R1968 Residential New Construction Baseline and Code Compliance Study

FINAL

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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
EA Team	The Connecticut Evaluation Administrator Team; oversees evaluations for the EEB
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; a measure of electric heating efficiency
HSPF2	Updated version of HSPF, in use as of Jan 2023
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

Acronym	Definition
REM/rate ™	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; a measure of cooling system efficiency
SEER2	Updated version of SEER, in use as of 2023
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)
U-value	Measure of heat flow comprehensively across a building assembly; in addition to insulation this includes a framing factor and the insulation grade (installation quality); Inverse of an R-value, lower is better
UC	Unconditioned
UDRH	User-Defined Reference Home, the hypothetical baseline home against which program homes are compared to calculate savings
UEF	Uniform Energy Factor, an updated metric 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) that will provide additional guidance on baseline scenarios in light of the RNC program shifting to an all-electric approach in 2023.

The study included site visits to 59 new, non-program single-family homes in Connecticut that were built between 2019 and 2022 under the 2018 Connecticut State Building Code, based on the 2015 International Energy Conservation Code (IECC). Data collection covered energy-related measures such as building envelope, mechanical systems, lighting, appliances, duct leakage, 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 in every analyzed measure. Program homes have an average HERS index value of 52, which is much better than the average score for non-program homes of 69. These energy models excluded solar panels, as the program does not incentivize on-site generation.

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 in 2014 and 2015 under the 2009 IECC with Connecticut amendments.[1] 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 similar (lower but not significantly significant) energy code compliance relative to the previous study (84%, down from 90%). The largest contributors to decreased compliance are ceiling insulation (69% compliance, down from 78%) and duct leakage (77%, down from 95%).

Considering the program shift to an all-electric design occurring in 2023, some inputs to the UDRH were consolidated to reflect a more appropriate electric baseline. Recommended inputs for heating and hot water equipment aggregate multiple fuel and equipment types 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 1.25 UEF for water heaters and 10.3 HSPF for heating systems. (The study also provides fossil-fuel UDRH values for homes that may enter the program before the shift to an all-electric path in 2023.) 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.

[1] https://energizect.com/sites/default/files/documents/R1602-RNC%20Baseline%20Report-FINAL%2020180503_Revised.pdf

Executive Summary

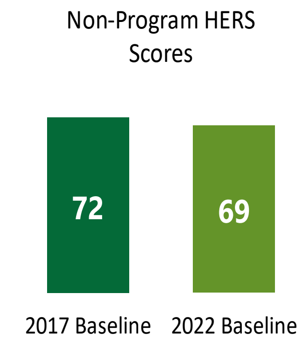
This study, conducted for the Connecticut Energy Efficiency Board (EEB) and submitted to the Connecticut Evaluation Administrator (EA) Team, details the results of a single-family residential new construction (RNC) baseline study. The study was designed to answer two key questions about the market at the end of the 2015 International Energy Conservation Code (IECC) 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 2023; however, this study was conducted before this decision had been made and therefore is limited in its capacity to describe baseline conditions for an all-electric program. As a follow up to this study, the EEB has planned a net-to-gross study of the RNC program to begin in 2023 (R2209) which will be better suited to separately assess the issues of net savings, baseline conditions, and program design changes. 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 incentives, technical assistance, and code compliance support to encourage energy-efficient construction and calculates savings by comparing program homes to a market baseline. By conducting periodic baseline studies, the Companies can better understand the 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 IECC. For simplicity, the report refers to this Connecticut code as the 2015 IECC. On-site data collection assessed home energy performance, including building envelope, mechanical systems, lighting, appliances, duct leakage, and air infiltration. Home Energy Rating System (HERS) ratings were performed at all homes, and sites were evaluated against the prescriptive requirements of the 2015 IECC. These results were also used to update the User Defined Reference Home (UDRH), against which the program claims savings (Appendix B). In October 2022, a new energy code came into effect, based on the more stringent 2021 IECC. The study makes recommendations with that change in mind.

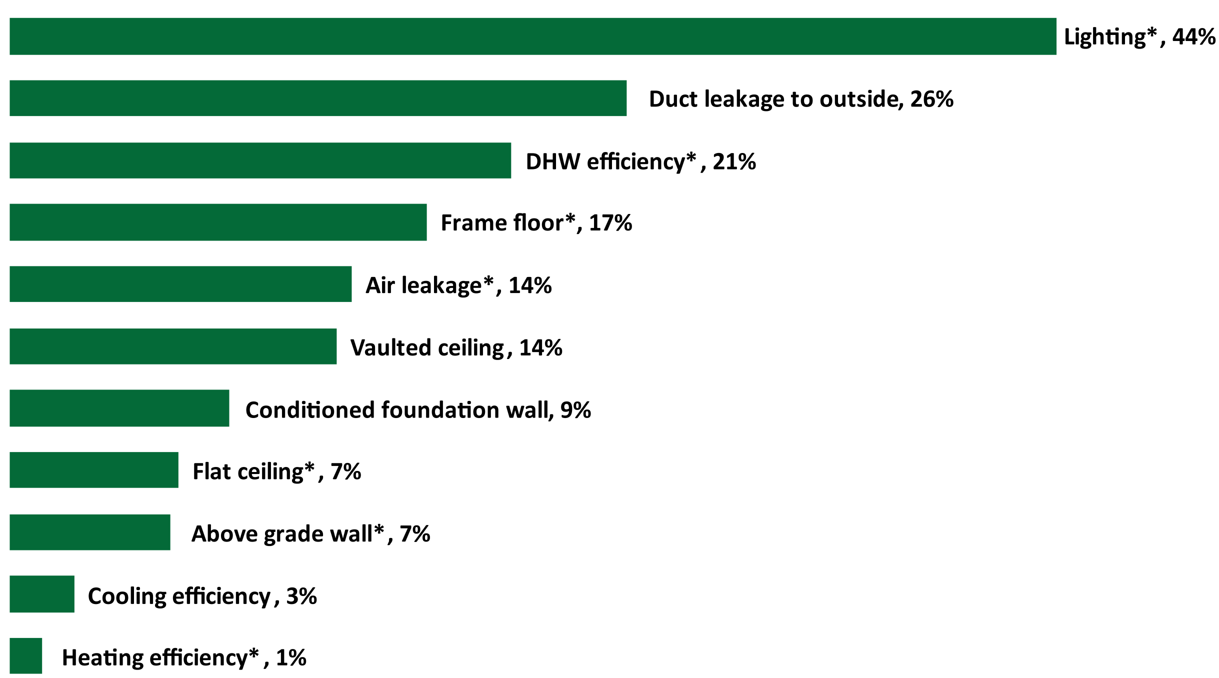
Key Findings & Recommendations

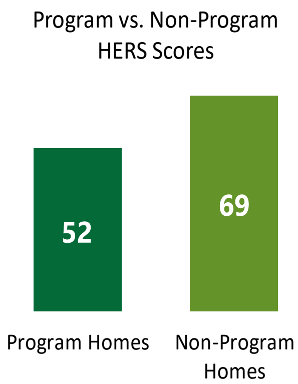
Average non-program HERS index values have improved slightly since the previous study. The average HERS index value decreased from 72 to 69 since the previous study (lower values mean higher efficiency). PV systems affect HERS values, but they are excluded from this analysis because the RNC program does 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 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. Duct leakage values varied widely, indicating an opportunity for improvement. Water heater efficiency showed a large improvement, but heating and cooling efficiencies showed only slight improvement. Measures followed by an asterisk in Figure 1 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

