

**R1968 Residential New Construction Baseline and Code Compliance Study**

REVIEW DRAFT

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# Acronyms

|  |  |
| --- | --- |
| Acronym | Definition |
| AC | Air Conditioner |
| ACH50 | Air Changes per Hour with a 50-pascal pressure gradient |
| ACS | American Community Survey |
| AFUE | Annual Fuel Utilization Efficiency |
| ASHP | Air-Source Heat Pump |
| BTU | British Thermal Unit |
| BTUh | British Thermal Units per Hour |
| CAC | Central Air Conditioner |
| CFA | Conditioned Floor Area |
| CFL | Compact Fluorescent Lamp |
| CFM25 | Cubic Feet per Minute with a 25-pascal pressure gradient |
| Companies | Eversource and United Illuminating, the utilities that administer the EnergizeCT programs |
| COP | Coefficient of Performance |
| DHW | Domestic Hot Water |
| ECM | Electronically Commutated Motor |
| EEB | The Connecticut Energy Efficiency Board |
| EER | Energy Efficiency Ratio |
| EF | Energy Factor, used for water heater efficiency |
| EPS | Expanded Polystyrene (rigid board continuous insulation) |
| ERI | Energy Rating Index, optional compliance path under IECC |
| ERV | Energy Recovery Ventilation |
| EV | Electric Vehicle |
| FGB | Fiberglass Batt |
| GSHP | Ground Source Heat Pump |
| HERS | Home Energy Rating System; summarizes a home’s efficiency (lower is better) |
| HPWH | Heat Pump Water Heater |
| HRV | Heat Recovery Ventilation |
| HSPF | Heating Season Performance Factor |
| HVAC | Heating Ventilation and Air Conditioning |
| IECC | International Energy Conservation Code |
| kWh | Kilowatt Hour |
| LED | Light-Emitting Diode |
| LTO | Duct Leakage to Outside |
| MSHP | Mini or Multi-Split Heat Pump (commonly referred to as a ductless mini-split) |
| MWh | Megawatt Hour |
| NMR | NMR Group Inc. |
| PV | Photovoltaic (solar) panels |
| REM/rateTM | Residential Energy Modeling and Rating software by NORESCO |
| RESNET | Residential Energy Services Network |
| RNC | Residential New Construction |
| R-value | A measure of material’s resistance to the flow of heat |
| SEER | Seasonal Energy Efficiency Ratio |
| SEER2 | Seasonal Energy Efficiency Ratio (v. 2); a measure of cooling system efficiency |
| SHGC | Solar Heat Gain Coefficient; a measure of how much infrared light passes through a window |
| TDL | Total Duct Leakage |
| TE | Thermal Efficiency |
| U-factor | Measure of heat flow through a material, lower is better, inverse of R-value (commonly used for glazing) |
| UC | Unconditioned |
| UDRH | User-Defined Reference Home, the hypothetical baseline home against which program homes are compared to calculate savings |
| UEF | Uniform Energy Factor, used for water heater efficiency |
| XPS | Extruded Polystyrene (rigid board continuous insulation) |

# Abstract

This report describes a single-family, residential new construction (RNC) baseline study conducted in Connecticut for the Connecticut Energy Efficiency Board and submitted to the Connecticut Evaluation Administrator (EA) Team. The study was designed to assess (1) how the market has changed over time and (2) what changes in building practices have occurred since the previous baseline study. The study also updated the User Defined Reference Home (UDRH), the baseline used to calculate savings for the Companies’ RNC program. The UDRH is described in Appendix B. The Connecticut Energy Efficiency Board (EEB) has also planned a 2023 net-to-gross study of the RNC program (R2209).

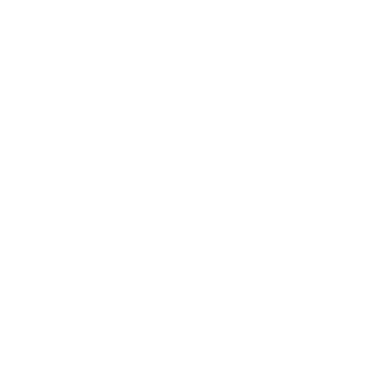
This baseline study included site visits to 59 new, non-program single-family homes in Connecticut that were built under the 2015 International Energy Conservation Code (IECC) with Connecticut amendments. Data collection covered all aspects of energy performance, including building envelope, mechanical systems, lighting, appliances, and air infiltration. Home Energy Rating System (HERS) ratings were performed at all homes.

Comparisons between program data and the non-program on-site inspections revealed that program homes outperform non-program homes on every analyzed measure. These measures range from shell measures to mechanical equipment, to overall HERS index values. According to the analysis, program homes have an average HERS Index value of 52, which is much better than the average score for non-program homes of 69.

Homes in this study (built under the 2015 IECC with Connecticut-specific amendments) have improved from those in the previous Connecticut baseline study which was conducted in 2017 and included homes built under the 2009 IECC with Connecticut amendments.[[1]](#footnote-2) HERS index values improved from 72, on average, to 69. Average R-values improved for every shell measure, as did heating, cooling, and hot water efficiencies.

**This study found a decrease in energy code compliance from the previous study, from 90% to 84%.** The largest contributors to decreased compliance are ceilings (down from 78% to 69% compliance) and duct leakage (down from 95% to 77%).

Considering the program shift to an all-electric design occurring this year, some inputs to the UDRH were consolidated to reflect a more accurate electric baseline. While building shell component inputs remained consistent (with updated values), recommended inputs for heating and hot water equipment collapsed down from multiple fuel and equipment type categories into one input. Average efficiency was calculated based on all heating or hot water equipment found in the non-program sample (heating systems were converted from AFUE to HSPF) resulting in the inputs of 1.24 EF for water heaters and 10.3 HSPF for heating systems. These are the best estimates that the data collected during this study could provide, but baseline conditions will have to be refined for this program in future evaluations.



# ****Executive**** Summary

This study, conducted for the Connecticut Energy Efficiency Board and submitted to the Connecticut Evaluation Administrator (EA) Team, details the results of a single-family residential new construction (RNC) baseline study. The study was designed to answer two key questions about the market at the end of the 2015 IECC code cycle: (1) how has the market baseline changed over time, and (2) what kinds of changes in building practices and equipment have occurred? The RNC program is shifting to an all-electric model in July of 2023; however, this study was conducted before this decision had been made and therefore is somewhat limited in its capacity to describe baseline conditions for an all-electric program design. As a follow up to the R1968 study, the Connecticut Energy Efficiency Board has planned a net-to-gross study of the RNC program to begin in 2023 (R2209) which will be better suited to assess these baseline conditions and fuel implications. Values recommended in this report should be used as interim program inputs until follow-up studies can better inform them.

The Connecticut RNC program offered by Eversource and United Illuminating (the Companies) provides financial incentives to builders and homeowners to encourage energy efficient construction and calculates savings by comparing its program homes to a market baseline. By conducting periodic baseline studies, the Companies can better understand the new construction market and claim savings against true market conditions.

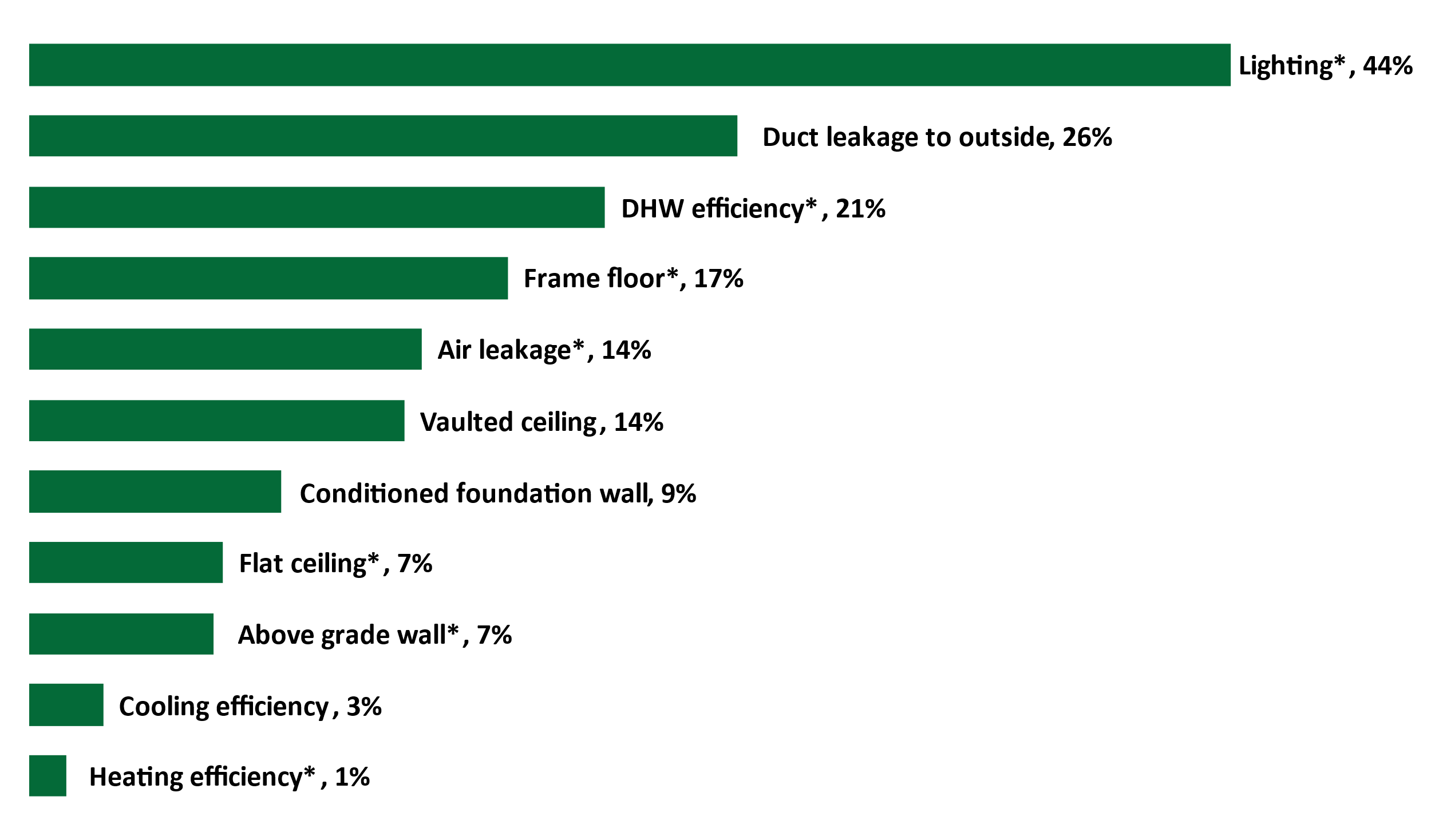
This study included site visits in 2022 to 59 new, non-program homes (34 spec- and 25 custom-built) across 45 Connecticut cities and towns. Because they were permitted between 2019 and early 2022, these homes were subject to the 2018 Connecticut State Building Code. This code includes energy-efficiency provisions based on the 2015 International Energy Conservation Code (IECC). For simplicity, the report refers to this Connecticut energy code as the 2015 IECC. On-site data collection covered all aspects of home energy performance, including building envelope, mechanical systems, lighting, appliances, and air infiltration. Home Energy Rating System (HERS) ratings were performed at all homes, and sites were evaluated against the requirements of the 2015 IECC. These results were also used to update the User Defined Reference Home (UDRH), against which the program claims savings for program homes (Appendix B).

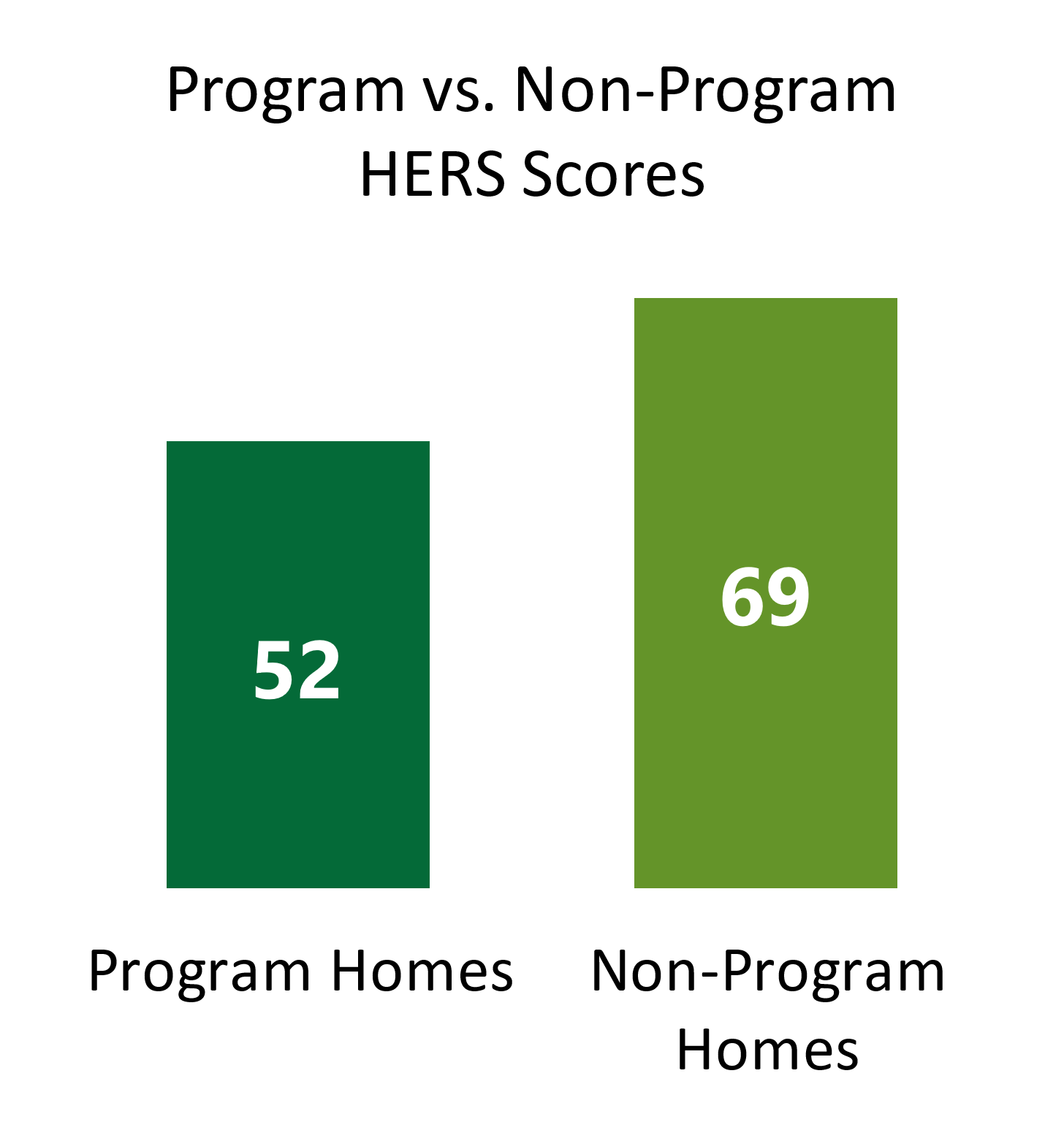
## Key Findings & Recommendations

Average non-program HERS index values have improved slightly since the previous study. The average HERS index value decreased from 72 to 69 since the previous study (lower values mean higher efficiency). PV systems affect HERS values, but they are excluded from this analysis because the RNC program does not incentivize on-site generation. Including PV systems in the energy models lowers the scores slightly: the average HERS index value when including all PV systems in the previous baseline study was 70 and 65 in the current study.

On average, building practices have improved since 2017 for all shell measures and mechanical equipment. The largest improvements were in the saturation of efficient lighting in new homes and duct leakage to the outside, though of course some measures are more impactful than others (e.g., ceiling insulation levels affect consumption more than insulation in foundation walls or frame floors). Building shell measures all improved since the previous baseline, most notably frame floor insulation, air leakage, and vaulted ceiling insulation. Water heater efficiency showed a large improvement but heating and cooling efficiencies showed only slight improvement. Measures followed by an asterisk\* represent statistically significant differences from the previous study’s findings; those include lighting, DHW efficiency, frame floor insulation, air leakage, flat ceiling insulation, wall insulation, and heating efficiency.

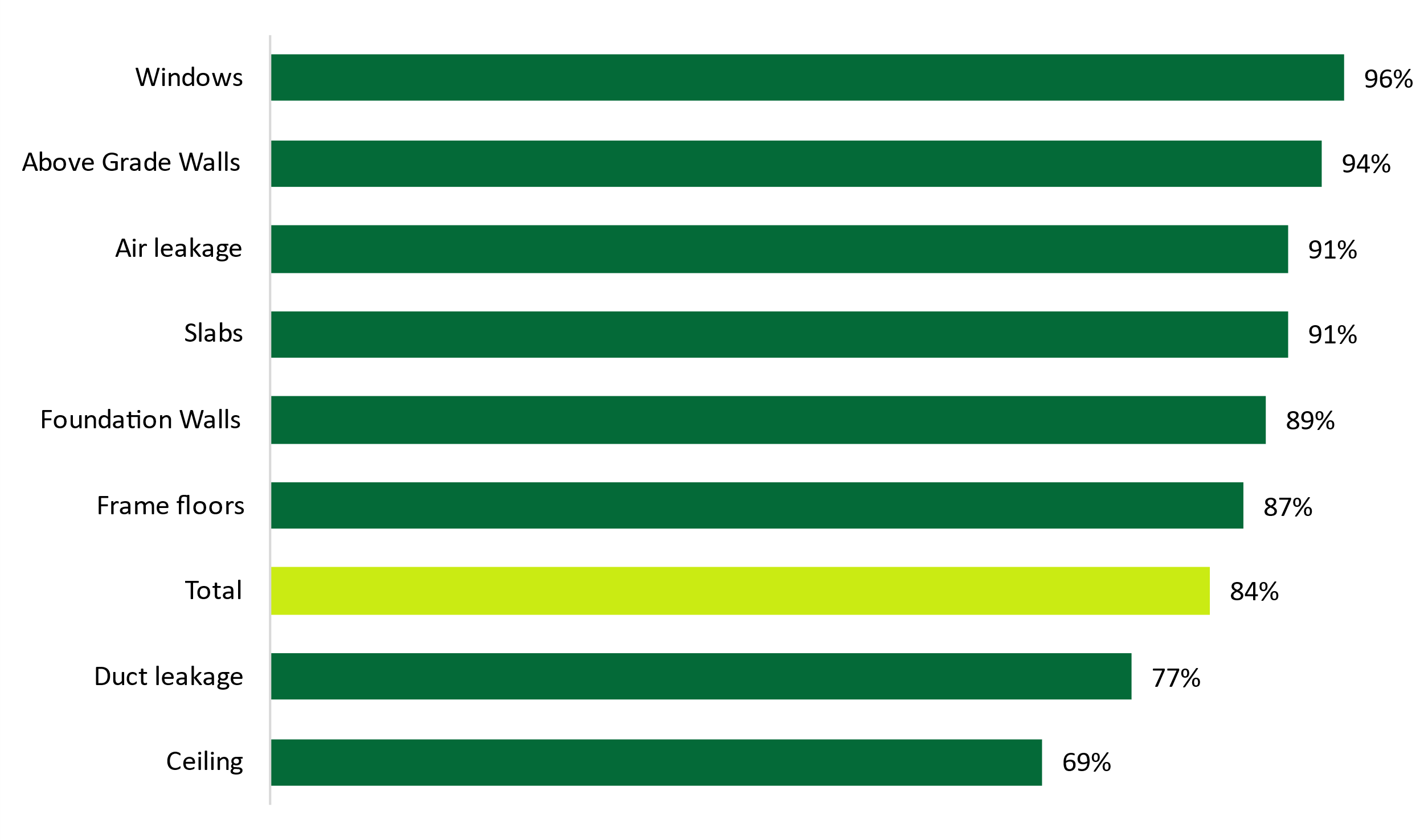
Figure 1: Measure Level Percent Improvement



Program HERS index values are 25% better than non-program values on average. Excluding PV systems, the average HERS value for program homes was 52, while the average for non-program homes was 69, a statistically significant difference. Including PV systems in energy models shows a similar trend: 47 for program and 65 for non-program homes. Average measure-level efficiencies in program homes were also significantly better than in non-program homes for air leakage (ACH50), exterior wall R-value, ceiling R-value, foundation wall R-value, water heater efficiency, and duct leakage.

Overall code compliance for non-program homes has decreased since the previous study. This study finds an overall code compliance rate of 84%, down from 90% in the previous study. While this decrease is notable, it is not statistically significant. The largest contributors to decreased compliance are ceilings (down from 78% to 69% compliance) and duct leakage (down from 95% to 77%). Note that while the efficiency of these measures increased relative to the previous study, for the code compliance analysis they are being compared to the 2015 IECC (with Connecticut amendments) as opposed to the less stringent 2009 IECC that covered the homes in previous study. Windows (96%) and above grade walls (94%) have the highest rates of code compliance, both an increase from the previous study.

