEDs (New York does not). ENERGY STAR-qualified LED saturation was statistically significantly higher in Rhode Island (24%) and Massachusetts (22%) in 2018 than in Connecticut (14%).[46] While Connecticut ENERGY STAR-qualified LED saturation in 2018 was greater than the average of the two New York visits (8%), New York's ENERGY STAR-qualified LED saturation doubled from 5% to 10% between 2017 and 2018.

[46] While on site, technicians collected model numbers for all screw-base LED bulbs (not integrated LED fixtures). Comparing these model numbers with the list of ENERGY STAR-qualified LED bulbs determined the ENERGY STAR status for each LED bulb.

Figure 6: ENERGY STAR LED Saturation in 2018 by State

(Source: on-site visits)



* Significantly different from CT at the 90% confidence level

Note: Massachusetts and New York data collection occurred in two phases: first at the end of 2017 (October through December) and then at the end of 2018 (October through December). Connecticut and Rhode Island data collection occurred roughly mid-way between (in April and May 2018)

LED storage patterns were fairly similar across states.

3.6.3 Additional Findings

Fifteen of the 81 homes who engaged in on-site visits in 2015 through the R154 study did so again in 2018. The LED saturation in those homes more than tripled, increasing from 9% to 29% over the three-year period, but the sample size is too small to draw conclusions.

In 2018, low-income households in Connecticut had significantly higher saturation levels (than their non-low-income counterparts) of CFLs (34% versus 20%) and slightly higher saturation of LEDs (26% versus 22%). Similarly, CFL saturation was statistically significantly higher among multifamily than single-family homes (34% versus 21%), but LED saturation was fairly similar (28% versus 22%).

More than one-third of sockets (36%) had specialty bulbs, but they were rarely efficient bulbs – 6% of sockets had specialty LEDs. Most commonly, specialty bulbs were reflectors/floods, and, while nearly one-third of those bulbs were LEDs (32%), slightly more were incandescent (36%).

Appendix D provides the full on-site results of lighting saturation, penetration, and storage, as well as comparisons across territories.

3.7 Miscellaneous End Uses

- **Vehicles and Solar:** Electric (2%) and plug-in hybrid (1%) vehicles and solar panels (2%) had not penetrated the market. Fourteen percent of those with solar panels had energy-storage batteries.
- **Common End Uses:** Nearly one in five homes had well pumps (19%) and sump pumps (17%).
- **Others:** Primarily fueled by propane (41%) or gasoline (29%), whole home generators were uncommon (6%).

Penetration of miscellaneous end uses comes solely from web-survey responses.

Only 2% of customers reported having electric cars and 1% had plug-in hybrid cars (Table 28). Similarly, only 2% of customers, primarily single-family, reported having PV solar panels. Based on web-survey respondents' attempts to estimate the capacity or size of their panels, the average installed capacity among that subset of customers was 7 kW (not shown in the table or verified on site[47]). Fourteen percent of customers with solar panels reported they had energy-storage batteries to accompany their panels.

Table 28: Vehicles and Solar – Penetration and Average Units per Household

(Source: web-survey)

End-Use	Single-Family, 1-4 units			Multifamily, 5+ units			Overall		
	n	Pen.	Units	n	Pen.[2]	Units	n	Pen.	Units
Electric-only vehicle	1,749	2%	0.04	677	<1%	0.02	2,426	2%	0.04
Plug-in hybrid vehicle	1,749	1%	0.02	677	<1%	0.02	2,426	1%	0.01
PV panels[1]	1,749	1%	n/a	677	1%	n/a	2,426	2%	n/a
Energy-storage battery	1,749	<1%	<0.01	677	-	-	2,246	<1%	<0.01

Note: n = number of respondents; Pen. = penetration; Units = Average units per household.
[1] Verified on site.

When presented with a list of common miscellaneous measures, customers most often reported having well pumps (19%) and sump pumps (17%); although, penetration was driven by single-family homes (Table 29). A small percentage (6%) reported having whole-home generators; of those 118 respondents, 41% used bottled gas such as propane, while others mainly used gasoline (29%) and natural gas (19%) to fuel the generators.

[47] Capacity was not verified on site. A more comprehensive on-site study in the future could collect this data.

Table 29: Miscellaneous Measure Penetration Rates

(Source: web-survey)[1]

End-Use	Single-Family, 1-4 units (n=1,749)	Multifamily, 5+ units (n=677)	Overall (n=2,426)
Well pump	23%	-	19%
Sump pump	20%	1%	17%
Pool	9%	5%	9%
Whole-home generator	7%	1%	6%
Spa	5%	-	4%
Aquarium	4%	1%	3%
Heated waterbed	1%	1%	1%

[1] Percentages do not sum to 100% because homes had more than one end use.

Respondents listed other equipment in their homes that they estimated used a great deal of energy. Most frequently they mentioned power tools and/or air compressors (2%) and medical equipment (1%). Others listed end uses such as musical and pet equipment (e.g., reptile heat lamps, fish tanks).

Section 4 Building Characteristics

- **Insulation Status:** Nearly one-quarter (23%) of predominant walls in single-family homes had little-to-no insulation – an unintuitive increase from the values seen in 2011 (14%), signaling results should be interpreted cautiously given differences between methodologies.
- **Insulation Material:** Predominant walls in single-family homes were most often insulated with fiberglass batts (FGB) (66%), and predominant flat and vaulted ceilings were most often insulated with FGB or rockwool (64% for flat ceilings and 78% for vaulted).
- **Windows:** The main windows in single-family homes were commonly double-pane (85%) and most often made of vinyl (64%). About two-fifths (43%) had low-E coatings.[48]
- **Ducts:** Varying slightly between supply versus return ducts, basements ducts were uninsulated in roughly one-half of single-family homes, while attic ducts were uninsulated in about one-third of single-family homes.

4.1 Building Shell

Building shell assessments come solely from on-site visit results. This report assesses those data from single-family on-site visits (the R1705/R1609 study provides a comprehensive weatherization assessment for multifamily homes).

Given that end-use saturation was this study's primary goal, weatherization assessments were a secondary priority for single-family on-site visits. Unlike the 2011 R5 study, this study did not use HERS raters to perform exhaustive examinations of insulation levels. Instead, this study used a more cursory approach, where trained technicians (who were not HERS raters) attempted to identify the predominant insulation type and amount by assessing insulation at pre-existing penetrations or in accessible cavities.[49] This exercise produced an assessment that nearly one-quarter of predominant above-grade walls in single-family homes (23%) had little-to-no insulation (Table 30). We suspect that these assessments may overstate the instances of low levels of wall insulation. In this study, a cursory inspection of walls with poorly installed or thin and degraded insulation might yield an assessment of the walls being uninsulated, whereas in a full HERS rating

[48] Low-E coating came into production in the 1970s (https://www.osapublishing.org/ao/abstract.cfm?URI=ao-47-13-C193) and 39% of single-family homes in the on-site sample were built after 1969 – a slightly smaller share than the percentage of homes with low-E coating (43%). Future studies could use these parameters in the RASS database to gain a sense of window replacement rates among older homes.

[49] Wall assessments were made, for example, by inspecting and probing for insulation at pre-existing penetrations (e.g., surrounding electrical outlet boxes) in the main walls of the home, ignoring any smaller, renovated home portions. In some cases, this outlet probing will not provide a sufficient perspective to fully identify wall insulation, particularly in the case of old and degraded insulation or poorly installed insulation that may not be installed flush to electrical boxes. While HERS raters inspect and measure all the walls in the home, sometimes with diagnostic tools, this study was limited to simpler assessments of predominant building assemblies for budgetary reasons.

that measured all walls, there would be more opportunity for additional investigation of insulation levels.

The 2011 R5 study was a comprehensive weatherization study. This 2018 study used a less comprehensive approach in assessing building shell and duct characteristics, making direct comparisons between the studies challenging. Specifically, the 2011 study used equipment (such as infrared cameras, blower doors, and duct blasters) and assessed all walls, ceilings, windows, and ducts to measure and characterize area, efficiency level, and material. In contrast, the 2018 study – with a different budget and scope – was limited to assessing predominant walls, windows, and ducts. Moreover, the 2011 on-site sample size (n=180) was twice that of 2018 (n=90). Lastly, in 2011, NMR assigned HERS index values for all homes visited. With a lower budget in 2018, NMR did not collect all of the data necessary, nor use certified HERS raters, which would have been necessary to assign HERS index values. Insulation rates represent the most questionable comparison between studies because, after revisiting 2011 raw data, it appeared that 14% of predominant walls in those homes had little-to-no insulation, compared to 23% of homes in the 2018 study.[50] Some of this difference may be due to sampling error, and as previously discussed, some of the difference may also come from the difference in the inspection approach.

Among homes where auditors were able to observe wall insulation, most predominant walls had FGB insulation (66%), slightly down from 74% in the 2011 study. No single R-value dominated the 2018 sample of above-grade wall insulation, and only 2% of predominant walls had relatively high R-values (R-21 or greater).

Table 30: Above-Grade Wall Insulation – Primary Type and R-Value by Year

(Sources: single-family on-site visits)

Predominant Wall	2011 (n=180)	2018 (n=90)
Little-to-no insulation	14%	23%
Type[1]		
FGB	74%	66%
Dense pack cellulose	3%	4%
Open-cell spray foam	1%	3%
FGB and rigid foam	5%	3%
Rock wool batts	1%	2%
R-value[2]		
1 to 10	n/a	30%
11 to 13	n/a	23%
14 to 18	n/a	3%
19 to 21	n/a	19%
21 or greater	n/a	2%

[1] Drawn from original 2011 data; not shown in R5 report. Rows excludes blown-in FGB, found only in 2011 (2%). Totals do not always sum to 100% due to rounding.
[2] Given the nature of 2011 data collection, R-values for *predominant* wall were less comparable.

[50] Each home has only one predominant wall, so for purposes of this analysis, percentage of predominant walls and percentage of homes are interchangeable.

As shown in Table 31, only a small share of single-family ceilings had little-to-no insulation; in fact, the proportion of predominant flat ceilings with little-to-no insulation decreased in the 2018 study relative to the 2011 study (18% versus 6%). Like in 2011, among insulated assemblies, FGB or rockwool were the predominant insulation type in both flat (attic space) and vaulted (no attic space) ceilings in 2018. Together, in 2018, those materials comprised nearly two-thirds of flat (64%) and more than three-quarters of vaulted (78%) predominant ceiling insulation. Most commonly, insulation was between R-14 and R-29.

Table 31: Ceiling Insulation – Primary Type and R-Value by Year

(Sources: single-family on-site visits)

Predominant Ceiling[1]	Flat		Vaulted	
	2011 (n=174)[2]	2018 (n=79)	2011 (n=107)[2]	2018 (n=21)
Little-to-no insulation	18%	6%	7%	10%
Type				
FGB or rockwool	56%	64%	77%	78%
Blown-in fiberglass or cellulose	14%	15%	6%	3%
FGB and blown-in/other	11%	16%	8%	-
Other (not FGB or blown-in)	1%	-	3%	10%
R-Value				
1 to 13	n/a	18%	n/a	10%
14 to 29	n/a	45%	n/a	53%
30 to 49	n/a	30%	n/a	16%
50 or greater	n/a	1%	n/a	11%

[1] The insulation types and R-values shown represent the assembly that comprises the largest ceiling area of the home. Totals do not always sum to 100% due to rounding.

[2] Drawn from original 2011 data; not shown in R5 report.

Over four-fifths (85%) of single-family homes have double-pane glazing in the majority of their windows, and about two-fifths (43%) utilized a low-E coating (Table 32). In 2011, about 70% of homes had some double-pane glazing present, and 56% of homes had at least a portion of glazing that consisted of double-pane glazing with a low-E coating.[51] Window framing was most often vinyl (64%) or wood (32%).

[51] Because 56% of homes in 2011 had low-e coatings, so we would expect this number to be fairly high – window replacement appears to be common.

Table 32: Windows – Primary Glazing and Framing Type
(Source: single-family on-site visits; n = 90)

Material	Proportion of Homes
Glazing[1]	
Double-pane	44%
Double-pane, low-E	39%
Single-pane	14%
Double-pane, low-E, gas filled[2]	2%
Triple- pane, low-E, gas filled[2]	2%
Frame	
Vinyl	64%
Wood	32%
Metal	2%
Fiberglass	2%

[1] Totals do not sum to 100% due to rounding.
[2] If not clearly labeled, gas fill is detected by evidence of plugs (i.e., fill ports).

4.2 Ducts

Almost all ducts observed on site in single-family homes were in unconditioned basements or in attics, exposed above attic insulation; uninsulated ducts were common, as were ducts in the R-6 to R-10 range (Table 33). Basement ducts were uninsulated in roughly one-half of homes, while attic ducts were uninsulated in about one-third of homes.[52]

[52] It would require deeper investigation into raw R5 data to provide a fair comparison, but in 2011, 33% of supply and 44% of return ducts were uninsulated. These do not vary dramatically from the general results in 2018.