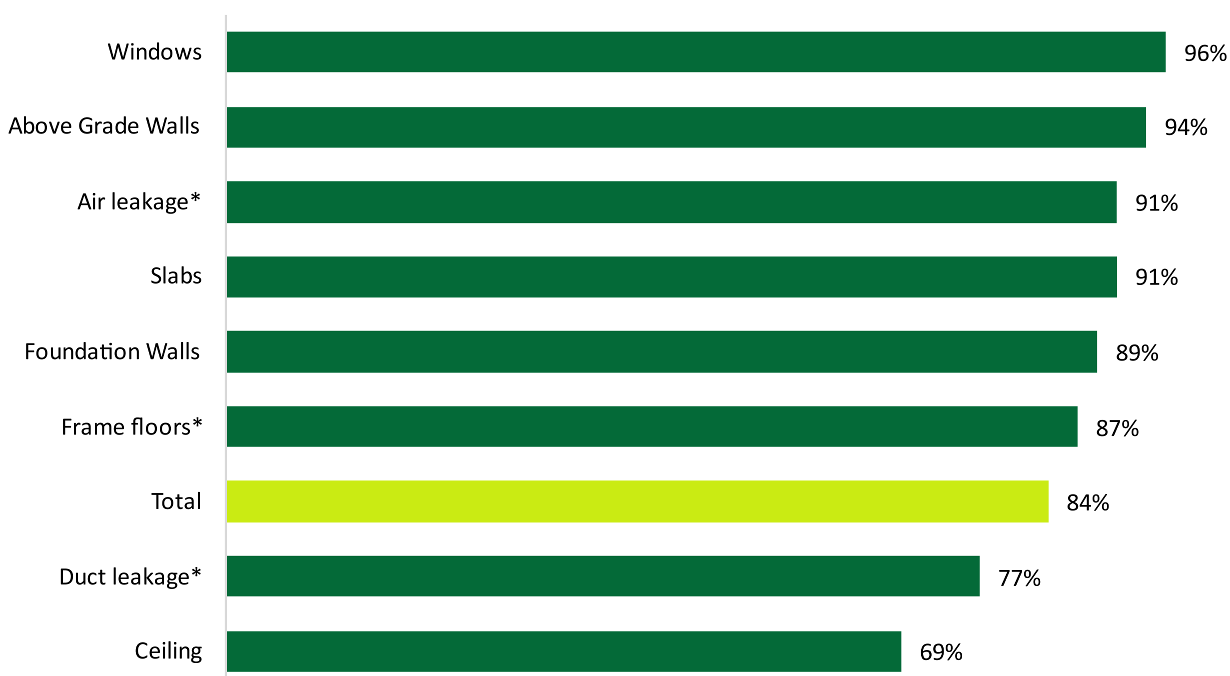




Program HERS index values are 25% better than non-program values on average. Excluding PV systems, the average HERS value for program homes was 52, while the average for non-program homes was 69, a statistically significant difference. Including PV systems in energy models shows a similar trend: 47 for 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 is similar to the previous study – slightly lower, but not significantly so. This study finds an overall code compliance rate of 84%; while this is down from 90% in the previous study, it is not statistically significant. The largest contributors to decreased compliance (homes that do not meet the prescriptive measure-level requirement) are ceilings (down from 78% to 69% compliance) and duct leakage (down from 95% to 77%), both statistically significant differences. Frame floors saw a statistically significant improvement, from 72% compliance to 87%. 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 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. Measures followed by an asterisk in Figure 2 represent statistically significant differences from the previous study's findings.

Figure 2: Measure-Level Code Compliance



RECOMMENDATIONS

Recommendation 1. Subject to the approval of Connecticut policymakers, adopt updated UDRH inputs based on this study's findings, but be prepared to adjust these values based on upcoming evaluation research in time for the PSD update in 2024. Table 1 summarizes the recommended single-family 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 state of the non-program market between 2019 and 2022 (homes built under the 2015 IECC). A detailed breakdown of the recommended UDRH inputs by measure can be found in Appendix B. Summary values are focused on values for the program to adopt as it shifts to an all-electric path. The appendix includes values that can be used for the fossil-fuel homes that enter the program before the program switchover to all-electric.

Heating, cooling, and water heating. 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. While the study provides average measure-level values for a variety of fuels, 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 uniform energy factor (UEF) 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 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 Recommendations 2 and 3 for additional discussion of this research). The study acknowledges that although the program shift to all-electric is imminent, homes using fossil-fuels are currently being built or may enter the program before it switches to an all-electric path. For these homes, the fossil fuel system on-site results found in Appendices B.3.12 and B.3.14 should be used.

Multifamily homes. The study did not include multifamily onsites and the study's building department visits yielded limited usable data on multifamily home energy efficiency. The study still, however, developed UDRH values for multifamily homes. To develop the multifamily UDRH recommendations, the study adjusted the single-family values based on the measure-level differences between single-family and multifamily program home energy models, in line with the approach used in the previous R1602 baseline study. Multifamily UDRH values and adjustment factors can be found in Appendix B.4.

Code changes. The homes in this study were built under the 2015 IECC, which has been superseded by the 2021 IECC, adopted in Connecticut in October 2022. Recommendation 2 describes the implications of adopting a UDRH that reflects homes built under a previous code cycle, and requests guidance from Connecticut policymakers.

Table 1: Summary of Recommended UDRH (Baseline) Inputs
(Short-Term Values, Likely to be Updated in 2024)

		Current		Recommended
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
	Gas/propane hydronic	89.6 AFUE	All others	10.3 HSPF
	ASHP	10.0 HSPF		
	GSHP	4.0 COP		
Cooling System Efficiency	GSHP	12.2 EER	GSHP	12.3 EER
	All others	14.6 SEER	All others	14.9 SEER
Water Heater EF	Gas/propane storage	0.65	1.25 UEF	
	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 ft^2		6.2		4.6
% Efficient Lighting (LED and CFL)		54%		100%

Recommendation 2. This study indicates the need for Connecticut policymakers to provide guidance on the practice of adopting an RNC baseline that – while representing the most recent assessment of industry standard practice – has been superseded by a substantially more stringent code. The UDRH recommendations described above were developed based on observations of homes built under the 2015 IECC. Accordingly, they generally fall short of the measure-level prescriptive requirements of the recently adopted 2021 IECC. (The 2021 IECC was adopted too late for homes built under that code cycle to be included in this study.) If the market adapts quickly to the requirements of the new 2021 IECC, the measure-level baseline values recommended by this study may overstate savings relative to industry standard practice. For this and other reasons (e.g., the program switching to all-electric), the study recommends using these UDRH values for use only in the short-term. Under the guidance of the EA Team, evaluation research in the coming year will investigate this topic and may provide feedback on industry

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standard practice early in the 2021 IECC code cycle, hopefully in time for adoption in the 2024 PSD update.