Figure : Measure-Level Code Compliance



## Recommendations

Recommendation 1. Adopt updated UDRH inputs based on this study’s findings, but be prepared to adjust these values based on upcoming evaluation research efforts. Table 1**Error! Reference source not found.** summarizes the recommended UDRH inputs by measure and compares them to the current inputs used by the RNC program to calculate gross energy savings. In most cases, recommended inputs are based on data collected at non-program homes. The recommended values reflect improvements to building practices since the previous baseline study, yielding a more efficient baseline that reflects the current state of the non-program market.

For heating and hot water equipment, the current UDRH includes separate baseline efficiency values based on the fuel and equipment type of the as-built home, e.g., a program home with a natural gas or propane furnace would be compared to a hypothetical baseline home with that same system type). In 2023, the RNC program is shifting to an all-electric model, indicating a need to reconsider this baseline approach. Accordingly, this study recommends (for all but GSHP homes) using a single blended heating efficiency value that averages the performance of the fossil fuel and electric systems seen onsite (converted to the same efficiency unit, HSPF). Similarly, the recommended input for water heater energy factor (EF) is an average value of all water heating equipment found in the non-program homes, including electric and fossil-fuel equipment. This blended approach takes into account the fact that while the program homes will be all-electric moving forward, the heating or water heating fuel of a hypothetical, non-program baseline home is unknown and could have used one of several fuels. The EEB will be launching a net-to-gross study of the RNC program in 2023 that will investigate this issue and consider alternative baseline values (see Recommendation 3 for additional discussion of this issue). A detailed breakdown of UDRH inputs by measure can be found in Appendix B.

Table 1: Summary of Recommended UDRH (Baseline) Inputs

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | | | Current Input | Recommended Input |
| Exterior Wall R-value | | | 20.8 | 22.3 |
| Exterior Wall U-value | | | 0.062 | 0.057 |
| Flat Ceiling R-value | | | 36.9 | 39.7 |
| Flat Ceiling U-value | | | 0.042 | 0.040 |
| Vaulted Ceiling R-value | | | 36.7 | 42.5 |
| Vaulted Ceiling U-value | | | 0.038 | 0.031 |
| Framed Floor R-value | | | 25.6 | 31.0 |
| Framed Floor U-value | | | 0.061 | 0.050 |
| Conditioned Foundation Wall R-value | | | 10.9 | 12.0 |
| Window U-factor | | | 0.30 | 0.29 |
| Heating System Efficiency | Gas/propane forced air | 93.8 AFUE | GSHP 4.0 COP  All others 10.3 HSPF | |
| Gas/propane hydronic | 89.6 AFUE |
| ASHP | 10.0 HSPF |
| GSHP | 4.0 COP |
| Cooling System Efficiency | GSHP | 12.2 EER | GSHP 12.3 EER  All others 14.9 SEER | |
| All others | 14.6 SEER |
| Water Heater EF | Gas/propane storage | 0.65 | 1.24 | |
| Gas/propane integrated | 0.89 |
| Gas/propane tankless | 0.94 |
| Electric | 1.42 |
| Air Infiltration ACH50 | | | 4.9 | 4.2 |
| Duct Leakage to Outside CFM25/100 sq. ft. | | | 6.2 | 4.6 |
| % Efficient Lighting (LED and CFL) | | | 54% | 96% |

Recommendation 2: Encourage increased compliance with the Connecticut energy code and focus code compliance efforts on measures that substantially impact energy performance or have low compliance rates. Rates of energy code compliance, while relatively high, have decreased since the previous study (although the decrease is not statistically significant). The Companies should continue code compliance enhancement trainings as part of the RNC program to increase savings attributed to the program. Similar code compliance enhancement efforts in Massachusetts have led to a code compliance rate of 88% as measured in the most recent baseline study in 2019. Trainings offered should focus on duct sealing and ceiling insulation techniques to achieve higher R-values and overall assembly U-values. Increasing savings from code compliance could be a way to mitigate the potential loss in savings from program attrition as the program shifts to all-electric.

**Recommendation 3: Conduct additional research on baseline conditions for the new all-electric program.** This study gathered information about the energy-efficiency practices used in new homes in Connecticut. However, it did not assess how the market might change after the program shifts to an all-electric path in the summer of 2023, as the study was conducted well before that transition. Therefore, additional research will be needed to identify a true baseline for the all-electric program that includes counterfactual estimates of how (and with what fuel) homes would have been constructed in the absence of the program. This study provides baseline values that should be viewed as interim values that will likely be updated sooner than the typical three-year baseline cycle. One such study (R2209 RNC NTG) has already been commissioned to gather this type of information, but additional studies will be needed after there has been some program participation in order to accurately assess potential energy savings and to refine initial baseline assumptions. These studies may need to consider issues such as the extent to which baseline scenarios differ based on access to natural gas, if all-electric homes have different shell characteristics than non-electric counterparts, how program participation might change after the switch to the new program design, and so forth.

Recommendation 4: Make a concerted effort to maintain program participation levels as the program shifts to all-electric. This study found that under the current program design including fossil fuels, program home average HERS index values still outperformed non-program homes by 25%. This means that the potential still exists for fossil fuel savings that will now go unrealized given the program shift to an all-electric design. In addition, this program change will likely lead to other savings losses as some builders drop out of the program. In order to maintain savings the program is seeing now, specific efforts will have to be taken to retain builders in the program. This could be achieved by ensuring incentives are sufficient, adding more training and support for builders, and increasing marketing and outreach.

Recommendation 5: Promote adoption of high-efficiency cold-climate heat pumps. The program change to an all-electric model will naturally increase heat pump installation within the program. However, the average HSPF of heat pumps installed in program homes analyzed as part of this study was only 10.4, only marginally better than the recommended UDRH input based on non-program systems (including electric and fossil fuel systems converted to HSPF) of 10.3. In order for the program to maximize savings over that baseline, the installation of higher efficiency heat pumps will be necessary in the future. Considering these systems will not have any fossil fuel backup heat, they should also be cold climate rated models.

Recommendation 6: Increase builders’ comfort with continuous wall insulation techniques. Standard new construction practice is heavily weighted towards using only fiberglass batts in wall cavities – 68% of non-program homes had only fiberglass batts in their walls. Builders who rely only on fiberglass batts in wall cavities are likely to reach R-21, but sacrifice optimizing the overall assembly U-value, particularly if they do not practice extremely high-quality installations that avoid gaps and compression. Continuous insulation offers a thermal break in the assembly between the framing and ambient conditions, and therefore is not penalized for framing factor or grade of insulation like cavity insulation. Currently, continuous insulation was only found in 7% of non-program homes in this study.

## Study Limitations

Software challenges and data issues. Most HERS raters working for program builders have shifted from using the REM/Rate energy modeling software to Ekotrope, which led to data request complications. REM/Rate files are stored locally on a computer or server; in past studies the Companies could provide these files easily to evaluators. Ekotrope, however, is a cloud-based application that does not automatically grant evaluators with access to energy model data. This led to delays in obtaining program data, and ultimately to the team needing to purchase a temporary access account to obtain the program data. If possible, the Companies should negotiate with Ekotrope to garner some type of administrative access to data for projects that are participating in the RNC program. Otherwise, purchasing access to program energy models should be accounted for in project budgets that require this access.

Recruitment challenges. Another limitation results from the recruitment of homeowners. The methodology targets homeowners and occupants rather than builders to avoid biasing the sample towards efficient builders who are more likely interested in participating in an energy-efficiency study. The study also only allows one home per development to avoid including homes built by the same builder with similar characteristics. However, since recruitment was dependent on homeowner responses, it is possible that the study is biased towards homeowners who are more interested in energy efficiency. This would likely have more of an effect in custom homes where homeowners are more involved in construction decisions than in spec homes. Still, we believe that recruiting homeowners has less potential to bias results than recruiting builders.

Inspecting completed homes. A final limitation of the study results from inspecting already completed homes. Once homes are finished and occupied, certain aspects of the home are difficult to visually inspect on-site. These include insulation in finished walls, insulation under basement slabs, and window U-factors. On-site auditors had to make assumptions on non-visible measures based on other aspects of the home when documentation was not present.

# Open bookOpen book Introduction

This report details a baseline study and code compliance assessment of single-family residential new construction (RNC) in Connecticut, completed by NMR Group on behalf of the Connecticut EEB. It describes energy-related characteristics of new, single-family homes based on primary data collection that included on-site visits to 59 new homes and visits to building departments.

The study determined the appropriate characteristics of the non-program baseline home, represented in energy modeling software as the User Defined Reference Home (UDRH), against which program home savings are calculated. The study also assessed the extent to which non-program homes comply with the Connecticut building energy code, based on an amended version of the 2015 International Energy Conservation Code.

## Purpose and Goals

The primary objective of this research is to provide the Connecticut EEB with the **current baseline conditions of new single-family housing units**. To that end, the study provides saturation and efficiency levels for key building equipment and features, such as:

* Building shell characteristics
* Heating, ventilation, and air conditioning (HVAC) equipment
* Domestic hot water (DHW) systems
* Lighting
* Appliances

In addition, the study describes:

* New home compliance with energy code
* Changes in the residential new construction sector over time, relative to previous market characterizations

## Background

The Residential New Construction program was last evaluated in December 2017 as part of the R1602 baseline study, which focused on homes completed in 2015 through 2016 under an older code based on the 2009 IECC. The study also compared the visited homes to the 2012 IECC which was adopted in late 2016; however, none of the visited homes were actually built under that code. The code that these homes were built under, based on the 2015 IECC, went into effect in October 2018 and is similar to the 2012 IECC. No study has examined homes built under the current code, and therefore the assumptions used for the User Defined Reference Home are outdated.

Specifically, this report includes two types of single-family homes built since 2019:

* Detached single-family home
  + Constructed on-site using a foundation; usually built with wood framing, but could be built from brick, metal, or another material
  + Modular home built at a factory in separate units then assembled and set onto a foundation
* Attached single-family home
  + Two-family home or duplex—this includes single-family attached homes (i.e., townhomes) if there are not more than two units attached

This study is the most recent iteration of multiple Residential New Construction Baseline and Code Compliance studies conducted in Connecticut by NMR. NMR conducted two prior studies in 2011 and 2017.

## Research Questions

The study addresses the following research questions:

* What are the average non-program baseline conditions to update UDRH assumptions?
* What is the extent of energy code compliance for new homes in Connecticut?
* How has the residential sector changed over time for new, single-family homes?
* How do non-program homes compare to program homes?

## Report Organization

The remainder of the report is structured as follows:

* Section 2 Methodology Overview: Study methodologies.
* Section 3 Comparisons: Comparisons to previous studies and between program and non-program homes
* Section 4 Code Compliance: Assessment of compliance with 2015 IECC
* Section 5 Building Shell: Key finding for building shell components
* Section 6 Mechanical Equipment: Key findings for mechanical equipment components
* Section 7 Lighting and : Key findings for plug-load components.
* Appendix A Detailed Data: Tables of detailed data from on-site visits.
* Appendix B UDRH Update: Detailed tables on recommended UDRH updates.
* Appendix C Detailed Methodology: Details on study methodology.
* Appendix D Comparison to 2019 Massachusetts Baseline: Comparisons of key measures between this study and the most recent RNC Baseline in Massachusetts.

# Head with gearsHead with gearsMethodology Overview

The study used two primary data collection activities to establish baseline practices: on-site inspections and building department data collection. See Appendix C for detailed information about each activity.

During on-site inspections, technicians collected data on building characteristics such as building shell, HVAC equipment, water heating equipment, appliances, and lighting. Technicians also assessed the air tightness of homes by conducting blower door tests and assessed compliance with the Connecticut energy code.

## Sampling Plan and Composition

For single-family new construction, the study targeted a sample of 70 homes built in 2019 or later. The team made soft targets by county based on new construction activity. NMR estimated new construction activity using permit data from the U.S. Building Permit Survey.[[2]](#footnote-3) Table 2 compares the single-family new construction target sample to the final sample. The final sample (n=59) is less than the target sample (n=70) due to the lack of response after several rounds of outreach. Nevertheless, the final sample does include homes from all over the state. Results presented in this report are unweighted.

Table 2: County-Level On-site Target and Final Samples

|  |  |  |  |
| --- | --- | --- | --- |
| County | % of Statewide  Construction Activity | Target Sample  (n=70) | Final Sample  (n=59) |
| Fairfield | 27% | 19 | 13 |
| Hartford | 21% | 15 | 6 |
| Litchfield | 6% | 4 | 2 |
| Middlesex | 6% | 4 | 6 |
| New Haven | 16% | 12 | 14 |
| New London | 11% | 8 | 9 |
| Tolland | 5% | 4 | 3 |
| Windham | 6% | 4 | 5 |
| **Total** | **100%** | **70** | **59** |

## Outreach and Recruitment

The sample for this study was comprised of homes permitted in 2019 or later to coincide with the Connecticut energy code adopted in 2018 (based on 2015 IECC) and ensure that the homes were permitted under this code. The team reviewed and cleaned new electric service request data from 2019 to 2022 to narrow the sample down to only single-family new homes that had not participated in the Connecticut residential new construction program. Postcards were sent to this comprehensive list of 3,660 addresses, which described the goals of the study and mentioned a $200 incentive offered for participation. The postcard also included a QR code which conveniently linked potential participants to a short survey where they could express interest in participating and provide contact information. Visits were then scheduled at the homeowner’s convenience. This study targeted a 60% spec-built home ratio in line with previous baseline studies in Connecticut and achieved a 58% ratio. An initial screening question was used during homeowner recruitment to determine if a home was spec- or custom-built[[3]](#footnote-4).

## On-site Data Collection Points

During on-site visits, HERS[[4]](#footnote-5) raters gathered information about the following types of measures:

* Water fixtures
* Lighting
* Appliances
* Renewables
* Electric vehicles and chargers
* Code compliance
* General home information (age, type, etc.)
* Areas and volume of home components
* Building shell characteristics (material, insulation types, insulation level etc.)
* Heating, cooling, and ventilation equipment
* Domestic hot water equipment

## Building Department Visits

In addition to on-site data collection, the team visited building departments as part of the study. The goal of this data collection was to assess the accuracy of building department data by comparing onsite results and program data and comparing MF results to single family. The sample was created by randomly selecting from new service request or program data and the targets were: 30 non-program multifamily buildings, 20 non-program homes also visited on-site, and 10 single family program homes.

Of the 60 total sites for which the team requested building department files, 37 responded with documentation. The remaining sites’ building departments either became unresponsive after multiple attempts or confirmed that they did not have documentation for the given address. Among those for which documentation was obtained, a majority of that documentation was only permits or blueprints which do not often contain meaningful information that can aid in analysis or comparisons. Blueprints sometimes contain assembly R-values or insulation types, but these are simply plans that the architect specifies based on code requirements; they do not reflect what was necessarily installed during construction. Types of documentation that would yield more confident results would be things like blower door test results, code compliance checklists, or HERS ratings which indicate third party verification of this information. These types of documents were rarely found during building department data collection. Due to this lack of meaningful data, results are not presented from building department data collection as sample sizes would be too small for comparisons.

## Analysis

Data collected at each home for this study went through a review and QC process by a different NMR technician that was not present on site. Once data was finalized, each component was analyzed to produce average R-values and efficiencies across the sample, split out by custom and spec homes. The resulting averages would serve as updated User Defined Reference Home (UDRH) values which are recommended to be used by the RNC program to calculate savings.

Code compliance was measured using the MA-REC methodology developed by NMR in Massachusetts. Details on this methodology can be found in Appendix C.6. In short, this methodology uses REM/Rate, an energy modelling software, to develop a code compliance scoring system that is more focused on estimating energy consumption than other prescriptive methods. It establishes the relative importance of various building shell components based on energy consumption in order to develop a scoring system, and then assesses the level of compliance for each of those measures in each home compared to a reference home built to code minimum standards. This methodology has been used in several baseline and code compliance studies across New England, including the previous code compliance study in Connecticut in 2018.

# Comparisons

This section compares results from this study to results from the two previous studies. It also compares results from non-program homes in this study to program homes built over the same period.

## Previous Baselines

Table 3 and Table 4 compare the results in this study to the results from the previous studies of non-program and program homes, respectively. The previous studies were conducted in 2017[[5]](#footnote-6) and 2011[[6]](#footnote-7) and thus reflect a ten-year record of homes in Connecticut.

For non-program homes, all building components and equipment have shown steady improvement over the ten-year period. All building shell R-values have increased, air leakage and duct leakage have decreased, and all mechanical efficiencies have increased. The largest improvement that has occurred is in the percent efficient lighting in non-program new homes, up from 54% in the previous study to 96% currently. Average water heater efficiency has improved to 1.24 (higher than what is achievable by fossil fuel equipment) due to the increasing adoption of heat pump water heaters with energy factors greater than one. Program homes have also shown improvement over the previous baseline in all areas except for flat ceiling R-value, although this is still high at an average of 45.4.

Table 3: Comparison of Non-program Homes Over Time

|  |  |  |  |
| --- | --- | --- | --- |
|  | 2011 | 2017 | 2022 |
| ACH50 | 5.8 | 4.9 | 4.2\* |
| Exterior Wall R-value | 19.0 | 20.8 | 22.3\* |
| Flat Ceiling R-value | 34.0 | 36.9 | 39.7\* |
| Vaulted Ceiling R-value | 32.0 | 36.7 | 42.5 |
| Framed Floor R-value | 20.5 | 25.6 | 31.0\* |
| Conditioned Foundation Wall R-value | N/A | 10.9 | 12.0 |
| Window U-factor | N/A | 0.31 | 0.29 |
| Heating System AFUEa | 90.7 | 93.5 | 94.8\* |
| Cooling System SEERb | 13.4 | 14.5 | 14.9 |
| Water Heating EFc | 0.74 | 0.98 | 1.24\* |
| Duct LTO CFM25/100 sq. ft. | 17.7 | 6.2 | 4.6 |
| % Efficient Lamps | 10% | 54% | 96%\* |
| a Includes only systems with AFUE ratings.  b Includes only systems with SEER ratings.  c Includes systems with EF ratings and UEF ratings converted to EF.  \*Indicates statistically significant difference from 2017 results at the 90% confidence interval. | | | |

Table 4: Comparison of Program Homes Over Time

|  |  |  |
| --- | --- | --- |
|  | 2017 | 2022 |
| ACH50 | 3.0 | 2.1 |
| Exterior Wall R-value | 22.3 | 24.1 |
| Flat Ceiling R-value | 46.0 | 45.4 |
| Vaulted Ceiling R-value | 40.0 | 48.5 |
| Framed Floor R-value | 28.0 | 32.0 |
| Foundation Wall R-value | 16.3 | 17.3 |
| Window U-factor | N/A | 0.27 |
| Heating System AFUEa | 94.9 | 95.5 |
| Cooling System SEERb | 15.3 | 15.4 |
| Water Heating EFc | 1.09 | 1.51 |
| Duct LTO CFM25/100 sq. ft. | 1.9 | 1.7 |
| % Efficient Lamps | 97% | 99% |
| a Includes only systems with AFUE ratings.  b Includes only systems with SEER ratings.  c Includes systems with EF ratings and UEF ratings converted to EF. | | |

## Non-Program versus Program Homes

Table 5 compares non-program and program single family homes in the current study. Program homes have statistically significant better air sealing (i.e., ACH50), wall insulation, ceiling insulation, foundation wall insulation, water heaters, and duct leakage. In other cases where results were not significantly different, program homes outperformed non-program homes.

Table 5: Comparison of Non-program and Program Single-Family Homes

|  |  |  |
| --- | --- | --- |
|  | Non-Program Homes | Program Homes |
| ACH50 | 4.2 (n=58) | 2.1a (n=73) |
| Exterior Wall R-value | 22.3 (n=59) | 24.1a (n=88) |
| Exterior Wall U-value | 0.057  (n=59) | 0.052  (n=88) |
| Flat Ceiling R-value | 39.7 (n=44) | 45.4a (n=82) |
| Flat Ceiling U-value | 0.040  (n=44) | 0.023  (n=82) |
| Vaulted Ceiling R-value | 42.5 (n=22) | 48.5a (n=66) |
| Vaulted Ceiling U-value | 0.031  (n=22) | 0.028  (n=66) |
| Framed Floor R-value | 31.0 (n=52) | 32.0  (n=34) |
| Framed Floor U-value | 0.050  (n=52) | 0.034  (n=34) |
| Foundation Wall | 12.0  (n=91) | 17.3a  (n=138) |
| Window U-factor | 0.29 (n=95) | 0.27  (n=570) |
| Heating System AFUE | 94.8  (n=61) | 95.5  (n=63) |
| Cooling System SEER | 14.9 (n=69) | 15.4  (n=84) |
| Water Heating EF | 1.24 (n=63) | 1.51a (n=72) |
| Duct Leakage to Outside (CFM25/100 Sq Ft CFA) | 4.6  (n=56) | 1.7a (n=69) |
| Lighting % Efficient | 96%  (n=59) | 99%  (n=74) |
| a Non-program and program values are significantly different at the 90% confidence level. | | |

# Code Compliance

This section describes the results from a code compliance analysis conducted to assess the rate at which homes in the non-program sample (and specific building components within the homes) comply with the governing building code; in this case based on 2015 IECC. Understanding code compliance levels can help to assess remaining opportunities for program intervention via code compliance enhancement activities and provide guidance on specific measures that need improvement.

