Vermont Residential New Construction Overall Final Report

For the 2015-2016 Study Period

May 8, 2019

SUBMITTED TO:
Vermont Public Service Department

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ES Executive Summary

The overall objective of the combined studies covered in this report is to provide the Vermont Public Service Department (PSD) with a residential new construction market assessment and baselines to help identify trends and opportunities for energy efficiency in Vermont. This report is one in a series of similar reports that were conducted in 1995, 2002, 2008, 2011 and then in 2015-2016.[1] This report summarizes the combined findings of a telephone survey of 163 homeowners conducted November 2015 through January 2016; on-site audits conducted October 2015 to May 2016 at 70 homes constructed in 2012 to 2016 across Vermont, of which 47 homes did not participate in Efficiency Vermont or Vermont Gas new construction programs (non-program homes) and 23 homes that did (program homes); in-depth interviews conducted July 2016 to January 2017 with five retail store managers that sell Heat Pump Water Heaters (HPWH) or Home Energy Management systems (HEMS) in Vermont, four distributors of heating, ventilation and air conditioning (HVAC) equipment providing sales and support throughout Vermont and ten HVAC contractors; and an assessment of code compliance with Vermont's 2011 *Residential Building Energy Standards (*RBES), which went into effect on effective October 1, 2011 for all non-program homes using REScheck software.[2]

For the first time Manual J calculations were performed for non-program homes and some program homes. A Manual J calculation is used to determine the heating and cooling loads of a home or building as well as sizing the capacity of HVAC equipment appropriately. It is one of the tools published by the Air Conditioning Contractors of America to help HVAC contractors design a heating and air conditioning system. Manual J calculations in this study help determine the extent to which HVAC systems are under or overbuilt in the study sample.

The results presented in this report reflect statewide data encompassing all three Vermont Energy Efficiency Utilities (EEUs), which include Efficiency Vermont, Burlington Electric Department, and Vermont Gas Systems. Because sample sizes were much larger for Efficiency Vermont than for either Burlington Electric Department or Vermont Gas Systems, EEU-specific results often emphasize Efficiency Vermont Efficiency Vermont and Vermont Gas Systems cooperate on RNC projects when service territories overlap as do Burlington Electric Department and Vermont Gas Systems.

HIGHLIGHTS

- For the first time in conducting these periodic market assessment studies, some inspected homes had heat pump water heaters. Six of the 70 homes had heat pump water heaters, three program and three non-program homes.

[1] Although this study spanned 2015-2016, to simplify referencing it is referred to as the 2015 study throughout this report.

[2] Program homes include all audited homes that participated in Efficiency Vermont residential new construction programs which includes Efficiency Vermont Certified homes, High Performance homes, and ENERGY STAR-certified homes. Program homes complied with RBES via the Home Energy Rating (HER) path and therefore were not assessed using the REScheck software.

- For the first time, no homes had a tankless coil water heating system.
- For the first time, some inspected homes used either central air source heat pumps (ASHP) or ductless mini-split heat pumps for heating. Auditors found three ASHPs and nine ductless mini-split heat pumps in 12 of the 70 homes—six program and six non-program homes. All these heat pumps were ENERGY STAR qualified.
- For the first time, Manual J calculations for sizing heating and cooling equipment were performed for non-program homes. A basic requirement of RBES 2011 for equipment sizing is: "Heating and cooling equipment must be sized in accordance with ACCA Manual S based on building loads calculated in accordance with ACCA Manual J or other approved heating and cooling calculation methodologies." [3] Manual J calculations for sizing heating equipment in 45 non-program homes showed only six non-program homes complied with heating equipment capacity requirements, and a majority had installed capacity exceeding 200% of the heating load. Manual J calculations for sizing cooling equipment in the 15 non-program homes with central cooling systems showed only one non-program home complied with central cooling equipment capacity requirements. Although nearly all observed cooling systems were oversized, the extent was not as drastic as for heating systems.
    - We were able to run Manual J for only four program homes. Two of the four program homes complied with heating equipment capacity requirements. Three of the four program homes had central cooling and none complied with Manual J sizing requirements.
- Use of LED lighting has soared in both program and non-program homes. Overall, the percentage of homes with LEDs rose from 10% in the 2011 study to 87% in the 2015 study. The saturation of LEDs rose from 1% in the 2011 study to 35% in the 2015 study.
- For the first time, over one-third (34%) of homes had central air conditioning. This is almost four times the percentages in the 2008 (10%) and 2011 (9%) studies. Also, in the 2015 study almost half (46%) of the homes with central air conditioning had ductless mini-split heat pumps,, 3% had air source heat pumps, and 20% had ground source heat pumps, which can provide both heating and cooling. However, in half of these homes the heat pumps were the primary heating system.
- The shift away from using oil for heating continued, dropping to only four percent of homes. This is a dramatic drop from oil being the primary heating fuel in 65% of homes in the 1995 study.
- Heating system efficiencies across the board were high suggesting this market is transformed. Most boilers (68%) had AFUEs greater than 92 and most (90%) were ENERGY STAR qualified, most (93%) natural gas and propane furnaces had AFUEs over 95 and all but one were ENERGY STAR-qualified, and all heat pumps in inspected homes were ENERGY STAR qualified.

[3] Vermont Residential Building Energy Code Handbook. Edition 3.1. Effective October 1, 2011. Page 61.

RESULTS SHOW IMPROVEMENT

This section addresses improvements in selected building envelope measures, air leakage, heating system efficiencies, types of water heaters, ENERGY STAR appliance saturation, and CFL and LED lighting.

Figure 1 shows how the average R-values of conditioned/ambient walls, flat ceilings, cathedral ceilings, and foundation walls have increased since the 1995 baseline study. Plotted data for the last three baseline studies includes the average R-values for program and non-program homes as well as the statewide average and RBES code.

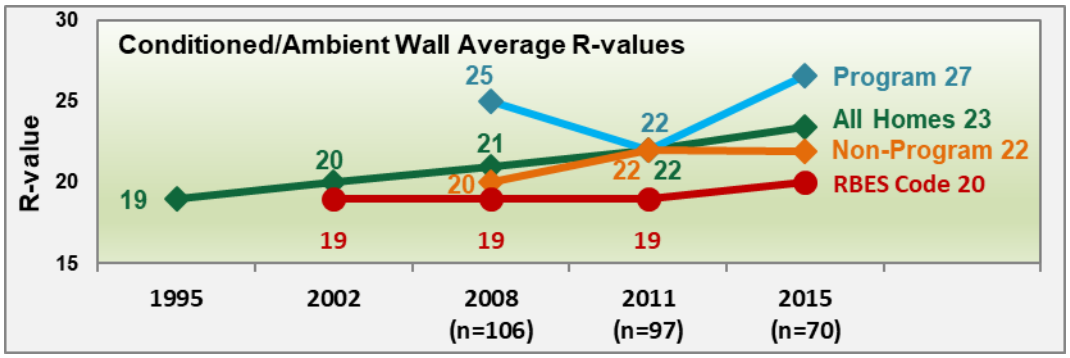
Conditioned/Ambient Walls: The average R-value of conditioned/ambient wall insulation has increased in each baseline study, from R-19 in 1995 to R-23 in 2015. In the 2008 and 2015 studies the average R-value is significantly higher in program homes than in non-program homes.

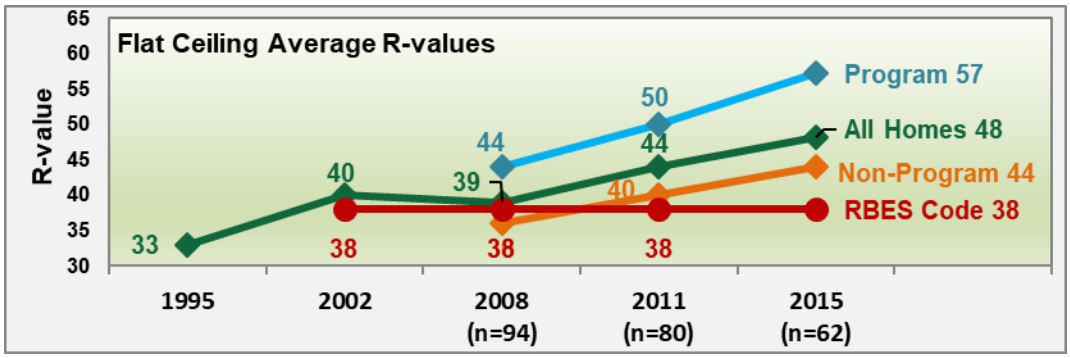
Flat Ceilings: The average R-value of flat ceiling insulation has increased from R-33 in 1995 to R-48 in 2015. In the 2008, 2011 and 2015 studies the average R-value in program homes is significantly higher than in non-program homes.

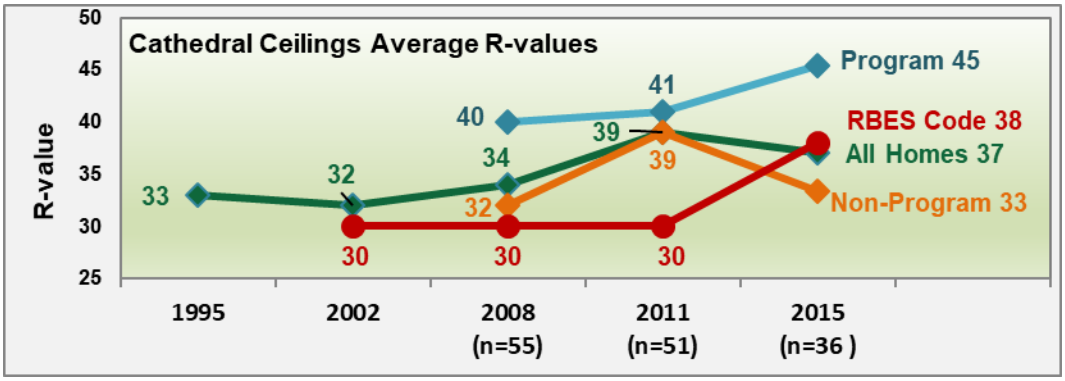
Cathedral Ceilings: The average R-value of cathedral ceiling insulation increased from R-33 in 1995 to R-39 in 2011 and then dropped to R-37 in 2015. While the average R-value in program homes increased from R-41 in 2011 to R-45 in 2015, the average R-value in non-program homes dropped from R-39 to R-33. (The percent of non-program homes with less than R-30 cathedral ceiling insulation increased from 11% in the 2011 study to 27% in the 2015 study.)

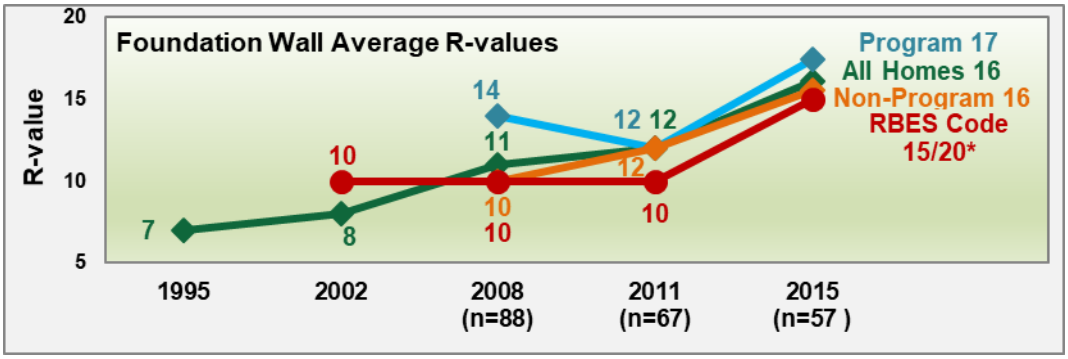
Foundation Walls: The average R-value of foundation wall insulation has increased in each baseline study, from R-7 in 1995 to R-16 in 2015. In 2011, average insulation levels were the same in program and non-program homes. In 2015, the average insulation level in program homes is only slightly higher than in non-program homes.

Figure 1: Average Wall, Ceiling and Foundation R-values Over Time









*R-15 continuous insulated sheathing on the interior or exterior of the home or R-20 cavity insulation at the interior of the basement wall.

Figure 2 shows that air leakage, measured in air changes per hour at 50 pascals (ACH50), has steadily decreased (improved) over the last five baseline studies, from 8.1 ACH50 in 1995 to 2.8 ACH50 in 2015. In the past three studies, program homes have consistently had significantly lower average ACH50 than non-program homes at the 90% confidence level.

Figure 2: Air Leakage Over Time

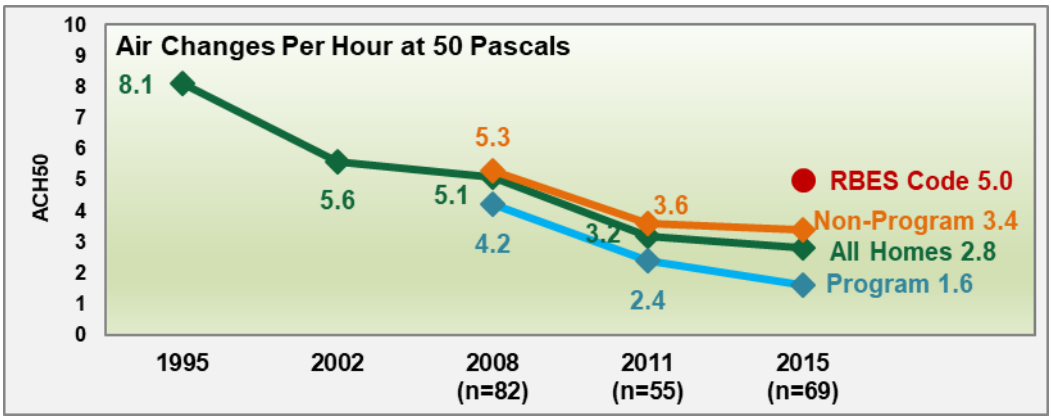


Figure 3 shows that the average AFUE (Annual Fuel Utilization Efficiency) of all boilers and furnaces has increased in each of the last three baseline studies, from 84.8 AFUE in 2002 to 93.0 AFUE in 2015. The average AFUEs of boilers and furnaces have consistently been higher in program homes than in non-program homes. However, there is very little difference in the average program and non-program AFUEs in the current study.