If Connecticut policymakers object to the Companies using a UDRH based on the previous code cycle in the short term, the Companies could adopt a more stringent baseline that is more closely tied to the 2021 IECC, as shown in Appendix 0. An alternative baseline might, for example, include the better of the on-site values identified in this study or the prescriptive code values for the 2021 IECC. The study does not recommend this approach for the time being but recognizes that policymakers may (reasonably) object to a baseline that – though conducted on recently-built homes – describes homes built under a code cycle that is no longer in effect and that is substantially outperformed by the new code version. Using a baseline derived from homes built under a previous code cycle is not unprecedented, however; the previous R1602 baseline study was completed under similar circumstances, where the UDRH was based on the previous code version, despite the fact that a new code had recently come into effect.

Table 2 compares the UDRH values recommended for short-term adoption with the prescriptive requirements of the 2015 IECC and 2021 IECC. The more efficient values in each row are shaded in green; the darker green reflects the most efficient value in the row.

Table 2: Short-Term UDRH Recommendations vs Prescriptive Code Requirements

Measure	Units	Value from Baseline	2015 IECC Requirement	2021 IECC Requirement
Exterior wall	R-value	22.3	20 or 13+5[1]	30 or 20+5 or 20ci2
	U-value	0.057	0.060	0.045
Flat ceiling	R-value	39.7	49[3]	60
	U-value	0.04	0.026	0.024
Vaulted ceiling	R-value	42.5	49[3]	60
	U-value	0.031	0.026	0.024
Frame floor over basement	R-value	31	30[4]	30
	U-value	0.05	0.033	0.033
Conditioned foundation wall	R-value	12	15/19[5]	15/19, or 13+5[5]
Air leakage	ACH50	4.2	3.0	3.0
Duct leakage	LTO	4.6	8.0	4.0

[1] Requires R-20 or R-13 in the cavity with R-5 continuous.
[2] 20ci refers to continuous R-20.
[3] R-38 satisfies R-49 requirement where uncompressed R-38 batt extends over the wall plate at the eaves.
[4] R-19 satisfies requirement if it fills the entire cavity.
[5] R-15 continuous or R-19 cavity, or R-13 cavity and R-5 continuous.

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, estimating NTG values for the RNC program) 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. This research will tie in with the research described in the previous recommendations, associated with assessing home performance against the new 2021 IECC.

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 may lead to other savings losses if builders drop out of the program rather than changing to all-electric practices. In order to maintain the fossil-fuel based 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 or ensuring thorough marketing and outreach.

Recommendation 5: 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, are similar but slightly lower than in the previous study (not a statistically significant difference). The Companies should continue code compliance enhancement trainings as part of the RNC program to increase spillover and/or market effects attributed to the program as a part of net-to-gross savings evaluations. 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 6: 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 7: Leverage code compliance enhancement trainings to improve documentation available at building departments. The study included visiting municipal building departments to assess the feasibility of using their data for baseline studies and to inform UDRH inputs for multifamily buildings, which were not included in on-site data collection.

However, documentation at building departments was found to be relatively sparse and rarely contained sufficient data for these purposes. The most common types of documentation found were permits and blueprints, which did not contain verified measure-level efficiency data. The Companies should leverage code compliance trainings to increase the consistency of documentation available for evaluations, such as code compliance checklists and certificates, HERS rating data, and blower door and duct blaster test results.

Recommendation 8: 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 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 at a cost of $2,500 for six months of API access. 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 or those that have more efficient homes. 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 only 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.

Section 1 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.

1.1 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

1.2 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. A similar situation occurred during this study as is noted above in reference to R1602 in which a new code was adopted during the study which is based on 2021 IECC. The timing did not allow for any homes built under this code to be included in this research, and therefore the recommendations made in this study will soon be outdated. This is particularly true given that the prescriptive requirements in 2021 IECC represent a substantial improvement over the 2015 IECC code examined in this study. As noted in the recommendations above, this will require an additional update to UDRH assumptions much sooner than the typical baseline cycle that has been implemented in the past.

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.

1.3 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?

1.4 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 findings for building shell components
- Section 6 Mechanical Equipment: Key findings for mechanical equipment components
- Section 7 Lighting and Appliances: 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

Section 2 Methodology 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, duct tightness by conducting duct blaster tests, and assessed compliance with the Connecticut energy code.

2.1 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, which yielded an estimate of 2,746 single family permits annually.[2] Table 3 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 3: 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**

[2] https://www.census.gov/construction/bps/

2.2 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].

2.3 On-site Data Collection Points

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

- 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
- Water fixtures
- Lighting
- Appliances
- Renewables
- Electric vehicles and chargers
- Code compliance

2.4 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

[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.

[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 scoring process. 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 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.

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.

2.5 Multifamily Adjustment Factors

Due to the lack of building department data, the study used similar methodology as the previous baseline study to estimate multifamily UDRH inputs, relying on ratios between program single family and multifamily homes. The program data included Ekotrope models for both single-family and multifamily units. The multifamily adjustment factor is calculated as the multifamily program value represented as a proportion of the single-family program value. To calculate multifamily adjustment factors for each measure, the single-family program average value was compared to the multifamily program average. The difference in efficiency between the single-family and multifamily samples was calculated as ratio change from the single-family efficiency. That ratio was then added to 1.0 to calculate the multifamily adjustment factor – the value that the single-family home average values were multiplied by to create the estimated multifamily efficiency value.

2.6 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, U-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.

Section 3 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.

3.1 Previous Baselines

Table 4 and Table 5 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] and 2011[6] 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. Statistical signifigance testing could not be performed on program data as standard deviation was not included in the previous study program data.

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[5] https://energizect.com/sites/default/files/documents/R1602-RNC%20Baseline%20Report-FINAL%2020180503_Revised.pdf

[6] https://energizect.com/sites/default/files/documents/ConnecticutNewResidentialConstructionBaseline-10-1-12_0.pdf

Table 4: 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 AFUE[a]	90.7	93.5	94.8*
Cooling System SEER[b]	13.4	14.5	14.9
Water Heating EF[c]	0.74	0.98	1.24*
Duct LTO CFM25/100 ft^2	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 5: 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 AFUE[a]	94.9	95.5
Cooling System SEER[b]	15.3	15.4
Water Heating EF[c]	1.09	1.51
Duct LTO CFM25/100 ft^2	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.

3.2 Non-Program versus Program Homes

Table 6 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 6: Comparison of Non-program and Program Single-Family Homes

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

[a] Non-program and program values are significantly different at the 90% confidence level.

Section 4 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.

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.

4.1 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% (although this drop is not statistically significant). 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 – both statistically significant differences. 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, which had lower prescriptive requirements.

Table 7: Non-Program Code Compliance by Measure

(On-site visits: All homes)

	Custom[7]	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 8: 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%[a]
Foundation Walls	85%	89%
Frame floors	72%	87%[a]
Duct leakage	95%	77%[a]
Ceiling	78%	69%
Total	**90%**	**84%**

[a] Statistically significant difference

[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.

4.2 HERS Index Value Results

Table 9 summarizes the HERS index values of the 58 non-program homes, modeled both with and without PV systems[8], as those 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 9: 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 10 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 10: 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

[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.