Table 33: Ducts – Predominant Insulation R-value
(Source: single-family on-site visits; n = 90)

Location	Supply Ducts (n=77)	Return Ducts (n=74)
Unconditioned Basement	*(n=39)*	*(n=39)*
Uninsulated	51%	53%
1 to 5	10%	12%
6 to 10	37%	30%
10 or greater	2%	5%
Attic (over insulation)	*(n=35)*	*(n=32)*
Uninsulated	32%	33%
1 to 5	13%	9%
6 to 10	51%	44%
10 or greater	5%	14%
Attic (under insulation)	*(n=1)*	*(n=1)*
Uninsulated	-	-
1 to 5	-	-
6 to 10	100% (1)	100% (1)
10 or greater	-	-
Enclosed Crawlspace	*(n=2)*	*(n=2)*
Uninsulated	-	50% (1)
1 to 5	-	-
6 to 10	100% (2)	50% (1)
10 or greater	-	-

4.3 Type, Age, and Size

As planned, the web-survey and on-site visits oversampled multifamily dwellings with five or more units to support the *R1705/R1609* study leading to discrepancies in sampled dwelling types compared to the population.[53] Weights adjusted for these discrepancies. Table 34 compares the samples with the population.

[53] The weighting approach accounted for this discrepancy (see Appendix B.1).

Table 34: Dwelling Type (Unweighted)

Dwelling Type	Web-Survey Responses (n=2,426)[1]	On-Site Observations (n=227)	Population (n=1,354,713)[2]
Single-family detached	47%	24%	61%
Multifamily (≥ 5 units)	28%	60%	17%
Multifamily (2-4 units)	17%	10%	16%
Single-family attached	9%	6%	6%

[1] Percentages do not sum to 100% due to rounding. [2] Source: U.S. Census Bureau. ACS 2012-2016. Proportions are based on occupied housing units.

The population of multifamily buildings in Connecticut (80%) was older than the web-survey (47%) and on-site (38%) multifamily samples, with more homes built before 1990. The single-family on-site sample somewhat overrepresented older homes (pre-1950) as compared to the Connecticut population (42% and 30%, respectively); as such, results drawn solely from on-site visits (versus web-sample-related results) are weighted by age.

Table 35: Home Age by Dwelling Type (Unweighted)

(Source: web survey, on-site visits, and U.S. Census)

Year Built	Single-Family, 1-4 units			Multifamily, 5+ units		
	Web-Survey (n=1,610)	On-Site Observations (n=87)[1]	Population (n=1,121,767)[1,2]	Web-Survey (n=502)	On-Site Observations (n=132)	Population (n=232,946)[1,2]
Before 1920	15%	18%	30%	3%	6%	21%
1920 to 1949	16%	24%		5%	5%	
1950 to 1979	38%	30%	43%	23%	21%	41%
1980 to 1989	14%	9%	12%	16%	5%	18%
1990 to 1999	8%	7%	8%	4%	4%	9%
2000 to 2010	6%	8%	7%	9%	12%	9%
2011 to 2014	2%	2%	1%	15%	8%	2%
2015 or after	1%	1%	<1%	25%	39%	<1%

[1] Percentages do not sum to 100% due to rounding.
[2] Source: U.S. Census Bureau. ACS 2012-2016. Proportions are based on occupied housing units. The earliest age in Census home age classification is 1939 or earlier.
Note: More than 300 web-survey respondents did not know the age of their home, and ages of some on-site homes was indecipherable, so sample sizes are lower.

The average web-survey respondent estimated that their home's conditioned floor area (CFA)[54] was 1,689 sq. ft. (Table 36). Single-family respondents most often estimated that their homes were between 1,000 and 2,000 square feet (51%), while the majority of multifamily respondents estimated that their units were between 500 and 1,500 sq. ft. (80%). Single-family on-site visits did not include measurement of CFA.

[54] The web survey defined CFA as "heated or cooled" areas of the home. The official definition of CFA can be found here: https://codes.iccsafe.org/content/chapter/16185/. Broadly, it is the sq. ft. of any area in the dwelling considered to be condition space volume (which is the volume in a dwelling unit serviced by space heating and cooling systems designed to maintain space conditions at 78°F for cooling and 68°F for heating), excluding conditioned garages and the floor area of any attics and crawl spaces considered to be conditioned space volume.

Table 36: Conditioned Floor Area

(Source: web-survey)

Square Feet	Single-Family, 1-4 units (n=1,508)	Multifamily, 5+ units (n=564)[1]	Overall (n=2,072)
Less than 500	2%	13%	4%
500 to 749	3%	21%	6%
750 to 999	9%	31%	12%
1,000 to 1,499	28%	28%	28%
1,500 to 1,999	24%	4%	21%
2,000 to 2,499	17%	1%	14%
2,500 to 2,999	10%	1%	8%
3,000 to 3,999	6%	<1%	5%
4,000 or more	1%	1%	1%
Average[2]	**1,811**	**966**	**1,689**

[1] The multifamily study measured actual building size on site (results not presented here).
[2] Some respondents could only estimate a range, so sample sizes are lower.

Section 5 Demographics

The web survey asked customers demographic questions – adjustment factors do not apply because on-site verification visits did not address demographics. The following offer a snapshot of the respondent demographics (weighted):

- Similar to Census statistics for Connecticut, roughly three-quarters of survey respondents lived in Hartford (25%), Fairfield (23%), and New Haven (26%) counties.
- The vast majority (98%) were answering questions about their primary residence. The average single-family respondent had lived in their home for 19 years while the average multifamily respondent had lived in theirs for almost eight years.
- Respondents (63%), like Census households (62%), were most likely to live in homes with two or fewer occupants. Excluding refusals, multifamily household sizes were noticeably smaller than that of single-family households – 71% of multifamily homes consisted of one or two occupants while 53% of single-family homes had one or two occupants.
- For the most part, homes were equally as likely to have children as they were to have occupants in any other age bracket under 75. However, single-family homes were more likely to have children than multifamily homes – bearing in mind that the average single-family household was larger (2.6 versus 1.9 occupants).
- Nearly three-quarters (72%) of survey respondents owned their homes. This is somewhat higher than Census statistics for Connecticut (66%). Single-family occupants (83%) were roughly four times as likely as multifamily occupants (21%) to own their homes.
- Excluding respondents who refused to answer, nearly one-half (46%) of survey respondents confirmed that their gross household income in 2017 was less than 60% of the area median income (AMI).[55] This is higher than Census data, which reports that about one-third (34%) of the population are considered low-income. Before weighting results, however, a little more than one-fourth (27%) of respondents were confirmed low-income; the weighting approach described in Appendix B.1 adjusted for this underrepresentation.
- Considerably more survey respondents (58%) attained their bachelor's degree or more education when compared to the population (40%). Weights corrected for this discrepancy to some extent.

Table 37 compares the web-survey sample to Census statistics for Connecticut.

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[55] Department of Health's 60% Area Median Income (AMI) thresholds for Connecticut. At the time of survey fielding, they matched the income-eligibility thresholds defined on the Energize Connecticut website: https://www.energizect.com/your-home/solutions-list/save-energy-and-money-all-year-long

Table 37: Demographic Comparison to Population

(Source: web-survey and U.S. Census)

Demographic	Sample (n=2,426)[1]		Population (n=1,354,713)[1]
	Weighted	Unweighted	
County			
Hartford	25%	24%	26%
Fairfield	23%	27%	25%
New Haven	26%	26%	24%
New London	7%	5%	8%
Litchfield	5%	4%	5%
Middlesex	6%	5%	5%
Tolland	5%	5%	4%
Windham	4%	3%	3%
Tenure			
Own	72%	66%	66%
Rent	28%	34%	34%
Household Size			
2 or fewer	63%	68%	62%
3	16%	15%	16%
4	13%	11%	14%
5 or more	8%	7%	8%
2017 Gross Household Income			
Less than $40,000	36%	23%	29%
$40,000 to $69,999	21%	22%	21%
$70,000 to $99,999	16%	20%	16%
$100,000 to $149,999	16%	21%	16%
$150,000 to $199,999	6%	7%	8%
$200,000 or more	6%	7%	10%
60% AMI			
Above	54%	73%	66%
Below	46%	27%	34%
Highest Level of Education			
High school/less than HS	15%	12%	34%
Some college or associated degree	27%	25%	26%
Bachelor’s degree or higher	58%	63%	40%

[1] Percentages exclude refusals so sample sizes differ by demographic.
[2] Source: U.S. Census Bureau. ACS 2012-2016. Proportions are based on occupied housing units.

Figure 7 illustrates the distribution of the 2,426 web-survey and 227 on-site sample homes. The top two maps include single-family homes with one to four units, and the bottom two include multifamily homes with five or more units.

Figure 7: Sample Geography

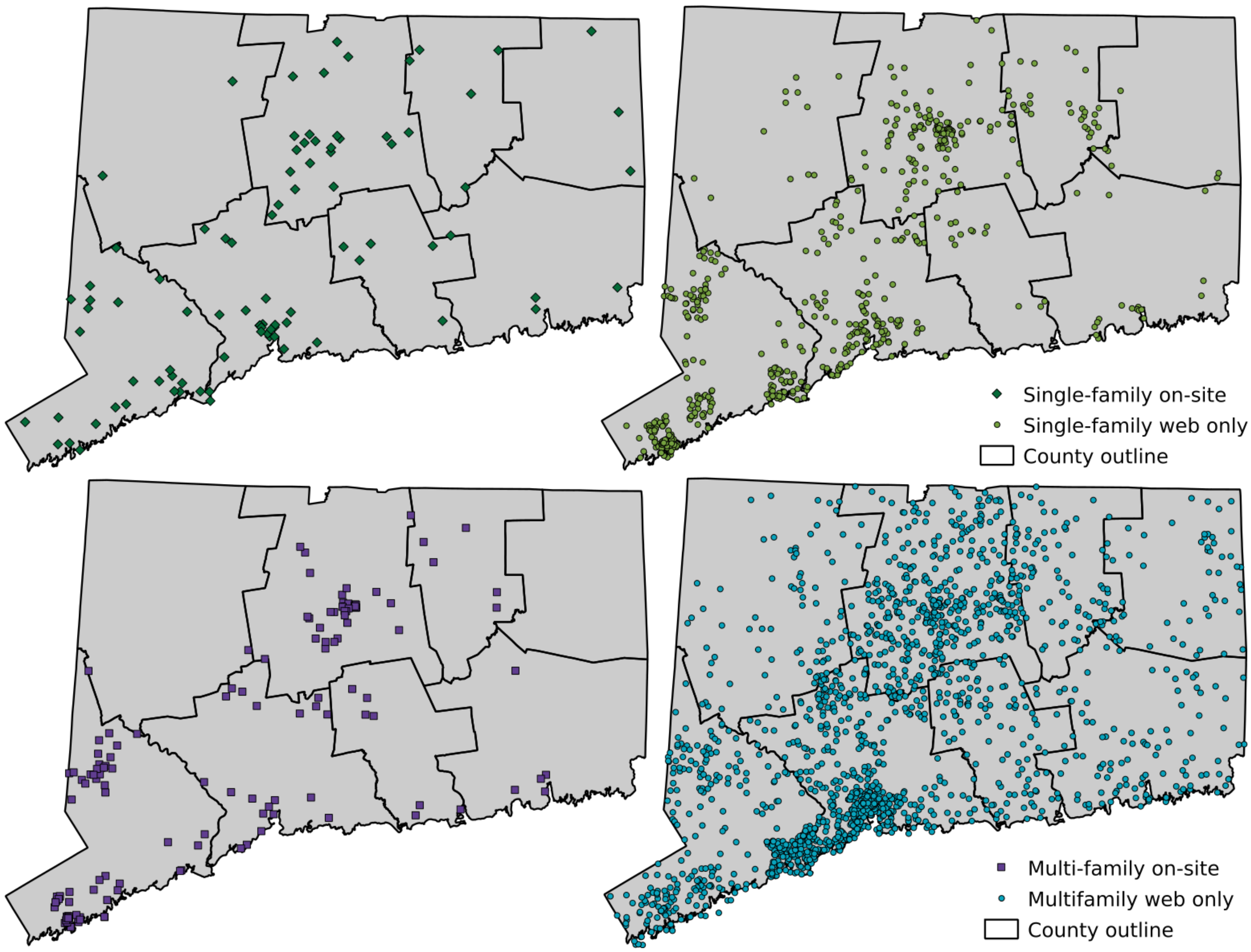

Table 38 through Table 40 compare demographics – collected through web-surveys – by dwelling type.

Table 38: Household Occupant Age

(Source: web-survey)

Age	Single-Family, 1-4 units (n=1,749)		Multifamily, 5+ units (n=677)		Overall (n=2,426)	
	Weighted	Unweighted	Weighted	Unweighted	Weighted	Unweighted
5 years or younger	12%	10%	10%	9%	11%	10%
6-18 years old	23%	21%	14%	10%	21%	18%
19-34 years old	30%	28%	41%	42%	32%	32%
35-54 years old	40%	39%	37%	34%	39%	37%
55-64 years old	35%	35%	21%	21%	32%	31%
65-74 years old	27%	28%	16%	17%	25%	25%
75-84 years old	11%	10%	5%	5%	10%	9%
85 years and older	4%	3%	3%	2%	4%	3%

[1] Percentages represent the proportion of homes with at least one occupant in the respective age range; as such, percentages do not sum to 100%.