Figure 3: Boiler and Furnace Efficiencies Over Time

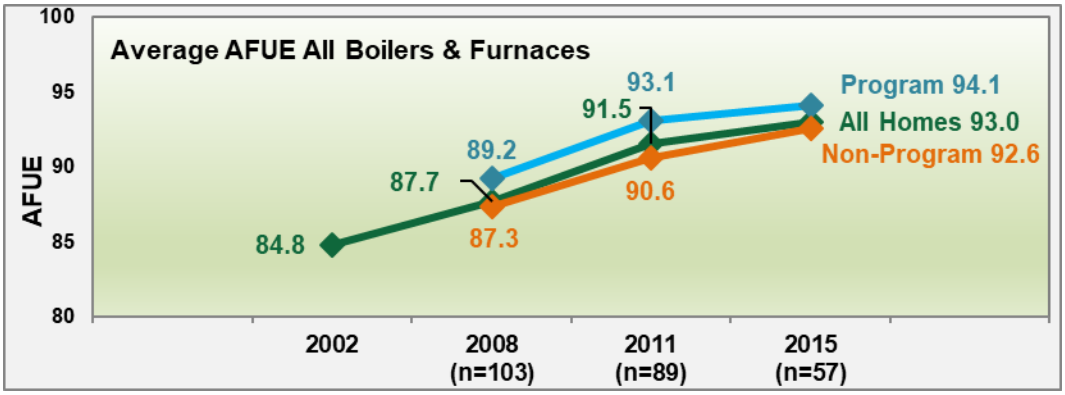
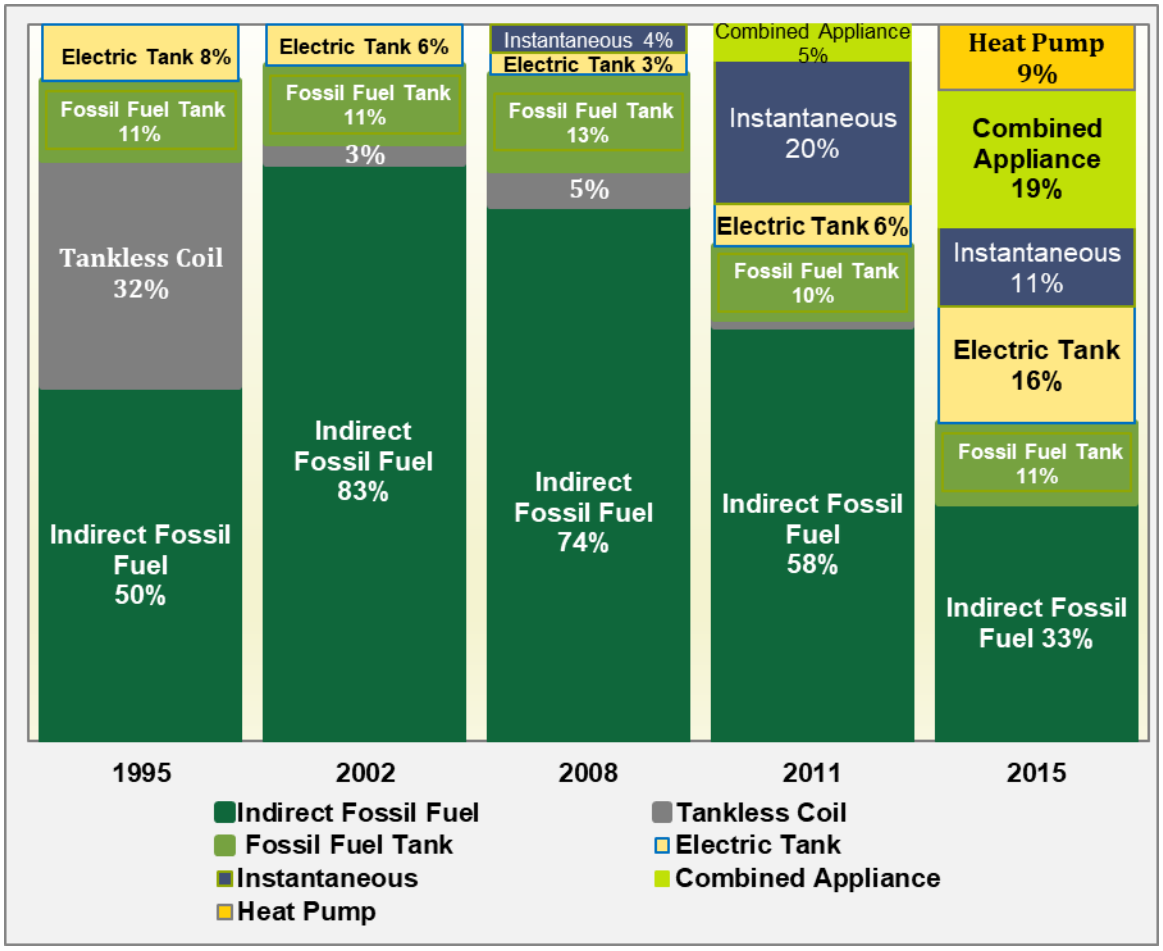


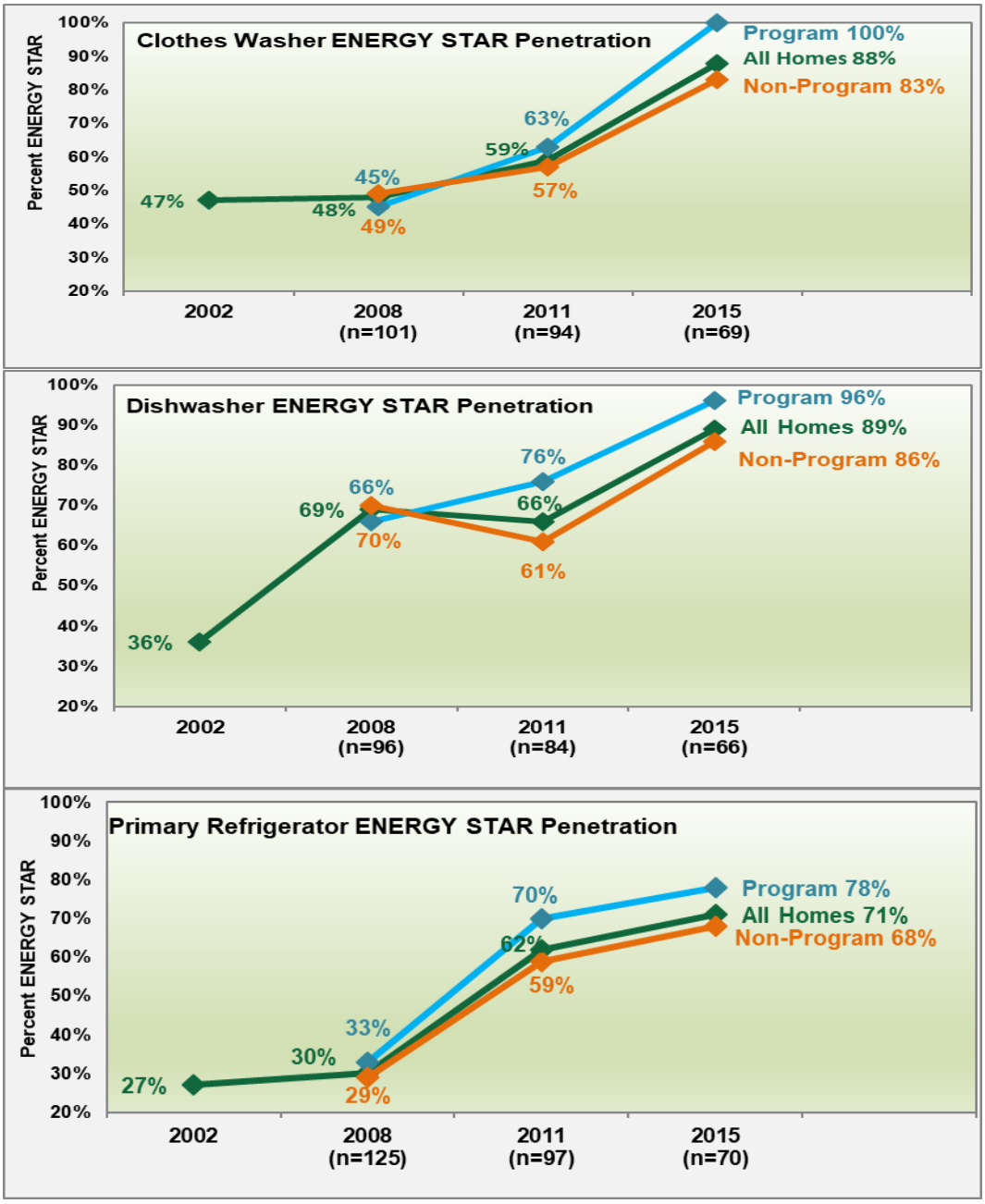
Figure 4 shows how the mix of water heater types in inspected homes has changed over time. The 2015 study is the first time any homes had heat pump water heaters and the first time there were no homes with tankless coil water heaters. Indirect fossil fuel water heaters have been the most common type of water heater observed in homes in all five baseline studies, though the percentage has continually decreased since the 2002 baseline study. Compared to the 2011 baseline study, the percentages of combined appliance and conventional electric tank water heaters increased and the percentage of instantaneus water heaters decreased in 2015.

Figure 4: Water Heater Types Over Time



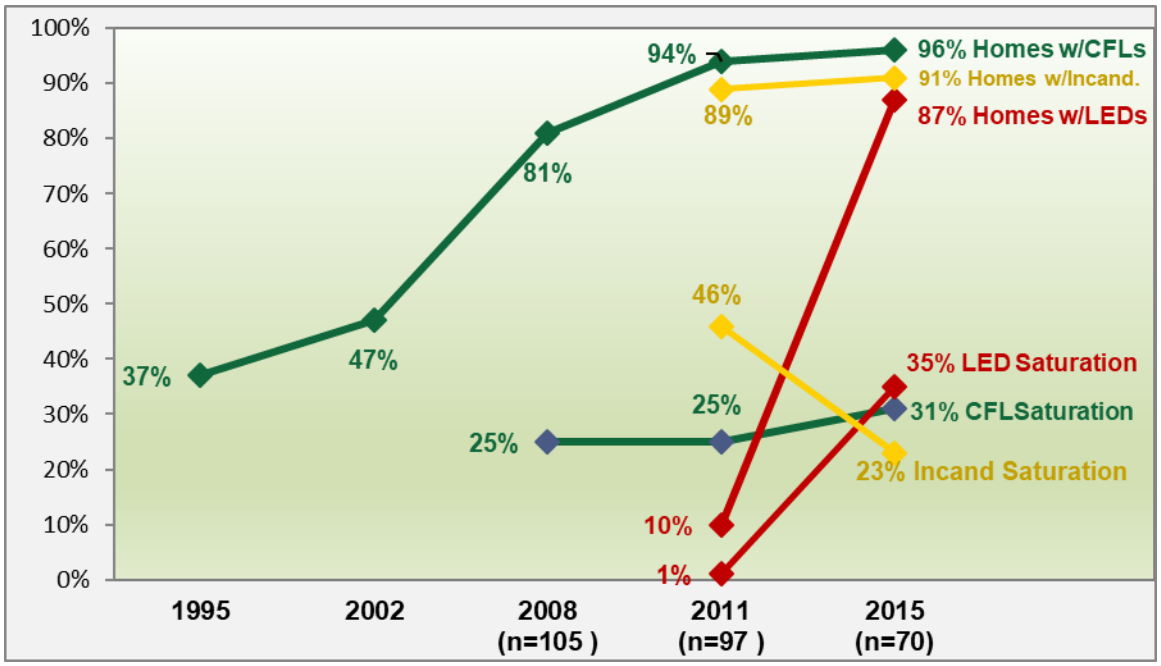
The penetrations of ENERGY STAR-qualified clothes washers and primary refrigerators in inspected homes have consistently increased over the last three baseline studies (Figure 5). The penetration of ENERGY STAR-qualified dishwashers dropped slightly in the 2011 study and then rose sharply in the 2015 study. In 2015, program homes are significantly more likely to have an ENERGY STAR clothes washer than non-program homes (100% vs. 83%), while the penetration rates of ENERGY STAR-qualified dishwashers and primary refrigerators are not significantly different in program and non-program homes.

Figure 5: ENERGY STAR Clothes Washers, Dishwashers and Primary Refrigerators



The percentage of homes with CFLs has grown from 37% in the 1995 study to 96% of homes in the 2015 study and the saturation of CFLs has increased from 25% of bulbs in 2008 to 31% in 2015 (Figure 6). However, the biggest changes between the 2011 and 2015 studies are the dramatic rise in the percentage of homes with LEDs (10% to 87%), the rise in the saturation of LED bulbs from 1% to 35%, and the fall in the saturation of incandescent bulbs from 46% to 23%. Several other recent residential new construction baseline studies showed similar increases in LED lighting. (See 5.10 Lighting for more detail.)

Figure 6: CFL and LED Lighting Over Time



RBES Code Compliance

The current compliance rate is 66%, when excluding owner built homes which are exempt from meeting the RBES (Table 1). When owner built homes are included in the analysis, the compliance rate decreases from 66% to 63%.[4] Almost one-half (45%) of the 47 inspected non-program homes passed the 2011 RBES via the UA method. All 23 program homes complied with RBES via the Home Energy Rating (HER) path and therefore were not assessed using the REScheck software. The baseline compliance rate accounts for a home's energy performance but does not factor in compliance with all basic RBES requirements.[5] Compliance is significantly lower than the 76% compliance rate from the prior 2011 baseline study, which looked at compliance under the 2005 RBES. NMR believes the decline in

[4] . "Owner/builders" are exempt from the RBES technical requirements but must still follow certification procedures.

[5] The HERS rating confirms compliance with the performance component of RBES, but doesn't ensure that all of the RBES basic requirements were met, nor does REScheck.

compliance results from the combination of increased basement insulation requirements and the removal of the efficient mechanical system credit in the 2011 RBES.

During the on-site inspections auditors identified potential opportunities for energy efficiency improvements in non-program homes and most frequently cited opportunities addressing lighting, air leakage and ceiling insulation.

Table 1: RBES Technical Compliance Rates using UA Method Over Time

	2002 Study[6]	2008 Study[7]	2011 Study	2015 Study
Percent of Homes excluding owner builders	n/a	n/a	76%	66%
Percent of Homes including owner builders	58%[a,c]	72%[a]	74%[b,c]	63%[b]

[a,b,c] Significant different values at the 90% confidence level are shown with the same letter.

EMERGING TECHNOLOGIES

Market actor interviews in late 2016 through January 2017 assessed the market for emerging technologies, including heat pumps, heat pump water heaters (HPWH), and home energy management systems[8] (HEMS).

HVAC Contractor Interviews: Ten in-depth telephone interviews with residential HVAC contractors from Vermont focused on the following emerging technologies: ground source heat pumps, ducted and ductless air source heat pumps, heat pump water heaters, solar hot water systems, high performance circulator pumps, furnaces with electronically commutated (ECM) fans, and central wood pellet boilers and furnaces. All contractors said they recommend heat pump technologies to customers for both space and water heating applications. The contractors reported installing HVAC equipment in 129 new housing units over the last year, which represents about 8% of the total HVAC installations. Overall, the contractors indicated installation and performance issues are uncommon and customers are generally satisfied with installed equipment. They cite positive feedback and a lack of complaints when they speak with customers. They also report that most installations appear to meet Efficiency Vermont or ENERGY STAR efficiency criteria. Nine of the ten interviewed contractors said they have participated in Efficiency Vermont or Burlington Electric Department programs and are satisfied with the programs.