Section 5 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 indicate that **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 11 summarizes the average key efficiencies for building shell measures.

Table 11: 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

5.1 Air Infiltration and Ventilation

The average air tightness of non-program new homes has improved since the previous study but is not compliant with the 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.

5.2 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.

5.3 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.

5.4 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.

5.5 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%.

5.6 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.

5.7 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.

Section 6 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.

6.1 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 prevalence of each primary heating fuel did not change significantly from the previous study: 44% natural gas, 39% propane, and 12% electric.

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] 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.

[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.

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.

6.2 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.

6.3 Thermostats

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%.

6.4 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) have both increased since the previous study, from 26% to 38% for instantaneous and from 6% to 13% for HPWH. The fuel mix of water heaters is comparable to that of the previous study, with no significant differences – approximately one-third each use natural gas, electricity, and propane.

The efficiency of water heating equipment has increased to 1.25 UEF, above what is achievable for fossil fuel equipment. The average water heater UEF for all water heater types found during non-program on-site inspections is 1.25, driven largely by the shift towards HPWH noted above which can have efficiencies greater than 4.0 UEF (the eight in visited homes had an average UEF of 3.54). 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.

6.5 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.

6.6 Renewables and Electric Vehicles

Solar PV penetration has slightly increased. Solar photovoltaic arrays were present at 10% of homes visited in the current study; up from 7% in 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.

Section 7 Lighting and Appliances

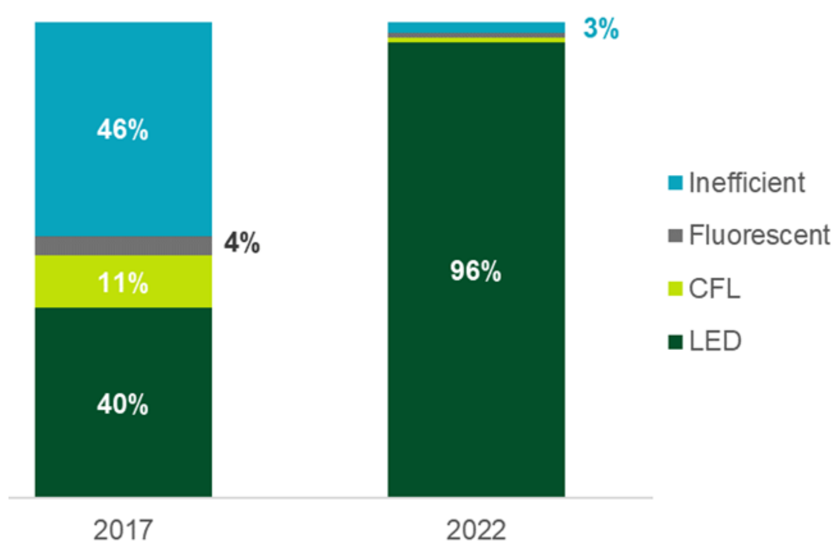
This section summarizes the key findings about lighting, appliances, and electronics in homes.

7.1 LIGHTING

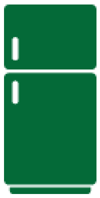
Saturation of LEDs has increased significantly since the previous study. In this study 96% of light sockets used an LED bulb or fixture compared to 40% of the homes in the previous study. All of the homes visited for this study had at least one LED bulb or fixture. While program homes have consistently 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 3: 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. This decrease could be due to increased stringency of ENERGY STAR standards since the previous study.

Table 12: 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%

The average efficiency of most appliances has improved since the 2017 study but has decreased slightly for refrigerators. The average values from on-site visits in the 2022 column are recommended to be used as a savings baseline for appliances for the RNC program.

Table 13: Appliance Efficiency

	2017	2022
Refrigerator	628	634
Freezer	434	374
Dishwasher	267	157
Clothes Washer	2.29	2.41
Clothes Dryer	3.56 (EF)	3.7 (CEF)

A

Appendix A Detailed Data

This section provides detailed results from the on-site data collection of non-program homes, 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.

A.1 General Home Characteristics

Table 14: 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 15: Conditioned Floor Area (ft^2)
(On-site visits: All Homes)

	Custom	Spec	Statewide
n	*25*	*34*	*59*
Mean	3,150	2,526	2,790
Min	1,116	625	625
Max	6,736	6,394	6,736
Median	2,796	2,340	2,448
Std. Dev.	1,646	1,096	1379
CV	.52	.43	.49
Conf. Int.	(2,609, 3,692)	(2,216, 2,835)	(2,495, 3,086)

Table 16: 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 17: 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%

A.2 Building Shell

A.2.1 Air Infiltration and Ventilation

Table 18: 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 19: 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 20: 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 21: 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%

A.2.2 Walls

Table 22: 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
Std. Dev.	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 23: 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 24: 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 25: 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 26: R-values for Walls to Buffer Spaces (Garages, Basements, etc.)
(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
Std. Dev.	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)

A.2.3 Ceilings

Table 27: 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 28: 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 29: 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 30: 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 31: 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 32: 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

A.2.4 Floors

Table 33: Average R-Value of Frame Floors between Conditioned & Unconditioned Space
(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	**0.0**
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 34: Floor Insulation Type between Conditioned & Unconditioned
(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 35: Average R-Value of Insulated Floors between Conditioned & Unconditioned Basement

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

	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 36: Floor Insulation Type between Conditioned & Unconditioned Basement

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

	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%

A.2.5 Foundation Walls

Table 37: 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)

Table 38: 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 39: 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 40: 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%

A.2.6 Slabs

Table 41: Slab Location
(On-site visits: Slabs)

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

Table 42: 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 43: 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.

A.2.7 Windows

Table 44: 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 45: Average Window SHGC (Confirmed Values Only)
(On-site visits: Homes with Confirmed Window SHGC)

	Custom	Spec	Statewide
n	*69*	*23*	*92*
Mean	0.29[a]	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 46: 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 47: 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 48: 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%)

A.3 Mechanical Equipment

A.3.1 Heating

Table 49: 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 50: 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 51: 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 52: 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%
Sealed Attic	8%	3%	5%
Vented Attic	4%	6%	5%
Garage	8%	0%	3%
Ambient	4%	0%	2%

Table 53: 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 54: 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 55: 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 56: 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
Std. Dev.	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 57: 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 58: 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 59: 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 60: 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 61: Furnace ENERGY STAR Status

(On-site visits: Furnaces)

	Custom	Spec	Statewide
n	*18*	*36*	*54*
Yes	84%	86%	85%
No	17%	14%	15%

Table 62: 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 63: 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 64: Boiler ENERGY STAR Status
(On-site visits: Boilers)

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

Table 65: Heat Pump Efficiency (HSPF)
(On-site visits and Survey: MSPHs 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
Std. Dev.	0.3	NA	0.4
CV	NA	NA	NA
Conf. Int.	(10.5,10.8)	NA	(10.3,10.7)

Table 66: 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
Std. Dev.	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)

A.3.2 Cooling

Ninety-seven percent of homes visited had a permanently installed cooling system.