Table 39: Home Occupancy

(Source: web-survey)

Demographic	Single-Family, 1-4 units (n=1,749)		Multifamily, 5+ units (n=677)		Overall (n=2,426)	
	Weighted	Unweighted	Weighted	Unweighted	Weighted	Unweighted
Tenure						
Own	83%	83%	21%	25%	72%	66%
Rent	17%	17%	79%	75%	28%	34%
Residency						
Primary	98%	98%	98%	97%	98%	98%
Secondary	2%	2%	2%	3%	2%	2%
Years in Home						
Average[1]	19.2	18.9	7.6	7.3	17.2	15.7
Months Occupied						
Average[1]	11.7	11.7	11.5	11.6	11.7	11.7
Day Time Occupancy[2]						
9am to 12pm	79%	78%	67%	61%	77%	73%
12pm to 5pm	83%	82%	68%	61%	80%	75%
5pm to 10pm	99%	99%	97%	98%	98%	99%

[1] Sample sizes vary.
[2] Nearly one-fourth (24%) of respondents refused to answer this question, likely out of concern for safety. So, sample sizes are lower than other questions.

Table 40: Socioeconomic Indicators

(Source: web-survey)

Demographic[1]	Single-Family, 1-4 units (n=1,749)[2]		Multifamily, 5+ units (n=677)[2]		Overall (n=2,426)	
	Weighted	Unweighted	Weighted	Unweighted	Weighted	Unweighted
Number of Occupants						
1	17%	17%	43%	42%	21%	24%
2	37%	37%	28%	31%	35%	36%
3	14%	13%	15%	12%	14%	13%
4	13%	12%	6%	4%	11%	9%
5 or more	9%	8%	2%	2%	8%	6%
Refused	*12%*	*13%*	*6%*	*9%*	*11%*	*11%*
Average	**2.6**	**2.3**	**1.9**	**1.7**	**2.5**	**2.1**
2017 Gross Household Income						
Less than $40,000	21%	13%	52%	24%	26%	16%
$40,000 to $69,999	15%	14%	14%	17%	15%	15%
$70,000 to $99,999	12%	14%	8%	13%	11%	14%
$100,000 to $149,999	13%	15%	7%	13%	12%	14%
$150,000 to $199,999	5%	5%	2%	4%	4%	5%
$200,000 or more	5%	5%	2%	4%	4%	5%
Refused	*30%*	*35%*	*15%*	*25%*	*27%*	*32%*
60% AMI[3]						
Above	41%	48%	29%	51%	39%	49%
Below	29%	17%	56%	23%	33%	19%
Refused	*30%*	*35%*	*15%*	*26%*	*28%*	*32%*
Highest Level of Education						
High school or less	14%	12%	14%	9%	14%	11%
Some college or associate's degree	25%	25%	28%	20%	26%	23%
Bachelor's degree or higher	55%	57%	53%	65%	53%	59%
Refused	*6%*	*6%*	*5%*	*5%*	*6%*	*6%*

[1] Note that percentages differ slightly from Table 37 due to the inclusion of refusals.
[2] Some percentages do not sum to 100% due to rounding.
[3] Source: Income Guidelines (*60% Annual Median Income for FFY 2017)*
https://www.energizect.com/your-home/solutions-list/save-energy-and-money-all-year-long

A

Appendix A Methodology Details

This appendix details fielding and sampling approaches and the end uses and attributes that web surveys and on-site verification visits examined.

A.1 Fielding and Sampling

The sampling approach oversampled multifamily respondents for two reasons:

1. To ensure adequate representation of multifamily households.
2. To provide sufficient completes from which to recruit multifamily households for the *R1705/R1609 Multifamily Baseline and Weatherization Opportunity* study (conducted by ERS).

To develop the RASS sample, the evaluation team requested a random pull of electric customers from the Companies. The request asked for 28,300 (71%) residential electric customer contacts from Eversource and 11,700 (29%) residential electric customer contacts from UI, requiring that all customer contacts have billing data dating from January 2016 through "the most recent month" in 2017. While fielding the web survey, the evaluation team submitted a subsequent data request in February 2017 for an additional 20,000 residential multifamily homes, specifically 14,000 likely-multifamily electric customers from Eversource and 6,000 likely-multifamily electric customers from UI.

After removing non-residential customers, gas accounts, and duplicated service addresses, the sample included 51,164 residential electric customers. As the Companies do not explicitly track dwelling type or income, it was difficult to accurately assess the demographic representativeness of the sample frame or accurately pull a sample that overrepresented multifamily homes. To target multifamily homes, the evaluation team used variables such as service address details and the presence of unit numbers to flag homes that were *likely-multifamily* buildings with five or more units. In addition, the evaluation team used rate codes and participation data regarding low-income programs to flag *likely-low-income* customers.[56]

Using a staged-fielding approach and leveraging the artificial *likely-multifamily* and *likely-low-income* flags helped ensure that survey responses somewhat mirrored the distribution of Census data in terms of dwelling type and income. As shown in Table 41, *likely-multifamily* homes were oversampled, and the evaluation team targeted a Eversource/UI split of 66%/34%. For details on comparing survey responses to Census distributions by dwelling type, see Table 34 and Table 37 for a comparison by county and income levels.

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[56] Partial program participation data was provided with the Companies sample information. Programs provided with the sample included Home Energy Solutions and Home Energy Solutions - Income Eligible programs.

Table 41: Sampling by Dwelling Type

Home Type[1]	Customer Sample Pull[2]		Web-Survey Sample Frame		Customer Population[3]
	Eversource[4]	United Illuminating	Eversource	United Illuminating	
n	26,893	24,271	20,100	10,200	1,354,713
Single-family	58%	63%	44%	35%	83%
Likely-multifamily	43%	37%	56%	65%	17%

[1] Single-family homes include mobile homes and housing complexes with one to four units, while multifamily homes include housing complexes with five or more units. Percentages for customer sample pull and sample frame are based on initial sample flags, not survey responses.
[2] Source: Random electric customer sample provided by Companies.
[3] Source: ACS Census 5-Year Estimates: 2012-2016. Proportions are based on occupied housing units.
[4] Percentages do not sum to 100% due to rounding.

Between December 15, 2017 and April 20, 2018, 30,300 electric residential customers in the Companies' territory received letters inviting them to respond to the web survey in exchange for a $10 Amazon electronic-gift card. Depending on their characteristics, some customers who did not initially respond received follow-up emails and letters reminding them to respond.[57] The study achieved a response rate of 8%, with 2,426 customers completing the survey. The following steps outline the three-wave approach used to achieve this response rate and adequate multifamily representation:

- **Wave 1:** Sent invitation letters on December 15, 2017 to 10,000 Eversource customers, as UI had not yet provided customer contacts. Wave 1 non-respondents received a reminder email (where email addresses were available) approximately one week after receiving the letter.
  - **Result:** Multifamily and low-income homes were underrepresented in comparison to Census statistics. Therefore, homes flagged as *likely-multifamily* in the sample frame received a follow-up email.
- **Wave 2:** Sent 10,000 invitation letters on January 26, 2018, to 7,000 UI customers and 3,000 Eversource customers. Wave 2 sample frame attempted to further over-represent multifamily homes and exhausted the remaining *likely-multifamily* sample frame for both Companies. Wave 2 non-respondents received a reminder email approximately one week after receiving the letter. The reminder email explicitly stated that the survey was targeting multifamily customers.
  - **Result:** While response rates from multifamily and low-income households improved slightly, multifamily homes were still underrepresented. At this point, the survey was altered to allow single-family customers to respond to the survey, but no longer offered them a $10 Amazon gift card in exchange. Further, the study sent 7,000 reminder letters on February 20, 2018, to 7,000 (53% Eversource, 47% UI) Wave 1 and 2 *likely-multifamily* flagged homes.

[57] To further target multifamily homes, email reminders to the second and third waves (or cohorts) were only sent to homes flagged as *likely-multifamily*.

- **Wave 3:** Sent invitation letters on April 6, 2018, to a new list of 10,300 (69% Eversource, 31% UI) *likely-multifamily* customers. Wave 3 non-respondents received a reminder email approximately one week after receiving the letter.

Some customers asked to respond to the survey via paper or telephone and were directed to visit a local library for internet access.[58] This may have contributed to slightly lower survey-sample representation among low-income customers (27% unweighted survey responses compared to 34% in Census data).[59] The survey did not ask *respondent* age, so it is unclear if the web-only mode impacted response rates among older customers. Research from mixed-mode surveys conducted via web and telephone in Massachusetts in 2015 showed that web and phone respondents differed primarily for three parameters: age, home ownership status, and income,[60] with web respondents being significantly more likely than phone respondents to be younger than 45 years old, homeowners, and non-low-income.

Table 42 compares the Companies' residential electric customer sample pull and the web-survey sample frame.

Table 42: Sampling by County and Dwelling Type

County	Home Type[1]	Customer Sample Pull		Web-Survey Sample Frame	
		Eversource	United Illuminating	Eversource	United Illuminating
n		26,893	24,271	20,100	10,200
Hartford	Single-family	19%	-	14%	-
	Multifamily	15%	-	19%	-
Fairfield	Single-family	11%	18%	8%	10%
	Multifamily	14%	15%	19%	26%
New Haven	Single-family	8%	46%	6%	26%
	Multifamily	5%	22%	6%	38%
New London	Single-family	5%	-	4%	-
	Multifamily	2%	-	2%	-
Litchfield	Single-family	5%	-	4%	-
	Multifamily	1%	-	2%	-
Middlesex	Single-family	4%	-	3%	-
	Multifamily	2%	-	2%	-
Tolland	Single-family	3%	-	2%	-
	Multifamily	3%	-	3%	-
Windham	Single-family	3%	-	2%	-
	Multifamily	1%	-	2%	-

[1] Single-family homes include mobile homes and housing complexes with one to four units, while multifamily homes include housing complexes with five or more units.

[58] The evaluation team conducted one survey over the phone with a visually-impaired respondent.

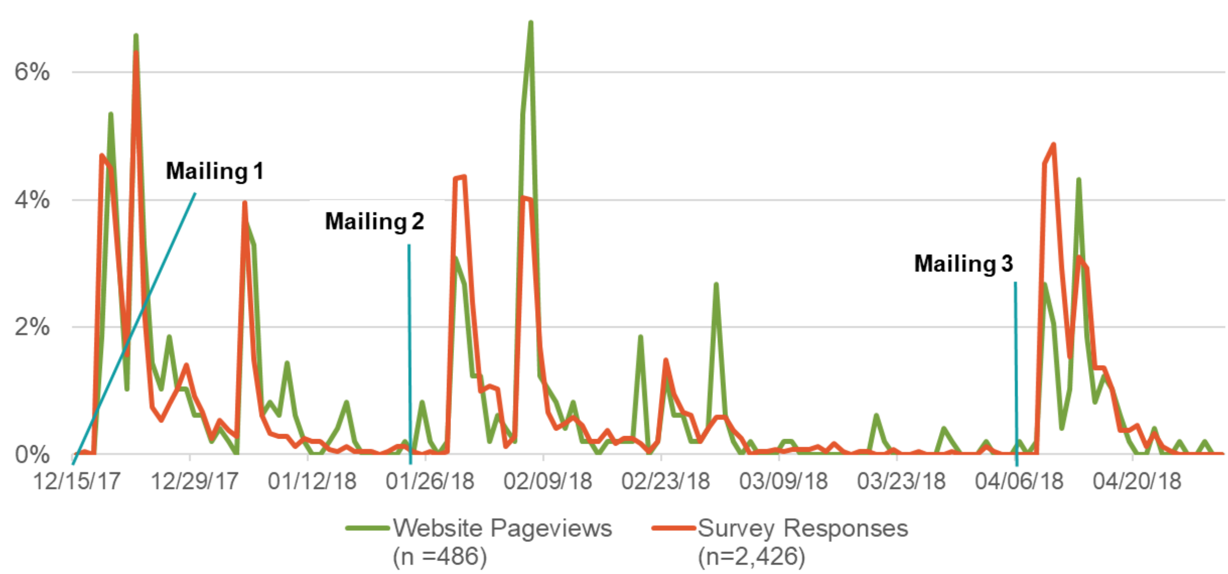
[59] Respondents who refused to answer income questions were binned into the non-low-income group, which also contributes to the underrepresentation of low-income customers.

[60] http://ma-eeac.org/wordpress/wp-content/uploads/MA-2015-16-Lighting-Market-Assessment-Final-Report-08August2016.pdf

In support of the lighting portion of the study, 81 customers who participated in the previous *R154* study were added to the sample (not reported in table above). These respondents received a special invitation letter and follow-up telephone calls.

Comparing outreach timing with web-survey response rates shows that response rates were highest approximately two to four days after the initial mailing. Customer visits to a temporary informational webpage appear to correlate with response rates (0.85 positive correlation). Figure 8 charts response rates and webpage visits over time with respect to the mailing waves.

Figure 8: Web-Survey Response Rates and Webpage Visits



A.2 End-Use and Attribute List

Table 43 through Table 48 identify the end uses and other characteristics asked about in the web survey and/or on-site verification visits. The study examined fuel types, presence, counts, ages, efficiency levels, and elements indicative of energy consumption. The level and mode of research varied by measure. Numbers in the table columns indicate the modes used: 1 means it was asked about only in the web-survey, 2 means it was examined only on site, and 3 means the evaluation team collected it through both modes.