HVAC Distributor Interviews: Interviews were conducted with four distributors of HVAC equipment providing sales and support throughout Vermont. Together, the four distributor companies are estimated to supply approximately 80% of the Vermont market. Questions covered ground source, ducted air-source ,and ductless heat pumps; heat pump water heaters; high performance circulator pumps; furnaces with an ECM fan; solar hot-water

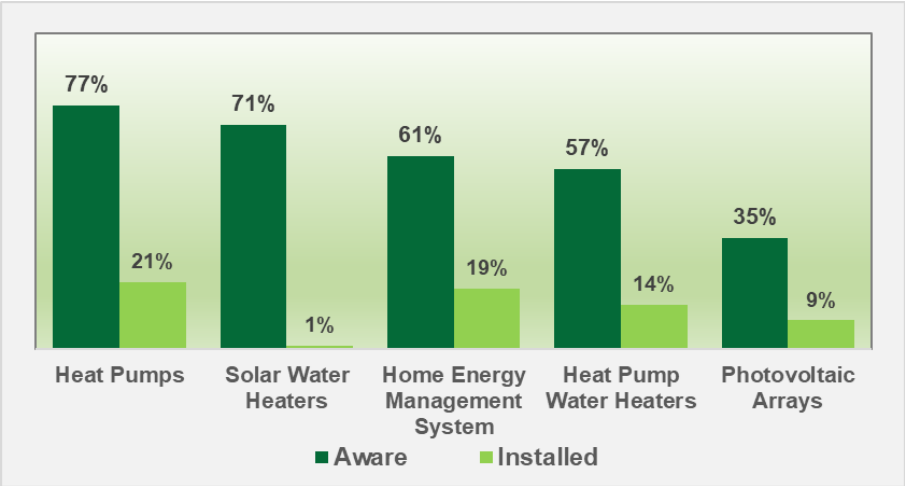
[6] Vermont Residential New Construction 2002: Baseline Construction Practices, Code Compliance, and Energy Efficiency. Prepared by Westhill Energy and Computing for the Vermont Department of Public Service. January 3, 2003.
[7] Residential Building Energy Standards Compliance Analysis. Prepared by Nexus Market Research, Dorothy Conant and KEMA. June 10, 2009.
[8] Home energy management systems were defined to include products that control or monitor energy use in a home, such as smart thermostats and home automation systems; however, they do not include systems that only control home security.

systems; and central wood pellet furnaces and boilers. Many question areas – including whether or not there are installation issues, contractors are satisfied with the product and promoting emerging technologies – hinge upon contractor confidence with the product. Distributors generally felt that in order to increase contractor confidence with the product (how the product works and how best to install the product, etc.), considerably more education and training is needed for contractors.

Retail Store Manager Interviews: Five in-depth telephone interviews were conducted with retail store managers that sell Heat Pump Water Heaters (HPWH) or Home Energy Management systems (HEMS) in Vermont. Three interviews addressed HPWHs and two addressed HEMS. Store managers said consumer awareness was generally low for both HPWHs and HEMs before entering the store. However, customers appear to be satisfied with their HPWHs - only one instance of negative feedback was reported from all three store managers who sell HPWHs. There was little customer feedback for HEMS, mostly regarding installation issues. Lack of education is a major obstacle. Most customers do not appear to understand the long-term energy savings potential of HPWH systems. For HEMS, lack of understanding on how the technology works is an impediment. However, cost has been the primary obstacle for both HEMS and HPWH systems. Both market supply and consumer demand for HPWH systems and HEMS is expected to increase over the next several years. However, improving consumer awareness of these technologies is an essential component of the market forecast.

Homeowner Awareness and Installation of Emerging and Renewable Technologies: Homeowner survey results show that most homeowners were aware of heat pumps (77%), solar water heaters (71%), home energy management systems (HEMS) (61%), and heat pump water heaters (57%). Only 35% said they were aware of photovoltaic arrays, but this low awareness may be due to the phrase “photovoltaic arrays” used in the survey questions, instead of “PV panels” or “solar panels.” Although awareness was generally high, the percentages of homeowners with these technologies installed in their homes were much lower, ranging from a high of 21% for heat pumps to 1% for solar water heaters. (Figure 7) High cost was cited most often as the reason for not installing solar water heaters (48%) and photovoltaic arrays (29%) among those respondents familiar with the technologies.

Figure 7: Awareness and Installations of Emerging and Renewable Technologies



In addition, auditors asked homeowners a series of questions related to emerging technologies during the on-site inspections. Specifically, the questions focused on home energy management systems, HVAC heat pumps, and heat pump water heaters.

- **Home Energy Management Systems**: Auditors questioned homeowners with home energy management systems installed in their home about their level of satisfaction with the system and what the system controlled. There were 13 home energy management systems in the single-family new construction sample. Twelve of the thirteen systems controlled the homes' heating and cooling set points and one also controlled the in-home lighting. One system's capabilities were not clearly identified. Most homeowners with a home energy management system (69%) reported that they were either "very satisfied" or "satisfied" with the system. No homeowners with a home energy management system were unsatisfied.
- **HVAC Heat Pump:** Owners of the 17 audited homes with heat pumps (air source, ground source, and ductless mini-splits) were asked to rate their satisfaction with the system(s). All but one homeowner responded with either "very satisfied" or "satisfied." One homeowner was "dissatisfied" with the heat pump/ductless mini split due to it being a "complicated system that breaks a lot and [is] too expensive."
- **Heat Pump Water Heater:** As part of the on-site inspections, auditors assessed the technical potential for heat pump water heater (HPWH) installation by identifying the features that are required to install a HPWH. Overall, 46% of homes meet all of the requirements to install a HPWH (i.e., they have sufficient space, ceiling height, temp. of at least 50 degrees, and a drain present). This percentage does not include the 9% of homes that already have a HPWH installed.

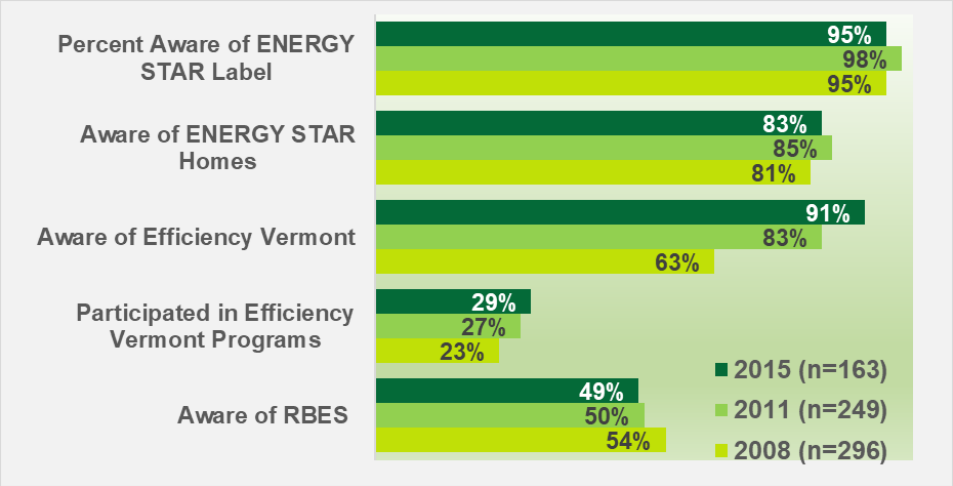
HOMEOWNER SURVEY RESULTS

Homeowners show high awareness over the last three baseline studies of the ENERGY STAR label and ENERGY STAR homes. Meanwhile, awareness of Efficiency Vermont has steadily grown from 63% in 2008 to 91% in 2015, but the percentage of homeowners saying

they have participated in Efficiency Vermont programs has only grown from 23% to 29%. (Figure 8)

Awareness of RBES has fallen slightly from 54% in 2008 to 49% in 2015. Overall, 43% of homeowners believe that their home meets RBES requirements, but only 19% reported that an RBES certificate was posted in their home. Auditors found an RBES certificate at eight (17%) of the 47 non-program homes. This is a significant increase from the 2011 study in which only one (2%) of the 64 non-program homes had an RBES certificate.

Figure 8: Homeowner Awareness



Also across the last three surveys almost all homeowners (92% to 98%) think their new homes are energy efficient.

Decision Factors: Location was by far the most important factor (42%) in homeowners' decision to buy a home. Getting a more efficient home with lower energy bills came in fifth (6%) after purchase price (10%), room layout or design (9%), and being involved in the decisions about the features of the home (9%).

CFL and LED Bulbs: Over two-thirds (69%) of the homeowners with CFLs installed in their homes are satisfied with the CFL bulbs. However, more homeowners with LEDs installed in their homes (89%) are satisfied with the LED bulbs.

Energy Efficiency Programs: Most homeowners (91%) are aware of Efficiency Vermont and 29% reported participating in an Efficiency Vermont program. Almost one-third (29%) of the 48 homeowners who said they participated in an EVT program mentioned the Efficiency Vermont new homes programs and 19% mentioned the LED bulb discount. Nearly all homeowners who participated in Efficiency Vermont programs are satisfied with the program(s) they participated in.

Efficiency Vermont New Home Programs: Most homeowners (83%) said that they had heard of ENERGY STAR homes. Fewer homeowners said they had heard of Energy Code Plus homes (28%), Efficiency Vermont High Performance homes (19%), or Efficiency Vermont Certified homes (30%). Sixty-three homeowners (39% percent of surveyed

homeowners) said their home was an ENERGY STAR or Efficiency Vermont program home and 67% of these homeowners said that they were aware that it was an ENERGY STAR or Efficiency Vermont home prior to buying or building the home.

Comparing what the 70 surveyed homeowners whose homes were inspected said when asked, “Is your new home an Efficiency Vermont Certified or ENERGY STAR home?” to Efficiency Vermont records it is clear some homeowners who think they have a program home do not and some who think they do not have a program home in fact do. Overall, 71% or 50 of the 70 surveyed homeowners whose homes were inspected were able to correctly identify their home as having participated in an Efficiency Vermont new home program or not. This is an improvement over the last baseline study when 59% of the owners of inspected homes correctly identified their homes as ENERGY STAR or not ENERGY STAR.

RECOMMENDATIONS

The challenge for Vermont is how to simultaneously encourage more builders to build Efficiency Vermont-certified homes and increase customer awareness of and demand for Efficiency Vermont-certified homes. The NMR team makes the following recommendations – some of which Vermont is already doing – to increase the energy-efficiency of new homes in Vermont and grow awareness among potential buyers of Efficiency Vermont-certified homes and energy code compliance[9]

Enroll new builders as there is room for improvement in non-program homes. All inspected program homes met 2011 RBES Fast-Track prescriptive requirements for flat ceilings, cathedral ceilings, and basement walls, but 26% of non-program homes with flat ceilings, 58% of non-program homes with cathedral ceilings, and 58% of non-program homes with basement walls fell short of meeting the 2011 RBES Fast-Track prescriptive requirements. Almost one-half (45%) of non-program homes had less than R-20 conditioned/ambient wall insulation. It is important to remember that many homes that do not meet a specific RBES prescriptive path requirement may meet the requirements of the HERS or UA-approach compliance paths, but there is room for improvement.

Emphasize the importance of complying with the RBES energy code. More than one-half (55%) of the 47 inspected non-program homes failed to pass 2011 RBES via the UA trade-off method. The homes with the least efficient REScheck models had uninsulated or under-insulated frame floors over unconditioned basements. Almost one-half (46%) of non-program homes did not comply with the programmable thermostat basic requirement and only 32% had mechanical ventilation with compliant CFM ratings.

Increase RBES energy code compliance. Based on the reduction of energy code compliance rates (63% in 2015 vs. 74% in 2011), work with stakeholders and policy makers to identify, develop and support programs and initiatives that fit Vermont’s unique building

[9] There are three methods for showing code compliance in Vermont: Fast-Track (prescriptive), REScheck (UA approach), and Home Energy Rating (HERS). It is important to remember when reading the following recommendations that a home that does not meet the prescriptive RBES code requirement for an individual building component may very well comply with the requirements of the REScheck or HERS rating compliance paths.

energy marketplace to increase code compliance rates, especially as the energy codes are planned to become more stringent over time.

Promote awareness of and the importance of posting and filing RBES certificates: Homeowner awareness of RBES has fallen slightly from 54% in 2008 to 49% in 2015. Although 43% of surveyed homeowners believe that their home meets RBES requirements only 19% reported that an RBES certificate was posted in their home. Auditors found an RBES certificate posted at only eight (17%) of the 47 inspected non-program homes.

Make sure program homes comply with Manual J heating or cooling equipment sizing requirements. Very few inspected non-program homes and some program homes complied with Manual J sizing requirements. Meeting sizing requirements becomes more important as the percentage of new homes with central air conditioning increases.

Continue to market and promote energy efficient homes and both home buyer and builder awareness of and participation in Efficiency Vermont new construction programs:

- **Strongly encourage builders to always post the Efficiency Vermont-qualified or ENERGY STAR-qualified certification on their homes and encourage Realtors to market these homes as Efficiency Vermont or ENERGY STAR-certified.** The homeowner survey results showed high awareness of ENERGY STAR homes (83%). However, owners of 20 of the 70 inspected homes either thought they had an Efficiency Vermont or ENERGY STAR certified home but did not (14 owners) or did not know their home was an Efficiency Vermont or ENERGY STAR certified home (6 owners). Vermont is participating in the NEEP Home Energy Labeling Information eXchange (Helix) project[10]. The purpose of this project is to develop a database capable of automatically populating real estate listings (whether they are accessed through local Multiple Listing Services (MLS) or portals like Trulia, Zillow and Realtor.com) with home energy information from HERS, ENERGY STAR, Home Energy Score and other sources when it is available and approved by the seller. Documenting the energy efficiency of a home may also increase resale value.
- **Make sure builders of program homes have easy access to marketing materials they can hand out to potential clients.** Clearly explain the benefits, and importance, of addressing energy efficiency from the very start of the planning and building process. Make marketing templates available and provide support to builders to encourage them to promote their program homes. Efficiency Vermont is currently generating information on the costs and benefits of building program homes to builders and developers of program homes and encouraging them to pass this information on to home buyers.
- **Offer contractor education regarding emerging technologies.** Distributors report that contractors are most comfortable with technologies they are familiar with and that contractor confidence is critical to a technology's success. In addition, distributors believe that education and training must be provided to contractors in order to

[10] https://neep.org/home-energy-labeling-information-exchange-helix

enhance their promotion of emerging technologies, such as heat pumps and heat pump water heaters.