Table 67: 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 68: 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%
Sealed attic	12%	3%	7%
Garage	4%	0%	2%

Table 69: 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 70: 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 71: All Cooling System Efficiency (SEER)

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

	Custom	Spec	Statewide
n	*32*	*37*	*69*
Mean	15.7[a]	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 72: 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 73: 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 74: 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 75: 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 76: 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 77: 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.

A.3.3 Thermostats

Table 78: 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 79: 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
Std. Dev.	4.0	2.3	3.2

Table 80: 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
Std. Dev.	3.0	3.0	3.0

A.3.4 Ducts

Table 81: Duct Materials
(On-site visits: Duct branches)

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

Table 82: 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%
Sealed attic	16%	5%	9%
Enclosed crawlspace	7%	0%	3%
Vented attic, under insulation	1%	2%	1%
Garage	1%	0%	0%

Table 83: 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 84: 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 85: 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 86: 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 87: 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 88: 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 89: Total Duct Leakage
(On-site visits: Duct Systems, CFM25 per 100 ft^2 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 90: Duct Leakage to the Outside
(On-site visits: Duct Systems, CFM25 per 100 ft^2 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)

A.3.5 Domestic Hot Water

Table 91: 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 92: 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 93: 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 94: 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 95: 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 96: All Water Heater Efficiency (UEF)

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

	Custom	Spec	Statewide
n	*23*	*34*	*57*
Mean	1.17	1.31	1.25
Min	0.67	0.63	0.63
Max	3.88	3.45	3.88
Median	0.95	0.93	0.93
Std. Dev.	0.85	1.01	0.94
CV	0.73	0.77	0.75
Conf. Int.	(0.88, 1.46)	(1.03, 1.60)	(1.05, 1.46)

Table 97: All Water Heater Efficiency (EF)

(On-site visits: All Water Heaters with EF or Converted UEF[10])

	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 98: 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)

[10] https://www.resnet.us/wp-content/uploads/RESNET-EF-Calculator-2017.xlsx

Table 99: Electric Water Heater Efficiency (UEF)
(On-site visits: Electric Water Heaters, Including HPWH)

	Custom	Spec	Statewide
n	*8*	*12*	*20*
Mean	1.62	2.19	1.96
Min	0.77	0.93	0.77
Max	3.88	3.45	3.88
Median	0.92	2.17	0.95
Std. Dev.	1.38	1.31	1.33
CV	0.85	0.60	0.68
Conf. Int.	(0.82, 2.43)	(1.57, 2.81)	(1.47, 2.45)

Table 100: 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 101: Fossil Fuel Water Heater Efficiency (UEF)
(On-site visits: Fossil Fuel Fired Water Heaters with UEF)

	Custom	Spec	Statewide
n	*15*	*21*	*36*
Mean	0.92	0.84	0.88
Min	0.67	0.63	0.63
Max	0.97	0.97	0.97
Median	0.95	0.93	0.93
Std. Dev.	0.08	0.12	0.11
CV	0.08	0.15	0.13
Conf. Int.	(0.89, 0.96)	(0.80, 0.89)	(0.85, 0.91)

Table 102: 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 103: Instantaneous Water Heater Efficiency (UEF)

(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 104: Heat Pump Water Heater Efficiency (UEF)

(On-site visits: HPWHs)

	Custom	Spec	Statewide
n	*2*	*6*	*8*
Mean	3.86	3.44	3.54
Min	3.83	3.39	3.39
Max	3.88	3.45	3.88
Median	3.86	3.45	3.45
Std. Dev.	0.04	0.02	0.19
CV	0.01	0.01	0.05
Conf. Int.	(3.81, 3.90)	(3.42, 3.46)	(3.43, 3.66)

Table 105: 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 106: 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 107: Electric Resistance Storage Water Heater Efficiency (UEF)

(On-site visits: Electric Resistance Water Heaters)

	Custom	Spec	Statewide
n	*6*	*6*	*12*
Mean	0.88[a]	0.94	0.91
Min	0.77	0.93	0.77
Max	0.95	0.95	0.95
Median	0.92	0.94	0.93
Std. Dev.	0.07	0.01	0.06
CV	0.08	0.01	0.06
Conf. Int.	(0.83, 0.93)	(0.93, 0.95)	(0.88, 0.94)

Table 108: Electric Resistance Storage Water Heater Efficiency (EF)
(On-site visits: Electric Resistance Water Heaters)

	Custom	Spec	Statewide
n	*6*	*6*	*12*
Mean	0.87[a]	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 109: Natural Gas and Propane Storage Water Heater Efficiency (UEF)
(On-site visits: Storage Water Heaters, Natural Gas and Propane)

	Custom	Spec	Statewide
n	*2*	*7*	*9*
Mean	0.77	0.68	0.70
Min	0.67	0.63	0.63
Max	0.87	0.72	0.87
Median	0.77	0.69	0.69
Std. Dev.	0.14	0.03	0.07
CV	0.18	0.04	0.10
Conf. Int.	(0.61, 0.93)	(0.67, 0.70)	(0.67, 0.74)

Table 110: 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 111: 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%

A.3.6 Faucet Aerators

Table 112: Flow Rate
(On-site visits: Faucets)

	Custom	Spec	Statewide
n	*95*	*137*	*232*
Mean	1.5[a]	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 113: Presence of Aerator on Faucets
(On-site visits: Faucets)

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

A.4 Renewables and Electric Vehicles

Table 114: 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 115: 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
Std. Dev.	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)

A.5 LIGHTING

Table 116: Lighting Saturation
(On-site visits: Light Sockets)

	Custom	Spec	Statewide
n	*1,511*	*1,749*	*3,260*
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 117: 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%

A.6 APPLIANCES

A.6.1 Refrigerators

Table 118: 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 119: 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 120: Primary Refrigerator Volume (ft^3)

(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 121: 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
Std. Dev.	102	94	98
CV	0.17	0.14	0.16
Conf. Int.	(575, 645)	(624, 676)	(613, 655)

Table 122: Secondary Refrigerator Summary
(Base: Secondary Refrigerators)

ENERGY STAR	Custom	Spec	Statewide
n	*12*	*13*	*25*
Yes	50%	61%	56%
No	50%	39%	44%
Volume (ft^3)	**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
Std. Dev.	124	105	114
CV	0.34	0.32	0.33
Conf. Int.	(309, 427)	(281, 376)	(310, 385)

A.6.2 Freezers

Table 123: Stand-alone Freezer Summary
(On-site visits and Survey: Stand-alone Freezers)

ENERGY STAR[1]	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 (ft^3)	**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
Std. Dev.	223	133	169
CV	0.60	0.35	0.45
Conf. Int.	(219, 518)	(300, 455)	(299, 448)

A.6.3 Dishwashers

Table 124: 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 125: Dishwasher Capacity
(On-site visits: Dishwashers with Capacity Information)

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

Table 126: 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 127: 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
Std. Dev.	105	61	82
CV	0.62	0.42	0.53
Conf. Int.	(136, 205)	(130, 164)	(139, 174)

A.6.4 Ovens and Ranges

Table 128: Oven and Range Configuration
(On-site visits: Oven and Range Units)

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

Table 129: 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 130: 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%

A.6.5 Clothes Washers

Table 131: 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 132: Clothes Washer Rated Energy Consumption (kWh/Year)
(On-site visits: Clothes Washers 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
Std. Dev.	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 133: 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

	Custom	Spec	Statewide
Max	3.10	3.30	3.30
Median	2.76	2.76	2.76
Std. Dev.	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)

A.6.6 Clothes Dryers

Table 134: 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 135: 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 136: 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 137: 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
Std. Dev.	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)

A.6.7 Dehumidifiers

Table 138: Dehumidifier ENERGY STAR Status
(On-site visits: Dehumidifiers)

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

Table 139: 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%

Appendix B UDRH Update

B.1 Summary of Recommended UDRH Inputs

This appendix provides the recommended User Defined Reference Home (UDRH) inputs for 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 developing these UDRH inputs.