Code compliance was measured using the MA-REC methodology developed by NMR in Massachusetts. Details on this methodology can be found in Appendix C.6. In short, this methodology uses REM/Rate, an energy modelling software, to develop a code compliance scoring system that is more focused on estimating energy consumption than other prescriptive methods. It establishes the relative importance of various building shell components based on energy consumption in order to develop a scoring system, and then assesses the level of compliance for each of those measures in each home compared to a reference home built to code minimum standards. This methodology has been used in several baseline and code compliance studies across New England, including the previous code compliance study in Connecticut in 2018.

## Compliance Key Findings

The overall code compliance rate for the non-program sample is 84%. This is a drop from the previous study, which found an overall compliance rate of 90%. Windows (96%) and above grade walls (94%) had the highest level of code compliance, while ceilings (69%) and duct leakage (77%) had the lowest. Ceilings and duct leakage have also seen a drop from the previous studies’ estimates, falling from 78% to 69% and 95% to 77%, respectively. Note that while the overall efficiency of these measures has improved, they are being compared to 2015 IECC in this study as opposed to 2009 IECC in the previous study.

Table 6: Non-Program Code Compliance by Measure

(On-site visits: All homes)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom[[7]](#footnote-8) | Spec | Statewide |
| *n* | *24* | *34* | *58* |
| Windows | 98% | 96% | 96% |
| Above Grade Walls | 94% | 94% | 94% |
| Slabs | 96% | 90% | 91% |
| Air leakage | 92% | 91% | 91% |
| Foundation Walls | 95% | 87% | 89% |
| Frame floors | 91% | 86% | 87% |
| Duct leakage | 72% | 78% | 77% |
| Ceiling | 89% | 64% | 69% |
| **Total** | **86%** | **83%** | **84%** |

Table 7: Non-Program Code Compliance Over Time

(On-site visits: All homes)

|  |  |  |
| --- | --- | --- |
|  | 2017 | 2022 |
| *n* | *70* | *58* |
| Windows | 94% | 96% |
| Above Grade Walls | 88% | 94% |
| Slabs | 94% | 91% |
| Air leakage | 98% | 91% |
| Foundation Walls | 85% | 89% |
| Frame floors | 72% | 87% |
| Duct leakage | 95% | 77% |
| Ceiling | 78% | 69% |
| **Total** | **90%** | **84%** |

## HERS Index Value Results

Table 8 summarizes the HERS index values of the 58 non-program homes, modeling both with and without PV systems[[8]](#footnote-9), which affect the HERS value of a given home. The average HERS index value of non-program homes including PV systems is 65; with PV removed it increases to 69. These averages are a decrease from the previous study which found an average HERS value of 70 including PV and 72 when excluding it.

Table 8: HERS Ratings of Non-Program Homes

(On-site visits: All homes)

|  |  |  |
| --- | --- | --- |
|  | Without PV | With PV |
| *n* | *58* | *58* |
| Mean | 69 | 65 |
| Min | 52 | 16 |
| Max | 89 | 89 |
| Median | 69 | 68 |
| St. Dev. | 8.7 | 13.2 |

Table 9 summarizes HERS index values for program homes. They are significantly lower than non-program when including or excluding PV at 47 and 52, respectively.

Table 9: HERS Ratings of Program Homes

(Program data: All SF homes, excludes MF)

|  |  |  |
| --- | --- | --- |
|  | Without PV | With PV |
| *n* | *74* | *74* |
| Mean | 52 | 47 |
| Min | 32 | -25 |
| Max | 60 | 60 |
| Median | 54 | 54 |
| St. Dev. | 6.6 | 19.8 |

# Building Shell

This section presents the notable findings for key building shell measures in non-program new homes including air infiltration and ventilation, above-grade walls, flat and vaulted ceilings, frame floors, conditioned foundations walls, and fenestration. Detailed findings on these measures can be found in Appendix A.2.

Overall, the findings from this study indicatethat **shell building practices have improved since the previous two studies (2011 and 2017).**

* All insulation measures average R-values increased compared to previous 2017 study:
  + Average exterior wall R-value has increased by 7%
  + Average flat ceiling R-value has increased by 8%
  + Average vaulted ceiling R-value has increased by 16%
  + Average frame floor R-value has increased by 17%
* Air tightness has improved by 14% compared to the previous 2017 study.

Table 10 summarizes the average key efficiencies for building shell measures.

Table 10: Key Building Shell Efficiencies

|  |  |
| --- | --- |
|  | 2022 |
| ACH50 | 4.2 |
| Exterior Wall R-Value | 22.3 |
| Flat Ceiling R-Value | 39.7 |
| Vaulted Ceiling R-Value | 42.5 |
| Framed Floor R-Value | 31.0 |
| Foundation Wall | 12.0 |
| Window U-Factor | 0.29 |

## Air Infiltration and Ventilation

The average air tightness of non-program new homes has improved since the previous study but is not compliant with current energy code. The average air infiltration rate, as measured in air changes per hour at a 50-Pascal pressure gradient (i.e., ACH50), decreased from 4.9 in the 2017 study to 4.2 in the current study. The 4.2 ACH50 value is greater (i.e., worse) than maximum allowable ACH50 value of 3.0 under the current CT energy code.

Only eight out of 59 (13%) homes had mechanical ventilation systems. Of those eight homes, three had ERVs, three had HRVs, and two had bath fans with automatic controls. This does not represent a significant change since the last study where seven homes had mechanical ventilation systems.

## Above Grade Walls

Ambient wall R-values have slightly improved since the previous study. The previous study found the average R-value of exterior walls in new non-program homes was 20.8 while the current study found an improved value of 22.3.

Few builders have adopted the use of continuous insulation in ambient walls. Only 11% of new non-program homes had continuous insulation in ambient walls. Continuous insulation materials include exterior XPS or EPS insulation. Continuous insulation techniques can be an effective way to increase R-values without relying on spray foams which have high embodied carbon.

The use of fiberglass batts in walls is more common in spec homes, while the use of spray foam insulation (CCF and OCF) is more common in custom homes. Spec homes use fiberglass batt insulation in 86% of ambient walls compared to 47% in custom homes. The use of CCF and OCF spray foam in ambient walls is 27% in custom homes, and 10% in spec homes.

## Flat Ceilings

Flat ceiling R-values have slightly improved since the previous study. The average R-value increased from R-35.8 in the previous study to R-39.7 in the current study.

Fiberglass batt insulation remains the dominant insulation type in flat ceilings and loose-fill fiberglass remains to be the second most common type of insulation. Fiberglass batts are in 57% of flat ceilings compared to 60% of flat ceilings in the previous study. Loose-fill fiberglass is in 20% of flat ceilings compared to 23% in the previous study. Loose-fill cellulose has become more common compared to the previous study, it was found in 16% of homes in this study compared to 5% in the previous study.

## Vaulted Ceilings

Vaulted ceiling R-values have improved since the previous study. The average R-value increased from R-36.7 in the previous study to R-42.5 in the current study.

The average vaulted ceiling R-value for custom homes is higher compared to spec homes. Spray foam (CCF or OCF) is the most common insulation type used in custom homes while fiberglass batt insulation is the most common type in spec homes. The average R-value for custom homes is R-43.8 compared to R-31.3 in spec homes. Custom homes have CCF or OCF spray foam insulation in 61% of homes, while spec homes have CCF or OCF insulation in 26% of homes. Spec homes have fiberglass batt insulation in 74% of vaulted ceilings, and custom homes have fiberglass insulation in 30% of vaulted ceilings.

Closed-cell spray foam has increased since the previous study while open-cell spray foam has decreased. CCF spray foam was found in 46% of vaulted ceilings in the current study compared to 9% in the previous study. OCF spray foam was found in 7% of vaulted ceilings compared to 20% in the previous study.

## Floors over Unconditioned Basement

The average R-value of floors over unconditioned basements has improved slightly since the previous study. The average R-value in floors over unconditioned basements has increased from 25.6 in the previous study to 29.9 in the current study.

Fiberglass batt insulation remains the dominant insulation type in floors over unconditioned basements, but has decreased compared to previous study. Fiberglass batt insulation over unconditioned basements is present in 68% of floors in this study, a decrease from 92% in the previous study.

The presence of rock wool insulation has increased since the previous study. The presence of rock wool insulation in frame floors has increased from just 2% in the previous study to 28%.

## Foundation Walls

The average R-value of conditioned basement walls has improved slightly since the previous study. The average R-value in conditioned basements, including conditioned basements with no insulation, has increased from 10.9 in the previous study to 12.0 in the current study.

Over One-third of all conditioned foundation walls are uninsulated. 36% of conditioned foundation walls had no insulation, offering great opportunities for improvement since foundation walls are easily accessible to add insulation.

## Fenestration

Triple pane windows have become much more common since the previous study. Triple pane windows made up 8% of glazing area in the current study, up from just 1% in the previous study.

**The presence of argon gas filled windows has increased since the previous study.** It can be difficult to confirm the presence of gas fill visually; therefore, auditors confirmed the presence of argon based on building documentation from the homeowner, NFRC rating stickers on-site, or if they confirmed the presence of gas insert plugs within the windows on-site. Twenty-two percent of window area was confirmed to contain gas fill, up from 12% in the previous study.

Most glazing has a low-emissivity coating. Ninety-five percent of glazing area in non-program homes had a low-emissivity coating. Low-e coatings are thin, transparent coatings on windows that improve the efficiency of the window. At 95% of total non-program glazing area, low-e coating appears to be the standard practice in most windows bordering conditioned space.

Confirmed U-factors have improved from 0.33 in the previous study to 0.29 currently. It can be difficult to confirm window U-factors post-construction. Auditors confirmed U-factors at 15 of the 59 homes through building documentation or NFRC stickers. This average U-factor is compliant with code: the prescriptive method requires a U-factor less than 0.32.

# Single gearSingle gear Mechanical Equipment

This section summarizes the key findings about mechanical equipment in homes including heating equipment, cooling equipment, thermostats, domestic hot water heater equipment, duct systems, and renewables and electric vehicles. Detailed tables of this data can be found in Appendix A.3.

## Heating Equipment

**Furnaces continue to make up the largest portion of primary systems.** Furnaces made up just under three-quarters (73%) of primary systems in the previous study; that number has increased to 78% in the current study. Boilers make up 10% of the primary systems in the current study, down from 20% in the previous study. Heat pumps (ASHP, GSHP and mini-splits) as a primary heating source have increased from 6% to 9%.

**The average efficiency of fossil fuel heating systems has increased since the previous study and is approaching average program efficiency.** The average AFUE of furnaces and boilers has increased from 93.1 in the previous study to 94.7 in the current study. Both furnaces and boilers individually had a higher average AFUE than compared to the last study. Boilers in the current study had an average AFUE of 93.9, compared to 91.8 in the previous study. Natural gas furnaces increased from 94.2 AFUE to 94.9, while propane furnaces increased from 93.2 AFUE to 95.3. While program homes still outperform the non-program sample in average AFUE, the 94.7 average in non-program homes is approaching the program home average of 95.5.

**The average heating efficiency of all heating systems after converting AFUE values to HSPF[[9]](#footnote-10) is 10.3, which is the recommended UDRH input.** Considering the program is changing to an all-electric model going forward, a traditional UDRH heating input in AFUE is no longer relevant despite a majority of systems found in this baseline heating with fossil fuels. To set a proper UDRH input for all electric homes, AFUE values found for heating systems in this non-program sample were converted to HSPF and an overall average value was calculated, resulting in a recommended input of 10.3 HSPF.

The saturation of ENERGY STAR certified primary heating systems has increased substantially. The previous study found 42% of primary heating systems to be ENERGY STAR certified, that number has increased to 83% of primary heating systems in the current study.

## Cooling

**Central air conditioners continue to be the primary cooling system in most homes, but the prevalence of heat pumps has increased slightly.** The last study found that 85% of homes had CACs as their primary system, and the current study found the same. Heat pumps (ASHP, MSHP and GSHP) have increased in prevalence as primary cooling systems from 9% of homes to 12%. This is driven by an increase in mini splits from 5% of homes in the previous study to 7%.

**The average efficiency of permanently installed air conditioning has increased slightly since the last study.** The average SEER of central air conditioners and heat pumps has increased from 14.6 in the previous study to 14.9 in the current study.

The saturation of ENERGY STAR certified central air conditioners has increased substantially. The previous study found 32% of central air conditioners to be ENERGY STAR certified, that number has increased to 60% in the current study.

## ThermometerThermostats

**Programmable thermostats continue to be the most prevalent thermostat type in new homes**. While programmable thermostats are still the most common, the share of programmable thermostats has decreased from 69% to 57% from the previous study. Smart thermostats have now replaced programmable +Wi-Fi thermostats as the second most common thermostat type. While smart thermostats were not recorded in the previous study, they now make up 21% of the thermostats in new homes. Programmable +Wi-Fi thermostats have decreased by 4% since the last study. Manual thermostats have also decreased by 5%.

## Domestic Hot Water

**The share of conventional standalone storage tanks has decreased from the previous study, while the share of instantaneous water heaters and heat pump water heaters have increased.** Storage, standalone water heaters were the most common type in the previous 2017 study, making up 52% (including commercial sized water heaters). This has decreased to 35% of water heaters in the current study. The presence of instantaneous and heat pump water heaters (HPWH) hav both increased since the previous study, from 26% to 38% for instantaneous and from 6% to 13% for HPWH.

**The efficiency of water heating equipment has increased to 1.24 EF, above what is achievable for fossil fuel equipment.** The average water heater EF for all water heater types found during non-program on-site inspections is 1.24, driven largely by the shift towards HPWH noted above which can have efficiencies greater than 3.0 EF. This means that in order to achieve water heating savings in the future, program homes will have to install HPWHs which is feasible considering the program shift to all electric homes.

**Saturation of ENERGY STAR water heating equipment continues to trend upwards.** Seventy percent of domestic hot water equipment was ENERGY STAR certified in 2022, up from 53% in 2017.

## Duct Systems

**Total duct leakage has increased since the previous study, but leakage to the outside has decreased.** Total duct leakage has increased from an average of 18.7 CFM25 per 100 square feet to 20.9, but the portion of that leakage that is leaving the conditioned area (leakage to outside) has decreased from 6.2 CFM25 to 4.6. Leakage to the outside has a larger impact on overall energy consumption.

**Most ducts found in new homes are insulated, but the R-value has not increased much since the previous study.** A vast majority of the ducts observed in new homes (94%) were insulated, and an even higher portion (97%) of ducts in unconditioned spaces were insulated. The average R-value of insulation for attic supply ducts increased slightly from R6.5 in the previous study to R6.7, and in all other unconditioned spaces it increased from R5.8 to R5.9.

## Renewables and Electric Vehicles

**Solar PV penetration has slightly increased.** Solar photovoltaic arrays were present at 10% of homes visited in the current study; a 3% increase since the previous study. The size of the arrays has remained similar at an average of 5.5 kW compared to the previous study average of 5.6 kW. The average for this study was brought down by a small array of 0.6 kW, compared to the last study’s minimum of 2.7 kW. Electric vehicles were found in two of the homes visited during this study.

# Lighting and Appliances

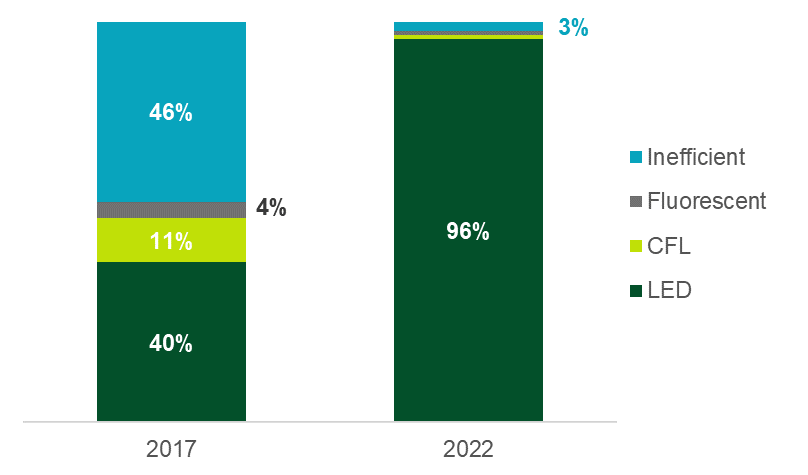
This section summarizes the key findings about lighting, appliances, and electronics in homes.

## **Lighting**

**Saturation of LEDs has increased significantly since the previous study.** In this study 96% of light sockets used an LED bulb or fixture compared to 40% of the homes in the previous study. All of the homes visited for this study had at least one LED bulb or fixture. While program homes have consistently had a large percentage of efficient lamps, the percentage of efficient lamps for non-program homes has increased signficantly over the years and is approaching program levels (96% non-program vs. 99% program). The percentage of efficient lamps in non-program homes has almost doubled in the last 5 years. It increased from 54% to 96%.

**Saturation of inefficient bulbs such as incandescents and halogens has decreased greatly.** Inefficient lamps were found in almost half (46%) of all light sockets in homes in the previous study, that has dropped to 3% of light sockets in this study.

Figure : Lighting Type Saturation Over Time



7.2 Appliances

ENERGY STAR appliance saturation has increased for refrigerators, freezers, and clothes dryers, but has decreased for other appliance types since the 2017 study. The largest increase in ENERGY STAR saturation was for clothes dryers which increased from 22% in 2017 to 69% in 2022. Freezers saw a large increase in ENERGY STAR qualified equipment from 27% to 54%. Refrigerators saw only a small increase from 68% to 70%. Dishwashers, clothes washers, and dehumidifiers all saw decreases in ENERGY STAR saturation.

Table 11: Share of ENERGY STAR Appliances

|  |  |  |
| --- | --- | --- |
|  | 2017 | 2022 |
| Refrigerator | 68% | 70% |
| Freezer | 27% | 54% |
| Dishwasher | 93% | 73% |
| Clothes Washer | 85% | 73% |
| Clothes Dryer | 22% | 69% |
| Dehumidifier | 91% | 79% |

1. Detailed Data

This section provides detailed results from the on-site data collection, broken out by measure category and by custom and spec homes. Significance testing was performed between custom and spec results, significantly different results are notated with the a superscript symbol.

Note, that given the high-level of detail in this section, some sample sizes are quite small. Readers should note the sample sizes when looking at values presented as percentages.

* 1. General Home Characteristics

Table : Types of Homes

(On-site visits: All Homes)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 25 | 34 | 59 |
| Detached Single-Family | 100% | 85% | 91% |
| Attached Single-Family | 0% | 15% | 9% |

Table : Conditioned Floor Area (ft2)

(On-site visits: All Homes)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 25 | 34 | 59 |
| Mean | 3150 | 2,526 | 2,790 |
| Min | 1,116 | 625 | 625 |
| Max | 6,736 | 6,394 | 6,736 |
| Median | 2,796 | 2,340 | 2,448 |
| Standard Deviation | 1,646 | 1,096 | 1379 |
| CV | .52 | .43 | .49 |
| Conf. Int. | (2609, 3692) | (2216, 2835) | (2495, 3086) |

Table 14: Number of Occupants in Home

(On-site visits: All Homes)

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Custom** | **Spec** | **Statewide** |
| n | 25 | 34 | 59 |
| One | 16% | 12% | 14% |
| Two | 44% | 44% | 44% |
| Three | 4% | 12% | 8% |
| Four | 24% | 26% | 25% |
| Five | 8% | 6% | 7% |
| Six | 4% | 0% | 2% |
| Average | 3 | 3 | 3 |
| Median | 2 | 2 | 2 |

Table 15: Bedrooms

(On-site visits: All Homes)

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Custom** | **Spec** | **Statewide** |
| n | 25 | 34 | 59 |
| One | 4% | 6% | 5% |
| Two | 16% | 9% | 12% |
| Three | 52% | 59% | 56% |
| Four | 16% | 26% | 22% |
| Five Or More | 12% | 0% | 5% |

* 1. Building Shell
     1. Air Infiltration and Ventilation

Table 16: Air Infiltration (ACH50)

(On-site visits: All Homes)\*

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 24 | 34 | 58 |
| Mean | 4.2 | 4.2 | 4.2 |
| Min | 1.3 | 1.0 | 1.0 |
| Max | 11.5 | 7.8 | 11.5 |
| Median | 3.2 | 4.3 | 4.2 |
| Std. Dev. | 2.8 | 1.4 | 2.1 |
| CV | 0.67 | 0.33 | 0.50 |
| Conf. Int. | (3.3, 5.2) | (3.8, 4.6) | (3.8, 4.7) |

\*A blower door test was not able to be completed at one home in the sample.