- **Continue offering financial incentives for emerging technologies.** Both market actor interviewees and surveyed homeowners indicated that high purchase prices were a key barrier to the adoption of HPWHs, solar water heaters, and solar PV. Interviewed distributors believe that the higher rebates and greater availability of low interest loan opportunities available in neighboring states increase customer uptake, and that if Vermont were to offer these more robustly then the Vermont market would grow more quickly.
- **Work to increase consumer awareness of base and high performance Efficiency Vermont Certified™ Homes.** Most surveyed homeowners (83%) said that they had heard of ENERGY STAR homes. However, fewer homeowners said that they had heard of Energy Code Plus homes (28%), Efficiency Vermont High Performance homes (19%), or Efficiency Vermont Certified homes (30%). (Note: Efficiency Vermont no longer provides incentives for ENERGY STAR-qualified homes. However, if a participating builder wants to have their Efficiency Vermont certified home also be ENERGY STAR-qualified the program will provide support for meeting ENERGY STAR requirements at no cost. If a builder wants to build an ENERGY STAR home that does not meet Efficiency Vermont-certified requirements the program will provide the necessary services for a fee.) Efficiency Vermont identifies potential new homes by tracking waste water permits (these are one of the first permits required when breaking ground for a project using waste water) and also participates in the annual Home Builders Association show.
- **Continue to describe the benefits of energy-efficient homes in marketing materials targeting consumers.** Stress that the **ONLY** way to be sure a home is energy efficient is to have it verified by a third party using blower door and duct blaster tests**.** This is what the Efficiency Vermont new construction program does. These steps also work to increase the resale value of the homes. Also inform potential buyers of new homes that energy-efficient homes come in all sizes, shapes, and price ranges.
- **Let buyers know how easy it is to find a builder who builds Efficiency Vermont-certified homes.** Continue to promote the Efficiency Vermont website and provide information on how many builders in Vermont have built ENERGY STAR or Efficiency Vermont-certified homes, how many of these homes have been built in Vermont, and a list of currently participating builders and examples of available spec-built Efficiency Vermont-certified homes.
- **Provide a list of questions addressing energy efficiency that homebuyers should ask about any house they are considering buying or building.** Make the list easy to print from the website and encourage homebuyers to go over the list with their builder if they decide to build a home, or with the real estate agent or builder marketing spec homes already under construction or finished.

REMAINDER OF REPORT

The remainder of this report presents more detail on state level homeowner survey and on-site inspection findings, Appendix A Comparisons to Earlier Vermont Baseline Studies compares the results of five Vermont new residential construction baseline studies: the 1995, 2002, 2008, 2011 and 2015 studies.

1 Section 1 Introduction

The overall objective of the combined studies covered in this report is to provide the Vermont Public Service Department (PSD) with residential single-family new construction market assessments and baselines to help identify opportunities for increased energy efficiency in Vermont. Specific objectives include assessing and/or documenting:

- Overall energy efficiency of new homes
- Energy efficiency of new single-family homes by feature
- Characteristics of new homes, including home offices
- Homeowner decision-making
- Homeowner awareness of and interest in energy efficiency and emerging technologies
- Homeowner familiarity with:
    - Efficiency Vermont and its programs
    - Efficiency Vermont new homes program
    - Residential Building Energy Standards
- Homeowner knowledge of and use of LED and CFL lighting
- HVAC contractor installation of energy-efficient equipment and installation practices

Single-family homes are defined to include both detached and attached single-family homes:

- Detached single-family home
    - Constructed on site using a foundation; usually built with wood framing, but also could be built from brick, metal, or another material
    - Modular home that is 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 if there are not more than two units attached

Table 2 summarizes the research methods, targeted populations, data collection time periods, and sample sizes.

Table 2: Vermont Residential New Construction Research Activities

Research Activity	Population	Data Collection Time Period	Sample Size
Telephone survey	Single-family Homeowners	Nov 2015 – Jan 2016	163
On-site Inspections	Single-family Homes	Oct 2015 – May 2016	70
In-depth Interviews	HVAC Contractors	July – Aug 2016	10
In-depth Interviews	Retailers	Nov – Dec 2016	5
In-depth Interviews	HVAC Distributors	Nov 2016 – Jan 2017	4

1.1 New Construction Housing Market

The 2015 market assessment study targets detached single-family homes and two-unit homes built between 2012 and 2015; it excludes single-family attached homes if more than two units are attached. Census Bureau reports of new housing unit permits issued in Vermont for single-family housing units and units in two-unit buildings report 939 units in 2012, 1,021 units in 2013, 1,047 units in 2014 and 1,028 units in 2015. The Census Bureau housing permit reports include all single-family attached housing with ground to roof walls separating the units as one-unit single-family homes regardless of how many units are attached—this means the number of housing permits issued for the types of housing specifically targeted in this study (single-family detached homes and two-unit homes) is lower than the number of one- and two-unit housing permits in the Census Bureau reports.

1.2 Homeowner Survey Sample and Precision

In order to develop the sample for the new construction homeowner survey, NMR utilized lists of requests for new permanent electrical service from January 2012 through February 2015, provided by Efficiency Vermont and Burlington Electric Department. Addresses without phone numbers underwent telephone matching in order to yield additional sample. These customers were screened to ensure that a new single-family home or duplex home began construction between January 2012 and February 2015.

Telephone surveys were conducted with a random sample of 163 owners of newly constructed single-family homes. The population of newly constructed single-family and two-family or duplex homes in Vermont is estimated to be approximately 3,006 between 2012 and 2014[11]. The 163 completed surveys yield a sampling error of about ±6% at the 90% confidence level for the entire state, about ±14% for the Vermont Gas territory, and ±6% for the Efficiency Vermont territory. Given the low level of single-family new construction activity in Burlington, the precision is very wide – ±35%. (Table 3)

Table 3: Population, Sample Size and Sampling Error

Group	Estimated Population	Completed Surveys	Sampling Error at 90% Confidence Level
Burlington Electric	18	5	±35%
Vermont Gas	954	34	±14%
Efficiency Vermont	2,988	158	±6%
Vermont Statewide*	3,006	163	±6%

*The statewide row reflects the sum of the Burlington Electric and Efficiency Vermont rows.

[11] Estimates derived from Census Bureau permit data. http://www.census.gov/construction/bps/stateannual.html These estimates include attached homes; an unknown portion of the single-family homes are attached homes in buildings with three or more units, which would be considered multifamily housing for this study.

1.3 On-Site Audit Sample and Precision

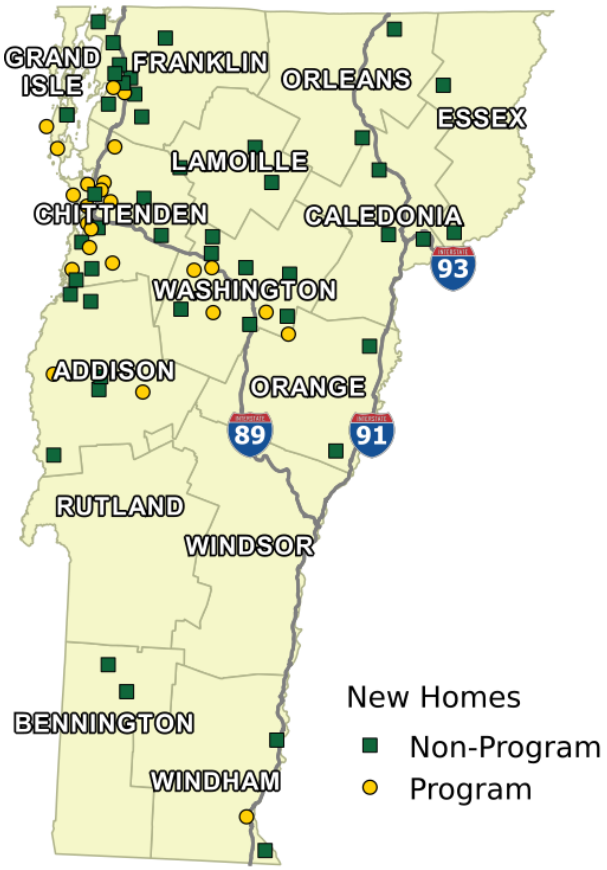
Volunteers for the on-site audits were recruited from the telephone surveys of 163 owners of newly constructed homes in Vermont. A total of 70 usable on-site audits were conducted between October 2015 and May 2016 at a mix of recently constructed program and non-program single-family homes across Vermont. Program homes include 23 homes that participated in Efficiency Vermont residential new construction services:

- Fourteen Efficiency Vermont certified base level homes
- Three Efficiency Vermont certified high performance level homes
- Six ENERGY STAR-certified homes

The Home Energy Rating (HERS) scores of the 23 program homes range from 7 (best) to 61. The average HERS score of program homes is 48; the HERS threshold for the 2011 RBES was 75.

Audits were performed in 49 towns across Vermont. Figure 9 displays the towns where the on-site audits were located and the relative number of site visits conducted in each town. Note that 38 (78%) of the towns had only a single on-site audit; the town with the most audits is Saint Albans with six inspected homes.

Figure 9: Location and Number of On-site Audits



Precision: The coefficient of variation is of central importance to determining the final precisions. A primary objective of this study is to document the building and equipment status of new single-family homes by feature. Because there is no single variable that quantifies a home's construction features, we identified results that we believe are influential in the determination of a home's overall efficiency. Table 4 shows the coefficients of variation and relative precisions at the 90% confidence level for several key building components and measurements that influence a home's energy efficiency. Some features are far more variable than others. In the current study, air infiltration is the most variable. The least variable characteristics are flat ceiling insulation R-value and the AFUE of fossil-fuel fired boilers and furnaces. Relative precisions range from ± 1% to ± 9% at the 90% confidence level for all measures except air infiltration.

Table 4: Coefficients of Variation and Relative Precision

Parameter	Sample Size	Coefficient of Variation	Relative Precision
Conditioned/Ambient Wall Insulation (R-value)	**70**	**0.37**	± 7%
Flat Ceiling Insulation (R-value)	**62**	**0.04**	± 1%
Cathedral Ceiling Insulation (R-value)	**36**	**0.34**	± 9%
Heating System Efficiency (AFUE)	**57**	**0.04**	± 1%
Air Infiltration (ACH50)	**69**	**0.83**	± 16%

On-site sample recruiting and scheduling was performed by NMR staff. Homeowners were introduced to the on-site audits through the telephone survey of 163 owners of new homes. Survey respondents were told what the on-site audit would involve, how long it would take, and about the incentives they would receive if they agreed to and were selected to have their home audited. NMR staff recruited from the list of survey participants who were willing to have their home audited. An incentive of $100 was offered to all homeowners agreeing to have their home audited.

Potential Bias Issues. Potential bias is a concern in any sample based on voluntary participation. There are many factors that may influence a homeowner's willingness to have their home audited. Homeowners familiar with Efficiency Vermont programs may be more willing to participate; homeowners who think their home is very energy efficient may be more willing to participate because they are proud of their home or less interested in participating because they feel confident their home is energy efficient and that the audit would not tell them anything they do not already know. Conversely, homeowners who think their home may not be as energy efficient as they thought it would be may be more interested in participating to learn what they could do to improve the energy efficiency of their home or less interested because they feel their home might not meet Vermont RBES code standards. Homeowners who acted as the general contractor for their home or who played an active role in specifying construction materials and mechanical equipment may be more interested in participating to see if they made wise choices.

Inspected homes include homes that are very energy efficient and some that are not. There are a mix of site built and modular homes; large and small homes; program homes (homes that participated in Efficiency Vermont residential new construction services) and non-program homes; homes that were purchased after they were finished and homes where the owner played a major role in specifying construction materials and mechanical equipment.

The percentage of single-family detached homes in the sample of audited homes (94%) is virtually the same as the percentage of homeowner telephone survey respondents living in single-family detached homes (95%). The percentage of program homes in the final sample (33%) is consistent with Efficiency Vermont's estimated penetration of single-family homes participating in Efficiency Vermont residential new construction programs. Overall, there is no need to weight data and no clear evidence of bias in the sample of inspected homes.

1.4 Market Actor Interview Samples

The interview samples for the contractor, distributor, and retailer interviews were generated from lists supplied by Efficiency Vermont as well as internet searches. Contractors were screened to include only those who had installed HVAC systems in at least 10 homes over the past few years. Due to a poor response from non-participants, nine of the ten contractor interviews were completed with participants in Vermont energy efficiency programs. The four HVAC equipment distributors interviewed are estimated to supply approximately 80% of the Vermont market.[12] Of the five retailer interviews completed, three were regarding HPWHs and two were regarding HEMS.

1.5 On-site Audit Data Collection

The on-site audits included collecting information on a multitude of home features. The main areas that data collection focused on are:

- General information including number of stories; size of conditioned floor area and volume (as defined by RESNET); number of fireplaces, stoves, and space heaters.
- Envelope features on the thermal boundary of homes including:
    - Wall, ceiling, floor, foundation, crawlspace, and slab insulation locations, R-values, and types (from rated values on product, or else estimated from visual inspection)
    - Stud framing information (via measurement)
    - Windows and skylights: location, dimensions, number of panes, presence of low-E coating, and U-value ratings (from window labels, if available), and percent of glazing on each home.
    - Exterior door location, dimensions, type, and thickness
    - Basement wall height (or whether on-grade slab foundation)
- Heating and cooling equipment for primary systems and all supplemental units, including make and model, type, location, fuel, size, and rated efficiency based on

[12] Email correspondence with Efficiency Vermont HVAC Program Manager, 10/26/2017.

model information. Also, number, type, and usage of thermostats as well as home energy management systems and whether or not high-performance circulator pumps or furnace fan motors have been installed. Where ductless heat pumps are installed, locations of indoor and outdoor units

- Water heating equipment including make and model, type (including solar), fuel, location, size, and efficiency rating based on model information. Plus, water heater and piping insulation R-values, and number of low-flow showerheads and faucet aerators.
- Appliances present at the home including dishwashers, clothes washers, ovens, primary and secondary refrigerators, freezers, room air conditioners, and dehumidifiers. Make and model, type, location, and approximate age; where available appliance size, efficiency, and ENERGY STAR status (based on visual inspection or model information).
- Survey of consumer electronics present at the home, including number and type of TVs, set top boxes, DVD/VCR players, DVR recorders, game consoles, computers, printers, and advanced power strips.
- Duct type, insulation, and sealing, including whether it is on the supply or return ducting, its location (conditioned vs. unconditioned space), insulation type and estimated R-value, and duct sealing material used, if any.
- Mechanical ventilation for homes, including ERVs; make, model, type, location, type of control, rated CFM, ventilation flow rates, and efficiency based on model information.
- Lighting inventory including all hardwired and plug-in fixtures--including information such as the room location, bulb type, control type, and occupancy sensors.
- Presence and size (kW) of photovoltaic system array and wind turbine.
- Blower door testing at all non-program homes.
- Presence of RBES certificate, Efficiency Vermont or ENERGY STAR certificate, or any other green building program certificates.

Two data collection forms were developed—one for non-program homes and one for program homes. Program homes were not specifically targeted; they were recruited during the normal recruiting process. Efficiency Vermont provided the REM/Rate files for sampled program homes. Building shell and mechanical equipment data for program homes were extracted from the REM/Rate files and auditors collected the remaining information during the on-site inspections.

Auditors defined conditioned space using the RESNET definition of conditioned floor area (CFA), the same definition used in the 2011 study. The RESNET definition of Conditioned Floor Area (CFA) includes all finished space that is within the (insulated) conditioned space boundary (that is, within the insulated envelope), regardless of HVAC configuration.

- CFA does not include spaces such as insulated basements or attics that are unfinished, if there is no intentional HVAC supply, or minimal supply (inadequate to be considered directly conditioned space).
- CFA does not include heated garages.

- CFA includes unfinished spaces that are directly conditioned, that is, they have “fully ducted” intentional HVAC supply (or other intentional heat source).