This report does not analyze all characteristics. However, the database houses all data listed below.

As shown in Table 43, after asking on the web survey about quantities, ages, configurations, and habits associated with appliances, the evaluation team verified that information on site. Technicians also recorded other characteristics indicative of energy consumption by logging things like make, model, and ENERGY STAR-labeling.

Table 43: Appliances – Details Collected by Data Collection Modes

End-Use	Fuel Type	Presence	Count	Age	ENERGY STAR	Details
Clothes washer	2	3	3	3	2	Loads per week and temperatures[1] IMEF[2]
Clothes dryer	3	3	3	3	2	Location[2] Moisture sensing[2]
Dishwasher	-	3	3	3	2	Loads per week[1]
Microwave	-	1	-	-	-	Number of times used per day[1]
Refrigerator	-	3	3	3	2	Type[3] Refrigerator volume and consumption[2] Location[3] Use[1]
Freezer	-	3	3	3	2	
Oven/range	3	3	3	-	-	-
Dehumidifier	-	3	3	3	2	Auto-setting[1]
Humidifier	-	1	1	1	-	-
Air purifier	-	3	3	3	2	-

1=web only, 2=on site only, 3=both web and on site.

The on-site verification visits researched details of lighting fixtures, including type and if it is controlled by a sensor, as well as make/model and wattages of installed and stored bulbs in the home (Table 44).

Table 44: Lighting – Details Collected by Data Collection Modes

End-Use	Fuel Type	Presence	Count	Age	ENERGY STAR[1]
CFL – standard	-	2	2	-	-
Specialty CFL	-	2	2	-	-
LEDs	-	2	2	-	2
LED recessed can	-	2	2	-	2
LED fixture	-	2	2	-	-
Specialty LED	-	2	2	-	2
Fluorescent	-	2	2	-	-
Halogen	-	2	2	-	-
Other bulb type	-	2	2	-	-

1=web only, 2=on site only, 3=both web and on site.
[1] ENERGY STAR status was based on model information collected on site.

Consumer electronics research captured presence, count, and if equipment was plugged into an APS (Table 45). Web surveys asked respondents to enumerate their consumer electronics and about APS usage, all of which was verified during on-site verification visits. While on site, the presence of APS was verified, and all equipment attached to the APS were recorded. Technicians logged peripheral electronics (e.g., printers) surrounding or connected to televisions and computers.

Table 45: Consumer Electronics – Details Collected by Data Collection Modes

End-Use	Fuel Type	Presence	Count	Age	ENERGY STAR	Details
Desktop computers	-	3	3	-	-	Use[1]
Laptops	-	3	3	-	-	Use[1]
Computer monitors	-	3	3	-	-	Use[1]
APS	-	3	3	-	-	Plugged-in devices[3]
TVs	-	3	3	-	-	-
Game consoles	-	3	3	-	-	-
Sound systems	-	3	3	-	-	-
Cell phones	-	1	1	-	-	-
Modem/router	-	3	2	-	-	-
Printer	-	3	2	-	-	-
Standalone sound equipment	-	3	2	-	-	-
Tablets	-	3	3	-	-	-
Wi-Fi connected devices	-	1	1	-	-	Controlled devices[1]

1=web only, 2=on site only (if attached to a television or computer), 3=both web and on site (if attached to a television or computer).

As shown in Table 46, on-site verification visits again offered the opportunity to hone-in on energy consumption factors. On site, the evaluation team collected make and model of heating, cooling, and water heating equipment; output capacity of heating and cooling units; and gallons and/or EF of water heating equipment. On-site technicians looked for the presence of boiler circulator pumps. Photos were taken of furnace unit nameplates, which were later used to determine the presence of ECM furnace fans.

Table 46: Heating, Cooling, Thermostats, Water Heating – Details Collected by Data Collection Modes

End-Use	Fuel Type	Presence	Count	Age	ENERGY STAR	Details
Heating system	3	3	3	3	2	Use[1] AFUE/COP[2]
Cooling system	3	3	3	3	2	Use[1] SEER/EER/COP[2]
Thermostats	-	3	3	-	-	Type [3] Settings[1]
Ducts	-	3	3	-	-	Insulation type[2] R-value[2]
Radiators	-	1	1	-	-	-
Radiant floor heating (bathroom)	-	1	-	-	-	-
Whole-house fan	-	2	2	-	-	-
HRV/ERV	-	2	2	2	2	-
Water heater	3	3	3	3	2	Conditioned space[3] Condensing water heater[1] AHRI[2]
Water heater blanket	-	2	2	-	-	R-value[2]
Circulator pump	-	2	2	-	-	-
ECM furnace fan	-	2	2	-	-	-

1=web only, 2=on site only, 3=both web and on site.

As shown in Table 47, while the web survey asked respondents about a number of miscellaneous end-uses, on-site verification visits researched a few key types of equipment, including PV, energy storage batteries, and the presence of electric vehicles.

Table 47: Miscellaneous End-Uses – Details Collected by Data Collection Modes

End-Use	Fuel Type	Presence	Count	Age	ENERGY STAR	Details
Electric vehicles	-	3	3	-	-	Charging station presence and power level[1] Make and model[1]
PVs	-	3	-	-	-	Capacity (kw)[3]
Energy-storage batteries	-	3	-	-	-	-
Pool	-	1	-	-	-	-
Whole-home generator	1	1	-	-	-	-
Air purifier	-	1	-	-	-	-
Heated waterbed	-	1	-	-	-	-
Aquarium	-	1	-	-	-	-
Sump pump	-	1	-	-	-	-
Well pump	-	1	-	-	-	-
Spa	-	1	-	-	-	-
Pool/spa heaters	1	1	-	-	-	-

1=web only, 2=on site only, 3=both web and on site.

Table 48 lists the building characteristics studied. Note that web surveys asked respondents to quantify rooms in their homes by type and to estimate the square footage of their homes. However, on-site verification visits limited that investigation to home type, number of stories, age of home, and number of bedrooms. To support the *R1705/R1609 Multifamily Baseline and Weatherization Opportunity* study, weatherization data was more comprehensively collected for multifamily sites. Those results will be available in the R1705/R1609 report. Web surveys also asked about home occupancy, education, and income. On-site verification visits did not address demographics.

Table 48: Building Characteristics – Details Collected by Data Collection Modes

Characteristic	Data Collection Mode(s)	Details
Home type	3	Type (primary/secondary)[1] Years as primary residence[1]
Stories	3	-
Age of home	3	-
Conditioned area	1	-
Last major renovation	1	-
Rooms	1	Count of bedrooms[3]
Windows	3	Low-E-coating and gas fill Pane[2] Frame material[3]
Insulation	2	Nominal R-Value[2]

1=web only, 2=on site only, 3=both web and on site.

B

Appendix B Analysis Details

B.1 WEIGHTING

To develop weights for the analysis, the evaluation team compared the web-survey sample with Census data representing the Connecticut customer population across the following five demographic variables and nine different proportional weighting schemes:

Dwelling type. Due to unintentional under-sampling of single-family detached homes and over-sampling of large multifamily complexes (50 or more units), weighting used five categories of home type: single-family attached, single-family detached, single-family 2-4 units, multifamily 5-49 units, and multifamily with 50 or more units.

Income. Respondents' income category was associated with the Department of Health's 60% AMI thresholds for the state.[61] The weighting schemes binned respondents who refused to answer income questions into the *non-low-income* group, which likely contributes to the underrepresentation of low-income customers.[62]

Education. Weighting classified respondents into two education groups: bachelor's degree or less than bachelor's degree and categorized respondents who refused to share their education level as *less than Bachelor's degree*.

Tenure. Owner or renter status was based on web-survey responses.

Program Participation. Based on comprehensive Company program participation data provided after the web-survey was completed.[63]

The chosen weighting scheme accounted for dwelling type, income, and program participation and was selected because (1) the weight provided the best fit on demographic variables and (2) weights were not extreme and did not produce volatile results. As shown in Table 49, this resulted in 20 proportional weights. The analysis applied the proportional weights to web-survey-based data analysis, including in the development of adjustment factors (described below). Analysis of on-site data used proportional weights scaled to the on-site sample.

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[61] https://www.energizect.com/your-home/solutions-list/save-energy-and-money-all-year-long

[62] The Companies' databases do not capture all low-income homes because not all homes enroll in income-eligible rate programs. Therefore, weights relied on the Census Bureau's American Community Survey income characterization of Connecticut.

[63] UI could not provide raw customer data for their population, so they provided an estimated participation rate for their population of electric customers.

Table 49: Web-Survey Weighting Scheme

Dwelling Type	Program Participation	Income	CT Customer Population[1]	Sample	Proportion Weight
Single-family, attached	Participant	Low-income	1,828	8	0.417
		Non-low-income	3,399	20	0.310
	Non-participant	Low-income	24,284	27	1.642
		Non-low-income	45,164	155	0.532
Single-family, detached	Participant	Low-income	11,846	25	0.865
		Non-low-income	45,070	129	0.638
	Non-participant	Low-income	157,384	87	3.303
		Non-low-income	598,787	889	1.230
Single-family, 2-4 units	Participant	Low-income	8,346	26	0.586
		Non-low-income	6,638	27	0.449
	Non-participant	Low-income	110,877	119	1.701
		Non-low-income	88,195	237	0.679
Multifamily, 5-49 units	Participant	Low-income	6,218	16	0.709
		Non-low-income	5,114	19	0.491
	Non-participant	Low-income	82,606	93	1.622
		Non-low-income	67,946	281	0.441
Multifamily, 50+ units	Participant	Low-income	2,590	5	0.946
		Non-low-income	1,966	9	0.399
	Non-participant	Low-income	34,408	44	1.428
		Non-low-income	26,125	210	0.227

[1] Census data was split into participant and non-participant categories based on a 7% participation rate for the CT population. The overall participation rate among both service territories was weighted by the Eversource/UI split.

B.3 Adjustment Factors

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.

Table 50 provides an example of the calculation method for the adjustment factor for oil boilers in single-family homes and the influence it had on overall penetration. In this example, 25% of *all* single-family web-survey respondents reported having an oil boiler and – when responding to the web survey – 16.5% of 90 on-site single-family respondents reported having them. On-site visits revealed that 25.2% of single-family on-site homes *actually* had oil boilers, yielding an adjustment factor of 1.53 (25.2% divided by 16.5%). Applying that adjustment factor to the full single-family web-survey sample revises the penetration rate from 25% to 38% (25% times 1.53). Calculations for average number of units per household used the same formula.[64]

Table 50: Adjustment Factor Calculation Approach – Example

Measure	Penetration[1]			Adjustment Factor	Revised Penetration (n=1,665)
	Full Web Sample (n=1,665)	On-Site Sample (n=90)			
		Web Reported	On-Site Verified		
Oil boiler - SF	25%	16.5%	25.2%	**1.53**	38%

[1] Percentages are weighted statistics.

Adjustment factors were calculated separately for single-family and multifamily homes, as well as for all homes. Many end uses did not require adjustment factors because the on-site verified results did not significantly differ from the web-survey results at the 90% confidence level. Adjustment factors were automatically 100% if fewer than five on-site homes reported having the end use (column Q in the *Adjustment Factor* tab).

[64] A common misconception is that we use adjustment factors to change individual's responses. However, adjustment factors are only applied to results for summary statistics.

Table 51 shows the penetration adjustment factors. Empty cells indicate that there was not a statistically significant difference between survey responses and on-site results (or that there were too few to consider for adjustment). The “Adjustment Factor” tab in the database includes all statistics involved in these calculations. Footnotes throughout this report denote if adjustment factors were applied to the results.

Table 51: Adjustment Factors Applied

(Source: NMR comparison between web-survey and on-site visits)

End Use	Single-Family, 1-4 units (n=1,724)	Multifamily, 5+ units (n=653)	Overall (n=2,377)
Appliances			
Clothes washer		0.70	0.85
Clothes dryer		0.68	0.83
Clothes dryer - electric		0.74	0.87
Clothes dryer - gas		0.35	0.67
Dishwasher	0.87	0.87	0.87
Stand-alone freezer (chest & upright)		0.31	0.60
Upright freezer		0.40	0.62
Chest freezer		0.18	0.55
Dehumidifier	0.73	0.05	0.58
Air purifier		0.40	
Oven - gas	0.76		
Stovetop		1.02	1.01
Stovetop - gas	0.81		0.83
Primary Heating Fuel			
Natural gas		1.57	1.24
Electric		0.58	0.65
Heating System			
Natural gas furnace	0.72		0.80
Propane furnace			0.37
Oil furnace	0.36		0.32
Oil boiler	1.53		
Electric furnace		0.14	0.15
Electric boiler		0.00	0.00
Central (ducted) air source heat pump	0.12	0.62	0.46
Electric baseboard	0.62		0.74
Electric space heater	3.66	0.47	2.09
Electric wall heater		0.00	0.00
Cooling System			
None	0.21	0.09	0.19
Central air		0.86	
MSHP/ASHP		0.16	0.52
Thermostat			
Standard	0.64	0.80	0.71
Basic programmable	0.65	0.56	0.62
Wi-Fi smart	0.28	0.12	0.28
Wi-Fi not smart	0.15	0.07	0.11
All		1.02	
Water Heater Fuel			

End Use	Single-Family, 1-4 units (n=1,724)	Multifamily, 5+ units (n=653)	Overall (n=2,377)
Electric	0.70	0.73	0.79
Natural gas		1.22	
Fuel oil	2.63	0.43	1.69
Water Heater System			
Natural gas standard		0.59	0.71
Natural gas tankless		4.19	2.08
Electric heat pump		0.00	0.05
Electric tankless			0.00
Fuel oil standard			0.52
Second water heater			0.18
Electronics			
APS	0.06	0.06	0.06

C

Appendix C Data Processing

This appendix details steps taken to clean, process, and merge data to prepare the Database's "Raw Data" tab, which partners web-survey data, on-site data, and customer electric billing data. The methodology (Section 2) and Database User Guide (Appendix G) describe the analysis processes and protocols which leverage these data.