Table 17: Mechanical Ventilation Types

(On-site visits: All Homes)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 25 | 34 | 59 |
| ERV | 12% | 0% | 5% |
| HRV | 12% | 0% | 5% |
| Bath fans w/ automatic controls | 13% | 6% | 3% |
| None | 68% | 94% | 87% |

Table 18: Mechanical Ventilation Configurations

(On-site visits: Mechanical Ventilation Systems)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | Custom | Spec | | | Statewide | | |
| n | 9 | 3 | | | 12 | | |
| Balanced | 67% | | 0% | | | | 50% |
| Exhaust only | 22% | | 67% | | | | 33% |
| Supply only | 11% | | | 0% | | 8% | |
| Air Cycler | 0% | | | 33% | | 8% | |

Table 19: Mechanical Ventilation Controls

(On-site visits: Mechanical Ventilation Systems)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 9 | 3 | 12 |
| Local Switch | 67% | 0% | 50% |
| Timer | 11% | 100% | 33% |
| Dehumidistat | 22% | 0% | 17% |

* + 1. Walls

Table 20: Conditioned to Ambient Wall R-value

(On-site visits: All Homes with Verified R-values)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 25 | 34 | 59 |
| Mean | 23.1 | 21.7 | 22.3 |
| Min | 19.0 | 19.0 | 19.0 |
| Max | 45.0 | 33.0 | 45.0 |
| Median | 21.0 | 21.0 | 21.0 |
| Standard Deviation | 5.2 | 3.1 | 4.2 |
| CV | 0.2 | 0.1 | 0.2 |
| Conf. Int. | (21.0, 25.4) | (21.0, 25.4) | (19.5, 25.4) |

Table 21: Conditioned to Ambient Wall Insulation Type

(On-site visits: All Homes)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 25 | 34 | 59 |
| FGB | 47% | 86% | 68% |
| CCF Spray Foam | 21% | 10% | 15% |
| Rock Wool, Board and XPS (Pink/Blue/Green) | 10% | 0% | 5% |
| EPS (Styrofoam) | 9% | 0% | 4% |
| OCF Spray Foam | 6% | 0% | 3% |
| FGB and CCF Spray Foam | 4% | 0% | 2% |
| FGB and XPS (Pink/Blue/Green) | 0% | 4% | 2% |
| Rock Wool, Board | 3% | 0% | 1% |

Table 22: Homes Using Continuous Insulation in Majority of Wall Area

(On-site visits: All Homes)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 25 | 34 | 59 |
| No | 88% | 97% | 93% |
| Yes | 12% | 3% | 7% |

Table 23: Conditioned to Ambient Wall Insulation Grade

(On-site visits: All Homes)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 25 | 34 | 59 |
| 1 (Best) | 64% | 56% | 60% |
| 2 (Typical) | 24% | 28% | 26% |
| 3 (Poor) | NA | NA | NA |
| Unknown | 12% | 16% | 14% |

Table 24: R-values for Walls to Buffer Spaces

(On-site visits: Homes with Buffer Walls)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 19 | 31 | 50 |
| Mean | 18.1 | 18.5 | 18.4 |
| Min | 2.6 | 1.3 | 1.3 |
| Max | 25.0 | 33.0 | 33.0 |
| Median | 21.0 | 21.0 | 21.0 |
| Standard Deviation | 6.5 | 6.8 | 6.7 |
| CV | 0.4 | 0.4 | 0.4 |
| Conf. Int. | (7.9, 24.0) | (21.0, 25.4) | (4.1, 24.0) |

* + 1. Ceilings

Table 25: Average Flat Ceiling R-value

(On-site visits: All Homes with Flat Ceilings)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 12 | 32 | 44 |
| Mean | 40.2 | 39.5 | 39.7 |
| Min | 35.4 | 32.4 | 32.4 |
| Max | 50.0 | 50.0 | 50.0 |
| Median | 38.0 | 38.7 | 38.0 |
| Std. Dev. | 4.4 | 9.8 | 8.7 |
| CV | 0.1 | 0.2 | 0.2 |
| Conf. Int. | (38.0, 45.5) | (37.8, 49.0) | (35.4, 49.2) |

Table 26: Primary Flat Ceiling Insulation Type

(On-site visits: All Homes with Flat Ceilings)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 12 | 32 | 44 |
| FGB | 77% | 48% | 57% |
| Fiberglass, loose fill | 9% | 24% | 20% |
| Cellulose, loose fill | 7% | 20% | 16% |
| FGB and Cellulose, Loose Fill | 7% | 0% | 2% |
| None | 0% | 8% | 5% |

Table 27: Flat Ceiling Insulation Grade

(On-site visits: All Homes with Flat Ceilings)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 12 | 32 | 44 |
| 1 (Best) | 45% | 54% | 51% |
| 2 (Typical) | 46% | 33% | 36% |
| 3 (Poor) | 9% | 6% | 7% |

Table 28: Average Vaulted Ceiling R-value

(On-site visits: All Homes with Vaulted Ceilings)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 14 | 8 | 22 |
| Mean | 48.8 | 31.3 | 42.5 |
| Min | 30.0 | 11.5 | 11.5 |
| Max | 80.0 | 48.0 | 80.0 |
| Median | 44.4 | 30.0 | 40.5 |
| Std. Dev. | 14.8 | 10.8 | 15.9 |
| CV | 0.3 | 0.3 | 0.4 |
| Conf. Int. | (38.0, 72.5) | (16.3, 45.0) | (30.0, 57.5) |

Table 29: Primary Vaulted Ceiling Insulation Type

(On-site visits: All Homes with Vaulted Ceilings)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 14 | 8 | 22 |
| FGB | 30% | 74% | 39% |
| CCF Spray Foam | 52% | 26% | 46% |
| CCF Spray Foam, FGB | 9% | 0% | 7% |
| OCF Spray Foam | 9% | 0% | 7% |

Table 30: Vaulted Ceiling Insulation Grade

(On-site visits: All Homes with Vaulted Ceilings)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 14 | 8 | 22 |
| 1 (Best) | 88% | 67% | 83% |
| 2 (Typical) | 12% | 33% | 17% |
| 3 (Poor) | NA | NA | NA |

* + 1. Floors

Table 31: Average R-Value of Insulated Floors between Conditioned & Buffer

(On-site visits: All Homes with Floors over Unconditioned Spaces)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 20 | 32 | 52 |
| Mean | 30.1 | 31.5 | 31.0 |
| Min | 0.0 | 19.0 | 1.1 |
| Max | 47.5 | 45.0 | 47.5 |
| Median | 30.0 | 30.0 | 30.0 |
| Std. Dev. | 11.5 | 5.2 | 8.3 |
| CV | 0.4 | 0.2 | 0.3 |
| Conf. Int. | (14.1, 40.5) | (29.4, 38.0) | (19.0, 38.0) |

Table 32: Floor Insulation Type between Conditioned & Buffer

(On-site visits: All Homes with Floors over Unconditioned Spaces)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 20 | 32 | 52 |
| FGB | 46% | 83% | 68% |
| Rock Wool | 45% | 17% | 28% |
| None | 6% | NA | 3% |
| CCF Spray Foam | 2% | NA | 1% |
| CCF Spray Foam and FGB | 1% | NA | <1% |

Table 33: Average R-Value of Insulated Floors between Conditioned & Unconditioned Basement

(On-site visits: All Homes with Floors over Unconditioned Spaces)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 15 | 27 | 42 |
| Mean | 28.8 | 30.5 | 29.9 |
| Min | 0.0 | 19.0 | 0.0 |
| Max | 58.0 | 38.0 | 58.0 |
| Median | 30.0 | 30.0 | 30.0 |
| Std. Dev. | 16.1 | 4.7 | 10.2 |
| CV | 0.6 | 0.2 | 0.3 |
| Conf. Int. | (21.5, 40.5) | (21.5, 38.0) | (19.0, 38.0) |

Table 34: Floor Insulation Type between Conditioned & Unconditioned Basement

(On-site visits: All Homes with Floors over Unconditioned Spaces)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 15 | 27 | 42 |
| FGB | 42% | 85% | 68% |
| Rock wool | 47% | 15% | 28% |
| None | 9% | NA | 4% |
| CCF spray foam and FGB | 2% | NA | 1% |

* + 1. Foundation Walls

Table 35: Cavity Insulation in Conditioned Foundation Walls

(On-site visits: All Conditioned Foundation Walls)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 42 | 49 | 91 |
| FGB | 60% | 57% | 58% |
| CCF Spray Foam (High Density) | 12% | 0% | 5% |
| None | 29% | 43% | 36% |

Table 36: Continuous Insulation in Conditioned Foundation Walls

(On-site visits: All Conditioned Foundation Walls)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 42 | 49 | 91 |
| None | 100% | 88% | 93% |
| Polyisocyanurate (foil faced) | 0% | 12% | 7% |

Table 37: Conditioned Foundation Wall Insulation Grade

(On-site visits: All Conditioned Foundation Walls)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 42 | 49 | 91 |
| 1 (Best) | 69% | 10% | 37% |
| 2 (Typical) | 0% | 37% | 20% |
| 3 (Poor) | 0% | 10% | 5% |
| No Cavity Insulation | 31% | 43% | 37% |

Table 38: Average R-value of Conditioned Basement Wall Insulation

(On-site visits: All Conditioned Foundation Walls)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 42 | 49 | 91 |
| Mean | 13.6 | 10.6 | 12.0 |
| Min | 0.0 | 0.0 | 0.0 |
| Max | 24.0 | 21.0 | 24.0 |
| Median | 17.0 | 13.0 | 13.0 |
| Std. Dev. | 9.4 | 8.0 | 8.8 |
| CV | 0.69 | 0.76 | 0.73 |
| Conf. Int. | (11.3, 16.0) | (8.7, 12.5) | (10.5, 13.5) |
|  |  |  |  |

* + 1. Slabs

Table 39: Slab Location

(On-site visits: Slabs)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 14 | 16 | 30 |
| Below grade | 64% | 69% | 67% |
| On grade | 36% | 31% | 33% |

Table 40: Presence of Slab Radiant Floor

(On-site visits: Slabs)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 14 | 16 | 30 |
| No | 79% | 100% | 90% |
| Yes | 21% | 0% | 10% |

Table 41: Presence of Slab Insulation

(On-site visits: Slabs)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 14 | 16 | 30 |
| No Insulation or Unconfirmed | 93% | 100% | 97% |
| Insulation Confirmed\* | 7% | 0% | 3% |

\*Only one home was confirmed to have slab insulation, 2 inches of XPS at the perimeter, R10.

* + 1. Windows

**Table 42: Average Window U-factor (Confirmed Values Only)**

(On-site visits: Homes with Confirmed Window U-Factors)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 69 | 26 | 95 |
| Mean | 0.29 | 0.30 | 0.29 |
| Min | 0.23 | 0.27 | 0.23 |
| Max | 0.32 | 0.34 | 0.34 |
| Median | 0.30 | 0.30 | 0.30 |
| Std. Dev. | 0.03 | 0.02 | 0.03 |
| CV | 0.11 | 0.06 | 0.10 |
| Conf. Int. | (0.28, 0.30) | (NA, NA) | (NA, NA) |

**Table 43: Average Window SHGC (Confirmed Values Only)**

(On-site visits: Homes with Confirmed Window SHGC)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 69 | 23 | 92 |
| Mean | 0.29a | 0.27 | 0.29 |
| Min | 0.27 | 0.24 | 0.24 |
| Max | 0.37 | 0.54 | 0.54 |
| Median | 0.28 | 0.24 | 0.28 |
| Std. Dev. | 0.03 | 0.06 | 0.04 |
| CV | 0.09 | 0.24 | 0.14 |
| Conf. Int. | (0.29, 0.30) | (NA, NA) | (NA, NA) |

**Table 44: Glazing Type (Percentage of Total Window Area)**

(On-site visits: Total Window Area)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n (Window Square Footage) | 11,780 | 9,818 | 21,598 |
| Double Pane, low-E | 78% | 66% | 73% |
| Double Pane, low-E, argon | 9% | 20% | 14% |
| Triple Pane, low-E, argon | 11% | 4% | 8% |
| Double Pane | 2% | 9% | 5% |
| Single Pane | 0% | <1% | <1% |

**Table 45: Window Frame Type**

(On-site visits: Windows)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 366 | 382 | 748 |
| Vinyl | 69% | 91% | 80% |
| Wood | 21% | 7% | 14% |
| Fiberglass | 6% | 0% | 3% |
| Metal, thermal break | 4% | 0% | 2% |
| Metal | 0% | 2% | 1% |

**Table 46: Glazing Percentage**

(On-site visits: All Homes)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 25 | 34 | 59 |
| Mean | 19%a | 14% | 16% |
| Min | 3% | 7% | 3% |
| Max | 88% | 25% | 88% |
| Median | 17% | 13% | 14% |
| Std. Dev. | 15% | 4% | 11% |
| CV | 79% | 33% | 67% |
| Conf. Int. | (14%, 25%) | (13%, 15%) | (14%, 19%) |

* 1. Mechanical Equipment
     1. Heating

Table 47: Primary Heating System

(On-site visits: All Homes)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 25 | 34 | 59 |
| Furnace | 56%a | 94% | 78% |
| Boiler (forced hot water) | 12% | 0% | 5% |
| Boiler (hydro-air) | 12% | 0% | 5% |
| ASHP | 4% | 3% | 3% |
| GSHP-closed loop | 8% | 0% | 3% |
| Mini-split | 8% | 0% | 3% |
| Electric baseboard | 0% | 3% | 2% |

Table : Primary Heating Efficiency (AFUE)

(On-site visits: Primary heating systems with AFUE rating)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 18 | 32 | 50 |
| Mean | 94.5 | 95.0 | 94.9 |
| Min | 80.0 | 85.0 | 80.0 |
| Max | 97.3 | 96.5 | 97.3 |
| Median | 96.0 | 96.0 | 96.0 |
| Std. Dev. | 3.9 | 2.3 | 2.9 |
| CV | 0.04 | 0.02 | 0.03 |
| Conf. Int. | (93.0, 96.0) | (94.4, 95.7) | (94.2, 95.5) |

Table 49: Primary Heating System Fuel

(On-site visits: All Homes)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 25 | 34 | 59 |
| Natural Gas | 32% | 53% | 44% |
| Propane | 40% | 38% | 39% |
| Electric | 20% | 6% | 12% |
| Wood - logs | 8% | 0% | 3% |
| Oil | 0% | 3% | 2% |

Table 50: Primary Heating System Location

(On-site visits: All Homes)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 25 | 34 | 59 |
| Uncond. basement/ enc. crawlspace | 52% | 68% | 61% |
| Conditioned area | 24% | 24% | 24% |
| Vaulted, IV only attic | 8% | 3% | 5% |
| Vented Attic | 4% | 6% | 5% |
| Garage | 8% | 0% | 3% |
| Ambient | 4% | 0% | 2% |
|  |  |  |  |

Table 51: Primary Heating System ENERGY STAR Status

(On-site visits: All Homes)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 25 | 33 | 58 |
| Yes | 80% | 85% | 83% |
| No | 20% | 15% | 17% |

Table 52: Secondary Heating System Equipment Type

(On-site visits: Secondary Heating Systems)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 13 | 8 | 21 |
| Furnace | 31% | 50% | 38% |
| Mini-split | 31% | 0% | 19% |
| Boiler (forced hot water) | 15% | 12% | 14% |
| Fireplace insert/Wood stove | 0% | 38% | 14% |
| ASHP | 8% | 0% | 5% |
| Electric baseboard | 8% | 0% | 5% |
| GSHP-closed loop | 8% | 0% | 5% |

Table 53: All Heating System Fuel

(On-site visits: All Heating Systems)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 42 | 47 | 89 |
| Propane | 32% | 35% | 33% |
| Electric | 31% | 15% | 23% |
| Natural Gas | 24% | 48% | 37% |
| Wood - logs | 10% | 0% | 5% |
| Oil | 2% | 2% | 2% |

Table 54: All Heating System Type

(On-site visits: All Heating Systems)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 42 | 47 | 89 |
| Furnace | 43% | 77% | 61% |
| Fireplace/woodstove | 10% | 11% | 10% |
| Boiler (forced hot water) | 12% | 2% | 7% |
| Mini-split | 14% | 0% | 7% |
| ASHP | 5% | 2% | 3% |
| Boiler (hydro-air) | 7% | 0% | 3% |
| Electric baseboard | 2% | 4% | 3% |
| GSHP-closed loop | 7% | 0% | 3% |
| Portable space heater | 0% | 4% | 2% |

Table 55: All Heating System Efficiency (AFUE)

(On-site visits: All Heating Systems with AFUE Rating)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 24 | 37 | 61 |
| Mean | 94.4 | 95.0 | 94.8 |
| Min | 80.0 | 85.0 | 80.0 |
| Max | 97.3 | 96.5 | 97.3 |
| Median | 96.0 | 96.0 | 96.0 |
| Standard Deviation | 3.7 | 2.2 | 2.9 |
| CV | 0.04 | 0.02 | 0.03 |
| Conf. Int. | (93.2, 95.7) | (94.5, 95.6) | (94.2, 95.4) |

Table : Furnace Fuel

(On-site visits: Furnaces)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 18 | 36 | 54 |
| Natural Gas | 39% | 56% | 50% |
| Propane | 61% | 42% | 48% |
| Oil | 0% | 3% | 2% |

Table : Furnace Efficiency (AFUE)

(On-site visits: Furnaces with AFUE Rating)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 18 | 36 | 54 |
| Mean | 94.7 | 95.0 | 94.9 |
| Min | 80.0 | 85.0 | 80.0 |
| Max | 97.3 | 96.5 | 97.3 |
| Median | 96.0 | 96.0 | 96.0 |
| Std. Dev. | 3.9 | 2.2 | 2.9 |
| CV | 0.04 | 0.02 | 0.03 |
| Conf. Int. | (93.2, 96.2) | (94.4, 95.7) | (94.3, 95.6) |
|  |  |  |  |

Table 58: Natural Gas Furnace Efficiency (AFUE)

(On-site visits: Furnaces with AFUE Rating)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 7 | 20 | 27 |
| Mean | 95.1 | 94.9 | 94.9 |
| Min | 92.0 | 92.1 | 92.0 |
| Max | 96.0 | 96.5 | 96.5 |
| Median | 96.0 | 96.0 | 96.0 |
| Std. Dev. | 1.5 | 1.7 | 1.6 |
| CV | 0.02 | 0.02 | 0.02 |
| Conf. Int. | (94.2, 96.1) | (94.2, 95.5) | (94.4, 95.4) |

Table : Propane Furnace Efficiency (AFUE)

(On-site visits: Furnaces with AFUE Rating)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 11 | 15 | 26 |
| Mean | 94.4 | 96.0 | 95.3 |
| Min | 80.0 | 95.0 | 80.0 |
| Max | 97.3 | 96.3 | 97.3 |
| Median | 96.0 | 96.0 | 96.0 |
| Std. Dev. | 5.0 | 0.3 | 3.2 |
| CV | 0.05 | 0.00 | 0.03 |
| Conf. Int. | (92.0, 96.9) | (95.9, 96.1) | (94.3, 96.4) |

Table 60: Furnace ENERGY STAR Status

(On-site visits: Furnaces)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| N | 18 | 36 | 54 |
| Yes | 84% | 86% | 85% |
| No | 17% | 14% | 15% |

Table : Boiler Efficiency (AFUE)

(On-site visits: Boilers)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 6 | 1 | 7 |
| Mean | 93.7 | 95.0 | 93.9 |
| Min | 87.0 | 95.0 | 87.0 |
| Max | 95.0 | 95.0 | 95.0 |
| Median | 95.0 | 95.0 | 95.0 |
| Std. Dev. | 3.3 | NA | 3.0 |
| CV | 0.03 | NA | 0.03 |

Table : Boiler Fuel

(On-site visits: Boilers)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 6 | 1 | 7 |
| Natural Gas | 50% | 0% | 43% |
| Propane | 33% | 100% | 43% |
| Oil | 17% | 0% | 14% |

Table : Boiler ENERGY STAR Status

(On-site visits: Boilers)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 6 | 1 | 7 |
| Yes | 100% | 100% | 100% |
| No | 0% | 0% | 0% |