In the 2008 study, conditioned space was defined as intentionally heated space, which is the same definition used in the 2002 baseline study, but different from the definition used in the 1995 baseline study (finished living space. The changes in how conditioned space was defined across the different baseline studies did not have a significant impact on reported conditioned floor areas in the studies.

2 Section 2 Home Characteristics

This section address the types of homes inspected, conditioned floor area and number of occupants. Tables show information on Vermont Gas in the first column, all Efficiency Vermont homes (including Vermont Gas homes) in the second column, program homes in the third column (lighter green column heading), non-program homes in the fourth column (lighter green column heading), and statewide information in the far-right column.

Almost all audited homes are primary residences (97%). Almost all are single-family detached homes (94%), with 88% of the detached homes built on site (Table 5).

Table 5: Home Type

Home Type	Vermont Gas	Efficiency Vermont	Program Homes	Non-Program Homes	Statewide
Number of Homes	*17*	*69*	*23*	*47*	*70*
Detached Single-Family	88%	94%	96%	94%	94%
Two-Family Building or Duplex	12%	6%	4%	6%	6%
Detached Homes with On Site/Modular Construction Information	**Vermont Gas**	**Efficiency Vermont**	**Program Homes**	**Non-Program Homes**	**Statewide**
Number of Homes	*17*	*65*	*22*	*44*	*66*
On Site	100%	88%	95%	84%	88%
Modular	0%	12%	5%	16%	12%
Primary or Seasonal Home	**Vermont Gas**	**Efficiency Vermont**	**Program Homes**	**Non-Program Homes**	**Statewide**
Number of Homes	*17*	*69*	*23*	*47*	*70*
Primary	100%	97%	100%	96%	97%
Seasonal / Vacation home	0%	1%	0%	2%	1%
Unknown	0%	1%	0%	2%	1%

Figure 10 shows most of the inspected homes (71%) were completed in 2013 or 2014 and Figure 11 shows examples of the different sizes of homes inspected.

Figure 10: Year Homes Completed

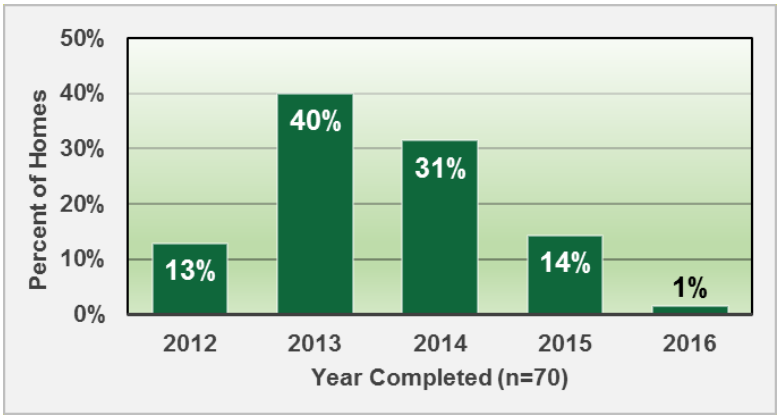


Figure 11: Examples of Audited Homes

Home sizes, measured in square feet of conditioned floor area, range from 952 to 6,278 square feet. Table 6 shows that the average home size is 2,496 square feet (14% higher than in the 2011 baseline study) and the median is 2,324 square feet (19% higher than in the 2011

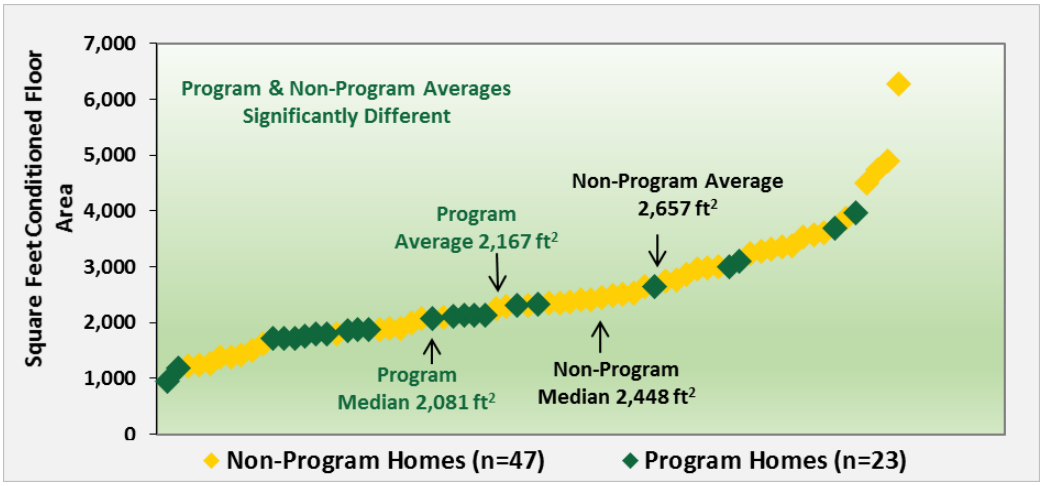
baseline study). The average size of program homes (2,167 ft^2) is significantly lower than the average size of non-program homes (2,657 ft^2). Figure 12 charts conditioned floor area, identifying program and non-program homes.

Table 6: Home Size—Conditioned Floor Area Statistics

Conditioned Floor Area (Sq. Ft.)	Vermont Gas	Efficiency Vermont	Program Homes	Non-Program Homes	Statewide
Number of Homes	*17*	*69*	*23*	*47*	*70*
Minimum	1,629	952	952	1,219	952
Maximum	4,727	6,278	3,968	6,278	6,278
Average	**2,704**	**2,506**	**2,167***	**2,657***	**2,496**
Median	2,502	2,328	2,081	2,448	2,324

*Significantly different at the 90% confidence level.

Figure 12: Conditioned Floor Area Program and Non-Program Homes



3 Section 3 RBES Code Compliance

The objective of this section is to assess the technical compliance of newly-constructed single-family homes with the 2011 Vermont Residential Building Energy Standards (RBES).

All of the homes in this study were built under the 2011 RBES. The code has two main requirements: (1) a technical requirement of minimum standards for energy-efficient construction practices and (2) a certification process that is self-certified by builders. Additionally, local officials have the prerogative to require inspections and the state has the right to conduct spot checks for enforcement. "Owner/builders" are exempt from the technical requirements but must still follow certification procedures.

Compliance for all 47 non-program homes was assessed using the REScheck software. REScheck compliance was calculated using the UA[13] trade-off method.[14] This method compares the area weighted U-values of a home to the same home with U-values set to prescriptive code levels; if the UA value of the as-built home is equal to or less than that of the same home built to prescriptive code levels, then the home is considered compliant.

The current compliance rate is 66%, when excluding owner built homes which are exempt from meeting the RBES (Table 7). When owner built homes are included in the analysis, the compliance rate decreases from 66% to 63%.[15] Almost one-half (45%) of the 47 inspected non-program homes passed the 2011 RBES via the UA method. All 23 program homes complied with RBES via the Home Energy Rating (HER) path and therefore were not assessed using the REScheck software. Both non-program homes assessed using the REScheck path and program homes assessed using the HER path may not meet all of the specific requirements from the RBES prescriptive path (i.e., pass/fail of basic RBES basic requirements). In such instances there may still be room for improvement.

Compliance is significantly lower than the 76% compliance rate from the prior 2011 baseline study, which looked at compliance under the 2005 RBES. NMR believes the decline in compliance results from the combination of increased basement insulation requirements and the removal of the efficient mechanical system credit in the 2011 RBES.

[13] UA = U-factor x area.
[14] NMR also assessed compliance using REScheck's performance approach.
[15] . "Owner/builders" are exempt from the RBES technical requirements but must still follow certification procedures.

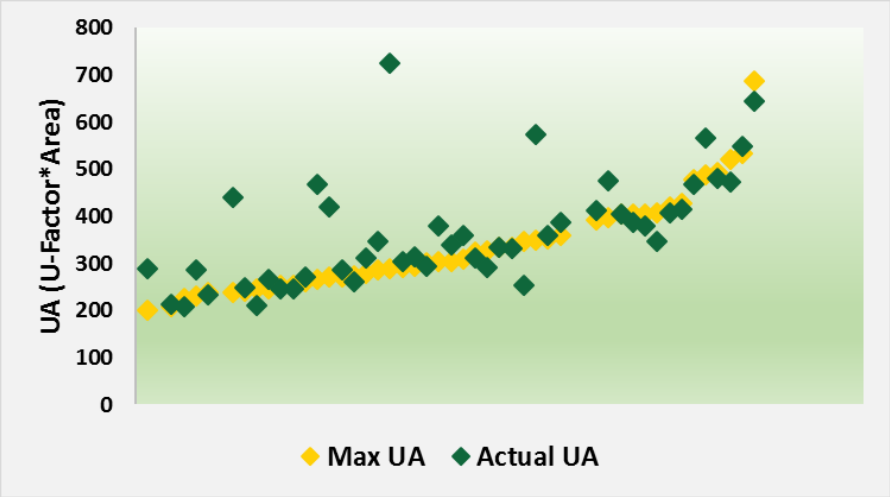
Table 7: RBES Technical Compliance Rates using UA Method Over Time

	2002 Study[16]	2008 Study[17]	2011 Study	2015 Study
Percent of Homes excluding owner builders	n/a	n/a	76%	66%
Number of Homes	-	-	*83*	*62*
Percent of Homes including owner builders	58%[a,c]	72%[a]	74%[b,c]	63%[b]
Number of Homes	*158*	*106*	*97*	*70*

[a,b,c] Significant different values at the 90% confidence level are shown with the same letter.

Figure 13 shows the maximum and actual UA for each of the 47 non-program homes. Each home has a yellow diamond representing the maximum allowable UA for the home as well as a dark green diamond showing the actual calculated UA value. If the dark green diamond is above the yellow diamond, the home does not comply with code; if the dark green diamond is below the yellow diamond, the home does comply with code. The home that has an actual UA above 700 had a completely uninsulated frame floor above an unconditioned basement.[18]

Figure 13: Maximum and Actual UA Values for Non-Program Homes Including Owner Builders



Altogether, the results of this study indicate that while homes on average meet the prescriptive requirements for efficiency characteristics, the elimination of the high efficiency mechanical equipment credit and the increase in the foundation wall R-value requirement are leading to a reduction in overall compliance. At the same time, mechanical equipment efficiencies far surpass the prescriptive standards.

[16] Vermont Residential New Construction 2002: Baseline Construction Practices, Code Compliance, and Energy Efficiency. Prepared by Westhill Energy and Computing for the Vermont Department of Public Service. January 3, 2003.
[17] Residential Building Energy Standards Compliance Analysis. Prepared by Nexus Market Research, Dorothy Conant and KEMA. June 10, 2009.

[18] This home has an unconditioned basement under the RESNET definition, but would have a conditioned basement under the RBES definitions..

3.1 COMPARISON TO OTHER ENERGY CODES IN NEW ENGLAND

Energy code standards across New England during the time of this study varied in their stringency, adoption mechanisms, and enforcement. This section compares the Vermont energy code (2011 RBES) with the residential energy code in Massachusetts, where NMR recently completed a code compliance study.

During the period of this study, Massachusetts had local adoption of residential energy standards and thus had towns with 2009 IECC equivalent standards, 2012 IECC equivalent standards, and some with a "Stretch Code" standard which had a similar stringency to the 2012 IECC.

To compare the Vermont codes to surrounding states it is easiest to look at the different packages in the fast-track method of compliance. The R-values listed in those packages are generally in line with the 2012 IECC stringency.

Enforcement of the residential energy codes in Massachusetts is largely performed by local building inspectors and is therefore subject to the individual inspector's knowledge, time, and focus. Vermont differs in that compliance is mandated to be builder-certified.

The Massachusetts code compliance study used a different method than was used for the 2015 Vermont study. The method used in Massachusetts, termed "MA-REC," was developed by NMR originally as a part of the 2015 Massachusetts residential baseline study. It incorporates a home's level of compliance with each prescriptive requirement in the IECC into an overall percentage of compliance. The Massachusetts team's previous method was the PNNL checklist of code compliance. The team adopted the MA-REC method over the PNNL checklist because it was more highly correlated with energy consumption.

In the 2015 Vermont study, compliance was based on a single "UA calculation" for each home.[19] This matches the way compliance is certified via the REScheck path in 2011 RBES. The MA-REC method measures the percent of compliance on a measure-level basis and weights each measure based on the measure's influence on energy consumption in the sample. For a full description of the MA-REC method, see Volume 4 of the 2015 Massachusetts Residential Baseline.[20] In addition, the Massachusetts study included far more newer homes than in the Vermont sample; 82% of Massachusetts homes were built in 2015-2016 compared to only 15% in Vermont.

The overall compliance rate found in the 2015 Massachusetts study was 86% for the 2012 IECC which is higher than the 66% compliance rate found in Vermont for the 2011 RBES; however, there are differences in code requirements, enforcement, compliance estimation methods, and study samples that all may affect the compliance rate.

[19] A "UA calculation" refers to finding an area weighted overall U-value for the home. In this study, a home's compliance is measured by how much larger or smaller the home's area weighted U-value is than that of a reference home.
[20] 2015-16 Massachusetts Single-Family Code Compliance/Baseline Study: Volume 4-FINAL REPORT.

4 Section 4 On-Site Inspection Findings

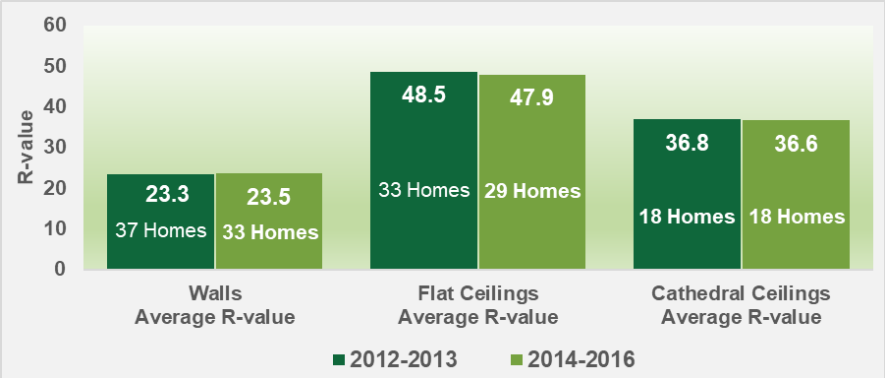
This section summarizes the findings of the on-site inspections of 70 homes—23 program homes and 47 non-program homes.

4.1 Building Envelope

This section addresses walls, ceilings, windows, floors, foundation walls, slabs, ducts, and air leakage. Vermont's 2011 Residential Building Energy Standards (RBES) went into effect on October 1, 2011. This study includes homes built from 2012 to 2016. To see if insulation levels in conditioned/ambient walls, flat ceilings, and cathedral ceilings increased as builders gained experience building to 2011 RBES,

Figure 14 compares the average R-values in 2012-2013 and 2014-2016 homes. As shown, there is almost no difference between the 2012-2013 and 2014-2016 homes.