C.1 Web-Survey Data Cleaning

After fielding, the study modified web-survey variables into clean binary and categorical variables to facilitate database-user friendliness. Because adjustment factors corrected for erroneous estimates at the aggregate level, the study only revised responses for clarity, consistency, and overtly incorrect responses; examples include the following:

- In addition to being coded themselves, open-ended responses necessitated revising other responses. For example, a customer noted in an open-end response that they made a mistake when recording their heating and corrected their response. The team changed that response.
- Some outlier responses implied respondents misinterpreted questions. For example, if a respondent lived in a home with five units and reported they had five dishwashers, the team assumed they had one dishwasher per housing unit and revised the quantity from five to one.
- When asked about temperature setting behavior, some respondents likely responded in terms of Celsius instead of Fahrenheit; we converted those responses to Fahrenheit (e.g., 20°C to 68°F). However, some gave very unlikely responses such as 4°F, so we discarded those responses.
- If a respondent recorded a vehicle model that is not offered in electric or hybrid forms, we revised their responses to indicate that they did not have an electric or hybrid vehicle.
- When asked about cooling systems, people mentioned opening their windows as a form of cooling. We cleaned out those responses.

C.2 On-Site Verification Data Cleaning

After completing the 227 on-site verification visits, the study thoroughly reviewed the data collected at each home and compared entries with on-site photographs to verify data were entered correctly and search for additional information online (e.g., model numbers implying age or efficiency levels). The on-site data were then merged with the web-survey data (at the customer level), aligning web-survey responses with on-site responses alongside each other or simply adding new variables.

C.3 Billing Data Attachment

After developing the web-survey sample frame, the evaluation team isolated and processed the billing records associated with the sampled accounts. The sample frame only had customers with a minimum of one to two months of billing data and excluded extremely large users that were found to be non-residential sites. The Companies also were able to provide billing data for all but three lighting panel participants (*R154*). The evaluation team took the following steps to process and clean the customer billing records:

- Checked for duplicate reads or billing records for the same timeframe and location.
- Removed master metered accounts, if detected.
- Disaggregated monthly usage to daily kWh based on the number of days between meter reads
- Aggregated daily usage into calendar monthly kWh[65]

After cleaning and merging the web-survey and on-site data, the evaluation team appended the cleaned monthly billing data.

[65] If the first or last month in the customer billing series contained less than 21 days, it was coded as missing and left out of the alignment of billing data to calendar months.

D

Appendix D Lighting Saturation, Penetration, and Storage

This appendix details the lighting-related findings from the *R1616/R1708* (2018) on-site visits, and compares them with findings from previous research in Connecticut and other states, including separate estimates for the 2017 and 2018 Massachusetts and New York visits (Section 3.6.2 presents the averages of the 2017 and 2018 visits for those two comparison states). For purposes of brevity, the lighting discussions refer to the Companies' services territories as *Connecticut* (but the samples referenced represent the areas Connecticut served by Eversource and UI). As a reminder, the timing of visits varied by location. Table 52 provides a list of comparable studies and their timing relative to Connecticut's effort.

Table 52: Lighting Saturation On-Site Visit Timing

(Conducted by NMR)

Area	October – December 2017	April – May 2018	October – December 2018
Connecticut		✓	
Rhode Island		✓	
Massachusetts	✓		✓
Upstate New York	✓		✓

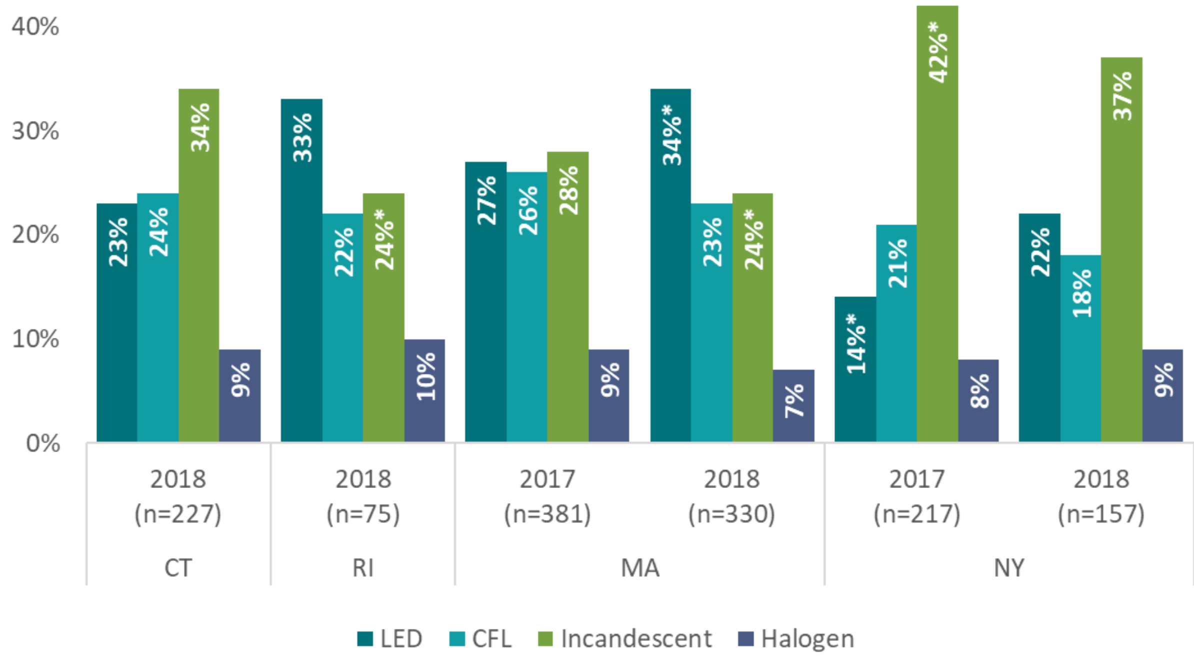
D.1 Saturation

Table 53 shows saturation for LEDs, CFLs, incandescent bulbs, and halogen bulbs in 2018 in Connecticut, Rhode Island, Massachusetts, and New York.[66, 67] Overall, Connecticut LED saturation (23%) was similar to New York in 2018 (22%), statistically significantly lower than Massachusetts (34%), and considerably lower than Rhode Island (33%). Inefficient bulb saturation in Connecticut was slightly higher. When compared to Upstate New York in 2018, the only state shown that lacks upstream LED programs, Connecticut had higher LED saturation and lower inefficient bulb saturation, providing evidence that program activity in Connecticut and other states encourages LED saturation and discourages inefficient bulb saturation (Figure 9). In that same year, incandescent saturation was statistically significantly higher in Connecticut (34%) than in Rhode Island (24%) and Massachusetts (24%), yet comparable to New York (37%).

[66] Massachusetts and New York data collection occurred in two phases: first at the end of 2017 (October through December) and then at the end of 2018 (October through December). Connecticut and Rhode Island data collection occurred roughly mid-way between (April and May 2018).
[67] NMR. "RLPNC Study 17-9 2017-2018 Residential Lighting Market Assessment Study." March 28, 2018. Accessed at: http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC_179_LtgMarketAssessment_28March2018_FINAL-1.pdf.

Figure 9: Socket Saturation by Year and State

(Source: on-site visits; base: all sockets)



* Signficantly different from CT 2018 at the 90% confidence level

Note: Massachusetts and New York data collection occurred in two phases: first at the end of 2017 (October through December) and then at the end of 2018 (October through December). Connecticut and Rhode Island data collection occurred roughly mid-way between (in April and May 2018)

Note: Percentages do not add to 100% as fluorescent bulbs, other bulb types, don't know, and empty sockets are not shown.

Table 53 compares socket saturation in Connecticut for 2012, 2015, and 2018. In 2018, nearly one-quarter (23%) of sockets in Connecticut homes were filled with LEDs, while, in 2015, only 10% of sockets held LEDS and, in 2012, only 2% of sockets held LEDs. In 2018, efficient bulbs – LEDs and CFLs combined – filled nearly one-half (47%) of all sockets, which was more than in in 2012 (28%), yet only slightly higher than in 2015 (45%), when CFL saturation peaked.[68] Conversely, inefficient bulbs – incandescents and halogens combined – filled about one-third (36%) of sockets in 2018, down considerably from 59% in 2012 and down slightly from 39% in 2015. Fifteen of the 81 homes who engaged in on site visits in 2015 through the R154 study did so again in 2018. The LED saturation in those homes more than tripled, increasing from 9% to 29% over the three-year period, but the sample size is too small to draw conclusions.

[68] NMR. "Connecticut Efficient Lighting Saturation and Market Assessment." October 2, 2012. Accessed at: https://www.energizect.com/sites/default/files/FINAL%20EISA%20Lighting%20Saturation%20and%20Market%20Assessment%20Report%20100212_pdf.pdf.

Table 53: Connecticut Socket Saturation by Year

(Source: on-site visits)

Bulb Type	2012	2015	2018
Sample Size	*100*	*81*	*227*
Number of sockets	*6,202*	*4,990*	*10,350*
Sockets per household	*62.02*	*61.60*	*45.53*
Bulbs per household	*60.78*	*59.14*	*44.62*
LED	2%	10%	23%
Incandescent	50%	33%	34%
CFL	26%	35%	24%
Halogen	9%	6%	9%
Fluorescent	11%	11%	7%
Other/empty	2%	5%	3%

Table 54 displays the mean, median, and range of saturation in 2018 by bulb type for Connecticut households. Roughly one-quarter (26%) of sockets in the average household were filled with LEDs. Interestingly, the only bulb types to reach 100% saturation were LEDs and CFLs; although, halogens and incandescents did achieve at least 90% saturation in one or more homes.

Table 54: Connecticut Socket Saturation in 2018

(Source: on-site visits)

Bulb Type	Saturation	Mean	Minimum	Median	Maximum
n	*10,350 Sockets*	*227 Households*			
LED	23%	25%	0%	20%	100%
Incandescent	34%	27%	0%	24%	90%
CFL	24%	30%	0%	26%	100%
Halogen	9%	9%	0%	4%	92%
Fluorescent	7%	6%	0%	2%	50%
Other/unclear	<1%	<1%	0%	<1%	31%
Empty socket	3%	2%	0%	<1%	29%

Table 55 and Table 56 present Connecticut 2018 socket saturation by dwelling type and income category. In 2018, low-income households in Connecticut had significantly higher saturation levels (than their non-low-income counterparts) of CFLs (34% versus 20%) and slightly higher saturation of LEDs (26% versus 22%). Similarly, CFL saturation was statistically significantly higher among multifamily than single-family homes (34% versus 21%), but LED saturation was fairly similar (28% versus 22%) regardless of dwelling type.[69]

[69] Significance was tested using a t-test equality of means and were considered significant at a 90% confidence level (p-value less than 0.1).

Table 55: Connecticut Socket Saturation by Dwelling Type in 2018

(Source: on-site visits)

Bulb Type	Saturation		Mean		Minimum		Median		Maximum	
	SF	MF	SF	MF	SF	MF	SF	MF	SF	MF
n	*10,350 Sockets*		*90 SF Households; 127 MF Households*							
LED	22%	28%	22%	29%	0%	0%	19%	21%	84%	100%*
Incandescent	37%	23%*	33%	21%*	0%	0%	31%	15%*	87%	90%
CFL	21%	34%*	25%	35%	0%	0%	23%	29%	81%	100%*
Halogen	10%	8%	9%	9%	0%	0%	7%	<1%*	61%	92%*
Fluorescent	7%	6%	7%	5%	0%	0%	3%	<1%	50%	42%
Other/unclear	<1%	<1%	<1%	<1%	0%	0%	<1%	<1%	1%	31%*
Empty socket	3%	1%	4%	2%	0%	0%	2%	<1%	29%	20%

* Significantly different from SF at the 90% confidence level.