Table 64: Heat Pump Efficiency (HSPF)

(On-site visits and Survey: MSHPs and ASHPs with HSPF Rating)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 8 | 1 | 9 |
| Mean | 10.6 | 9.8 | 10.5 |
| Min | 10.3 | 9.8 | 9.8 |
| Max | 11.0 | 9.8 | 11.0 |
| Median | 10.6 | 9.8 | 10.5 |
| Standard Deviation | 0.3 | NA | 0.4 |
| CV | NA | NA | NA |
| Conf. Int. | (10.5,10.8) | NA | (10.3,10.7) |

Table 65: All System Efficiency (HSPF Conversion)

(On-site visits: All heating system efficiencies converted to HSPF)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 32 | 38 | 70 |
| Mean | 10.3 | 10.2 | 10.3 |
| Min | 8.6 | 9.2 | 8.6 |
| Max | 11.0 | 10.4 | 11.0 |
| Median | 10.4 | 10.4 | 10.4 |
| Standard Deviation | 0.4 | 0.2 | 0.3 |
| CV | 0.04 | 0.02 | 0.03 |
| Conf. Int. | (10.2,10.4) | (10.2,10.3) | (10.2,10.3) |
|  |  |  |  |

* + 1. Cooling

Table 66: Primary Cooling System Type

(On-site visits: All Homes)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 25 | 34 | 59 |
| Central Air-split | 72%a | 94% | 85% |
| Mini-split | 12% | 3% | 7% |
| GSHP-closed loop | 8% | 0% | 3% |
| Room Air Conditioner | 4% | 3% | 3% |
| ASHP | 4% | 0% | 2% |

Table 67: Primary Cooling System Location

(On-site visits: Primary Cooling Systems)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 25 | 34 | 59 |
| Unconditioned basement/ enclosed crawlspace | 40% | 65% | 54% |
| Conditioned area | 32% | 26% | 29% |
| Vented attic | 12% | 6% | 8% |
| Vaulted, IV only attic | 12% | 3% | 7% |
| Garage | 4% | 0% | 2% |

Table 68: Primary Cooling System ENERGY STAR Status

(On-site visits: Primary Cooling Systems)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 25 | 31 | 56 |
| Yes | 52% | 48% | 50% |
| No | 48% | 52% | 50% |

Table 69: Primary Cooling System Efficiency (SEER)

(On-site visits: Primary Cooling Systems)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 22 | 32 | 54 |
| Mean | 15.5 | 14.2 | 14.7 |
| Min | 13.0 | 13.0 | 13.0 |
| Max | 22.5 | 20.0 | 22.5 |
| Median | 14.8 | 14.0 | 14.0 |
| Std. Dev. | 2.7 | 1.3 | 2.1 |
| CV | 0.18 | 0.09 | 0.14 |
| Conf. Int. | (14.5, 16.4) | (13.8, 14.5) | (14.2, 15.2) |

Table 70: All Cooling System Efficiency (SEER)

(On-site visits : Cooling Systems with SEER Value)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 32 | 37 | 69 |
| Mean | 15.7a | 14.2 | 14.9 |
| Min | 13.0 | 13.0 | 13.0 |
| Max | 22.5 | 20.0 | 22.5 |
| Median | 14.5 | 14.0 | 14.0 |
| Std. Dev. | 3.0 | 1.2 | 2.3 |
| CV | 0.19 | 0.09 | 0.16 |
| Conf. Int. | (14.8, 16.6) | (13.8, 14.5) | (14.4, 15.3) |

Table 71: Central Air Conditioner Efficiency (SEER)

(On-site visits: Central ACs with SEER Rating)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 24 | 34 | 58 |
| Mean | 14.2 | 14.0 | 14.1 |
| Min | 13.0 | 13.0 | 13.0 |
| Max | 17.5 | 15.0 | 17.5 |
| Median | 14.0 | 14.0 | 14.0 |
| Std. Dev. | 1.3 | 0.7 | 1.0 |
| CV | 0.09 | 0.05 | 0.07 |
| Conf. Int. | (13.8, 14.6) | (13.8, 14.2) | (13.9, 14.3) |

Table 72: Central Air Conditioner ENERGY STAR Status

(On-site visits: Central Air Conditioners)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 24 | 34 | 58 |
| No | 75% | 50% | 60% |
| Yes | 25% | 50% | 40% |

Table 73: Heat Pump Cooling Efficiency (SEER)

(On-site visits and Survey: MSHPs and ASHPs with SEER Rating)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 8 | 1 | 9 |
| Mean | 20.1 | 20.0 | 20.1 |
| Min | 17.8 | 20.0 | 17.8 |
| Max | 22.5 | 20.0 | 22.5 |
| Median | 20.0 | 20.0 | 20.0 |
| Std. Dev. | 1.8 | NA | 1.7 |
| CV | 0.09 | NA | 0.08 |
| Conf. Int. | (19.1, 21.2) | (NA, NA) | (19.2, 21.0) |

Table 74: Heat Pump ENERGY STAR Status

(On-site visits: Heat Pumps)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 8 | 1 | 9 |
| Yes | 100% | 0% | 89% |
| No | 0% | 100% | 11% |

Table 75: Ductless MSHP Cooling Efficiency (SEER)

(On-site visits and Survey: Ductless MSHPs with SEER Rating)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 6 | 0 | 6 |
| Mean | 20.2 | – | 20.2 |
| Min | 17.8 | – | 17.8 |
| Max | 22.5 | – | 22.5 |
| Median | 20.2 | – | 20.2 |
| Std. Dev. | 2.1 | – | 2.1 |
| CV | 0.10 | – | 0.10 |
| Conf. Int. | (18.8, 21.6) | – | (18.8, 21.6) |

Table 76: ASHP Cooling Efficiency (SEER)

(On-Sites and Survey: ASHPs with SEER Rating)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 2 | 1 | 3 |
| Mean | 20.0 | 20.0 | 20.0 |
| Min | 20.0 | 20.0 | 20.0 |
| Max | 20.0 | 20.0 | 20.0 |
| Median | 20.0 | 20.0 | 20.0 |
| Std. Dev. | 0.0 | NA | 0.0 |
| CV | 0.00 | NA | 0.00 |
| Conf. Int. | (20.0, 20.0) | (NA, NA) | (20.0, 20.0) |

There were two room air conditioners found during on-site visits, one was ENERGY STAR certified. They both had an EER of 10.8.

* + 1. Thermostats

Table 77: Thermostat Type

(On-site visits: Thermostats)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 50 | 56 | 106 |
| Programmable | 46% | 66% | 57% |
| Smart | 24% | 18% | 21% |
| Programmable + Wi-Fi | 22% | 4% | 12% |
| Manual | 8% | 13% | 10% |

Table 78: Winter Set Point

(On-site visits: Thermostats with Verified Winter Set Points)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 46 | 51 | 97 |
| Mean | 68.1 | 69.1 | 68.7 |
| Min | 55 | 65 | 55 |
| Max | 75 | 76 | 76 |
| Median | 68 | 68 | 68 |
| Standard Deviation | 4.0 | 2.3 | 3.2 |

Table 79: Summer Set Point

(On-site visits: Thermostats with Verified Summer Set Points)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 46 | 51 | 97 |
| Mean | 72.6 | 72 | 72.3 |
| Min | 66 | 66 | 66 |
| Max | 80 | 80 | 80 |
| Median | 73 | 72 | 72 |
| Standard Deviation | 3.0 | 3.0 | 3.0 |

* + 1. Ducts

Table 80: Duct Materials

(On-site visits: Duct branches)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 88 | 126 | 214 |
| Metal | 49% | 53% | 51% |
| Flex Duct | 51% | 47% | 49% |

Table 81: Duct Locations

(On-site visits: Duct branches)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 88 | 126 | 214 |
| Unconditioned basement | 22% | 36% | 30% |
| Conditioned 1-3 floor | 18% | 25% | 22% |
| Vented attic | 18% | 19% | 19% |
| Conditioned basement | 17% | 14% | 15% |
| Vaulted, IV only attic | 16% | 5% | 9% |
| Enclosed crawlspace | 7% | 0% | 3% |
| Vented attic, under insulation | 1% | 2% | 1% |
| Garage | 1% | 0% | 0% |

Table 82: Duct Insulation Type

(On-site visits: Duct branches)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 88 | 126 | 214 |
| Fiberglass wrap | 60% | 69% | 65% |
| Bubble wrap, tight | 35% | 25% | 29% |
| None | 5% | 7% | 6% |

Table 83: Unconditioned Duct Insulation Type

(On-site visits: Duct branches in unconditioned spaces)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 42 | 69 | 111 |
| Fiberglass wrap | 57% | 72% | 67% |
| Bubble wrap, tight | 43% | 23% | 31% |
| None | 0% | 4% | 3% |

Table 84: All Duct Insulation R-Value

(On-site visits: Duct branches)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 88 | 125 | 213 |
| Mean | 5.8 | 6.0 | 5.9 |
| Min | 0.0 | 0.0 | 0.0 |
| Max | 8.0 | 8.2 | 8.2 |
| Median | 6.0 | 6.0 | 6.0 |
| Std. Dev. | 2.0 | 2.1 | 2.1 |
| CV | 0.34 | 0.35 | 0.35 |
| Conf. Int. | (5.4, 6.1) | (NA, NA) | (NA, NA) |

Table 85: Unconditioned Duct Insulation R-Value

(On-site visits: Duct branches in unconditioned space)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 42 | 69 | 111 |
| Mean | 6.1 | 6.2 | 6.2 |
| Min | 4.0 | 0.0 | 0.0 |
| Max | 8.0 | 8.2 | 8.2 |
| Median | 6.0 | 6.0 | 6.0 |
| Std. Dev. | 1.8 | 2.0 | 1.9 |
| CV | 0.29 | 0.32 | 0.31 |
| Conf. Int. | (5.6, 6.5) | (5.8, 6.6) | (5.9, 6.5) |

Table 86: Attic Supply Duct Insulation R-Value

(On-site visits: Attic supply duct branches)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 17 | 26 | 43 |
| Mean | 6.8 | 6.6 | 6.7 |
| Min | 4.0 | 0.0 | 0.0 |
| Max | 8.0 | 8.0 | 8.0 |
| Median | 8.0 | 8.0 | 8.0 |
| Std. Dev. | 1.7 | 1.9 | 1.8 |
| CV | 0.26 | 0.29 | 0.28 |
| Conf. Int. | (6.1, 7.5) | (6.0, 7.2) | (6.2, 7.2) |

Table 87: Non-Attic Unconditioned Duct Insulation R-Value

(On-site visits: Non-attic unconditioned duct branches)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 26 | 45 | 71 |
| Mean | 5.6 | 6.1 | 5.9 |
| Min | 4.0 | 0.0 | 0.0 |
| Max | 8.0 | 8.2 | 8.2 |
| Median | 6.0 | 6.0 | 6.0 |
| Std. Dev. | 1.6 | 2.0 | 1.9 |
| CV | 0.29 | 0.33 | 0.31 |
| Conf. Int. | (5.1, 6.1) | (5.6, 6.5) | (5.5, 6.3) |

Table 88: Total Duct Leakage

(On-site visits: Duct Systems, CFM25 per 100 Sq. Ft. Floor Area)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 22 | 29 | 51 |
| Mean | 22.0 | 20.0 | 20.9 |
| Min | 5.9 | 5.9 | 5.9 |
| Max | 46.7 | 54.4 | 54.4 |
| Median | 24.4 | 16.2 | 17.9 |
| Std. Dev. | 13.0 | 12.1 | 12.4 |
| CV | 0.59 | 0.60 | 0.59 |
| Conf. Int. | (NA, NA) | (NA, NA) | (NA, NA) |

Table 89: Duct Leakage to the Outside

(On-site visits: Duct Systems, CFM25 per 100 Sq. Ft. Floor Area)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 25 | 31 | 56 |
| Mean | 4.1 | 5.1 | 4.6 |
| Min | 0.0 | 0.0 | 0.0 |
| Max | 26.3 | 27.1 | 27.1 |
| Median | 2.1 | 3.6 | 3.2 |
| Std. Dev. | 5.8 | 5.3 | 5.5 |
| CV | 1.44 | 1.05 | 1.20 |
| Conf. Int. | (2.1, 6.0) | (3.5, 6.7) | (3.4, 5.9) |

* + 1. Domestic Hot Water

Table 90: Water Heater Type

(On-site visits: Water Heaters)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 28 | 35 | 63 |
| Instantaneous | 36% | 40% | 38% |
| Storage, stand-alone | 29% | 40% | 35% |
| HPWH | 7% | 17% | 13% |
| Storage, indirect heat | 18% | 3% | 10% |
| Instantaneous, combi boiler | 11% | 0% | 5% |

Table 91: Water Heater Fuel

(On-site visits: Water Heaters)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 28 | 35 | 63 |
| Natural Gas | 29% | 37% | 33% |
| Electricity | 29% | 34% | 32% |
| Propane | 39% | 26% | 32% |
| Oil | 0% | 3% | 2% |
| Wood - logs | 4% | 0% | 2% |

Table 92: Water Heater Location

(On-site visits: Water Heaters)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 28 | 35 | 63 |
| Uncond. basement | 57% | 80% | 70% |
| Cond. basement | 25% | 9% | 16% |
| Cond. 1-3 floor | 11% | 11% | 11% |
| Enc. crawlspace | 4% | 0% | 2% |
| Garage | 4% | 0% | 2% |

Table 93: Water Heater Storage Tank Sizes

(On-site visits: All Storage Tanks Including Standalone, Heat Pump, and Indirect)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 15 | 21 | 36 |
| <40 | 0% | 10% | 6% |
| 40 to 49 | 27% | 14% | 19% |
| 50 to 59 | 40% | 62% | 53% |
| 60 to 79 | 13% | 5% | 8% |
| 80 or greater | 20% | 10% | 14% |

Table 94: ENERGY STAR Status

(On-site visits and Survey: Water Heaters Excluding Indirect)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 28 | 35 | 63 |
| Yes | 75% | 66% | 70% |
| No | 25% | 34% | 30% |

Table 95: All Water Heater Efficiency (EF)

(On-site visits: All Water Heaters with EF or Converted UEF)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 28 | 35 | 63 |
| Mean | 1.12 | 1.33 | 1.24 |
| Min | 0.66 | 0.64 | 0.64 |
| Max | 4.09 | 3.57 | 4.09 |
| Median | 0.93 | 0.93 | 0.93 |
| Std. Dev. | 0.83 | 1.04 | 0.95 |
| CV | 0.74 | 0.78 | 0.77 |
| Conf. Int. | (0.86, 1.38) | (1.04, 1.61) | (1.04, 1.43) |

Table 96: All Water Heater Recovery Efficiency

(On-site visits: All Water Heaters)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 28 | 35 | 63 |
| Mean | 1.18 | 1.35 | 1.27 |
| Min | 0.78 | 0.71 | 0.71 |
| Max | 4.34 | 4.07 | 4.34 |
| Median | 0.96 | 0.97 | 0.97 |
| Std. Dev. | 0.89 | 1.03 | 0.97 |
| CV | 0.75 | 0.77 | 0.76 |
| Conf. Int. | (0.91, 1.46) | (1.06, 1.63) | (1.07, 1.47) |

Table 97: Electric Water Heater Efficiency (EF)

(On-site visits: Electric Water Heaters, Including HPWH)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 8 | 12 | 20 |
| Mean | 1.66 | 2.27 | 2.03 |
| Min | 0.66 | 0.95 | 0.66 |
| Max | 4.09 | 3.57 | 4.09 |
| Median | 0.93 | 2.25 | 1.00 |
| Std. Dev. | 1.48 | 1.35 | 1.40 |
| CV | 0.89 | 0.60 | 0.69 |
| Conf. Int. | (0.80, 2.53) | (1.63, 2.91) | (1.51, 2.54) |

Table 98: Fossil Fuel Water Heater Efficiency (EF)

(On-site visits: Fossil Fuel Fired Water Heaters)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 19 | 22 | 41 |
| Mean | 0.91 | 0.85 | 0.88 |
| Min | 0.68 | 0.64 | 0.64 |
| Max | 0.97 | 0.97 | 0.97 |
| Median | 0.95 | 0.92 | 0.93 |
| Std. Dev. | 0.07 | 0.12 | 0.10 |
| CV | 0.08 | 0.14 | 0.12 |
| Conf. Int. | (0.89, 0.94) | (0.80, 0.89) | (0.85, 0.90) |

Table 99: Instantaneous Water Heater Efficiency (EF)

(On-site visits: Instantaneous Water Heaters, Including Combi Boilers)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 13 | 14 | 27 |
| Mean | 0.95a | 0.92 | 0.93 |
| Min | 0.89 | 0.81 | 0.81 |
| Max | 0.97 | 0.97 | 0.97 |
| Median | 0.95 | 0.93 | 0.95 |
| Std. Dev. | 0.02 | 0.05 | 0.04 |
| CV | 0.02 | 0.05 | 0.04 |
| Conf. Int. | (0.94, 0.96) | (0.90, 0.94) | (0.92, 0.95) |

Table 100: Heat Pump Water Heater Efficiency (EF)

(On-site visits: HPWHs)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 2 | 6 | 8 |
| Mean | 4.06 | 3.56 | 3.68 |
| Min | 4.03 | 3.50 | 3.50 |
| Max | 4.09 | 3.57 | 4.09 |
| Median | 4.06 | 3.57 | 3.57 |
| Std. Dev. | 0.04 | 0.03 | 0.23 |
| CV | 0.01 | 0.01 | 0.06 |
| Conf. Int. | (4.01, 4.11) | (3.54, 3.58) | (3.55, 3.82) |

Table 101: Indirect Water Heater Efficiency (EF)

(On-site visits: Indirect Water Heaters)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Custom | Spec | | Statewide | |
| n | 5 | 1 | | 6 | |
| Mean | 0.84 | 0.87 | | 0.84 | |
| Min | 0.72 | 0.87 | | 0.72 | |
| Max | 0.87 | 0.87 | | 0.87 | |
| Median | 0.87 | 0.87 | | 0.87 | |
| Std. Dev. | 0.07 | NA | | 0.06 | |
| CV | 0.08 | | NA | | 0.07 |
| Conf. Int. | (0.79, 0.89) | | (NA, NA) | | (0.80, 0.89) |

**Table 102: Electric Resistance Storage Water Heater Efficiency (EF)**

(On-site visits: Electric Resistance Water Heaters)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Custom | | Spec | Statewide |
| n | 6 | | 6 | 12 |
| Mean | 0.87a | | 0.97 | 0.92 |
| Min | 0.66 | | 0.95 | 0.66 |
| Max | 1.00 | | 1.00 | 1.00 |
| Median | 0.91 | | 0.97 | 0.95 |
| Std. Dev. | 0.12 | | 0.03 | 0.10 |
| CV | 0.14 | 0.03 | 0.11 | |
| Conf. Int. | (0.78, 0.95) | (0.96, 0.99) | (0.87, 0.97) | |

Table 103: Natural Gas and Propane Storage Water Heater Efficiency (EF)

(On-site visits: Storage Water Heaters, Natural Gas and Propane)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Custom | | Spec | Statewide |
| n | 2 | | 7 | 9 |
| Mean | 0.77 | | 0.69 | 0.71 |
| Min | 0.68 | | 0.64 | 0.64 |
| Max | 0.86 | | 0.72 | 0.86 |
| Median | 0.77 | | 0.70 | 0.70 |
| Std. Dev. | 0.13 | | 0.02 | 0.06 |
| CV | 0.17 | 0.04 | 0.09 | |
| Conf. Int. | (0.62, 0.92) | (0.68, 0.71) | (0.67, 0.74) | |

Table 104: Domestic Hot Water Pipe Insulation

(On-site visits: Water Heaters)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 28 | 35 | 63 |
| Not at all | 57% | 51% | 54% |
| Completely | 36% | 43% | 40% |
| Partially | 7% | 6% | 6% |
|  |  |  |  |

* + 1. Faucet Aerators

Table 105: Flow Rate

(On-site visits: Faucets)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 95 | 137 | 232 |
| Mean | 1.5a | 1.4 | 1.5 |
| Min | 1.2 | 1.2 | 1.2 |
| Max | 2.5 | 2.5 | 2.5 |
| Median | 1.5 | 1.2 | 1.2 |
| Std. Dev. | 0.4 | 0.4 | 0.4 |
| CV | 0.23 | 0.28 | 0.26 |
| Conf. Int. | (1.5, 1.6) | (1.4, 1.5) | (1.4, 1.5) |

Table 106: Presence of Aerator on Faucets

(On-site visits: Faucets)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 184 | 244 | 428 |
| Yes | 98% | 99% | 99% |
| No | 2% | 1% | 1% |

* 1. Renewables and Electric Vehicles

Table 107: Penetration of Renewables and Electrification Measures

(On-site visits: All Homes)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 25 | 34 | 59 |
| Solar PV | 12% | 5% | 10% |
| Electric Vehicle (EV) | 8% | - | 3% |