Table 140 lists the data sources used in the R1968 study to develop the recommended UDRH inputs. Values that feed into the recommended values 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 140: 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)	Once program goes all-electric: 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

B.2 UDRH Methodology

B.2.1 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. 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.

B.2.2 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.

B.3 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.

B.3.1 Above Grade Walls

A 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 141).[11]

Table 141: Above Grade Wall Average Uo Values – Current Inputs and Study Results and Suggestions[1]

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.

The IECC 2021 code, as amended and adopted in Connecticut, requires a U-factor of 0.045. This is equivalent to the previous code's requirement of 0.060 (achievable with R-20 cavity insulation requirement) **plus** an additional R-5 continuous insulation.

B.3.2 Frame Floors

B Recommendation: Base frame floor values on onsite visit results. Use one Uo value for floors over unconditioned basements and enclosed crawl spaces, one for floors over garage, and another over ambient space and open crawl spaces.

This study recommends following the baseline study findings, which results in one UDRH value for floors over garages, one for ambient space and open crawl spaces (treated the same given the lack of onsites with open crawlspaces), and one value for floors over unconditioned basements and enclosed crawl spaces (Table 142).[12]

[11] 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.
[12] 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.

Table 142: 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	**0.046**

The only change in frame floor insulation requirements under the new 2021 IECC is that an exception permitting R-19 if there was insufficient depth for R-30 has been removed.

B.3.3 Ceilings

C 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 143).

Table 143: 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**

The IECC 2021 code, as amended and adopted in Connecticut, requires a U-factor of 0.024, equivalent to R-60.

B.3.4 Foundation Walls

D 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 144: Foundation Wall Average Insulation 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**

There is no change in requirements for basement walls under the new code.

B.3.5 Slab Floors

E 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.[13] Therefore, this study recommends continuing to use standard practice assumptions as done in the current UDRH (Table 145).

Table 145: 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**

The new code requires a slab insulation depth or width of four feet rather than two.

[13] 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.

B.3.6 Windows

F 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 146).

Table 146: 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**

Permissible window U-factors have been reduced to 0.30 under the new code.

B.3.7 Skylights

G 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.

B.3.8 Doors

H 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.

B.3.9 Air Infiltration

I 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 (Table 147).

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 147: 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**

IECC 2021 permits a trade-off of air infiltration with shell improves up to a maximum of 5 ACH50 for non-prescriptive path homes.

B.3.10 Duct Leakage

J Recommendation: Use the diagnostic test results from the study's onsite visits to update duct leakage to the outside inputs.

Table 148 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.[14] Homes with zero duct leakage are included in the non-program and program averages.

Table 148: 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 ft^2	6.2	4.6 (n=56)	1.6 (n=68)	**4.6**

The testing exception for ducts fully within conditioned space has been removed in IECC 2021.

B.3.11 Duct Insulation

K 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 149). Ducts in conditioned space would be modeled the same in the UDRH and rated home.

[14] 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.

Table 149: Duct Insulation – Current Inputs and Study Results and Suggestions

Unit	Current UDRH Input	Average Results: Non-Program (R1968 site visits)	Average Results: Program (2022 program data)	Suggested Input
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**

B.3.12 Heating

L ***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. Average fossil-fuel values from onsites are provided for any fossil fuel homes that enter the program before the switch to an all-electric program design.***

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 will no longer be relevant once the program adopts this new design. 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[15]. The recommendations by system type are shown in Table 150. As noted in the Executive Summary recommendations, we provide average values from the non-program site visits for fossil-fuel systems; these average values could be used as UDRH inputs for fossil fuel homes that enter the program before the program shifts to its all-electric design.

Table 150: Heating Systems – Current Inputs and Study Results and Suggestions

Fuel and System Type	Current UDRH Input	Average Results: Non-Program (R1968 site visits)	Average Results: Program (2022 program data)	Suggested Inputs
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**

[15] https://up.codes/viewer/connecticut/iecc-2015/chapter/RE_4/re-residential-energy-efficiency#R405

Fuel and System Type	Current UDRH Input	Average Results		Suggested Inputs
		Non-Program (R1968 site visits)	Program (2022 program data)	
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**

B.3.13 Cooling

M ***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 151: Cooling Systems – Current Inputs and Study Results and Suggestions

Unit	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**

B.3.14 Water Heaters

N Recommendation: Collapse water heater categories into just one UEF 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. Average fossil-fuel values from onsites are provided for any fossil fuel homes that enter the program before the switch to an all-electric program design.

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 152, the study makes the following recommendations for single-family water heater UDRH inputs. Once the program switches to an all-electric path, 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. Fossil-fuel baseline values (from non-program site visits) could be used for new projects entering the program before it shifts to an all-electric design.

Table 152: 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 (Current: EF, RE. Recommended: UEF, 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**

Fuel and System Type	Current UDRH Input	Average Results		Suggested Inputs
		Non-Program (R1968 site visits)	Program (2022 program data)	
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	1.96, 2.04 (n=20)	3.62 (n=16)	**1.25 1.27**
Location				
Location	Unconditioned Space	Unconditioned space	Unconditioned space	**Unconditioned Space**

B.3.15 Lighting

- ***Recommendation: Assume 100% efficient lighting in the UDRH since the program does not claim lighting savings.***

The efficient lighting percentages include CFL and LED bulbs. This is a percentage of efficient hardwired fixtures that are found in qualifying locations.[16] The team recommends setting the percent efficient lighting in the reference home to 100% since the program no longer claims lighting savings. The non-program average of 96% reinforces this decision (Table 153).

Table 153: 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)	**100%**

100% efficient lighting is required under the new code, compared to 90% under the previous version.

[16] 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.

B.3.16 Thermostats

P 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 154). 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 thermostats.

Table 154: 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)	NA	**Programmable**
Setpoint (Degrees F)				
Heating	69	68.7 (n=97)	N/A	**68.7**
Cooling	73	72.3 (n=97)	NA	**72.3**

B.3.17 Mechanical Ventilation

Q 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 155: 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**

The IECC 2021 code relaxes mechanical ventilation fan efficacy requirements (CFM per Watt) by approximately 50% compared to the previous code.

B.4 Multifamily Adjustment Factors

One of the research tasks included in this study involved building department data collection for selected multifamily buildings in order to compare to single-family on-site data and create adjustment factors. However, building department data collection proved to be unfruitful and therefore the study used comparisons between single-family and multifamily program energy models to create these adjustment factors. This methodology was also used in the previous baseline study, R1602. Details on this methodology can be found in Appendix C.6. Table 156 lists the adjustment factor for each measure and the associated multifamily UDRH recommendation.