Figure 14: Average Insulation Levels in 2012-2013 vs. 2014-2016 Homes



4.1.1 Conditioned/Ambient Walls

For conditioned/ambient walls, the most common characteristics seen in sampled homes are: 2x6 16 inch on center framing (74% of homes), fiberglass batt insulation (59% of homes), and Grade II (acceptable quality) insulation installations (54% of homes). The average R-value of these exterior walls is R-23.

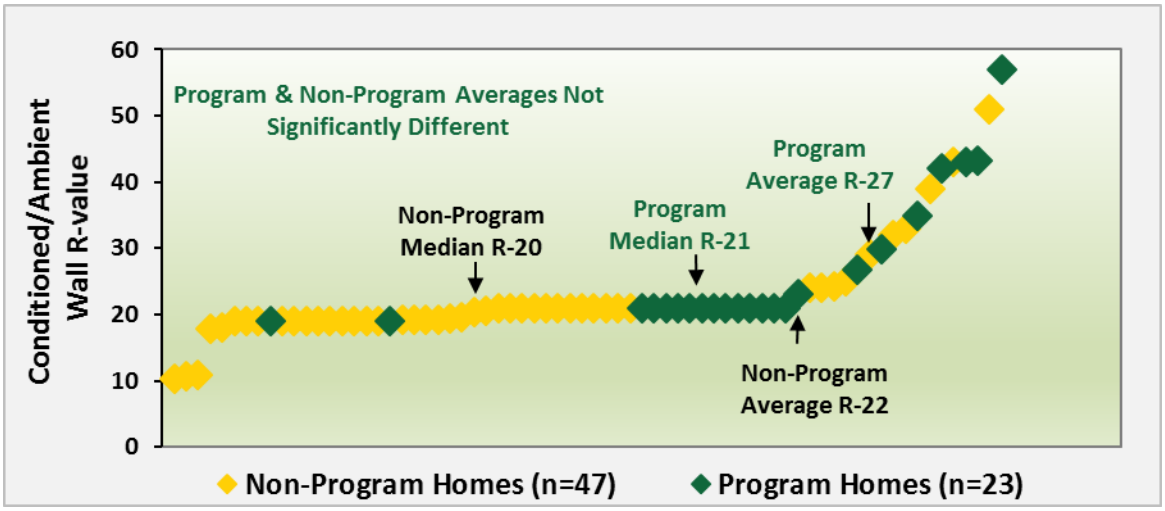
The average R-value in program homes (R-26.6) is significantly higher than the average R-value in non-program homes (R-21.9). Conditioned/ambient wall R-values range from R-10 (uninsulated log walls) to R-57 (a double-stud wall with both cellulose and mineral wool insulation).

On the whole, two-thirds (67%) of the homes have average wall R-values that fall between R-19 and R-21, quite close to the R-20 RBES fast track prescriptive code standard; 45% of

non-program homes and 9% of program homes have less than R-20, a statistically significant difference. Most program homes (70%) have average wall R-values greater than R-20 and up to R-30, compared to only 40% of non-program homes, a statistically significant difference. There are no significant differences between the percentage of program and non-program homes with average R-values above R-30: 14% have more than R-30. Only 3% of homes (two non-program homes) have log walls, which are not subject to the R-20 standard.

Figure 15 charts the individual recorded values for conditioned/ambient wall insulation in all 70 inspected homes and separately identifies program and non-program homes.

Figure 15: R-values for Conditioned/Ambient Walls — Program and Non-Program Homes



4.1.2 Ceilings

This section addresses flat and cathedral ceilings. Auditors recorded insulation information on both flat and cathedral ceiling areas:

Across the sample, about half the homes have only flat ceilings (49%), 11% have only cathedral ceilings, and 40% both flat and cathedral ceilings. Overall, the vast majority of homes (89%) have some flat ceiling area (i.e., unconditioned attic space), and about half (51%) have some cathedral ceiling area. There are no statistically significant differences here between program and non-program homes.

4.1.2.1 Flat Ceilings

Among homes with flat ceilings, the most common characteristics seen in sampled homes are: 2x4 24 inch on center framing (27% of homes), cellulose insulation (74% of homes), and Grade I (high quality) insulation installations (73% of homes). The average R-value of flat ceilings in sampled homes is R-48.2.

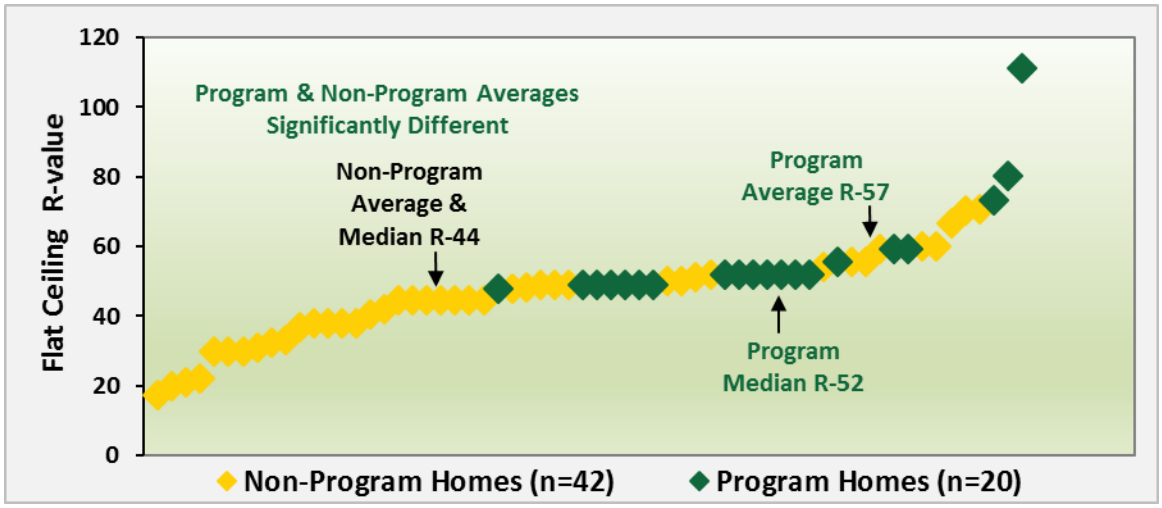
For flat ceiling construction types, the following differences between program and non-program homes are statistically significant:

- Program homes have an extremely high rate of 2x4 24 inch on center flat ceiling framing (70%, 14 out of 20 homes), whereas this is found in only 7% of the non-program homes (three homes).
- The non-program homes are more likely than program homes to have: 2 x 6 16 inch on center (21% vs. 5%) and 2x4 16 inch on center (10% vs. 0%).

The average R-value of flat ceiling insulation is R-48.2. However, the range of average R-values in flat ceilings varies dramatically, from R-18 to a remarkably high R-111. The average R-value of flat ceiling insulation is significantly higher in program homes (R-57.2) than in non-program homes (R-44.0).

Figure 16 charts the individual recorded values for flat ceiling insulation in all 62 inspected homes with flat ceilings. In several cases, homes have different levels of insulation in different flat ceiling areas. For these homes, the average insulation level was calculated using the RBES Handbook procedure for determining the average R-value for a building component with two or more thermal values.

Figure 16: Recorded R-value for all Flat Ceilings—Program and Non-Program Homes

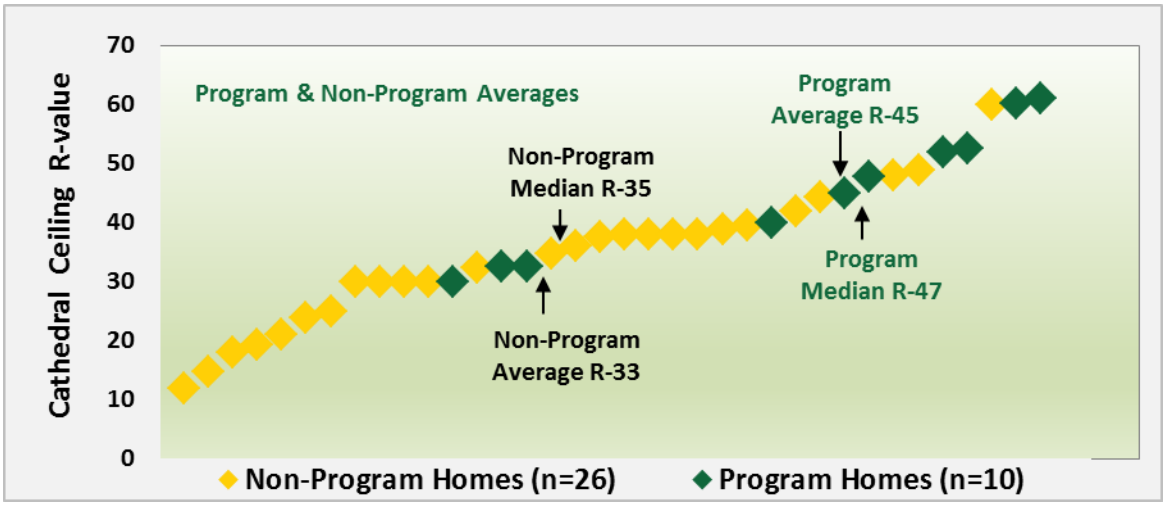


4.1.2.2 Cathedral Ceilings

Among the 36 homes with cathedral ceilings, the most common characteristics seen in sampled homes are: 2x10 16 inch on center framing (39% of homes), cellulose insulation (36%) followed closely by spray foam insulation (31%), and Grade I (high quality) insulation installations (64% of homes). The average R-value of these ceiling areas in the sampled homes is R-36.7. Insulation levels vary widely across homes, from R-12 to R-61. All program homes meet or exceed RBES requirements versus less than half (42%) of non-program homes.

Figure 17 charts the individual recorded values for cathedral ceiling insulation in all 36 inspected homes with cathedral ceilings and separately identifies program and non-program homes.

Figure 17: Recorded R-value for all Cathedral Ceilings—Program and Non-Program Homes



4.1.3 Windows

This section addresses window U-values and both overall and south oriented glazing percentages. Auditors recorded the area in square feet and the orientation of windows in homes. U-value information was available for 19 of the 23 program homes, but auditors found it difficult to verify the U-value for most windows in non-program homes. Documented U-value information was available for only nine non-program homes where the original NFRC (National Fenestration Rating Council) sticker was visible or the U-value was listed on an available REScheck document or plan. The U-values auditors gathered at these nine homes range from 0.17 to 0.32, with an average (using the UA method) of 0.30.

When auditors were unable to verify the U-value of a window, the window was assumed to have a U-value of 0.32. Anderson 200 series windows are an entry level wood window, often termed their builder grade window. U-values for 200 series low-e glass tilt-wash double-hung windows range from 0.29 to 0.31. We believe U-0.32 is a conservative, but reasonable, U-value for non-program homes where auditors were unable to verify window U-values. U-0.32 is also the highest U-value allowed under the RBES 2011 Fast Track and RBES 2015 Prescriptive compliance methods.

Table 8 shows the estimated statewide average U-value of windows is 0.31. Windows in unconditioned space were excluded. Program homes have a significantly lower (more energy efficient) average U-value (0.29) than non-program homes (0.32).

Table 8: Average Window U-values per Home

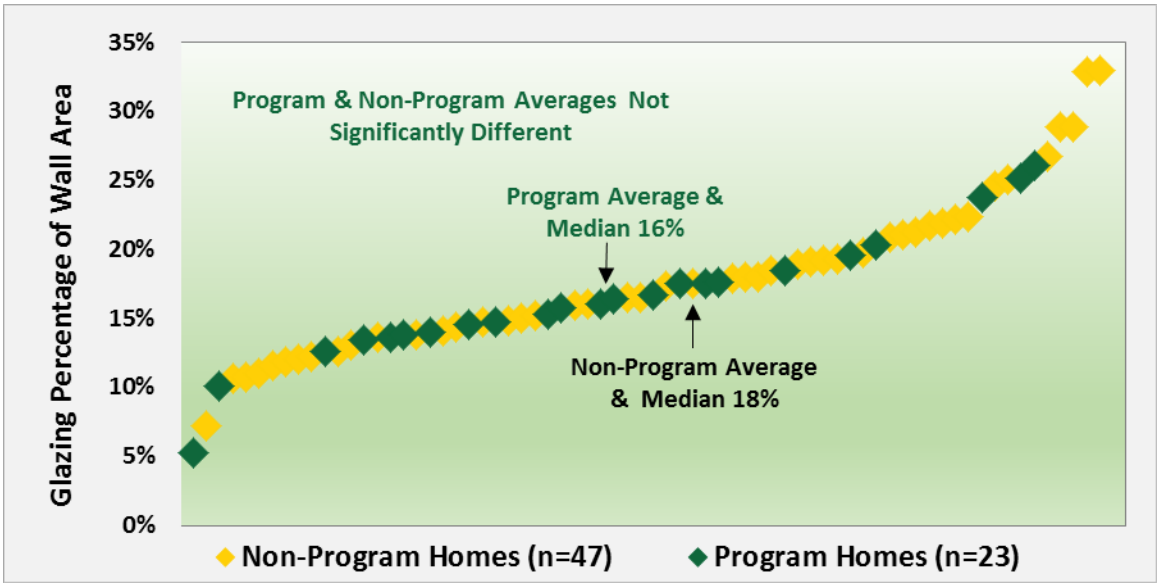
Window U-value	Vermont Gas	Efficiency Vermont	Program Homes	Non-Program Homes	Statewide
Number of Homes	*17*	*69*	*23*	*47*	*70*
Minimum	0.29	0.15	0.15	0.29	0.15
Maximum	0.32	0.32	0.32	0.32	0.32
Average	**0.31**	**0.31**	**0.29***	**0.32***	**0.31**
Median	0.30	0.33	0.30	0.32	0.32

*Significantly different at the 90% confidence level.

Glazing percentage is defined as window area not including windows in unconditioned basements as a percentage of conditioned to ambient wall area. Glazing percentages range from a low of 5% to a high of 33%. The maximum allowable glazing percentage under RBES 2011 is 20%.[21] Just over one-fourth (26%) of inspected homes have glazing percentages 20% or higher. Statewide, the average glazing percentage is 18% and the median is 17%..

Figure 18 charts the individual glazing percentages for all 70 homes separated by program and non-program homes.

Figure 18: Glazing Percentages Per Home



4.1.4 Floors

This section focuses on conditioned floors over unconditioned basements. Auditors recorded insulation information on floors over unconditioned spaces or ambient conditions that form

[21] Under RBES 2015 the 20% maximum glazing requirement applies only to log homes following the Prescriptive compliance method.

part of the thermal boundary of the home. Auditors recorded information about how the floors were framed, and the type, amount, and grade of the installed insulation.

Most of the sampled homes with basements have conditioned basements. Only six of the sampled homes have frame floors over unconditioned basements, and all of these are non-program homes in the Efficiency Vermont territory. The ceilings of these six basements are left uninsulated in all but one instance (83%). These unconditioned basement spaces were generally completely uninsulated: four of these six homes have no foundation wall insulation in these basement areas; the two other homes have only partially insulated foundation walls, resulting in an incomplete thermal boundary.