Table 108: PV System Capacity (kW)

(On-site visits: PV Arrays)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 4 | 4 | 8 |
| Mean | 6.8 | 4.4 | 5.5 |
| Min | 4.1 | 0.6 | 0.6 |
| Max | 10.5 | 8.4 | 10.5 |
| Median | 6.2 | 4.2 | 5.7 |
| Standard Deviation | 3.1 | 4.0 | 3.6 |
| CV | 0.47 | 0.92 | 0.65 |
| Conf. Int. | (4.2, 9.3) | (1.0, 7.7) | (3.5, 7.6) |

* 1. Lighting

Table 109: Lighting Saturation

(On-site visits: Light Sockets)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 1511 | 1749 | 3260 |
| LED Bulb | 46%a | 67% | 58% |
| LED Fixture | 49%a | 29% | 38% |
| Incandescent | 2%a | 3% | 2% |
| Fluorescent | 1% | 1% | 1% |
| CFL | 1%a | 1% | 1% |
| Halogen | 1% | 0% | 1% |

Table : Lighting Penetration

(On-site visits: Homes Containing At Least One of Bulb Type)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 24 | 34 | 58 |
| LED Bulb | 96% | 100% | 98% |
| LED Fixture | 92% | 97% | 95% |
| Incandescent | 46% | 29% | 36% |
| CFL | 29% | 18% | 22% |
| Fluorescent | 21% | 9% | 14% |
| Halogen | 17% | 12% | 14% |

* 1. Appliances
     1. Refrigerators

Table 111: Primary Refrigerator ENERGY STAR Status

(On-site visits: Primary Refrigerators)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 23 | 35 | 58 |
| Yes | 73% | 68% | 70% |
| No | 27% | 32% | 30% |

Table 112: Primary Refrigerator Configuration

(On-site visits and Survey: Primary Refrigerators)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 23 | 35 | 58 |
| Bottom Freezer | 78% | 83% | 81% |
| Side by Side | 13% | 11% | 12% |
| Top Freezer | 9% | 6% | 7% |

Table 113: Primary Refrigerator Volume (ft3)

(On-site visits and Survey: Primary Refrigerators)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 23 | 35 | 58 |
| 20 to 26 | 86% | 86% | 86% |
| 16 to 19 | 14% | 14% | 14% |

Table 114: Primary Refrigerator kWh/Year

(On-site visits and Survey: Primary Refrigerators)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 23 | 35 | 58 |
| Mean | 621 | 650 | 634 |
| Min | 417 | 289 | 289 |
| Max | 776 | 755 | 776 |
| Median | 633 | 667 | 662 |
| Standard Deviation | 102 | 94 | 98 |
| CV | 0.17 | 0.14 | 0.16 |
| Conf. Int. | (575, 645) | (624, 676) | (613, 655) |

Table 115: Secondary Refrigerator Summary

(Base: Secondary Refrigerators)

|  |  |  |  |
| --- | --- | --- | --- |
| ENERGY STAR | Custom | Spec | Statewide |
| n | 12 | 13 | 25 |
| Yes | 50% | 61% | 56% |
| No | 50% | 39% | 44% |
| **Volume (ft3)** | **Custom** | **Spec** | **Statewide** |
| n | 12 | 13 | 25 |
| 20 to 26 | 57% | 42% | 50% |
| 16 to 19 | 29% | 29% | 29% |
| <16 | 14% | 29% | 21% |
| **Age** | **Custom** | **Spec** | **Statewide** |
| n | 12 | 13 | 25 |
| 2022 | 8% | 8% | 8% |
| 2021 | 33% | 23% | 28% |
| 2020 | 8% | 8% | 8% |
| 2019 | 8% | 23% | 16% |
| 2018 | 8% | 8% | 8% |
| 2017 | 17% | 8% | 12% |
| 2016 | 8% | 0% | 4% |
| 2008 | 0% | 8% | 4% |
| 2002 | 0% | 8% | 4% |
| 1998 | 8% | 0% | 4% |
| 1997 | 0% | 8% | 4% |
| **Configuration** | **Custom** | **Spec** | **Statewide** |
| n | 12 | 13 | 25 |
| Top Freezer | 42% | 54% | 48% |
| Bottom Freezer | 17% | 8% | 12% |
| Single Door | 42% | 54% | 48% |
| **kWh** | **Custom** | **Spec** | **Statewide** |
| n | 12 | 13 | 25 |
| Mean | 368 | 329 | 348 |
| Min | 218 | 145 | 145 |
| Max | 608 | 501 | 608 |
| Median | 357 | 328 | 328 |
| Standard Deviation | 124 | 105 | 114 |
| CV | 0.34 | 0.32 | 0.33 |
| Conf. Int. | (309, 427) | (281, 376) | (310, 385) |

* + 1. Freezers

Table 116: Stand-alone Freezer Summary

(On-site visits and Survey: Stand-alone Freezers)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| ENERGY STAR1 | | Custom | Spec | | | Statewide |
| n | | 6 | 8 | | | 14 |
| Yes | | 60% | 50% | | | 54% |
| No | | 40% | 50% | | | 46% |
| **Age** | | **Custom** | **Spec** | | | **Statewide** |
| n | | 6 | 8 | | | 14 |
| 2021 | | 0% | 38% | | | 21% |
| 2020 | | 0% | 25% | | | 14% |
| 2019 | | 17% | 12% | | | 14% |
| 2018 | | 17% | 0% | | | 7% |
| 2016 | | 0% | 12% | | | 7% |
| 2014 | | 67% | 0% | | | 29% |
| 2005 | | 0% | 12% | | | 7% |
| **Volume (ft3)** | | **Custom** | **Spec** | | | **Statewide** |
| n | | 6 | 8 | | | 14 |
| >25 | | 0% | 13% | | | 7% |
| 9 to 25 | | 17% | 49% | | | 36% |
| <9 | | 83% | 38% | | | 57% |
| **Configuration** | | **Custom** | **Spec** | | | **Statewide** |
| n | | 6 | 8 | | | 14 |
| Chest | | 33% | 50% | | | 43$ |
| Upright | | 67% | 50% | | | 57% |
|  | |  |  | | |  |
| **kWh** | **Custom** | | | **Spec** | **Statewide** | |
| n | 6 | | | 8 | 14 | |
| Mean | 369 | | | 377 | 374 | |
| Min | 193 | | | 216 | 193 | |
| Max | 690 | | | 557 | 690 | |
| Median | 258 | | | 424 | 346 | |
| Standard Deviation | 223 | | | 133 | 169 | |
| CV | 0.60 | | | 0.35 | 0.45 | |
| Conf. Int. | (219, 518) | | | (300, 455) | (299, 448) | |

* + 1. Dishwashers

Table 117: Dishwasher ENERGY STAR Status

(On-site visits: Dishwashers with ENERGY STAR Status)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 25 | 34 | 59 |
| Yes | 68% | 77% | 73% |
| No | 32% | 23% | 27% |

Table 118: Dishwasher Capacity

(On-site visits: Dishwashers with Capacity Information)

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Custom** | **Spec** | **Statewide** |
| n | 25 | 34 | 60 |
| Full Size (8+ settings) | 43% | 57% | 100% |

Table 119: Dishwasher Year of Manufacture

(On-site visits: Dishwashers with Age Information)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 25 | 34 | 59 |
| 2005 | 4% | 0% | 2% |
| 2012 | 0% | 3% | 2% |
| 2015 | 4% | 3% | 2% |
| 2018 | 8% | 6% | 7% |
| 2019 | 16% | 17% | 17% |
| 2020 | 28% | 43% | 37% |
| 2021 | 28% | 23% | 25% |
| 2022 | 12% | 6% | 8% |

Table 120: Dishwasher Rated Energy Consumption (kWh/Year)

(On-site visits: Dishwashers with kWh/year)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 25 | 34 | 59 |
| Mean | 171 | 147 | 157 |
| Min | 60 | 60 | 60 |
| Max | 607 | 366 | 607 |
| Median | 176 | 130 | 144 |
| Standard Deviation | 105 | 61 | 82 |
| CV | 0.62 | 0.42 | 0.53 |
| Conf. Int. | (136, 205) | (130, 164) | (139, 174) |

* + 1. Ovens and Ranges

Table 121: Oven and Range Types

(On-site visits: Oven and Range Units)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 32 | 43 | 75 |
| Oven and range | 56% | 70% | 64% |
| Oven only | 22% | 19% | 20% |
| Range only | 22% | 11% | 16% |

Table 122: Range Fuel

(On-site visits: Ranges)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 25 | 35 | 60 |
| Electric | 32% | 14% | 22% |
| Natural Gas | 12% | 49% | 33% |
| Propane | 56% | 37% | 45% |

Table 123: Oven Fuel

(On-site visits: Ovens)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 25 | 38 | 63 |
| Electric | 60% | 37% | 46% |
| Natural Gas | 4% | 45% | 29% |
| Propane | 36% | 18% | 25% |

* + 1. Clothes Washers

Table 124: Clothes Washer ENERGY STAR Status

(On-site visits: Clothes Washers)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 25 | 34 | 59 |
| Yes | 68% | 77% | 73% |
| No | 32% | 23% | 27% |

Table 125: Clothes Washer Rated Energy Consumption (kWh/Year)

(On-site visits: Clothes Washers with kWh/year)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 25 | 34 | 59 |
| Mean | 170.8 | 146.9 | 156.9 |
| Min | 60 | 60 | 60 |
| Max | 607 | 366 | 607 |
| Median | 176 | 130 | 144 |
| Standard Deviation | 105.4 | 61 | 82.5 |
| CV | 0.62 | 0.42 | 0.53 |
| Conf. Int. | (136.1, 205.5) | (130.0, 163.9) | (139.4, 174.4) |

Table 126: Clothes Washer Rated Efficiency (IMEF)

(On-site visits: Clothes Washers with IMEF)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 25 | 34 | 59 |
| Mean | 2.32 | 2.47 | 2.41 |
| Min | 0.80 | 1.30 | 0.80 |
| Max | 3.10 | 3.30 | 3.30 |
| Median | 2.76 | 2.76 | 2.76 |
| Standard Deviation | 0.67 | 0.55 | 0.60 |
| CV | 0.29 | 0.22 | 0.25 |
| Conf. Int. | (2.10, 2.54) | (2.32, 2.62) | (2.28, 2.53) |

* + 1. Clothes Dryers

Table 127: Clothes Dryer ENERGY STAR Status

(On-site visits: Clothes Dryers)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 25 | 34 | 59 |
| Yes | 68% | 69% | 68% |
| No | 32% | 31% | 32% |

Table 128: Clothes Dryer Fuel

(On-site visits: Clothes Dryers)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 25 | 34 | 59 |
| Electric (208/240V) | 80% | 80% | 80% |
| Electric (110V) | 12% | 11% | 12% |
| Natural gas | 0% | 9% | 5% |
| Propane | 8% | 0% | 3% |

Table 129: Clothes Dryer Moisture Sensor Status

(On-site visits: Clothes Dryers with Moisture Sensor Status)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 25 | 34 | 59 |
| Yes | 100% | 100% | 93% |
| No | 0% | 0% | 0% |

Table 130: Clothes Dryer Rated Energy Efficiency (CEF)

(On-site visits: Clothes Dryers with CEF)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 25 | 34 | 59 |
| Mean | 3.60\* | 3.78 | 3.70 |
| Min | 2.09 | 3.07 | 2.09 |
| Max | 3.94 | 3.94 | 3.94 |
| Median | 3.73 | 3.93 | 3.92 |
| Standard Deviation | 0.48 | 0.24 | 0.36 |
| CV | 0.13 | 0.06 | 0.10 |
| Conf. Int. | (3.44, 3.76) | (3.71, 3.84) | (3.63, 3.78) |

* + 1. Dehumidifiers

Table 131: Dehumidifier ENERGY STAR Status

(On-site visits: Dehumidifiers)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 14 | 15 | 29 |
| Yes | 79% | 93% | 86% |
| No | 21% | 7% | 14% |

Table 132: Dehumidifier Year of Manufacture

(On-site visits: Dehumidifiers)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Custom | Spec | Statewide |
| n | 14 | 15 | 29 |
| 2010 | 0% | 6% | 3% |
| 2011 | 7% | 0% | 3% |
| 2013 | 7% | 0% | 3% |
| 2014 | 0% | 7% | 3% |
| 2017 | 7% | 7% | 7% |
| 2018 | 7% | 0% | 3% |
| 2019 | 21% | 20% | 20% |
| 2020 | 21% | 26% | 24% |
| 2021 | 21% | 20% | 20% |
| 2022 | 7% | 13% | 10% |

1. UDRH Update
   1. Summary of Recommended UDRH Inputs

This appendix provides the recommended User Defined Reference Home (UDRH) inputs for Eversource and United Illuminating’s (the Companies’) RNC program. The recommendations in this appendix are based on the results of the baseline study onsite inspections and analysis of program data. The following section details the reasoning behind the decisions that went into finalizing those UDRH inputs.

Table 133 lists the data sources used in the R1968 study to develop the recommended UDRH inputs. Values that feed into the recommended UDRH inputs include: the results of the non-program onsite results, the current UDRH, standard market practices, or features of 2019-2022 program homes. The table also notes – at a high level – other key UDRH revisions that are recommended, such as adding inputs or revising the way in which measures are categorized.

Table : Recommended Sources and Other Adjustments for UDRH Revisions

| **Measure** | **Recommended Source** | **Other Recommended Adjustments** |
| --- | --- | --- |
| Above Grade Walls | Onsite results | -- |
| Frame Floors | Onsite results | -- |
| Ceilings | Onsite results | -- |
| Foundation Walls | Onsite results | -- |
| Slab Floors | Standard market practices | -- |
| Windows | Onsite results | -- |
| Skylights | Rated home | -- |
| Doors | Rated home | Remove specification from UDRH |
| Air Infiltration | Onsite results | -- |
| Duct Leakage to Outside | Onsite results | -- |
| Duct Insulation | Onsite results | Decrease number of separate duct locations; downgrade bubble-wrap R-value |
| Heating | Onsite results (ASHP/MSHP) and current UDRH (GSHP) | Create one input for GSHP (COP) and one for all other heat pumps (HSPF) based on average value of all baseline systems converted to HSPF since program will be all electric |
| Cooling | Onsite results | -- |
| Water Heaters | Onsite results | Create one input for all water heaters |
| Lighting | Onsite results | -- |
| Thermostat Type | Onsite results | -- |
| Thermostat Setpoints | Onsite results | -- |
| Mechanical Ventilation | Rated home | Remove ventilation from UDRH to avoid rewarding homes without ventilation |

* 1. UDRH Methodology
     1. Data Collection

As previously discussed, the R1968 baseline study included onsite visits in 2022 to 59 new, non-program single-family homes (34 spec- and 25 custom-built) across 45 Connecticut cities and towns. Data collection covered all aspects of home energy performance, including building envelope, mechanical systems, lighting, appliances, and air infiltration. Home Energy Rating System (HERS) ratings were performed at all homes, and sites were evaluated against the requirements of the 2015 IECC. This data collection formed the basis of the values suggested for the updated UDRH.

* + 1. Analysis

The process of developing the UDRH recommendations included analyses of the following:

* Non-program home data collected during the R1602 baseline study onsite visits
* Program Ekotrope models for single-family and multifamily homes that participated in the RNC program from 2019 to 2022

Generally, the recommended UDRH value for single-family homes is based on the mean value from the R1968 non-program baseline study, and in some cases, is adjusted based on the findings from the program home analysis.

* 1. Measure Specific Findings

The tables in this section are organized as follows:

* **UDRH specification.** The current UDRH specifications (i.e., those currently used by the RNC program to calculate savings for program homes) are compared to the following two values:

1. the mean value from the non-program single-family homes that were included in the R1968 baseline study, and
2. the mean value from the program Ekotrope models for single-family homes that participated in the RNC program from 2019 to 2022.

* **Recommendations.** For each measure, the suggested values to include in the updated UDRH are presented separately for single-family units. These recommended values are found in the far-right columns of each table in bold red font. The logic behind each single-family UDRH recommendation is described above the corresponding table.
  + 1. Above Grade Walls
* ***Recommendation: Assign above-grade wall Uo-values by specific location, and base insulation values on onsite results.***

The R1968 study recommends continuing to split wall locations in the UDRH using the Uo values from the baseline sample, as proposed below, including walls that abut (1) ambient space, (2) garages, (3) unconditioned attics, and (4) unconditioned basements (Table 134).[[10]](#footnote-11)

Table 134: Above Grade Wall Average Uo Values – Current Inputs and Study Results and Suggestions1

| **Above Grade Wall Type and Location** | **Current UDRH Input** | **Average Results** | | **Suggested Input** |
| --- | --- | --- | --- | --- |
| **Non-Program**  **(R1968 site visits)** | **Program**  **(2022 program data)** |
| **Between Conditioned Space and:** | | | | |
| Ambient | 0.062 | 0.057 (n=59) | 0.052 (n=88) | **0.057** |
| Garage | 0.066 | 0.065 (n=46) | 0.054 (n=68) | **0.065** |
| Attic | 0.068 | 0.063 (n=16) | 0.059 (n=31) | **0.063** |
| Basement | 0.091 | 0.091 (n=39) | 0.077 (n=34) | **0.091** |
| **Between Unconditioned Space and:** | | | | |
| Any Unconditioned Location | 0.098 | 0.062 (n=8) | N/A | **0.062** |

1 “Uo values,” a measurement of thermal performance, refer to the average weighted U-value across the wall assembly.

* + 1. Frame Floors
* ***Recommendation: Base frame floor values on onsite visit results. Use one Uo value for floors over unconditioned basements and enclosed crawl spaces, and a different Uo value for floors over garage, ambient space, and open crawl spaces.***

This study recommends following the baseline study findings, which results in one UDRH value for floors over garages, ambient space, and open crawl spaces, and one value for floors over unconditioned basements and enclosed crawl spaces (Table 135).[[11]](#footnote-12)

Table 135: Frame Floor Average Uo Values – Current Inputs and Study Results and Suggestions

| **Frame Floor Location** | **Current UDRH Input** | **Average Results** | | **Suggested Input** |
| --- | --- | --- | --- | --- |
| **Non-Program**  **(R1968 site visits)** | **Program**  **(2022 program data)** |
| Over Unconditioned Basement or Enclosed Crawlspace | 0.061 | 0.050 (n=46) | 0.036 (n=30) | **0.050** |
| Over Garage | 0.047 | 0.040 (n=25) | 0.033 (n=27) | **0.040** |
| Over Ambient Space | 0.047 | 0.046 (n=10) | 0.032 (n=33) | **0.046** |
| Over Open Crawlspace | 0.047 | N/A | N/A | **0.047** |

* + 1. Ceilings
* ***Recommendation: Update the single-family ceiling Uo-values with those collected through onsite visits..***

The study recommends updating the current single-family specification to the new non-program average from the baseline sample (Table 136).

Table 136: Ceiling Average Uo Values – Current Inputs and Study Results and Suggestions

| **Ceiling Type** | **Current UDRH Input** | **Average Results** | | **Suggested Input** |
| --- | --- | --- | --- | --- |
| **Non-Program**  **(R1968 site visits)** | **Program**  **(2022 program data)** |
| Flat | 0.042 | 0.040 (n=44) | 0.023 (n=82) | **0.040** |
| Vaulted | 0.038 | 0.031 (n=22) | 0.028 (n=66) | **0.031** |

* + 1. Foundation Walls
* ***Recommendation: Update the single-family specifications to the UDRH to the current R-values from onsite findings.***

The study recommends updating foundation walls the new UDRH to average conditioned foundation wall and unconditioned foundation wall R-value found during onsite visits

Table 137: Foundation Wall Average R-Values – Current Inputs and Study Results and Suggestions

| **Foundation Wall Type** | **Current UDRH Input** | **Average Results** | | **Suggested Input** |
| --- | --- | --- | --- | --- |
| **Non-Program**  **(R1968 site visits)** | **Program**  **(2022 program data)** |
| Conditioned | 10.9 | 12.0 (n=91) | 17.3 (n=138) | **12.0** |
| Unconditioned | 0.23 | 0.8 (n=200) | N/A | **0.8** |

* + 1. Slab Floors
* ***Recommendation: Given lack of available data from onsite visits, apply slab R-values based on standard practices instead of onsite results; no change to the current UDRH.***

It is difficult to verify slab insulation in non-program homes because inspections are conducted after construction is complete, and slab insulation is at that point often covered by soil or the house itself.[[12]](#footnote-13) Therefore, this study recommends continuing to use standard practice assumptions as done in the current UDRH (Table 138).