These factors are typically modest adjustments, but the multifamily adjustment factor for ACH50 (2.18) seems particularly large. This is not because of a difference in testing methods between single-family and multifamily homes. Multifamily units that participate in the RNC program receive individual blower door tests, like single-family homes. In both cases, all measured air leakage is treated as air leakage to outside. However, the large difference in average ACH50 between single-family program and multifamily program homes could be the result of a difference in requirements. Single-family homes are required to have an ACH50 of 3 or less, while multifamily units have a higher threshold: units greater than 850 square feet are required to have an air leakage of no more than 5 ACH50 and units less than 850 square feet no more than 6.5 ACH50. A similar ratio between single family and multifamily infiltration values were seen in the previous baseline study.

Table 156: Multifamily Adjustment Factors and Suggested Inputs

Fuel and System Type	SF Input	MF Adjustment Factor	Suggested MF Input
Above Grade Walls			
Conditioned to Ambient U-value	0.057	1.077	**0.061**
Conditioned to Garage U-value	0.065	NA	**0.065**
Conditioned to Attic U-value	0.063	0.898	**0.057**
Conditioned to Unconditioned Basement and Enclosed Crawl Spaces U-value	0.091	NA	**0.091**
All Unconditioned to Any U-value	0.062	NA	**0.062**
Frame Floors			
Conditioned over Unconditioned Basement and Enclosed Crawl Spaces U-value	0.050	NA	**0.050**
Conditioned over Garage U-value	0.040	0.788	**0.032**
Conditioned over Ambient U-value	0.046	2.094	**0.096**
Conditioned over Open Crawl U-value	0.047	NA	**0.047**
Ceilings			
Flat Attic U-value	0.040	1.000	**0.040**
Vaulted U-value	0.031	0.893	**0.028**
Foundation Walls			
All Conditioned R-Value	12.0	0.566	**6.8**
All Unconditioned R-Value	0.8	NA	**0.8**

Fuel and System Type	SF Input	MF Adjustment Factor	Suggested MF Input
Slab Floors			
On Grade Unheated Slab Under R-Value	0	NA	**0**
On Grade Unheated Slab Perim R-Value	5	NA	**5**
On Grade Heated Slab Under R-Value	15	NA	**15**
On Grade Heated Slab Perim R-Value	10	NA	**10**
Below Grade Unheated Slab Under R-Value	0	NA	**0**
Below Grade Unheated Slab Perim R-Value	0	NA	**0**
Below Grade Heated Slab Under R-Value	15	NA	**15**
Below Grade Heated Slab Perim R-Value	10	NA	**10**
Windows			
U-value	0.29	0.967	**0.280**
SHGC	0.29	0.906	**0.263**
Skylights			
U-value	Same as rated home	NA	**Same as rated home**
SHGC	Same as rated home	NA	**Same as rated home**
Doors			
Door U-value	Same as rated home	NA	**Same as rated home**
Air Infiltration			
ACH50	4.2	2.180	**9.16**
Shelter Class	Same as rated home	NA	**Same as rated home**
Heating Systems			
Natural Gas Air Distribution AFUE	94.9	0.987	**93.7**
Natural Gas Hydronic Distribution AFUE	95.0	0.997	**94.7**
Natural Gas Unit Heater AFUE	NA	NA	**NA**
Propane Air Distribution AFUE	95.3	NA	**95.3**
Propane Hydronic Distribution AFUE	95.0	NA	**95.0**
Propane Unit Heater AFUE	NA	NA	**NA**
Oil Air Distribution AFUE	85.0	NA	**85.0**
Oil Hydronic Distribution AFUE	87.0	NA	**87.0**
Oil Fired Unit Heater AFUE	NA	NA	**NA**
Wood Fuel Fired Unit Heater % EFF	NA	NA	**NA**
Kerosene Fuel Fired Unit Heater AFUE	NA	NA	**NA**
ASHP & Ductless Mini-Splits HSPF	10.3	1.019	**10.5**
GSHP COP	4.0	1.436	**5.7**
Dual Fuel Heat Pump HSPF (AFUE)	NA	NA	**NA**

Fuel and System Type	SF Input	MF Adjustment Factor	Suggested MF Input
Cooling Systems			
Air conditioner SEER (CAC, ASHP, Ductless Mini-spit)	14.9	1.000	**14.9**
GSHP EER	12.3	NA	**12.3**
Water Heaters			
Natural Gas Conventional EF	0.74	NA	**0.74**
Natural Gas Integrated EF	0.87	NA	**0.87**
Natural Gas Instantaneous EF	0.94	1.00	**0.94**
Propane Conventional EF	0.68	NA	**0.68**
Propane Integrated EF	0.87	NA	**0.87**
Propane Instantaneous EF	0.93	NA	**0.93**
Oil Conventional EF	0.65	NA	**0.65**
Oil Integrated EF	NA	NA	**NA**
Oil Instantaneous EF	NA	NA	**NA**
Heat Pump	NA	NA	**NA**
Electric Conventional EF	NA	NA	**NA**
Electric Integrated EF	NA	NA	**NA**
Electric Instantaneous EF	NA	NA	**NA**
Heat Pump and Electric Conventional EF	2.03	NA	**2.03**
Duct Insulation			
Attic Supply Ducts	6.7	NA	**6.7**
All Other Ducts in Unconditioned Space	5.9	NA	**5.9**
Duct Leakage			
Leakage to Outside CFM25/100Sqft	4.6	1.563	**7.19**
Lighting			
% Efficient Lamps	100%	NA	**100%**
Thermostats			
Set Points	68.7, 72.3	NA	**68.7, 72.3**

B.5 Alternative UDRH Approach

The results from this study that inform the UDRH recommendations above came from data collected at homes built under the 2015 IECC. A new code based on 2021 IECC was adopted in Connecticut in October 2022, after on-site visits had occurred. The newly adopted code represents a substantial increase in stringency for most measures, meaning that the values obtained in this study may soon be out of date to the extent builders begin to follow and comply with the new code.

Table 157 compares the average values from on-site visits in this study to the prescriptive requirements of both the 2015 IECC (applicable code to these homes) and the 2021 IECC (active code as of October 2022). The values from this study fall short not only of the new 2021 IECC prescriptive requirements, but for most requirements, they also fail to meet the prescriptive values of the code cycle under which they were built – the 2015 IECC. **Readers should note that the code values shown here are prescriptive values only; there is no specific expectation that all homes would meet each value on average, given the existence of other compliance paths.** Prescriptive compliance represents only one of three compliance paths open to builders; to comply, homes must meet each of these values at the measure-level. However, homes can also comply with code via the performance path or Energy Rating Index (ERI) path (modeling the home in an energy model tool), where the builder can make trade-offs at the measure level and still comply overall. Thus, a home that follows the performance or ERI path could still comply with code but fail to meet specific prescriptive requirements. Accordingly, the prescriptive values shown here are for reference only.