None of the program homes (including the one Burlington Electric Department home in the sample) have floors over unconditioned basements as part of their thermal boundary – all basements in program homes are within the thermal envelope.

4.1.5 Foundation Wall Insulation

Most foundation walls in new homes qualify as basement walls under RBES, i.e. they are in conditioned space, and mostly below grade. All 17 program homes with basement walls had fully insulated basement walls, whereas two of the 40 non-program homes with basement walls had uninsulated basement walls. When present, the most common basement wall insulation observed was rigid foam board. In fact, program homes used almost exclusively rigid foam board, while spray foam and fiberglass batts were also common in non-program homes.

The verified basement wall insulation installation quality in half of the homes with cavity-based insulation was Grade I, and another quarter was Grade II; there were no Grade III Installations. The average insulation level in program homes was approximately R-17; Efficiency Vermont and non-program homes both averaged R-16, and Vermont Gas homes were not far behind at R-15.

4.1.6 Slab Location and Insulation

Statewide, nearly all observed new homes (86%) have some slab foundations. They include a mix of unheated and heated slabs. Below grade and mixed grade slabs (walk-out basements with both on grade and below grade slabs) account for a little more than two fifths of homes each, 43% and 45% respectively

Slab on grade floors of conditioned spaces are required to have at least R-15 perimeter insulation, with higher requirements for some RBES compliance paths. In addition, R-15 insulation is required under heated slabs. Because slab insulation is rarely visible in finished homes, in many cases the auditors were unable to determine the location and R-value of slab insulation. Among the 23 homes where auditors could verify slab insulation and R-value, most above-grade slabs (57%) had perimeter and under-slab insulation.

4.2 DUCTS

RBES encourages careful design of HVAC systems to ensure that all ductwork is within conditioned space. Approximately two thirds of the 22 homes with ducts had all ducts fully contained within conditioned space. In the two homes with ducts in the garage, the ducts were in framed floors over the garage and not visible.

Information about duct sealing and construction was not available for most program homes. When known, slightly more than half of homes (53%) have only sheet metal ducts, just over a quarter (27%) have flexible ducts, and one fifth (20%) have a mixture of the two.

2011 RBES requires that all ductwork joints be sealed with a durable and appropriate material such as mastic, in contrast with previous RBES versions which only required the sealing of ducts in unconditioned space. In 59% of observed homes statewide, all ductwork is sealed. Two non-program homes (10%) have some or no duct sealing, and the remaining 32% is comprised of program homes for which limited information was collected/available.

Ducts in unconditioned space are required to be insulated to levels comparable to the protection they would receive if they were in conditioned space. For example, ductwork in attics should be beneath the attic insulation. Two program homes had ducts in frame floors over garages, one with R-6 insulation and the other unknown. Two non-program homes had attic ductwork, and in one of the homes the ducts were buried under the ceiling insulation. Finally, four non-program homes had ducts in unconditioned basements.

4.3 AIR LEAKAGE

This section addresses air leakage in inspected homes. Auditors conducted blower door tests to measure air infiltration rates at 46 of the 47 non-program homes and Efficiency Vermont provided blower door test results for the 23 program homes.

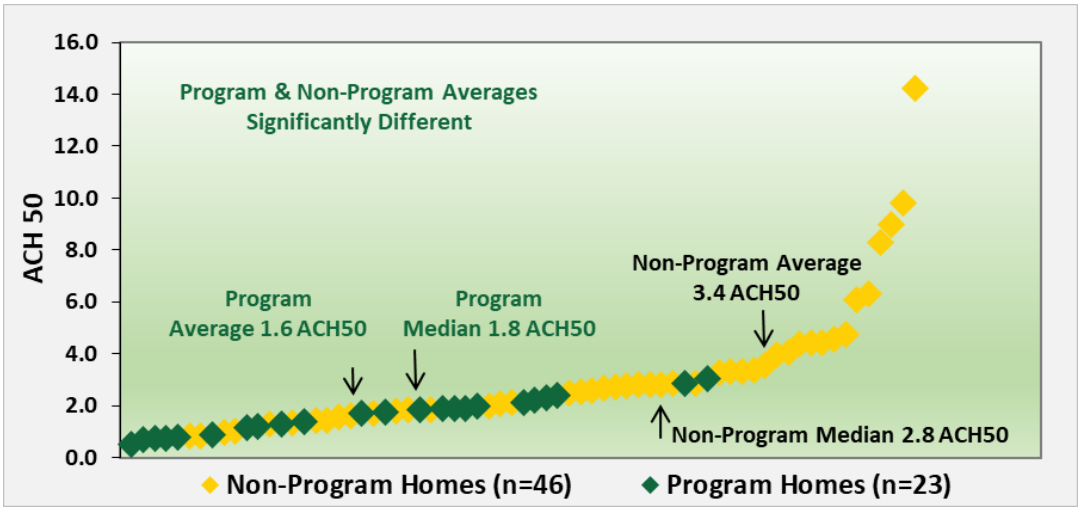
The statewide average air infiltration is 2.8 ACH50. Program homes have a significantly lower average leakage (1.6 ACH50) than non-program homes (3.4 ACH50). The equivalent natural air changes per hour (ACHnat) are 0.16 ACHnat statewide, 0.09 ACHnat for program

2005 RBES did not have specific air infiltration requirements. However, 2011 RBES requires 5 ACH50 or less. Efficiency Vermont's Residential New Construction services now require air infiltration rates of 3 ACH50 or less for Efficiency Vermont Certified Base Level homes and 1 ACH50 or less for High Performance Level homes. Program homes are significantly more likely than non-program homes to have leakage that is one ACH50 or lower (26% vs. 8%) and greater than one but not higher than two ACH50 (48% vs. 24%).

- No program homes have leakage over 3 ACH0, while over one third (39%) of non-program homes have leakage higher than 3 ACH50, a statistically significant difference.
- Most non-program homes (87%) meet the 2011 RBES requirement of 5 ACH50 or less.

Statewide percentages are 74% ACH50 of 3 or less, up from 50% in the 2011 baseline study, and 17% higher than 3 ACH50 but not more than 5 ACH50, down from 35% in the 2011 baseline study. Figure 19 charts the air changes per hour measured at 50 Pascals (ACH50) for each of the 69 tested homes and separately identifies program and non-program homes. The home with the highest ACH50 leakage (14.2) is a 1,219-square foot non-program single-family detached home where poor attention to detail on the second floor ceiling resulted in significant air leakage rates.

Figure 19: ACH50 Envelope Leakage — Program and Non-Program Homes



4.4 HVAC Equipment

This section addresses space heating systems, including the fuels used and types, location and efficiencies of heating systems in inspected homes.

4.4.1 Heating

Two-thirds (66%) of 70 inspected homes use natural gas, propane, or oil boilers or furnaces as their primary heating source. The remaining homes mostly use pellet or wood stoves and in one case a wood furnace (23%).The last 11% use ground source heat pumps (GSHP), air source heat pumps (ASHP) or ductless mini-splits. Owners of ten homes with boilers or furnaces say that wood is their primary heating fuel. Owners of five homes with a ground source, air source, or ductless mini-split heat pump also say their primary source of heat is a wood or pellet stove.

4.4.1.1 Primary Heating Systems and Fuels

Figure 20 shows the percentage of homes by heating system type and fuel. Hot-water boilers are the most common primary heating source. One third (33%) of homes use boilers and another 16% use boiler based combined appliances. More than one-third of homes (39%) use propane as their primary heating fuel. In the previous baseline, two thirds of homes used propane (67%) and only 5% had primary wood stoves. The high percentage of homes where the owners are using wood as the primary heating fuel reflects several homes having both a

wood fired system and a full size non-wood fired furnace, boiler, or heat pump heating system sized to heat the home. The owners of these homes simply choose to use the wood-fired system as their primary heating source.

Figure 20: Primary Heating System Types and Fuels

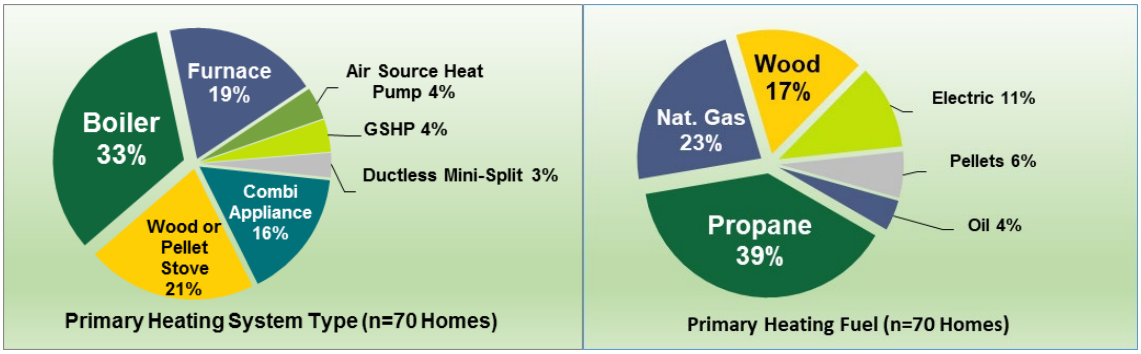
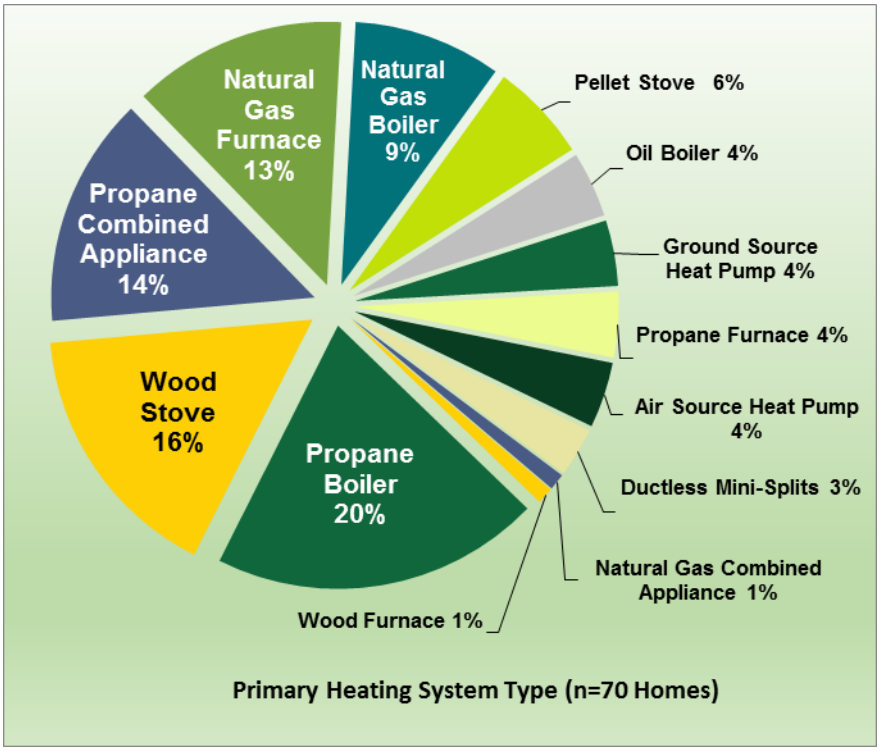


Figure 21 shows the percentages of various primary fuel/heating system type combinations. As shown, 20% of heating systems are propane boilers, followed by wood stoves (16%), propane combined appliances (14%), natural gas furnaces (13%), natural gas boilers (9%), pellet stoves (6%), ASHPs (4%), oil boilers (4%), propane furnaces, (4%), GSHPs (4%), and ductless mini-splits (3%). The remaining 2% of homes have either a wood furnace or a natural gas combined appliance.

Figure 21: Primary Heating Systems



4.4.1.2 Heating System Efficiency

Annual Fuel Utilization Efficiency (AFUE) ratings were determined for all furnaces, boilers, and combined appliances except one—a wood-fired furnace.

Statewide, the average heating system AFUE is 93.0 and the median is 95.0. Over one third (35%) of furnaces, boilers, and combined appliances have AFUEs above 95.0 and most (86%) are ENERGY STAR qualified. All program homes have heating system efficiencies greater than 87 AFUE, while 22% of non-program homes have heating systems with an AFUE of 87 or lower. Program homes have significantly more heating systems in the greater than 87 to 90 AFUE range and the over 95 AFUE range than non-program homes. Overall, however, there is no significant difference between the average AFUEs of program and non-program heating systems.

Auditors found 17 heat pumps during the on-site audits: three air source heat pumps (ASHP), five ground source heat pumps (GSHP), and nine ductless mini-split systems in 14 homes—five program and nine non-program homes. All heat pump systems in these homes are ENERGY STAR qualified. In eight of these homes, the heat pumps are the primary heating system: Two homes use ASHPs, four use GSHPs, and two homes use a single ductless mini-split as the primary heating source. In the remaining six homes the heat pump systems provide supplemental heat.

The average HSPF for the nine ductless mini splits is 10.0 and the average for the two air source heat pumps with HSPF data is 12.3. The rated COPs of the five GSHPs in five homes (two program and three non-program homes) range from 3.5 to 4.7 and the average rated COP is 4.1.

One additional non-program home has a Conditioning Energy Recovery Ventilator (CERV) system with a Geo Boost by Build Equinox. Build Equinox literature states that the Geo Boost Converts the CERV into an air source/geothermal hybrid heat pump with an external ground loop. Several homes participating in Efficiency Vermont's new construction programs have these systems and Efficiency Vermont treats them as Energy Recovery Ventilation (ERV) systems, not heating systems.

4.4.1.3 Furnace Fan Motors, Boiler Outdoor Resets, and High Efficiency Circulator Pumps

As part of the non-program on-site inspections auditors assessed the presence of electrically commutated motors (ECMs) in furnaces, outdoor reset controls for boilers, and high efficiency circulator pumps for boilers. Within non-program homes, 30% of furnaces have ECMs, 13% of boilers have outdoor reset controls, and 34% of boilers have high efficiency circulator pumps.

4.4.1.4 Heating System Location

Most heating systems (85%) are in conditioned space. All heating systems in program homes are in conditioned space. This is significantly different than in non-program homes, where 79% of heating systems are in conditioned space.

4.4.1.5 Homes that Heat Primarily with Wood or Pellets

Owners of 15 homes with a natural gas, propane or oil boiler or furnace, or ASHP, GSHP or ductless mini-split say that they primarily heat with wood. All but two of these homes are non-program homes. Even though the non-wood/pellet systems in these homes are not considered the primary heating source by the owners, the boilers, furnaces or heat pump systems in eight of these 15 homes are ENERGY STAR-qualified. When rating homes that have a wood or pellet stove and also have a natural gas, propane or electric heating system capable of meeting the home's heating load Efficiency Vermont treats the non-wood/pellet system as the primary heating system.

4.4.1.6 Thermostats

Homes in the sample have between one and five thermostats installed. Statewide, 57% of homes have one thermostat installed, 29% have two installed, and 14% have more than two thermostats installed. Statewide, 54% of new homes have programmable thermostats, 41% have manual thermostats, and 5% have Wi-Fi thermostats. The number of homes with programmable thermostats (54%) has increased significantly in comparison to the previous study (33%). Program homes are significantly more likely to have programmable thermostats than non-program homes—83% of thermostats are programmable in program homes versus 53% in non-program—this is a statistically significant difference. There is also a statistically significant difference in the number of manual thermostats installed in program homes (13%) compared to non-program homes (57%).