Table 56: Connecticut Socket Saturation by Income Category in 2018

(Source: on-site visits)

Bulb Type	Saturation		Mean		Minimum		Median		Maximum	
	NLI	LI	NLI	LI	NLI	LI	NLI	LI	NLI	LI
	10,350 Sockets		*167 NLI Households; 60 LI Households*							
LED	22%	26%	24%	27%	0%	0%	20%	20%	100%	100%
Incandescent	37%	27%	32%	21%*	0%	0%	31%	18%*	87%	90%
CFL	20%	34%*	24%	37%*	0%	0%	19%	29%	100%	100%
Halogen	11%	6%	11%	7%	0%	0%	8%	<1%*	81%	92%*
Fluorescent	7%	6%	6%	6%	0%	0%	3%	<1%*	42%	50%
Other/unclear	1%	0%	<1%	<1%	0%	0%	<1%	<1%	31%	1%*
Empty socket	3%	2%	3%	<1%*	0%	0%	<1%	<1%	26%	29%

Note: LI = low-income and NLI = non-low-income.
* Significantly different from NLI at the 90% confidence level.

Table 57 shows specialty bulb saturation. Specialty bulbs include three-way bulbs of any kind; dimmable CFLs and fluorescents; circline fluorescents; non-A-line LEDs, incandescent, and halogen bulbs; and non-twist/spiral CFLs. More than one-third (36%) of sockets in Connecticut households in 2018 were filled with specialty bulbs. Specialty LEDs filled 7% of sockets.

Table 57: Connecticut Specialty Bulb Socket Saturation in 2018

(Source: on-site visits)

Specialty Bulb	Saturation	Mean	Minimum	Median	Maximum	Standard Deviation
n	*10,350 sockets*			*227 households*		
All specialty	36%	30%	0%	29%	91%	21%
Specialty LED	7%	6%	0%	0%	83%	12%
Specialty CFL	6%	7%	0%	<1%	77%	13%

Table 58 looks at specialty bulbs in more detail, showing saturation by lamp shape and specialty features. Incandescent bulbs still largely dominate specialty sockets. LED saturation is highest among reflectors/floods (32%), but reflectors/floods are still more commonly incandescent (36%).

Table 58: Connecticut Saturation of Specialty Sockets by Shape in 2018

(Source: on-site visits; Base: specialty bulbs)

Feature	Quantity of Bulbs	LEDs	CFLs	Halogens	Incandescents
Reflector/flood	1,634	32%	13%	19%	36%
Candle	888	15%	1%	1%	83%
Globe	373	8%	11%	5%	76%
Bullet/torpedo	223	1%	0%	91%	8%
Dimmable	418	19%	13%	13%	55%
3-way*	163	18%	22%	6%	52%

* 3-way does not sum to 100% as some of these bulbs were fluorescent or other/don't know bulb types were not included in this table.

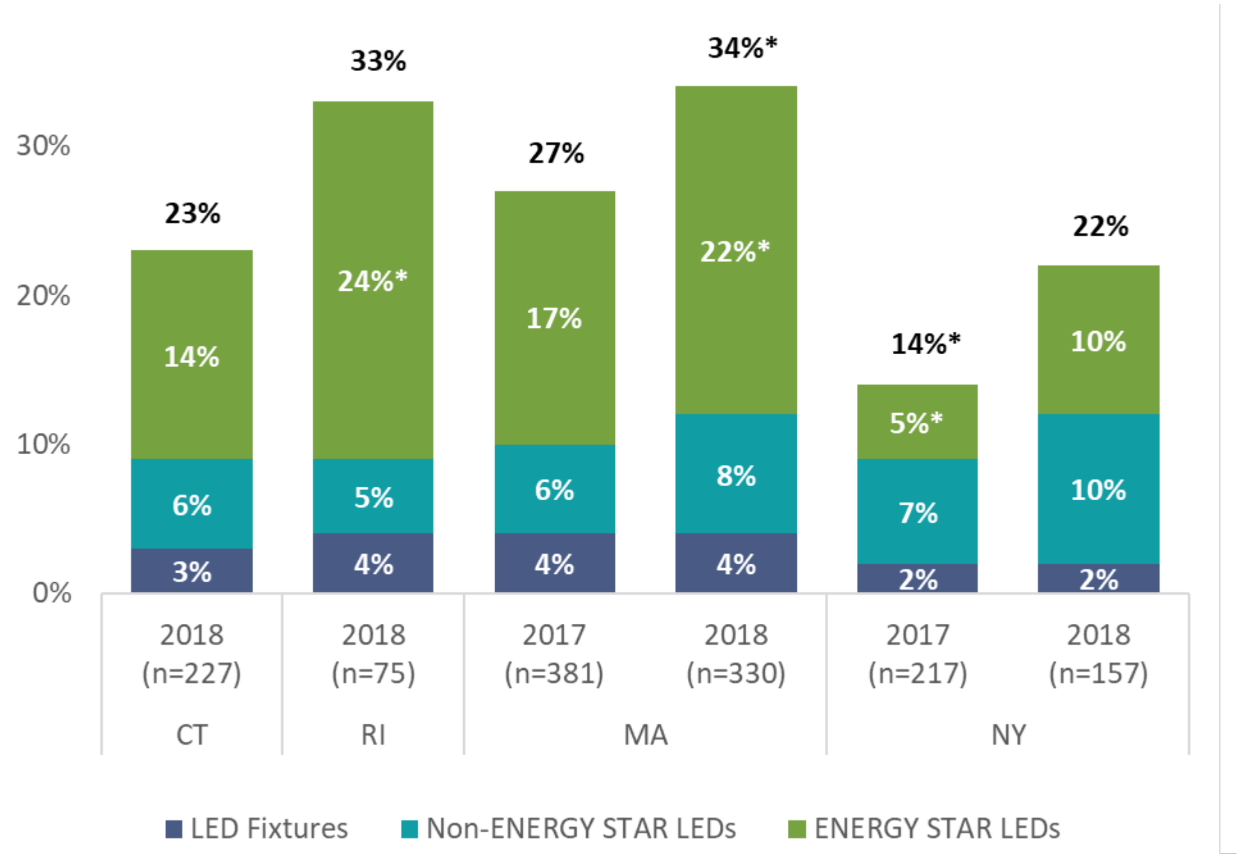
Figure 10 provides the ENERGY STAR LED saturation for Connecticut and Rhode Island in 2018, as well as the saturation for Massachusetts and New York in 2017 and 2018 (the values above each stack represent the overall LED saturation in each state, as discussed with Figure 9).[70] Like Massachusetts and Rhode Island, Connecticut programs provide incentives only for ENERGY STAR-qualified LEDs (the New York comparison area does not have active upstream lighting programs). ENERGY STAR-qualified LED saturation was statistically significantly higher in Rhode Island (24%) and Massachusetts in 2018 (22%) than in Connecticut (14%). In fact, Connecticut ENERGY STAR-qualified LED saturation was closer in mid-2018 to that of New York (10%) as measured in late 2018. These results imply that the Connecticut program may not have had as much impact on LED saturation as programs in its neighboring states, but cumulatively speaking,

[70] While on site, technicians collected model numbers for all screw-base LED bulbs (not integrated LED fixtures). Comparing these model numbers with the list of ENERGY STAR-qualified LED bulbs determined the ENERGY STAR status for each LED bulb.

the program still boosts overall LED saturation beyond what occurs in the absence of program support.

Figure 10: Recent ENERGY STAR LED Saturation by State

(Source: on-site visits)



* Significantly different from CT at the 90% confidence level

Note: Massachusetts and New York data collection occurred in two phases: first at the end of 2017 (October through December) and then at the end of 2018 (October through December). Connecticut and Rhode Island data collection occurred roughly mid-way between (in April and May 2018)

D.2 Penetration

As shown in Table 59, from 2012 to 2018, LED penetration in Connecticut increased by more than six times. In 2012, only 19% of homes had at least one LED; that penetration jumped to 42% in 2015 and then doubled in 2018 to 83%. In contrast, CFL penetration – while still higher than that of LEDs – decreased somewhat (96% to 88%) after peaking in 2015 (99%).

Table 59: Connecticut Efficient Bulb Penetration by Year

(Source: on-site visits)

Bulb Type	2012	2015	2018
Sample Size	*100*	*81*	*227*
LED	19%	42%	83%
CFL	96%	99%	88%

D.3 Storage Behavior

In Connecticut in 2018, 139 out of 227 households (61%) had at least one bulb in storage, averaging 10.2 stored bulbs per home – enough to fill more than one-fifth (22%) of the sockets in an average home. As shown in Table 60, nearly one-half (46%) of stored bulbs were incandescent, while LEDs made up just one-fifth (20%) of stored bulbs. Storage patterns were relatively similar across states.

Table 60: Stored Bulbs in 2018 by State

(Source: on-site visits)

Bulb Type	Connecticut	Rhode Island	Massachusetts	New York
Sample Size	*227*	*75*	*381*	*217*
Number of stored bulbs	*2,315*	*690*	*5,524*	*2,626*
Incandescent	46%	51%	51%	58%
LEDs	20%	25%	22%	19%
CFLs	20%	17%	9%	8%
Halogen	11%	7%	2%	3%
Fluorescent	3%	1%	16%	12%
Average stored bulbs per home	**10.2**	**9.2**	**14.5**	**12.1**

Table 61: Connecticut Stored Bulbs in 2018 by Bulb Type

(Source: on-site visits)

Specialty Bulb	Mean	Minimum	Median	Maximum	Standard Deviation
Sample Size	*227*	*227*	*227*	*227*	*227*
Incandescent	4.7	0	0	88	9.5
LED	2.1	0	0	49	4.9
CFL	2.0	0	0	23	4.0
Halogen	1.1	0	0	15	2.0
Fluorescent	0.3	0	0	20	2.0

E

Appendix E Upstream Lighting NTG

This section summarizes current lighting saturation and the changes in saturation since the last on-site lighting inventory in 2012, compares historical and prospective NTG values for the residential lighting program, and provides a detailed comparison to Massachusetts and New York. This analysis is meant to help provide context for other, more robust, NTG estimates produced for Connecticut as part of CT R1615 analysis and is not meant to supplant existing and planned NTG values.[71]

E.1 Historical LED Saturation and Program Support

The Connecticut EEB collected an on-site lighting inventory for Connecticut as part of the 2012 Northeast Residential Lighting Hours-of-Use Study and again in 2015 for the Connecticut R154 LED Lighting Study. The 2012 included 90 single-family households in Connecticut and the 2015 study included 81 visits with single-family and multifamily households. Conducted in April and May of 2018, the *R1616/R1708* study included on-site visits with 227 single-family and multifamily homes.

As presented in Appendix D.1, LED saturation increased exponentially between 2012 and 2018. In 2012, LEDs were present in 2% of all sockets and less than 1% of stored bulbs were LEDs. In 2018, LEDs were present in 23% of sockets (an average increase of 10.6 LEDs per home). In addition, in 2018, an average of 2.1 LEDs were found in storage.

The increase in LED saturation corresponds with increasing levels of support for LEDs offered by the Companies, though it is important to note that the Companies only support ENERGY STAR LEDs and total growth includes both ENERGY STAR and non-ENERGY STAR LEDs.[72] Between 2013 and 2018, Eversource and UI supported LEDs through their upstream and direct install programs (Table 62). Table 63 presents a year-by-year breakdown of saturation and program-supported LEDs: between 2013 and July 2018 Eversource and UI supported a total of 16.2 million LEDs through two primary channels (upstream and direct install), with about 14.9 million of them supported through the upstream program.

Over the past five and one-half years, the Companies have supported an average of 11 LEDs per household in Connecticut through their upstream program.[73] Including the direct-install channels brings the average number of LEDs supported up to 12 per home. The average number of LEDs

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[71] NMR Group Inc., DNV GL, and Cadmus, *R1615 Light Emitting Diode (LED) Net-to- Gross Evaluation*. Submitted on August 7, 2017. Available at https://www.energizect.com/sites/default/files/R1615_CT%20LED%20Net-To-Gross%20Evaluation%20Report_Final_8.5.17.pdf.

[72] Note that the increase in LED saturation included an increase in non-ENERGY STAR LEDs, which were not supported by the program. As discussed in Section Regional Comparison3.6.2, Connecticut's ENERGY STAR LED saturation appears to be lagging that found in the comparison program states.

[73] This number of bulbs supported per household is calculated using the 2017 Census population of 1,301,670 households in Connecticut.

supported in participating homes by the direct-install programs varied by year, with an average of 21 LEDs in 2018, 23 in 2017, 20 in 2016, 22 in 2015, 24 in 2014, and 24 in 2013.[74]

Table 62: LED Bulbs Supported by Connecticut Companies by Year

(Source: program records)

Program Year	Eversource		United Illuminating	
	Upstream LEDs	Direct Install	Upstream LEDs	Direct Install
2013	335,816	11,017	85,768	1,884
2014	1,150,538	116,091	345,558	21,686
2015	1,622,512	211,017	480,499	15,128
2016	2,316,469	283,072	753,030	51,898
2017	5,003,752	365,498	1,195,495	96,134
2018 (through July)	1,509,266	125,971	119,338	49,833
Total	**11,938,353**	**1,112,666**	**2,979,688**	**236,563**
Overall Total	**16,267,270**			

Table 63: Connecticut LED Saturation and Program Support by Year

(Sources: on-site visits and program records)

Program Year	LED Saturation	Count of Program Supported Bulbs		
		Upstream LEDs	Direct Install	Total
2013	2%[1]	421,584	12,901	**434,485**
2014	n/a	1,496,096	137,777	**1,633,873**
2015	10%[1]	2,103,011	226,145	**2,329,156**
2016	n/a	3,069,499	334,970	**3,404,469**
2017	n/a	6,199,247	461,632	**6,660,879**
2018 (through July)	23%[2]	1,628,604	175,804	**1,804,408**
Total		**14,918,041**	**1,349,229**	**16,267,270**

[1] Source: R154 Lighting Study
[2] Based on on-site visits conducted from April through May of 2018.