Table 138: Slab Floors Average R-Values – Current Inputs and Study Results and Suggestions

| **Slab Floor Type** | **Current UDRH Input** | **Average Results** | | **Suggested Inputs** |
| --- | --- | --- | --- | --- |
| **Non-Program**  **(R1602 site visits)** | **Program**  **(2015 program data)** |
| **Unheated** | | | | |
| **Below Grade** | | | | |
| Under insulation | 0 | 0 (n=19) | N/A | **0** |
| Perimeter insulation | 0 | 0 (n=19) | N/A | **0** |
| **On-Grade** | | | | |
| Under insulation | 0 | 0 (n=8) | N/A | **0** |
| Perimeter insulation | 5 | 1.2 (n=8) | N/A | **5** |
| **Heated** | | | | |
| **Below Grade** | | | | |
| Under insulation | 15 | 0 (n=1) | N/A | **15** |
| Perimeter insulation | 10 | 0 (n=1) | N/A | **10** |
| **On-Grade** | | | | |
| Under insulation | 15 | 0 (n=2) | N/A | **15** |
| Perimeter insulation | 10 | 0 (n=2) | N/A | **10** |

* + 1. Windows
* ***Recommendation: Update the single-family ceiling U-factor and SHGC with those collected through onsite visits..***
* The study recommends updating the current single-family specification to the new non-program average from the baseline sample (Table 139).

Table 139: Window Average U-Factor and SHGC – Current Inputs and Study Results and Suggestions

| **Unit** | **Current UDRH Input** | **Average Results** | | **Suggested Input** |
| --- | --- | --- | --- | --- |
| **Non-Program**  **(R1968 site visits)** | **Program**  **(2022 program data)** |
| U-Factor | 0.3 | 0.29 (n=95) | 0.27 (n=570) | **0.29** |
| SHGC | 0.3 | 0.29 (n=95) | 0.32 (n=570 | **0.29** |

* + 1. Skylights
* ***Recommendation: For skylights, continue to use the U-factors and SHGC values from the rated home.***

Average U-value and SHGC values for program homes are derived from three values found during analysis of REM/Rate files; no confirmed values were found during onsite visits for non-program homes. The current UDRH specification for skylights mirrors the design of the rated home, meaning that the UDRH will have the same kind of skylight as the rated home. Given the lack of verifiable data from the baseline sample, the study recommends keeping the skylight UDRH inputs the same as the rated home.

* + 1. Doors
* ***Recommendation: For doors, continue to use the U-values from the rated home.***

Given the lack of verifiable data from onsite visits (door specification stickers are generally removed upon installation), the study recommends setting the door specification to be the same as the rated home.

* + 1. Air Infiltration
* ***Recommendation: Use the diagnostic test results from the study’s onsite visits to create ACH50 inputs. Assign the UDRH to the same shelter class as the rated home.***

The study recommends adopting the non-program average air infiltration of 4.2 ACH50 for air leakage, which is based on diagnostic tests at 58 homes in the Connecticut baseline study (Table 140).

Shelter class is a measurement of a site’s wind conditions, and it impacts a home’s air infiltration. The study recommends continuing the practice of putting the UDRH in the same shelter class as the rated home, to create a consistent comparison between the program home and the reference home.

Table 140: Air Infiltration – Current Inputs and Study Results and Suggestions

| **Unit** | **Current UDRH Input** | **Average Results** | | **Suggested Input** |
| --- | --- | --- | --- | --- |
| **Non-Program**  **(R1968 site visits)** | **Program**  **(2022 program data)** |
| ACH50 | 4.9 | 4.2 (n=58) | 2.1 (n=73) | **4.2** |
| Shelter Class | Same as rated home | N/A | N/A | **Same as rated home** |

* + 1. Duct Leakage
* ***Recommendation: Use the diagnostic test results from the study’s onsite visits to update duct leakage to the outside inputs.***

Table 141 suggests that the UDRH use the onsite visit average result of 4.6 CFM25 per 100 square feet of conditioned floor area (CFA) for the duct leakage to the outside UDRH values in single-family homes. For this study, duct systems located entirely within conditioned space were assumed to have zero duct leakage to the outside. This assumption is consistent with program practices.[[13]](#footnote-14) Homes with zero duct leakage are included in the non-program and program averages.

Table 141: Duct Leakage to Outside – Current Inputs and Study Results and Suggestions

| **Unit** | **Current UDRH Input** | **Average Results** | | **Suggested Input** |
| --- | --- | --- | --- | --- |
| **Non-Program**  **(R1968 site visits)** | **Program**  **(2022 program data)** |
| CFM25 per 100 sq. ft. | 6.2 | 4.6 (n=56) | 1.6 (n=68) | **4.6** |

* + 1. Duct Insulation
* ***Recommendation: Continue to split duct insulation specifications into two duct categories: supply ducts in unconditioned attics, and supply or return ducts in all other unconditioned locations. Use the baseline findings for R-values.***

This study recommends the same specifications, including values for two categories: (1) supply ducts in unconditioned attics and (2) all other supply and return ducts in unconditioned locations, and recommends using the average R-values from onsite visits (Table 142). Ducts in conditioned space would be modeled the same in the UDRH and rated home.

Table 142: Duct Insulation – Current Inputs and Study Results and Suggestions

| **Unconditioned Duct Location** | **Current UDRH Input** | **Average Results** | | **Suggested Input** |
| --- | --- | --- | --- | --- |
| **Non-Program**  **(R1968 site visits)** | **Program**  **(2022 program data)** |
| Attic (Supply Only) | 5.6 | 6.7 (n=43) | 7.9 (n=33) | **6.7** |
| Other Unconditioned Spaces (Supply and Return) | 4.9 | 5.9 (n=71) | 7.9 (n=56) | **5.9** |

* + 1. Heating
* ***Recommendation: Considering the program change to an all-electric model, collapse heating UDRH categories into only two; a COP for GSHP and an HSPF for all other systems. This average HSPF value is calculated by converting all fossil fuel efficiencies in AFUE to HSPF and taking an average of all system and fuel types.***

The current UDRH specifications are split by fuel type and across distribution types. Given the program switch to all-electric, UDRH inputs for fossil fuel systems in AFUE are no longer relevant. Therefore, the team recommends one UDRH input based on an average HSPF from all systems included in the non-program sample, after converting the fossil fuel systems from AFUE to HSPF. The formula used for doing so is: (AFUE)\*0.03413\*(Source-Site Conversion Factor). The source site conversion factor used in this case is 3.16, specified in section R405.3 the Connecticut energy code[[14]](#footnote-15). The recommendations by system type, as shown in Table 143, are as follows:

Table 143: Heating Systems – Current Inputs and Study Results and Suggestions

| **Fuel and System Type** | **Current UDRH Input** | **Average Results** | | **Suggested Inputs** |
| --- | --- | --- | --- | --- |
| **Non-Program**  **(R1968 site visits)** | **Program**  **(2022 program data)** |
| **Natural Gas (AFUE)** | | | | |
| Air Distribution | 93.8 | 94.9 (n=29) | 95.8 (n=40) | **NA** |
| Hydronic Distribution | 89.6 | 95 (n=1) | 95 (n=2) | **NA** |
| Unit Heater | Same as rated home | NA | NA | **NA** |
| **Propane (AFUE)** | | | | |
| Air Distribution | 93.8 | 95.3 (n=27) | 96.1 (n=15) | **NA** |
| Hydronic Distribution | 89.6 | 95 (n=2) | NA | **NA** |
| Unit Heater | Same as rated home | NA | NA | **NA** |
| **Oil (AFUE)** | | | | |
| Air Distribution | Same as rated home | 85 (n=1) | NA | **NA** |
| Hydronic Distribution | Same as rated home | 87 (n=1) | NA | **NA** |
| Unit Heater | Same as rated home | NA | NA | **NA** |
| **Electric and Other Fuels** | | | | |
| Kerosene Unit Heater (AFUE) | Same as rated home | NA | NA | **NA** |
| ASHP & Ductless Mini-Split (HSPF) | 10 | 10.5 (n=9) | 10.4 (n=14) | **10.3** |
| GSHP (COP) | 4 | 3.5 (n=3) | 3.9 (n=2) | **4** |
| Dual-Fuel Heat Pump (HSPF) | 10 | NA | NA | **NA** |
| **Location** | | | | |
| Location | Unconditioned Space | Unconditioned space | Unconditioned space | **Unconditioned Space** |

* + 1. Cooling
* ***Recommendation: Continue to use a single average SEER value across all CAC, ducted ASHPs, and ductless mini-splits based on onsite results; use that same efficiency for the GSHP input (after converting from SEER to EER). Eliminate the specification for dual fuel heat pumps.***

The current UDRH uses the same specification for central air conditioners (CAC), ducted air source heat pumps, and ductless mini-split heat pumps. The study recommends continuing that practice by selecting a new SEER that is the average of the CAC, air source heat pump, and ductless mini-split efficiency ratings included in the R1968 non-program home onsite visits, and in addition, assigning that same value to GSHPs (which requires a conversion from SEER to EER). This is due to low sample for GSHPs, and is in line with practices for updating the UDRH previously.

Table 144: Cooling Systems – Current Inputs and Study Results and Suggestions

| **System Type** | **Current UDRH Input** | **Average Results** | | **Suggested Input** |
| --- | --- | --- | --- | --- |
| **Non-Program**  **(R1968 site visits)** | **Program**  **(2022 program data)** |
| CAC, ASHP, MSHP (SEER) | 14.6 | 14.9 (n=69) | 14.9 (n=68) | **14.9** |
| GSHP (EER) | 12.2 | 21.6 (n=3) | NA | **12.3** |
| Dual Fuel Heat Pump (SEER)\_ | 14.6 | NA | NA | **NA** |
| Location | Unconditioned Space | Unconditioned Space | Unconditioned Space | **Unconditioned Space** |

* + 1. Water Heaters
* ***Recommendation: Collapse water heater categories into just one EF and RE for all systems to accommodate the all-electric program. These specifications are based on average values from all systems found in the non-program sample regardless of fuel and type.***

Water heater efficiency is rated in terms of the energy factor (EF) and recovery efficiency (RE). UEF is a newer replacement for Energy Factor, but REM/Rate still uses EF, rather than UEF, for modeling. As shown in Table 145, the study makes the following recommendations for single-family water heater UDRH inputs. All water heaters, including fossil fuel and electric, should be combined into a single specification based on the average efficiency of all such systems from the non-program onsite visits. This results in a UDRH input for water heaters that is higher than what is achievable by fossil fuel systems or conventional electric resistance storage tank water heaters. Using this approach, program homes essentially need to incorporate these high efficiency HPWH systems in order to demonstrate energy savings relative to such an efficient UDRH input.

* Table 145: Water Heaters – Current Inputs and Study Results and Suggestions

| **Fuel and System Type** | **Current UDRH Input** | **Average Results** | | **Suggested Inputs** |
| --- | --- | --- | --- | --- |
| **Non-Program**  **(R1968 site visits)** | **Program**  **(2022 program data)** |
| **Natural Gas (EF, RE)** | | | | |
| Conventional Storage | 0.65, 0.79 | 0.74, 0.84 (n=4) | 0.68 (n=3) | **NA** |
| Integrated | 0.89, 0.92 | 0.87, 0.95 (n=2) | NA | **NA** |
| Instantaneous | 0.94, 0.95 | 0.94, 0.96 (n=15) | 0.93 (n=39) | **NA** |
| **Propane EF, RE)** | | | | |
| Conventional Storage | 0.65, 0.79 | 0.68, 0.79 (n=5) | 0.72 (n=3) | **NA** |
| Integrated | 0.89, 0.92 | 0.87, 0.95 (n=3) | NA | **NA** |
| Instantaneous | 0.94, 0.95 | 0.93, 0.96 (n=12) | 0.93 (n=11) | **NA** |
| **Oil (EF, RE)** | | | | |
| Conventional Storage | Same as rated home | 0.65, 0.71 (n=1) | NA | **NA** |
| Integrated | Same as rated home | NA | NA | **NA** |
| Instantaneous | Same as rated home | NA | NA | **NA** |
| **Electric (EF, RE)** | | | | |
| All Types | 1.42, 0.98 | 2.03, 2.04 (n=20) | 3.62 (n=16) | **1.24, 1.27** |
| **Location** | | | | |
| Location | Unconditioned Space | Unconditioned space | Unconditioned space | **Unconditioned Space** |

* + 1. Lighting
* ***Recommendation: Assume efficient lighting saturation is in line with the average non-program homes visited during R1968 onsite visits.***

The efficient lighting percentages include CFL and LED bulbs. This is a percentage of efficient hardwired fixtures that are found in qualifying locations.[[15]](#footnote-16) The team recommends adopting the non-program average of 96% (Table 146).

Table 146: Lighting – Current Inputs and Study Results and Suggestions

| **Lighting** | **Current UDRH Input** | **Average Results** | | **Suggested Input** |
| --- | --- | --- | --- | --- |
| **Non-Program**  **(R1968 site visits)** | **Program**  **(2022 program data)** |
| % Efficient Lighting | 54% | 96% (n=59) | 99% (n=74) | **96%** |

* + 1. Thermostats
* ***Recommendation: Apply the average thermostat setpoints from the non-program homes to single-family homes, and set programmable thermostats as the UDRH input for thermostat type.***

R1968 study recommends using the non-program average setpoint values for single-family homes; 68.7F for heating and 72.3F for cooling (Table 147). The study also recommends setting the UDRH thermostat type to be a programmable thermostat for single-family homes, as these are the vast majority of installed

Table 147: Thermostat Type and Degrees Fahrenheit Setpoints – Current Inputs and Study Results and Suggestions

| **End-Use** | **Current UDRH Input** | **Average Results** | | **Suggested Input** |
| --- | --- | --- | --- | --- |
| **Non-Program**  **(R1968 site visits)** | **Program**  **(2022 program data)** |
| **Type** | | | | |
| Heating and Cooling | Programmable | Majority Programmable (n=97) | 0.052 (n=88) | **Programmable** |
| **Setpoint (Degrees F)** | | | | |
| Heating | 69 | 68.7 (n=97) | N/A | **68.7** |
| Cooling | 73 | 72.3 (n=97) | NA | **72.3** |

* + 1. Mechanical Ventilation
* ***Recommendation: Apply the mechanical ventilation of the home being rated.***

There were only eight non-program homes in the sample with ventilation systems: two bathroom fans on automatic timers, three HRV systems, and three ERV systems. The study recommends continuing a specification of “same as rated home” to avoid penalizing program homes for which the increased energy consumption of ventilation systems would reduce savings.

Table 148: Mechanical Ventilation – Current Inputs and Study Results and Suggestions

| **Ventilation** | **Current UDRH Input** | **Average Results** | | **Suggested Input** |
| --- | --- | --- | --- | --- |
| **Non-Program**  **(R1968 site visits)** | **Program**  **(2022 program data)** |
| Mechanical Ventilation | Same as rated home | NA | NA | **Same as rated home** |

1. Detailed Methodology

Appendix C provides the detailed research questions we sought to answer through this research and the detailed methodology for each of the research tasks undertaken to meet those research objectives.

* 1. Research Objectives
* Update baseline assumptions used in the UDRH for program savings calculations.
* Assess the extent of energy code compliance for program and non-program homes
* Update UDRH assumptions for MF homes.
* Compare program and non-program homes to previous baseline studies to understand changes over time.
* Compare building department files to onsite data for a sub-sample of single-family homes.
* Compare building department files to program energy models for a sub-sample of multifamily buildings.
  1. Sampling and Recruitment

The sample for this study was comprised of homes permitted in 2019 or later to coincide with the Connecticut energy code adopted in 2018 (based on 2015 IECC) and ensure that the homes were permitted under this code. This sample, identified through New Electric Service data requests from 2019 to 2022, was cleaned and reviewed by NMR to make a comprehensive list of new-single family homes that were occupied at the time of site visits.

From the sample, 3660 eligible participant addresses were mailed recruitment postcards with the Energize Connecticut and Company logos that described the study, mentioned the $200 incentive, and provided contact information for questions. The post cards also included a QR code that linked potential participants to an online form where they could express interest in participating. Shortly after the post-cards were mailed out, NMR began phone and email outreach to these same eligible participants. Only one home per housing development was scheduled for an on-site visit to avoid sampling multiple houses built by the same builder with similar building characteristics.

Table : On-Site Recruitment Target

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **County** | **2018-2020 Permits** | **Share of Permits** | **Sample**  **Target** | **Recruited Sample** |
| Fairfield | 675 | 27% | 19 | 13 |
| Hartford | 531 | 21% | 15 | 6 |
| Litchfield | 145 | 6% | 4 | 2 |
| Middlesex | 144 | 6% | 4 | 6 |
| New Haven | 408 | 16% | 12 | 14 |
| New London | 284 | 11% | 8 | 9 |
| Tolland | 136 | 5% | 4 | 3 |
| Windham | 154 | 6% | 4 | 5 |
| Total | **2,746** | **100%** | **70** | **59** |

Additionally, NMR achieved a 58% spec to custom-built home ratio, under the soft target maximum of 60%. Results presented in this report are unweighted. An initial screening question during homeowner recruitment was used to determine if a home was spec- or custom-built:

*How did you purchase your home?*

1. Purchased land and worked with an architect and/or builder to build the home. **(Custom)**
2. Had a house plan and a lot and hired a contractor/builder to build the home. **(Custom)**
3. I am the owner and builder. **(Custom)**
4. Purchased a lot from a builder, selected one of several house plans offered by the builder and selected from various available upgrade options. **(Spec)**
5. Purchase a home that was under construction and selected from various available upgrade options. **(Spec)**
6. Purchased a finished home. **(Spec)**
   1. On-site Data Collection Points

During on-site inspections, NMR trained auditors collected the data necessary to conduct a HERS assessment to compare with Ekotrope data. The list below details the specific inputs obtained during the assessment.

**General home characteristics**

* Conditioned floor area, conditioned volume, house type, number of stories, number of bedrooms, home age, and orientation

**Building shell characteristics**

* Area, framing, insulation type, R-value, and installation grade by location for walls, ceilings, floors, foundations, crawlspaces, and slabs
* Exterior or unconditioned door location, dimensions, type, and thickness
* Window and skylight frame type; number of panes; presence of low-e coating, u-factor, and SHGC values (when documentation is available); dimensions; overhangs; and window orientation
* Air infiltration levels (blower door diagnostic test)

**Heating and cooling equipment**

* Primary and supplementary heating and cooling systems
* Type, fuel, manufacturer, model number, ENERGY STAR status, capacity, age, efficiency, and location
* Presence of pipe insulation and R-value
* Presence of ECMs and boiler outdoor reset controls
* Count, type, setpoints, of thermostats

**Domestic water heaters**

* Type, fuel, manufacturer, model number, ENERGY STAR status, capacity, age, efficiency, and location
* Presence and R-value of pipe insulation and storage tank wrap
* Number of low-flow showerheads and faucet aerators
* Presence of demand controls
* Heat pump water heater viability if HPWH not present (sufficient air volume in basement, drain present, ability for basement to maintain temperature in winter, sufficient height of basement)

**Duct system characteristics**

* Duct location
* Insulation type and R-value
* Duct leakage levels to outside for homes with duct systems located in unconditioned space (duct blaster diagnostic test)
* Number of return registers

**Lighting**

* Number of fixtures and bulbs by room location (both hardwired and plug-in)
* Bulb type (i.e., LED, CFL, incandescent)
* Bulb shape
* Control type

**Appliances**

* Primary and secondary refrigerators, freezers, clothes washers, clothes dryers, dishwashers, ovens/ranges, room air conditioners, and dehumidifiers
* Type, fuel, manufacturer, model number, ENERGY STAR status, age, efficiency, and location

**Mechanical ventilation**

* Whole home mechanical ventilation systems, including Energy Recovery Ventilators (ERVs) and Heat Recovery Ventilators (HRVs)
* Make and model, type, location, type of control, rated cubic feet per minute (CFM), and efficiency based on model information
* Type and flow rate (in CFM) of automatically controlled bathroom fans

**Renewables**

* Presence and capacity of solar photovoltaics or other renewable technologies
* Energy storage battery make, model, and capacity
* Electric vehicle and charger penetration
* Electric vehicle charger make, model, and level

**Strategic electrification**

* Panel size and unused amperage
* Electric meter type
  1. On-site Data Collection Procedures

NMR faces the challenge of inspecting completed homes with building envelope components that are not easily accessible or visible. These included:

* Wall insulation
* Window U-factor
* Vaulted ceiling insulation
* Exterior foundation wall insulation
* Slab insulation
* Garage and cantilevered frame floor insulation
* Band joist insulation
* Attic top plate sealing
* NMR relied on the following approaches to gain access to measures for data collection:
* **On-site visual verification of actual component.** Actual observations in the field are the first and most important source of data. When direct access to the component was not possible, we looked for non-invasive alternative methods to gather whatever information we could. For example, when trying to determine exterior wall insulation, we might have removed an electrical outlet cover to probe for the presence of insulation and visually confirm the type of insulation directly or with a borescope.
* **On-site visual verification of similar component.** Once NMR exhausted opportunities to examine the actual component, we used similar locations to inform our assessment. For example, we might have found visible/accessible above-grade wall insulation in an attic knee wall or a walkout basement that could inform our assessment of the enclosed wall cavities.
* **Documentation from the homeowner.** In some cases, the occupant possessed documentation with information on hard-to-access home components. This could include invoices from the insulation contractor, detailed plans, or photos taken during construction. This documentation can provide useful information on insulation types and R-values in inaccessible cavities, window U-factors, and the presence of insulation on exterior foundation walls or under slabs. We asked for this documentation as needed. Additionally, for homes that had completed the web survey, at times survey data could be used to inform assumptions made by NMR technicians.
  1. Building Department Visits

In addition to on-site data collection, NMR visited building departments as part of the study. The EA Team requested NMR collect information to shed light on the following minor objectives:

1. Compare building department files to onsite data for a sub-sample of single-family homes.
2. Compare building department files to program energy models for a sub-sample of multifamily buildings.