In order to not overstate savings due to adopting a baseline informed by homes built under the previous code cycle (particularly when the 2021 IECC represents a substantial improvement), policymakers in Connecticut may be interested in a different approach to setting a program baseline, such as one that assumes at least code minimum values. In such an arrangement, values from on-site visits would only be used as a baseline if they exceed code minimums and otherwise the code requirement could be used. In this study, frame floor insulation is the only measure that exceeds the new 2021 IECC prescriptive code, and therefore the code minimum requirement would be used as a baseline for all other measures. As noted in the Executive Summary, these comparisons are provided for reference; this study encourages policymakers to weigh in on this issue, and future research could delve into the implications of adjusting the baseline.

Table 157: Baseline Results Compared to Code Requirements

Measure	Units	Value from Baseline	2015 IECC Requirement	2021 IECC Requirement
Exterior wall	R-value	22.3	20 or 13+5[1]	30 or 20+5 or 20ci[2]
	U-value	0.057	0.060	0.045
Flat ceiling	R-value	39.7	49[3]	60
	U-value	0.04	0.026	0.024
Vaulted ceiling	R-value	42.5	49[3]	60
	U-value	0.031	0.026	0.024
Frame floor over basement	R-value	31	30[4]	30
	U-value	0.05	0.033	0.033
Conditioned foundation wall	R-value	12	15/19[5]	15/19, or 13+5[4]
Air leakage	ACH50	4.2	3.0	3.0
Duct leakage	LTO	4.6	8.0	4.0

[1] Requires R-20 or R-13 in the cavity with R-5 continuous.
[2] 20ci refers to continuous R-20.
[3] R-38 satisfies R-49 requirement where uncompressed R-38 batt extends over the wall plate at the eaves.
[4] R-19 satisfies requirement if it fills the entire cavity.
[5] R-15 continuous or R-19 cavity, or R-13 cavity and R-5 continuous.

Appendix C 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.

C.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.

C.2 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, 3,660 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 158: 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

County	2018-2020 Permits	Share of Permits	Sample Target	Recruited Sample
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)**

C.3 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), including exterior
- 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

C.4 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.

C.5 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 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 to create meaningful comparisons.

Table 159:Record Availability at Building Department Sites

	SF on-site homes	Participant MF	Non-Participant MF
n	17	8	32
Records Available	82%	75%	53%
No Records Available	18%	25%	47%

Table 160: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%

C.6 Multifamily Adjustment Factors

Due to the lack of building department data to estimate multifamily efficiency, similar methods to the previous baseline study were used to create adjusted multifamily UDRH inputs from single family results using program data.

The program data included Ekotrope models for both single-family and multifamily units. The multifamily adjustment factor is the multifamily program value represented as a proportion of the single-family program value. To calculate multifamily adjustment factors for each measure, the single-family program average value was compared to the multifamily program average. The difference in efficiency between the single-family and multifamily samples was calculated as ratio change from the single-family efficiency. That ratio was then added to 1.0 to calculate the multifamily adjustment factor – the value that the single-family home average values were multiplied by to create the estimated multifamily efficiency value. lists the multifamily adjustment factors by measure.

For example, looking specifically at conditioned to ambient above grade walls, single-family program homes had an average U-value of 0.052 and multifamily program homes had an average of 0.056. The difference between these two values represented as a percentage of the single-family program value is 7.69%. To get the MF adjustment factor, the percentage change is added to 1.0 as a decimal (0.0769) to get 1.0769. To estimate the MF recommended specification the SF recommended specification is multiplied by the MF adjustment factor: 0.057 * 1.0768 = 0.061.

For some measures, it was impossible to calculate a multifamily adjustment factor because that measure was not present in the multifamily program sample or the single-family program sample. Those measures have factors listed as "NA." Typically, if an adjustment factor is "NA," the multifamily recommendation is the same as the single-family recommendation due to lack of better data. Additionally, for measures in which the single-family recommendation is "same as rated home" the multifamily recommendation is also "same as rated home."

C.7 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[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 Connecticut 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.[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):

$$Points_{Possible} = \frac{(P_{TC} \times 10)}{W_{TC}}$$

[17] https://www.energycodes.gov/rescheck

[18] 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.

Where:

$$P_{TC} \ = Percentage\ of\ Total\ Consumption\ for\ Any\ Measure$$

$$W_{TC} = Window\ Pecentage\ of\ Total\ Consumption$$

The example below details how this calculation works for floors.

$$Points\ Possible\ Floors\ is\ 4.1. = \frac{(8.2\% \times 10)}{20\%}$$

Where:

$$P_{TC\ \mathrm{Floors}} = Percentage\ of\ Total\ Consumption\ for\ Floors\ is\ 8.2\%$$

$$W_{TC} = Window\ Pecentage\ of\ Total\ Consumption\ is\ 20\%$$

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.[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:

$$PC_{Base} = \frac{(CB_{Cons} \ - AB_{Cons}\ )}{AB_{Cons}}$$

Where:

$$PC_{Base} = Percentage\ difference\ between\ "code - built"\ and\ "as - built"\ models$$

$$AB_{Cons} = As - built\ consumption$$

$$CB_{Cons} = Code - built\ consumtpion$$

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.

$$Percentage\ difference\ for\ Floors\ (PC_{Base})\ is - 0.4\ = \frac{(3\ \mathrm{MMBtu} - 5\ \mathrm{MMBtu})}{5\ \mathrm{MMBtu}}$$

Where:

$$AB_{Cons} = 5\ MMBtu\ for\ Floor\ Consumption$$

$$CB_{Cons} = 3\ MMBtu\ for\ Floor\ Consumption$$

[19] By providing only the maximum possible points this method does not apply extra credit for exceeding the prescriptive code requirements.

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:

$$Points_{Scored} = \begin{cases} Points_{Possible} \times (1 + PC_{Base})\ if\ PC_{Base} < 0 \\ Points_{Possible}\ if\ PC_{Base} \geq 0 \end{cases}$$

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.

$$\text{Points Scored for Floors is } 2.5 = 4.1 \times (1 - 0.4)$$

Where:

$$PC_{Base}\ for\ Floors = -0.4$$

$$Points\ Possible\ Floors = 4.1$$

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 be 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.

Appendix D Comparison to 2019 Massachusetts Baseline

D.1 Key Characteristics of 2019 Massachusetts Study

The Massachusetts homes built at the end of 2015 IECC (between 2017 and 2019) provide a strong comparison to the 2016 Connecticut baseline, as they were built to similar code requirements. The Massachusetts study[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

D.2 Comparison Results

Conditioned Floor Area

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

Table 161: Conditioned Floor Area (ft^2)

	2019 MA Baseline (2015 IECC)	2022 CT Baseline (2015 IECC)
n (homes)	100	59
Minimum	531	625
Maximum	7,964	6,736
Mean	2,978	2,790
Std. Dev	1,307	1,379

HERS Index Values

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

[20] https://ma-eeac.org/wp-content/uploads/MA19X02-B-RNCBL_ResBaselineOverallReport_Final_2020.04.01_v2.pdf.

Table 162: 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 163 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 163: 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 ft^2) 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 164: 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 165: 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%	----

	2019 MA Baseline (2015 IECC)	2022 CT Baseline (2015 IECC)
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 166: 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 167: 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 ft^2 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 ft^2	≤ 4 CFM25 per 100 ft^2
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 168: 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%