E.1.1 Comparison Areas

This study relied on three comparison areas (Massachusetts, New York, and Rhode Island) to benchmark the saturation values observed for Connecticut for the following reasons:

Massachusetts. Because Massachusetts is a neighboring program state with a similar portfolio of residential lighting programs and a history of conducting nearly annual on-site lighting inventory studies, it provided additional insights into year-to-year changes in saturation lacking in Connecticut. Note: saturation data collected in Massachusetts was collected six months before and six months after that collected in Connecticut, making direct comparisons more difficult. Therefore, the body of this report includes averages, while the appendices report findings from each individual phase.

[74] https://www.ctenergydashboard.com/Public/PublicHESActivity.aspx

Rhode Island. Neighboring state Rhode Island has a similar portfolio of residential lighting programs and the latest saturation data were collected concurrently with the most recent Connecticut effort.

Portions of Upstate New York[75]. In 2014, the Massachusetts Program Administrators chose portions of Upstate New York as a comparison area because they presented a unique opportunity to understand how the residential lighting market has responded in the absence of upstream residential lighting program support. In 2012, New York State Energy Research and Development Authority (NYSERDA) discontinued upstream support for standard spiral CFLs, and nearly all upstream incentives (including LEDs) in 2014. The decision to exit the market was made by the New York Department of Public Service, operating under the hypothesis that the residential lighting market would continue to transform without further intervention from NYSERDA. Note: saturation data in New York was collected six months before and six months after that collected in Connecticut, making direct comparisons more difficult. Therefore, the main body of the report reports averages, while the appendices report findings from each individual visit.

While NYSERDA no longer offers upstream programs in Upstate New York, in the intervening years, utilities in these portions of New York have continued to provide varying levels of support for LEDs through program offerings such as direct install programs, energy-efficiency kits, and online marketplaces/portals. In addition, in 2017, Con Edison began to support LEDs through traditional upstream channels in their service area (including Westchester County, which is one-fifth of the total number of households included in the comparison area panel). It is our understanding that Con Edison upstream program activity was low in 2017 but has ramped up in 2018. As part of the Massachusetts RLPNC 17-9 study,[76] the evaluation team detected no differences in LED saturation among Westchester County households and households in other portions of the comparison area. This leads to the conclusion that the new upstream program activity has had little or no impact on saturation for the overall New York comparison area, but it must be acknowledged as a potential threat to validity for using New York as a non-program comparison area. It is important to note that, throughout this report, saturation values for Massachusetts and New York were taken directly from publicly available reports (http://ma-eeac.org/) and have not been adjusted or weighted to reflect demographics of Connecticut. This approach likely does not greatly impact the overall results, as according to the RLPNC 17-9 and 18-10 reports, weighting had minimal impact on saturation values, typically changing saturation values by less than 1%. Table 64 compares saturation by state and by year.

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[75] Comprising Westchester County and 40-mile radiuses around the cities of Albany, Buffalo, Rochester, and Syracuse.
[76] NMR. "RLPNC Study 17-9 2017-2018 Residential Lighting Market Assessment Study." March 28, 2018. Accessed at: http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC_179_LtgMarketAssessment_28March2018_FINAL-1.pdf.

Table 64: LED Saturation (Year End) by State

(Source: on-site visits)

Year End[1]	Connecticut	Rhode Island	Massachusetts	New York
2012	2%	1%	2%	1%
2013	n/a	n/a	3%	n/a
2014	n/a	n/a	6%	3%
2015	10%	n/a	12%	7%
2016	n/a	n/a	18%	10%
2017	n/a	n/a	27%	14%
Mid-2018	23%	33%	n/a (31% simple avg.)	n/a (18% simple avg.)
2018	n/a	n/a	34%	22%

[1] Massachusetts and New York data collection occurred in two phases: first at the end of 2017 (October through December) and then at the end of 2018 (October through December). Connecticut and Rhode Island data collection occurred roughly mid-way between (April and May 2018). For ease of comparison, we provide the simple average of 2017 and 2018 saturation in Massachusetts and Rhode Island.

E.1.2 Program Support Comparison

A relative level of program support can be measured by dividing total supported upstream LEDs by the number of households in each program state (Connecticut, Massachusetts, and Rhode Island).[77] As Table 65 shows, the general level of upstream LED program support in the three states followed a similar pattern, with increasing levels of support between 2013 and 2017; however, over the full period, Connecticut supported a larger number of average LEDs per household than Rhode Island and Massachusetts (9.9 versus 8.9 and 8.2). While there were differences in LEDs supported on a per household basis in any given year, the overall level of support appears generally comparable with the average bulbs supported per household in all three areas, exceeding eight over the five years compared. Note: some differences between the areas may likely be attributed to reporting periods, program and funding cycles, and various program record intricacies between the three states. This analysis is meant as a high-level comparison of general program activity between the areas.

[77] Connecticut site visits were restricted to Eversource and UI households. As such, the relative level of program support and potential for lamps leaving the service territory should be acknowledged. UI and Eversource serve 96% of electric customers in the state.

Table 65: Upstream LED Support per Household by Year and State
(Source: program records)

Program Year	Average Bulbs per Household		
	Connecticut	Rhode Island	Massachusetts
2013	0.3	0.2	0.4
2014	1.1	0.7	0.7
2015	1.6	1.5	1.1
2016	2.3	2.6	1.7
2017	4.6	3.9	4.3
Total	**9.9**	**8.9**	**8.2**

E.1.3 Annual Saturation Interpolation

Since Connecticut did not conduct regular saturation studies, it was necessary to determine a way to fill-in missing years to support analysis. Given the nearly annual studies conducted in Massachusetts, a state with similar program support, we sought to leverage data to help interpolate missing values for Connecticut. Table 66 provides saturation by year and area, using observed saturation percentage change in Massachusetts as a proxy for years not observed in Connecticut, interpolated values for mid-2018 for Massachusetts and New York, and a value for saturation in New York for 2013 (based on straight line interpolation).

Table 66: LED Saturation by State and Year (Filled In)
(Source: on-site visits)

Year End	Saturation (Year Ending)			
	Connecticut	Rhode Island	Massachusetts	New York
2012	2%	1%	2%	1%
2013	2%	3%	3%	2%
2014	5%	6%	6%	3%
2015	10%	12%	12%	7%
2016	14%	18%	18%	10%
2017	20%	27%	27%	14%
Mid-2018	23%	33%	31%	18%
2018	n/a	n/a	34%	22%

E.1.4 Annual Stored LED Values

LED storage rates increased in both Massachusetts and New York between 2012 and 2017, with higher levels of storage in Massachusetts compared to New York. Unfortunately, the growth is not uniform and does not appear to follow a general market adoption curve. This is perhaps not surprising given the nature of lamp storage. Most customers only purchase new lamps when an existing lamp needs replacing.[78] When purchasing LEDs, customers were increasingly purchasing multipacks,[79] and reserving extra LEDs to replace future burnouts. LEDs may remain in storage for several years before being installed. This can lead to stored lamps increasing/decreasing on a per home basis at any given point in time. The evaluation team speculates that increases in stored LEDs were driven in part by retailers increasingly offering larger multipacks of LEDs and in program areas, program administrators increasingly providing incentives for these larger multipacks. Based on this, stored LEDs will likely increase in the near-term and then decrease over time. Therefore, the number of LEDs found in storage in Connecticut in May 2018 is likely a close approximation for the number one would expect to find in Massachusetts at a comparable time (but this is more of a leap of faith without any reliable way to predict storage behavior) (Table 67).

Table 67: Average LEDs in Storage by State and Year

(Source: on-site visits)

	Saturation (Year Ending)		
Year End	Connecticut	Massachusetts	New York
2012	0.1	0.1	0.1
2013	n/a	0.3	n/a
2014	n/a	0.3	0.4
2015	0.6	0.9	0.4
2016	n/a	1.6	1.0
2017	n/a	2.3	1.5
Mid-2018	2.1	n/a	n/a

E.2 NTG Calculations

NTG calculations rely on annual-observed saturation percent change in Massachusetts as a proxy for percent change in LED saturation in Connecticut.[80] This section explores historical NTG values using interpolated inputs. The reliance on interpolated inputs should be kept in mind when interpreting the NTG estimates.

E.2.1 Market Gains

As shown in Table 66, the change in LED saturation can be estimated for Connecticut and New York (counterfactual or baseline) for each year 2013 – 2017, for 2018 through May, and for the entire period, 2013 through May 2018.

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[78] MA RLPNC 17-9 Lighting Market Assessment.
[79] MA RLPNC 17-12 Lighting Decision Making.
[80] See the interpolated saturation estimates in Table 66.

To calculate net impacts, a baseline (or counterfactual) scenario was first established. In this case, the counterfactual is what would have happened if the upstream program had not existed – in other words, what the lighting market in Connecticut would have done in the absence of the program. This study used data collected in the New York comparison area (an area with no upstream program) to represent the counterfactual.

Based on changes in saturation in Connecticut and the New York comparison area, Table 68 provides estimated separate market-level LED gains based on the assumed population of Connecticut (1,301,670 households [ACS]) and the average number of sockets in Connecticut households of 46 sockets per home (% Saturation Gain * 1,301,670 households * 46 Sockets).[81] The average number of stored LEDs was available for Connecticut in 2015 (according to the R154 Lighting Study) and 2018, so the team used the Massachusetts average number of stored bulbs (as they both had an active upstream LED lighting program before 2018) for the unobserved years. The table below shows these results and includes NMR's estimate of installed and stored LEDs had the program not been in place (counterfactual).

Table 68: Connecticut Annual LED Market Gains[82]

(Source: Table 66 and Table 67)

Program Year	Connecticut LEDs Gained[1]				Counterfactual * LEDs Gained[2]			
	Sat.	Installed LEDs[3]	Avg. Stored LEDs	Stored LEDs	Sat.	Installed LEDs	Avg. Stored LEDs	Stored LEDs
2013	<1%	119,754	0.3	123,072	1%	196,915	0.25	41,024
2014	3%	1,796,305	0.3	123,072	1%	196,915	0.4	102,560
2015	5%	2,993,841	0.9	369,216	4%	787,661	0.4	164,096
2016	4%	2,395,073	1.6	656,384	3%	590,746	1.0	164,096
2017	4%	2,395,073	2.3	943,552	4%	787,661	1.5	410,240
2018 (YTD)	5%	2,993,841	2.1	1,107,648	4%	787,661	1.8	615,360
Total[4]	**21%**	12,693,886	**1.2**	**3,322,944**	**17%**	3,347,558	**1.4**	**574,336**

[1] Values shaded in gray are interpolated based on observed values from Massachusetts.
[2] Values shaded in gray are interpolated.
[3] For the estimates based on onsite data, program bulbs exceeded gained LEDs in 2015 and 2018.
[4] Total stored LEDs equal to the difference between 2013 and 2018.

[81] LED gain is highly subject to assumptions regarding number of households and sockets. While the values are based on the best available data (Census & on-site saturation values), this is a potential threat to validity, which bears enumerating.
[82] Evaluators considered limiting analysis to only changes in ENERGY STAR LEDs but lacked enough data on ENERGY STAR LEDs from earlier saturation studies to take this approach. Limiting analysis to only ENERGY STAR LEDs would introduce additional uncertainty to the estimates. In addition, limiting analysis to only ENERGY STAR LEDs would exclude the possibility of accounting for spillover generated by program activity.

E.2.2 NTG Estimates

The study produced estimates of annual NTG ratios, as well as an overall ratio for 2013 to 2018. As mentioned above, the need to interpolate inputs such as installed and stores bulbs for both Connecticut and the counterfactual (New York) conditions leads to some uncertainty in the validity of these estimates. Therefore, we focus the discussion on the overall estimates rather than the annual ones, although they were estimated similarly.

Net LED gain was calculated by subtracting gain in New York from gain in Connecticut. For example, to calculate the full period net LEDs, the LED gain in Connecticut from 2013 to 2018 (12,693,886) was subtracted by counterfactual LEDs gains (3,987,533), resulting in a net gain of 9,346,327 (as shown in the last row of Table 69). The same was done for stored LEDs (2018: 3,322,944 – 574,336 = 2,748,608). Based on these values, upstream NTG estimates were calculated by dividing net LEDs gained by the number of LEDs supported through the Connecticut upstream program (14,918,071). NTG values were 63% without stored LEDs and 86% with stored LEDs (Table 69).[83] With the exception of 2013 (when New York supported only LEDs, while Connecticut supported mostly CFLs and some LEDs), the year-by-year estimates at first appear to follow an expected pattern of declining NTG values, however after decreasing between 2014 and 2017, the 2018 estimate increases to over 100%. The fluctuation in annual values could be attributed to lags in reporting program support and the speculative approach to interpolating annual saturation and storage data. Again, it should be stressed that these inconsistencies may imply that this analytical approach is questionable, and these estimates should be interpreted with caution.