NMR attempted to collect data on three sample of buildings at building departments:

1. **Non-participant multifamily buildings:** The team identified non-participant multifamily buildings using the new permanent electric service data request data screened against the program tracking data. The team reviewed and randomly selected MF addresses from the data and attempted outreach to building departments in the identified towns, targeting 30 total buildings. This outreach included phone, email, and in person visits. The team reviewed and photograph available documentation for these sites to collect data on similar measures as the single-family on-site visits including shell and mechanical data.
2. **Single-family on-site homes:** NMR randomly selected 20 of the on-site homes for which to review building department files. The purpose of this review was to assess the accuracy of building department data compared to verified on-site results.
3. **Participant multifamily buildings:** NMR selected 10 multifamily participant buildings from the program model sample for which to review building department files. The purpose of this review was to see the accuracy of building department data for multifamily buildings.

Of the 60 total sites for which the team requested building department files, 37 responded with documentation. The remaining sites’ building departments either became unresponsive after multiple attempts or confirmed that they did not have documentation for the given address. Among those in which documentation was obtained, a majority of that documentation was only permits or blueprints which do not often contain meaningful information that can aid in analysis or comparisons. Blueprints sometimes contain assembly R-values or material types, but these are simply plans that they architect specifies based on code requirements, they do not reflect what was necessarily installed during construction. Types of documentation that would yield more confident results would be things like blower door test results, code compliance checklists, or HERS ratings which indicate third party verification of this information. These types of documents were rarely found during building department data collection. Due to this lack of meaningful data, results are not presented from building department data collection as sample sized would be too small to create meaningful comparisons.

Table 150:Record Availability at Building Department Sites

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Single-family on-site homes** | **Participant Multi-family** | **Non-Participant Multi-family** |
| n | 17 | 8 | 32 |
| Records Available | 82% | 75% | 53% |
| No Records Available | 18% | 25% | 47% |

Table 151:Type of Documentation Available at Building Departments

|  |  |
| --- | --- |
| **Type** | **Building Department Sites with Records** |
| n | 36 |
| Permit | 94% |
| Other | 50% |
| Blueprints | 47% |
| Blower Door Test Results | 25% |
| Compliance Certificate | 17% |
| Manual J/ Manual S | 14% |
| Inspection Checklist | 11% |
| IECC Energy Certificate | 6% |
| Duct Leakage Test Results | 6% |
| Home Energy Rating Certificate | 3% |
| ENERGY STAR Qualified Homes | 3% |

* 1. Code Compliance

Compliance with the 2018 Connecticut energy code based on 2015 IECC was measured using the MA-REC approach developed by NMR in Massachusetts. This approach uses energy modeling to develop a code compliance scoring system that is more calibrated to estimated energy consumption than a traditional prescriptive approach such as PNNL’s REScheck software[[16]](#footnote-17). Unlike the PNNL approach, the MA-REC approach focuses only on code requirements that directly impact energy consumption. The methodology does not account for administrative or non-energy-related code requirements, and it does not consider the compliance path utilized by the builder. This methodology compares homes to the 2015 IECC prescriptive requirements, with Rhode Island amendments. Thus, the MA-REC approach does not account for trade-offs that may take place under the UA trade-off and performance paths for compliance. For this reason, it is possible that the MA-REC approach overstates the level of non-compliance and potential savings associated with homes that use the UA trade-off or performance paths for compliance. These paths allow for prescriptive non-compliance with certain measures assuming there are other measures that exceed the prescriptive requirements. The MA-REC approach does not attempt to address these complicating factors and this should be considered when reviewing the results associated with this methodology.

The MA-REC approach utilizes REM/Rate energy consumption estimates to determine the relative importance of various code-related building components.[[17]](#footnote-18) The consumption estimates of individual measures are compared to the overall estimated consumption for a sample of homes to develop a detailed point system that is calibrated to overall estimated energy consumption.

A ten-point scale is used in which the most impactful measure (in terms of relative estimated energy consumption) receives an achievable score of ten points. Other measures are compared to the most important measure to develop an achievable point value between zero and ten points. The following formula provides an example of how the total possible points for each measure is developed (in this case, assuming window U-factor was the most important measure in terms of relative consumption):

Where:

The example below details how this calculation works for floors.

Where:

Once the point system is developed, two models are used to calculate compliance for each home. One is an as-built model, or a model that represents the home as it actually exists, and the other is a code-built model that represents the same home built to meet prescriptive code requirements. The measure-level percentage change between the code-built models and as-built models is used to assign a point value to each of the measures included in this methodology. If the as-built model meets or exceeds the code for a given measure (less consumption), that measure is provided with the total possible points.[[18]](#footnote-19) If the as-built model is less efficient than code, then the measure is provided with partial credit depending on the percentage change of the as-built consumption relative to the code-built consumption. The following formulas are used for these calculations:

Where:

Below is an example of how this step in the calculation would work for a home that does not meet the floor code provision. In this scenario, the as-built model has a higher consumption than the code-built model because the code-built home is more efficient.

Where:

The last step in the calculations is to convert the percentage difference in consumption between the models into an adjusted score for that component.

Where:

Once again, this step is shown using the same floor example from above. The first equation from above is used since the code-built model is more efficient than the as-built model. Had the as-built model been more efficient than the code-built model, the home in this example would receive the full 4.1 points for floors.

Where:

Specifically, this methodology includes points and compliance calculations for the following building components:

* Above-grade wall insulation and installation quality
* Air leakage
* Duct leakage and insulation
* Foundation wall insulation and installation quality
* Frame floor insulation and installation quality
* Roof insulation and installation quality
* Slab insulation and installation quality
* Window efficiency

The number of points applied to individual components varies depending on the sample of homes and the code that is under consideration. For example, the distribution of points for 2015 IECC compliance would differ from 2018 IECC compliance because certain measures might not applicable to the 2015 IECC. The total possible points per measure varies between the samples because the relative impact of the measures shifts between different codes and between different samples of homes; hence, it is critically important for the sample to represent the market. However, the relative number of possible points across the codes is not a critical comparison because the objective of this methodology is to compare compliance percentages. The total possible points simply provides an anchor with which to calculate the compliance percentages, or for determining the relative weight of each measure. This approach is similar to the PNNL scoring system, in which the total possible points varies across different codes due to the number and importance of various code requirements and scores are normalized from 0% to 100% to facilitate cross code comparisons.

1. Comparison to 2019 Massachusetts Baseline
   1. Key Characteristics of 2019 Massachusetts Study

The Massachusetts homes built at the end of 2009 IECC (between 2013 and 2016) provide a strong comparison to the 2016 Connecticut baseline, as they were built to similar code requirements. The Massachusetts study[[19]](#footnote-20) included the following:

* On-sites at 100 homes completed in the 2015 IECC code cycle, 51 homes completed under the Base Code, and 49 homes completed under the Stretch Code
* 2015 IECC homes included in the sample were completed between 2017 and early 2019, with the majority completed in 2018
* Fifty-two spec homes and 48 custom homes
* Site recruited through homeowners, not builders
* Sampling plan similar to 2022 Connecticut baseline, based on county
  1. Comparison Results

***Conditioned Floor Area***

The Massachusetts sample had a slightly larger average CFA than the Connecticut 2015 IECC sample: 2,978 sq. ft. of CFA compared to 2,790.

Table : Conditioned Floor Area (sq. ft.)

|  | **2019 MA Baseline**  **(2015 IECC)** | **2022 CT Baseline**  **(2015 IECC)** |
| --- | --- | --- |
|
| n (homes) | 100 | 59 |
| Minimum | 531 | 625 |
| Maximum | 7964 | 6736 |
| Mean | 2978 | 2790 |
| Std. Dev | 1307 | 1379 |

***HERS Index Values***

The Massachusetts sample fairs slightly better than the Connecticut sample by mean HERS Index value – averaging 59 versus 65 in Connecticut.

Table : HERS Index Values

|  | **2019 MA Baseline**  **(2015 IECC)** | **2022 CT Baseline**  **(2015 IECC)** |
| --- | --- | --- |
|
| n (homes) | 100 | 58 |
| Minimum | -10 | 16 |
| Maximum | 95 | 89 |
| Mean | 59 | 65 |

***Building Envelope***

Table 165 compares the R-values of key building shell measures between the Massachusetts and Connecticut samples. The Massachusetts sample has higher average R-values in flat ceiling, but the Connecticut sample has higher average R-values in all other shell measures.

Table : Wall, Ceiling, and Floor R Values

|  |  |  |
| --- | --- | --- |
|  | **2019 MA Baseline**  **(2015 IECC)** | **2022 CT Baseline**  **(2015 IECC)** |
| Energy code version | 2015 IECC | 2015 IECC |
| **Conditioned to Ambient Wall Insulation** | | |
| n (homes) | 100 | 59 |
| Average R-value | 21.8 | 22.3 |
| Prescriptive code requirement | R-20 or R-13+5\* | R-20 or R-13+5\* |
| **Flat Ceiling Insulation** | | |
| n (homes) | 73 | 59 |
| Average flat ceiling R-value | 43.8 | 39.7 |
| Prescriptive code requirement | 49\*\* | 49\*\* |
| **Vaulted Ceiling Insulation** | | |
| n (homes) | 61 | 22 |
| Average vaulted ceiling R-value | 41.6 | 42.5 |
| Prescriptive code requirement | 49\*\*\* | 49\*\*\* |
| **Floor Insulation over Unconditioned Basements** | | |
| n (homes) | 69 | 42 |
| Average R-value | 30.1 | 31.0 |
| Prescriptive code requirement | 30\*\*\*\* | 30\*\*\*\* |
| \* First value is cavity insulation, second is continuous insulation or insulated siding; "13+5" means R-13 cavity insulation plus R-5 continuous insulation or insulated siding.  \*\*R38 acceptable if the full height of uncompressed insulation extends over the wall top plate at the eaves (energy truss system).  \*\*\*Cathedral ceiling exception: code allows for up to 20% (capped at 500 sq. ft.) of ceiling to be as little as R-30, if in a cathedral ceiling.  \*\*\* Or insulation sufficient to fill the framing, R19 minimum. | | |

***Heating Equipment***

Furnaces are the primary heating equipment for most homes in the Massachusetts and Connecticut sample, with 75% of Massachusetts homes and 78% of Connecticut homes using a furnace as their primary system. Boilers are the second most common primary heating equipment in the Connecticut sample with it being the primary system in 10% of homes. In the Massachusetts’ sample, heat pumps were the second most common primary heating equipment as 14% of homes had a heat pump as their primary system. Fossil fuel systems in the Connecticut sample are slightly more efficient on average than those in the Massachusetts sample.

Table : Heating System Type, Fuel and Efficiency

|  |  |  |
| --- | --- | --- |
|  | **2019 MA Baseline (2015 IECC)** | **2022 CT Baseline (2015 IECC)** |
| n (homes) | 100 | 59 |
| **Primary Heating Fuel** | | |
| Propane | 40% | 39% |
| Natural gas | 45% | 44% |
| Electric | 14% | 12% |
| Oil | ---- | 2% |
| **Primary Heating System Type** | | |
| Furnace | 75% | 78% |
| Boiler (forced hot water) | 5% | 5% |
| Boiler (hydro-air) | 4% | 5% |
| MSHP | 8% | 3% |
| Combi Boiler | 2% | --- |
| GSHP | 1% | 3% |
| ASHP | 5% | 3% |
| Overall AFUE (fossil fuel systems) | 94.0 | 94.8 |

***Cooling Equipment***

Both Massachusetts and Connecticut homes have similar rates of central air-splits, with 80% of Massachusetts homes and 85% of Connecticut homes using one as their primary system. The average central air-split SEER is the same in both the Connecticut and Massachusetts samples at 14.9.

Table : Cooling Systems

|  |  |  |
| --- | --- | --- |
|  | **2019 MA Baseline (2015 IECC)** | **2022 CT Baseline (2015 IECC)** |
| **Primary System Type** | | |
| n (homes) | 100 | 59 |
| Central air-split | 80% | 85% |
| MSHP | 8% | 7% |
| ASHP | 6% | 2% |
| GSHP-closed loop | 1% | 3% |
| Window/portable | 4% | 3% |
| No air conditioning | 1% | ---- |
| **SEER** | | |
| n (systems) | 157 | 69 |
| Average SEER | 14.9 | 14.9 |

Water Heating Equipment

The instantaneous water heater was the most common type in both the Massachusetts and Connecticut sample, with Massachusetts having a slightly larger proportion (43% versus 38%). Connecticut had a larger proportion of storage, standalone and indirect water heaters when compared to Massachusetts. In the Massachusetts sample, almost half(44%) of all water heating systems used natural gas, compared to a third (33%) in Connecticut . Electric water heaters were more common in Connecticut with approximately a third of systems (32%) using electricity as a fuel, while in Massachusetts only 26% of systems used electricity. The average efficiency of water heaters was comparable among the states, with Massachusetts having a slightly higher EF at 1.29 compared to 1.24 in Connecticut.

Table : Water Heating Systems

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | | **2019 MA Baseline (2015 IECC)** | **2022 CT Baseline (2015 IECC)** | |
| **Water Heater Type** | | | | |
| n (water heaters) | | 108 | 63 | |
| Instantaneous | | 43% | 38% | |
| Storage, standalone | | 29% | 35% | |
| Heat pump water heater (electric | | 17% | 13% | |
| Indirect (w/ storage tank) | | 7% | 10% | |
| Combi appliance | | 3% | 5% | |
| Solar DHW | | 1% | --- | |
| **Water Heater Fuel** | | | | |
| Natural Gas | | 44% | 33% | |
| Propane | | 29% | 32% | |
| Electric | | 26% | 32% | |
| Solar | | 1% | --- | |
| Oil | | --- | 1% | |
| **Water Heater Efficiency (EF)** | | | | |
| n (systems) | 106 | | | 63 |
| Average EF | | 1.29 | 1.24 | |

Duct Leakage and Air Infiltration

Connecticut homes have slightly higher duct leakage to outside values when compared to Massachusetts homes (4.6 CFM25 in Connecticut and 4.3 in Massachusetts). Blower door numbers are also higher for Connecticut than Massachusetts, at 3.1 ACH50 in Massachusetts and 4.2 ACH50 in Connecticut.

Table :Duct Leakage to Outside and Air Infiltration

|  |  |  |
| --- | --- | --- |
|  | **2019 MA Baseline (2015 IECC)** | **2022 CT Baseline (2015 IECC)** |
| Energy code version | 2015 IECC | 2015 IECC |
| **Duct Leakage to the Outside (CFM25/100 sq. ft. of CFA)** | | |
| n (homes tested) | 87 | 56 |
| CFM25 per 100 square feet of conditioned space | 4.3 | 4.6 |
| Code requirement | ≤ 4 CFM25 per 100 sq. ft. | ≤ 4 CFM25 per 100 sq. ft. |
| **Air Infiltration (ACH50)** | | |
| n (homes tested) | 100 | 58 |
| ACH50 | 3.1 | 4.2 |
| Code requirement | Visual or ≤ 3 | Visual or ≤ 3 |

***Lighting***

Connecticut had a slightly higher efficient bulb saturation than the Massachusetts sample at 96% compared to 89%.

Table :Compliance with IECC Lighting Requirement

|  |  |  |
| --- | --- | --- |
|  | **2019 MA Baseline (2015 IECC)** | **2022 CT Baseline (2015 IECC)** |
| *n (homes)* | *100* | *59* |
| Efficient bulb socket saturation | 89% | 96% |
| LED Penetration | 100% | 100% |

1. https://energizect.com/sites/default/files/documents/R1602-RNC%20Baseline%20Report-FINAL%2020180503\_Revised.pdf [↑](#footnote-ref-2)
2. https://www.census.gov/construction/bps/ [↑](#footnote-ref-3)
3. Note, “custom homes” refers to homes for which homeowners were actively involved in the design of the home while “spec homes” refers to homes that were already complete when purchased or for which homeowners selected among a few specified options from pre-made designs from a builder (e.g., whether to include an optional bonus room). Details on how those determinations were made can be found in Appendix C.2. [↑](#footnote-ref-4)
4. A HERS Index score is a standardized assessment of a home’s energy-efficiency performance based on the home’s construction and energy-using equipment. RESNET oversees the process of scoring homes using the HERS index. RESNET’s HERS Index is a widely adopted rating system used across the United States with standardized procedures, evaluator certification, and quality control infrastructure. A score of 100 means the home is as efficient as the RESNET defined reference home, which is based on the 2006 IECC. A score of zero signifies that a home uses no more energy than it produces on site with renewable sources and a score of less than zero signifies that home produces more renewable energy on site than it consumes. [↑](#footnote-ref-5)
5. https://energizect.com/sites/default/files/documents/R1602-RNC%20Baseline%20Report-FINAL%2020180503\_Revised.pdf [↑](#footnote-ref-6)
6. https://energizect.com/sites/default/files/documents/ConnecticutNewResidentialConstructionBaseline-10-1-12\_0.pdf [↑](#footnote-ref-7)
7. One custom home was not fully complete during the time of the visit causing a discrepancy in air leakage and duct leakage results. This home was removed from the code compliance sample. [↑](#footnote-ref-8)
8. HERS index values are presented with PV excluded since the program does not incorporate those systems into their incentive structure. Additionally, program HERS ratings are completed as the home is being built and so PV systems would only be included if they had been installed by the builder at the time of the rating, whereas the non-program sample of homes were visited post construction and occupancy, giving the homeowner time to install PV. [↑](#footnote-ref-9)
9. The equation used for this conversion was (AFUE)\*0.03413\*(Source-Site Conversion Factor). The source-site conversion factor of 3.16 was derived from section R405.3 of the Connecticut energy code. [↑](#footnote-ref-10)
10. Average Uo values for non-program and program homes are derived from REM/Rate or Ekotrope energy modeling software and account for insulation R-values, insulation installation quality, framing factors, etc. [↑](#footnote-ref-11)
11. There were no floors over open crawl spaces in the R1602 site visits, but in the UDRH these are given the same value as floors over ambient space because they have similar thermal properties. [↑](#footnote-ref-12)
12. To verify slab R-values in the study, auditors searched for visible insulation onsite, asked homeowners for any documentation or plans they had on the premises, and asked homeowners if they knew anything about the slab insulation. [↑](#footnote-ref-13)
13. These systems were tested and some displayed some duct leakage to the outside. Most programs do not require that HERS raters test these systems and instead assume that they have zero duct leakage to the outside. For this reason, the duct leakage associated with systems located in conditioned space was assumed to be zero even if the system was tested and displayed some amount of leakage. [↑](#footnote-ref-14)
14. https://up.codes/viewer/connecticut/iecc-2015/chapter/RE\_4/re-residential-energy-efficiency#R405 [↑](#footnote-ref-15)
15. REM/Rate has four separate lighting inputs. The value presented in this table includes the percentage of CFL and LED hardwired fixtures that are found in all rooms of the home except the following: garage, exterior, unfinished basements, and closets. Garage fixtures, exterior fixtures, and the percentage of hard-wired fixtures that are pin-based fluorescent tubes are all separate REM/Rate lighting inputs. Specific values for these REM/Rate inputs can be provided if necessary. [↑](#footnote-ref-16)
16. https://www.energycodes.gov/rescheck [↑](#footnote-ref-17)
17. REM/Rate is an energy modeling tool that is used to develop Home Energy Rating Scores (HERS) and to support many residential new construction programs. [↑](#footnote-ref-18)
18. By providing only the maximum possible points this method does not apply extra credit for exceeding the prescriptive code requirements. [↑](#footnote-ref-19)
19. https://ma-eeac.org/wp-content/uploads/MA19X02-B-RNCBL\_ResBaselineOverallReport\_Final\_2020.04.01\_v2.pdf. [↑](#footnote-ref-20)