[83] No adjustments were made for direct-install program activity as utilities in New York also engage in direct-install program activity.

Table 69: Connecticut LED Upstream Program NTG[1]

Program Year	Connecticut LEDs Gained versus Counterfactual		Connecticut Upstream LEDs[4]	Upstream NTG (Installed Only)	Upstream NTG (Including Storage)
	Installed LEDs	Stored LEDs			
2013	-77,061	82,048	421,584	0%	1%
2014	1,599,389	20,512	1,496,096	107%	108%
2015	2,206,180	205,120	2,103,011	105%	115%
2016	1,804,327	492,288	3,069,499	59%	75%
2017	1,607,412	533,312	6,199,247	26%	35%
2018 (through July)[3]	2,206,180	492,288	1,628,604	135%	166%
Total	9,346,327	2,748,608	14,918,041	63%	86%

[1] Year-by-year NTG ratios are estimates based on interpolated saturation values and actual program records of LEDs supported.
[2] We include 2013 to capture the full period, despite the fact that New York had more LEDs installed in that year than Connecticut. New York was actually a program state in 2013. NYSERDA supported LEDs but not CFLs during that year. In contrast, while Connecticut supported just over 400,000 LEDs, it supported over two million CFLs in 2013.
[3] Note that the Connecticut energy-efficiency programs were impacted by a budget sweep in 2018, which reduced funding for energy-efficiency programs in the first half of 2018 – likely resulting in lower program performance and fewer LEDs being distributed.
[4] Upstream activity values are based on the Companies' program records.

Appendix F Program Participation and Attitudes

This section profiles respondents' participation statuses and summarizes web-survey responses about Energize CT, energy-related actions, and attitudinal questions.

F.1 Program Participation

The Companies' databases indicated that, between 2015 and 2017, 7% of Eversource electric residential customers and 6% of UI electric residential customers took part in an Energize CT downstream program. Response rates were slightly higher among program participants: 7% of web-survey respondents and 8% of on-site homes were program participants according to customer databases (Table 70). However, before weighting, 12% of surveyed homes had been flagged as participants; the weighting approach described in Appendix B.1 accounted for this overrepresentation.

Table 70: Eversource and United Illuminating Program Participation
(Source: program participation database – January 2015 through December 2017)

Company	Percent who Participated in Energy Efficiency Programs[1]				
	Electric Customer Population	Web-Survey Respondents[3]	Onsite Homes[3]	Web-Survey Respondents[3] - Weighted	Onsite Homes[3] - Weighted
Eversource	7%	8%	7%	5%	5%
United Illuminating	6%	24%	31%	15%	21%
Total n[2]	**1,442,831**	**2,426**	**227**	**-**	**-**
Total Participated	7%	12%	11%	7%	8%

[1] Source: Companies' electric customer participation database.
[2] UI could not provide raw customer data for their population, so they provided an estimated participation rate for their population of electric customers. To estimate an overall participation rate among both service territories, we calculated a weighted average by Company.
[3] Verified participation based on the Companies' program records.

Sixteen percent of web-survey respondents self-reported or confirmed they had participated in one of the Companies energy-efficiency programs at some point in the past two years. The web survey asked those who had not reported participating in Home Energy Solutions or Home Energy Solutions – Income Eligible programs about their familiarity with the home energy assessment offered by the Companies. Results, summarized in Table 71, demonstrate the following key findings:

- Non-participants were not overwhelmingly familiar with the home energy assessment program. When asked to rate their familiarity on a scale of 1 to 5, where 1 is *not at all familiar* and 5 is *extremely familiar*, they rated their familiarity 2.5, on average.[84]
- Not shown, participants – who said they had not participated but program records indicated they had – provided a statistically significantly higher rating (3.2) at the 90% confidence level than their counterparts than those who were not flagged as participants (2.5).[85]
- Nearly one-sixth (13%) reported that they had received a home energy assessment. While less than one-tenth (6%) reported participating in a rebate program.

Table 71: Program Familiarity and Participation

(Source: web-survey)

Survey Question	Single-Family, 1-4 units	Multifamily, 5+ units	Overall
Confirmed or Self-Reported Participation	**(n=1,749)**	**(n=677)**	**(n=2,426)**
Home energy assessment	15%	5%	13%
Rebate program	7%	1%	6%
Either	18%	6%	16%
Familiarity with HES/HES-IE Program (1 to 5 scale) among non-participants	**(n=1,491)**	**(n=641)**	**(n=2,132)**
Average rating	**2.6**	**2.2**	**2.5**

The web survey also asked both participants and non-participants about home improvements they made (both with or without a rebate) in the past two years, any home improvements they have plans to make in the coming year, and their familiarity with and use of utility and Energize CT finance programs. Their responses, shown in Table 72, Table 73, and Table 74, indicate the following key findings:

- Nearly two-thirds (64%) of respondents reported making some type of energy upgrade in the past two years and roughly the same share (65%) had no plans to do so in the next two years.
- Over one-half (54%) of respondents reported upgrading the lighting in their home in the past two years either to LED or other energy-efficiency lighting, and 12% reported having plans to do so in the next year. Approximately one in six respondents reported upgrading windows and doors (18%) or appliances (15%).

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[84] Instead of referring to it as Home Energy Solutions or Home Energy Solutions - Income Eligible Program, the web survey defined the home energy assessments as follows: "The Connecticut utility companies, as part of Energize CT, offer a program called Home Energy Solutions. This program involves technicians visiting customers' homes, evaluating their homes' energy efficiency, providing the customers with information about ways to save energy, and possibly installing some energy saving products such as light bulbs or weather-stripping materials."

[85] Overall, of the 284 respondents verified to have participated (using program records), 45% self-reported that they had *not* participated in a program. Of the 356 respondents that self-reported participating,13% were not verified to be participants in the program data.

- Respondents who self-reported as program participants were more likely to have made home improvements in the past two years; 73% reported upgrading lighting and 36% reported making insulation, sealing, and/or weatherization improvements. One-half (51%) of self-reported program participants who made an improvement in the past two years reported receiving a rebate towards the upgrade and/or product replacement. Likely less aware of program participation due to tenure, only one-third (32%) of multifamily customers self-reporting as participants recalled receiving a rebate.
- Respondents were very unfamiliar with rebate and finance programs available through Energize CT and the Companies. When asked to rate their familiarity with utility rebates on a scale of 1 to 5, where 1 is *not at all familiar* and 5 is *extremely familiar*, they rated their familiarity 1.7, on average. This question excluded renters that indicated they did not have any involvement with paying for home improvements.
- The majority of those who made upgrades did not use financing (78%).[86] Those who did, used their credit card(s) (15%); roughly three-fifths (59%) reported paying off the balance immediately.

[86] Nearly one-fifth (17%) of respondents who reported making an improvement in the past two years and who said they not using any financing (78% of all respondents who reported making a home improvement) reported receiving a rebate for at least one of those improvements in a different question.

Table 72: Planned and Recent Home Improvements

(Source: web-survey)

Survey Question	Single-Family, 1-4 units	Multifamily, 5+ units	Overall
Home Improvements in Past Two Years[1]	**(n=1,749)**	**(n=677)**	**(n=2,426)**
Upgraded lighting (LED or high efficiency)	58%	32%	54%
Sealing, insulation, or weatherization improvements	23%	9%	21%
Upgraded windows or doors	16%	7%	18%
Upgraded appliances	20%	8%	18%
Replaced roof or siding	15%	6%	14%
Home energy audit (not through Energize CT or utility)	1%	2%	2%
Upgraded HVAC or water heating equipment	1%	0%	1%
Other	<1%	<1%	<1%
None	31%	58%	36%
Don't know	<1%	3%	<1%
Planned Improvements (within next year)[1]	**(n=1,749)**	**(n=677)**	**(n=2,426)**
Upgrade windows or doors	17%	6%	10%
Upgrade appliances	8%	3%	7%
Sealing, insulation, or weatherization improvements	16%	3%	14%
Upgrade lighting (LED or high efficiency)	12%	10%	12%
Replace heating, cooling, or water heater	9%	4%	8%
Home energy audit (not through Energize CT or utility)	6%	3%	5%
Replace roof or siding	4%	0.7%	3%
Other	<1%	<1%	<1%
None	63%	77%	65%
Don't know	<1%	3%	1%

[1] Percentages do not sum to 100% because customers could select multiple responses.

Table 73: Energy-Efficiency Upgrades by Self-Reported Participants

(Source: web-survey)

Survey Question	Single-Family, 1-4 units	Multifamily, 5+ units	Overall
Home Improvements in Past Two Years[1]	**(n=312)**	**(n=44)**	**(n=356)**
Upgraded lighting (LED or high efficiency)	75%	44%	73%
Sealing, insulation, or weatherization improvements	37%	23%	36%
Upgraded windows or doors	25%	15%	24%
Upgraded appliances	25%	4%	23%
Replaced roof or siding	18%	10%	17%
Home energy audit (not through Energize CT or utility)	7%	9%	7%
Upgraded HVAC or water heating equipment	1%	0%	1%
Other	<1%	0%	<1%
Don't know	<1%	3%	<1%
Received a Rebate for Any Improvement	**(n=312)**	**(n=44)**	**(n=356)**
Yes	52%	32%	51%
No	48%	68%	49%
Received a Rebate for Improvements[1]	**(n=312)**	**(n=44)**	**(n=356)**
Upgraded lighting (LED or high efficiency)	36%	26%	35%
Sealing, insulation, or weatherization improvements	20%	14%	20%
Upgraded windows or doors	8%	2%	7%
Upgraded appliances	0%	0%	0%
Replaced roof or siding	3%	0%	2%
Other	1%	0%	1%

[1] Percentages do not sum to 100% because customers could select multiple responses. Table includes respondents who reported that they participated in a program.

Table 74: Familiarity with Rebate and Finance Programs and Payment for Renovations

(Source: web-survey)

Survey Question	Single-Family, 1-4 units	Multifamily, 5+ units	Overall
Familiarity with Finance Program (average rating; 1 to 5 scale)	**(n=1,464)**	**(n=190)**	**(n=1,654)**
Rebates from utilities	1.7	1.7	1.7
On-bill financing from utilities	1.5	1.5	1.5
Zero-percent financing	1.4	1.4	1.4
Other financing opportunities	1.4	1.5	1.4
Use of Finance Program[1]	**(n=704)**	**(n=62)**	**(n=766)**
No rebates or financing	78%	80%	78%
Credit cards	15%	11%	15%
Financing offered by contractor	2%	-	2%
Home equity or other bank loan	2%	-	2%
Zero percent payment plan	1%	3%	2%
Other rebate or tax credit	1%	6%	1%
Residential Energy-Efficiency Financing	1%	-	1%
Energize CT heating loan	1%	-	1%
Smart-E loan	1%	-	1%
On-bill financing from utilities	<1%	-	<1%
Cozy Home Loan	-	-	-

[1] Percentages do not sum to 100% due to multiple responses.

F.2 Awareness and Attitudes on Environmental Issues

One-half of the web-survey sample were randomly selected to answer questions about their attitude towards global warming, effects of climate change, and identification and understanding of global energy consumption as it relates to environmental issues.

Two-thirds (67%) indicated they understand the issues involved with global warming either fairly or very well (Table 75). Almost three-quarters (72%) believed global warming effects have already begun.

Table 75: Familiarity with Global Warming

(Source: web-survey)

Survey Question	Single-Family, 1-4 units	Multifamily, 5+ units	Overall
How well do you understand *global warming*?	**(n=891)**	**(n=355)**	**(n=1,246)**
Not at all	4%	2%	3%
Not very well	12%	11%	12%
No opinion	18%	17%	17%
Fairly well	46%	51%	46%
Very well	21%	19%	21%
Which statement reflects your view of when the effects of global warming will happen?	**(n=891)**	**(n=355)**	**(n=1,246)**
They have already begun to happen	72%	73%	72%
They will start happening within a few years	1%	0.5%	1%
They will start happening within your lifetime	2%	5%	3%
They will not happen within your lifetime, but they will affect future generations	2%	1%	2%
They will never happen	5%	3%	4%
Don't know	18%	17%	17%

As shown in Table 76, respondents most often considered themselves either a *moderate environmentalist* (45%) or *not an environmentalist* at all (32%). When asked about their level of activity in environmental movements, most frequently they thought of themselves as *sympathetic towards the movement, but not active* (42%).

Table 76: Environmentalist and Attitudes Towards Environmental Movement

(Source: web-survey)

Survey Question	Single-Family, 1-4 units	Multifamily, 5+ units	Overall
Do you consider yourself an environmentalist?	**(n=891)**	**(n=355)**	**(n=1,246)**
Yes, strong environmentalist	9%	12%	9%
Yes, moderate environmentalist	46%	38%	45%
No, not an environmentalist	32%	32%	32%
Don't know	13%	18%	13%
Do you think of yourself as…	**(n=891)**	**(n=355)**	**(n=1,246)**
An active participant in the environmental movement	23%	19%	23%
Sympathetic towards the movement, but not active	41%	45%	42%
Neutral	19%	19%	19%
Unsympathetic towards the environmental movement	3%	2%	3%
No opinion	9%	10%	9%
Don't know	5%	5%	5%