4.4.2 Cooling

This section addresses cooling systems, including the types, locations, efficiencies and capacities of cooling systems in inspected homes. Auditors collected output capacity and efficiency data on all types of cooling equipment found during on-site inspections.

Just over one third of inspected homes have installed air conditioning (ductless mini-split heat pump, central air conditioner, ground source heat pump or air source heat pump) and an additional 13% of inspected homes have room air conditioners.

Ductless mini-splits are the most frequent type of air conditioning, present in 16% of homes. One in ten homes (11%) has central air conditioning. There are no significant differences between program and non-program homes.

Excluding five GSHP systems, which had an average EER of 20.5, the statewide average SEER of installed air conditioning systems is 18.4. The average SEER for program homes (19.5) is slightly higher than the average for non-program homes (18.0).

4.4.3 Ventilation

The Team identified homes that have balanced mechanical ventilation in the form of energy recovery ventilation (ERV) or heat recovery ventilation (HRV) systems. Overall, 21 out of 70 homes (30%) have either an ERV or HRV for mechanical ventilation. This includes 13 non-program homes and eight program homes. In total there were 27 ERVs or HRVs. The sensible recovery efficiency of these systems ranged from 63% to 76%.

4.5 MANUAL J HVAC SIZING REQUIREMENTS

Proper sizing of HVAC systems is important to ensure systems operate efficiently and maximize occupant comfort. Improperly sized equipment may have reduced life spans due to short-cycling, or risk damage to the home from mold growth due to inadequate moisture removal.

4.5.1 Sizing: Heating

Manual J calculations were performed for 45 of the 47 non-program homes evaluated; one home was heated with wood only, and a second was missing necessary blower door data. Only six non-program homes complied with heating equipment capacity requirements, and a majority had installed capacity exceeding 200% of heating load. Data needed to perform Manual J heating calculations were also available for four program homes: two of these homes complied with heating equipment capacity requirements and two did not.

Although Manual J is the recognized method for calculating heating system sizes, data for non-program homes showed that this is far from the case in practice. There are long-standing rules of thumb that heating systems should provide 35–45 BTU per square foot, or 38–50 BTU per square foot as one manufacturer recommends: these shortcuts may be a common practice.

Heating system BTU output per square foot of conditioned floor area for all 70 inspected homes, including program homes, with heating system output capacity information range from 9 to 150 BTU capacity output per square foot of conditioned floor area. The statewide average is 46 BTU. This is very close to the statewide average of 48 BTU capacity output per square foot of conditioned floor area in the 2011 baseline study.

Program homes are significantly more likely to have 25 to 50 BTU and significantly less likely to have greater than 50 to 100 BTU heating capacity per square foot than non-program homes. Also, program homes have a significantly lower average BTU output per square foot (35.9) than non-program homes (51.9).

4.5.2 Sizing: Cooling

Manual J calculations were performed for 15 non-program homes with cooling systems. A 115% of design load limit for air conditioning applies to eight homes with cooling systems, with the remaining seven being subject to the 125% limit for heating-dominated heat pumps. Only one system, a heat pump system primarily used for heat, satisfies Manual S sizing requirements. The data required for Manual J cooling calculations was also available for three program homes, none of which comply with sizing requirements.

Although nearly all observed cooling systems were oversized, the extent was not as drastic as for heating systems, and the number of homes with cooling is too small to make inferences about reliance upon sizing rules of thumb. Homes that comply with load ratio sizing requirements have an average cooling EUI of 1.40 BTU/ft^2, whereas non-compliant homes have an average of 14.41 BTU/ft^2.

Installed cooling capacity per square foot of CFA per home values range from 1.4 to 30 BTU with a statewide average of 13.2. Not surprisingly, central air systems have the largest capacities.

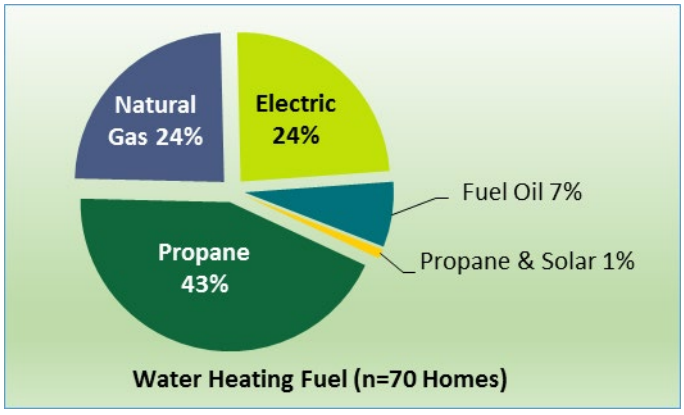
4.6 WATER HEATING

This section addresses the types of water heating systems observed in inspected homes and water heating fuels, efficiency, location, and tank size.

4.6.1 Water Heating Fuel

Figure 22 shows the percentages of homes using different fuels to heat water. More homes use propane (43%) than any other fuel. Natural gas and electric (24% each) are the next most frequently used fuels. Program homes have significantly more natural gas water heaters than non-program homes and significantly less propane water heaters.

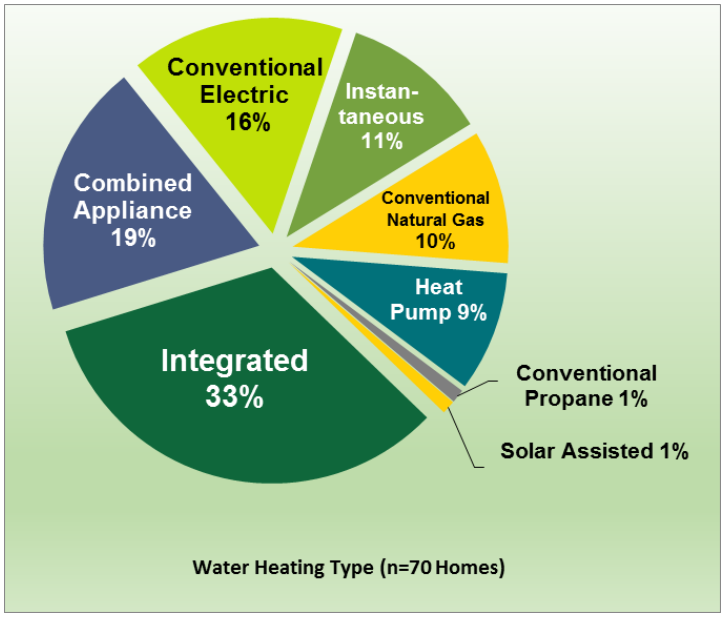
Figure 22: Water Heating Fuel



4.6.2 Water Heater Types

Figure 23 shows the share of each water heater type found in the inspected homes. Most water heating systems incorporate a boiler. This is the first baseline study with homes that have heat pump water heaters; 9% of homes, a mix of program and non-program homes, have heat pump water heaters. Program homes are significantly more likely than non-program homes to have natural gas integrated tank and natural gas conventional tank water heaters and significantly less likely to have propane or oil integrated tank water heaters.

Figure 23: Types of Water Heating Systems



4.6.3 Water Heater Location

Almost nine out of every ten water heaters (87%) are located in conditioned space. Program homes have significantly more water heaters in conditioned space (100%) than non-program homes (81%).

4.6.4 Water Heater Energy Factors

Excluding integrated water heaters (which do not carry an ENERGY STAR certification), 55% of water heaters are ENERGY STAR qualified, 44% do not meet ENERGY STAR criteria, and one that did not have a model number is unknown. There are no significant differences in Energy Factors between program and non-program homes. The statewide average Energy Factor is 0.93.

The energy factors of integrated systems were estimated using 75% of the boiler AFUE.[22] For combined appliance water heaters Vermont uses the REM/Rate default Energy Factor of 0.75 if there is no documented Energy Factor available. Energy Factors were not available for any of the combined appliances so, to treat program and non-program homes consistently, all Energy Factors for these systems were assumed to be 0.75.

4.6.5 Water Heater Tank Size

The capacities of tank water heating systems range from 30 to 119 gallons. The average capacity of all integrated water heating tanks is 45 gallons; the minimum capacity is 30 gallons and the maximum is 80 gallons. The average capacity of conventional stand-alone tank systems is 57 gallons; the minimum capacity is 35 gallons and the maximum is 119

[22] In previous studies the Energy Factors of integrated systems were calculated as 92% of the boiler efficiency, using Northeast Home Energy Rating System Alliance Manual 2007, Chapter 4: NE HERS Rating Technical Guidelines. Since 2015 Vermont has been using guidance from then-Architectural Energy that for indirect tanks off a boiler the Energy Factor should be 75% of the boiler AFUE.

gallons. The average capacity of heat pump water heater tanks is 58 gallons; the minimum capacity is 50 gallons and the maximum is 80 gallons.

4.7 RENEWABLES

Auditors collected data on renewable energy during on-site visits. Twelve homes (seven non-program and five program) have photovoltaic (PV) arrays compared to only three non-ENERGY STAR homes in the previous baseline study. PV arrays range from 1 to 8.7 kW in size with an average size of 4.16 kW. Solar panels are present at 17% of the sampled homes[23].

Only one new home has any type of solar water heating (solar DHW). It has a "do-it-yourself" breadbox water heater The homeowner uses the unit for showers throughout the summer.

4.8 APPLIANCES

This section addresses data collected during the home inspections on refrigerators, freezers, clothes washers, clothes dryers, dishwashers, ranges and ovens, dehumidifiers, and televisions and peripherals.

All visited homes have at least one refrigerator and a range with an oven. Almost all the homes have a clothes washer (99%) and clothes dryer (97%). Program homes are more likely to have a dishwasher than non-program homes (100% vs. 92%). Half of the homes have a separate freezer and one in three homes (33%) have a second working refrigerator. Over one-third of the homes have a dehumidifier (39%). A number of appliances have significantly higher penetration rates than were found in the previous study. In particular, separate freezers (50% vs. 21%), secondary refrigerators (33% vs. 12%), and dehumidifiers (39% vs. 10%) all show increased penetration rates compared to the previous study.

4.8.1 ENERGY STAR Appliances

Auditors were asked to note the presence of the ENERGY STAR label on any appliances. If no ENERGY STAR label was found, then model numbers were recorded (when visible) during the on-site visits; the ENERGY STAR status of these models was checked on the ENERGY STAR website. Note, however, that this database identifies only those models that meet the current ENERGY STAR criteria. Therefore, older models that met the ENERGY STAR criteria in effect when sold were also identified and included.as ENERGY STAR-qualified appliances.

Significantly more clothes washers (88% vs. 59%) and dishwashers (89% vs. 66%) are ENERGY STAR qualified compared to the previous study. In 2015, program homes are significantly more likely to have an ENERGY STAR clothes washer than non-program homes (96% vs. 83%). Almost three quarters of the primary refrigerators are ENERGY STAR qualified (71%), compared to only 17% for secondary refrigerators. The ENERGY STAR criteria for clothes dryers was introduced on January 1st, 2015 and there were five clothes

[23] Solar photovoltaic arrays are not eligible to be funded through the Energy Efficiency charge in Vermont.

dryers encountered that were manufactured after that date with all five being ENERGY STAR dryers.

4.8.2 Separate Freezers

Separate freezers are older than most appliances in new homes; almost one-third of the freezers (31%) are at least ten years old. Seventeen percent of separate freezers are 15 years or older. Most separate freezers (60%) are less than 15 cubic feet in size. Three-fifths of separate freezers are chest and the rest are upright models.

4.8.3 Clothes Washers

Most of the clothes washers are under five years old (91%); 39% are from 2014 or 2015. Over two thirds of the clothes washers (68%) are front load models. Program homes are significantly more likely than non-program homes to have front-loading models and significantly less likely to have top-loading models.

4.8.4 Clothes Dryers

Close to nine out of ten (87%) clothes dryers in new homes are under five years old. Over four out of five dryers (81%) use electricity. Program homes are significantly more likely than non-program homes to have electric clothes dryers and significantly less likely to have propane clothes dryers.

4.8.5 Ranges and Ovens

Only two percent of ranges are over five years old. Over one-third of ranges use electricity (43%), and over one third (38%) use propane. Program homes are significantly more likely to use natural gas and less likely to use propane compared to non-program homes.

Almost one half of all ovens use electricity (48%) and almost one third use propane (32%). Program homes are significantly more likely than non-program homes to have a natural gas oven and significantly less likely to have a propane oven.

4.8.6 Dehumidifiers

More than one third (39%) of inspected homes have dehumidifiers. Seventy-two percent of dehumidifiers are five years old or less and 77% are ENERGY STAR qualified.

4.9 Home Offices

Almost one quarter of homes (23%) have a dedicated home office. Almost two-thirds of home offices are between 100 and 200 square feet in size, while about one-third (31%) are less than 100 square feet.

4.10 LIGHTING

This section addresses the types of lighting in inspected homes, the saturations of different bulb types, and the proportions and numbers of CFL and LED bulbs installed.

Statewide, 87% of new homes have at least one LED bulb installed. This represents a significant increase from the previous residential new construction baseline study, when only 10% of homes statewide had LED bulbs installed. CFL bulbs, including both screw-in and pin-based CFL bulbs, are installed in 96% of homes. LED bulbs are slightly more common in non-program homes than program homes (89% vs. 83%), though the difference is not statistically significant.

Statewide, 35% of sockets are filled with LED bulbs, compared to 31% with CFLs, 23% with incandescent bulbs, 6% with halogen bulbs,4% with fluorescent bulbs, and 1% empty sockets. The only significant difference between program and non-program homes is that program homes are significantly more likely to have CFLs installed (47%) than non-program homes (24%). Increased LED lighting is also seen in other recent residential new construction baseline studies. Table 9 shows LED bulb saturation in six recent studies. Except for the Vermont study, all studies include only non-program homes. The studies are listed chronologically, based on the average age of the homes in the study. As shown, LED bulb saturation grew from 20% in the first study of 2013 to 2016 homes (95% built in 2014 or 2015) to 60% in the last study of 2015 to 2017 homes (98% built in 2016 or 2017).

Table 9: Other Baseline Study LED Bulb Saturation

Study	Homes	Years Homes Built	LED Lighting Socket Saturation
MA RNC Baseline Study[24]	50 non-program 2009 IECC homes	2013-2015	20%
VT RNC Baseline Study	23 program and 47 non-program homes	2012-2016	35%
MA RNC Baseline Study[25]	95 non-program 2012 IEEC and stretch code homes	2013-2016	31%
CT RNC Baseline Study[26]	70 non-program 2009 IECC homes	2014-2015	40%
RI RNC Baseline Study[27]	40 non-program 2012 IECC homes	2015-2017	50%
MA RNC Mini Baseline Study[28]	50 non-program 2012 IECC homes	2015-2017	60%

[24] NMR Group, Inc. & Dorothy Conant. 2015-16 Massachusetts Single-Family Code Compliance/Baseline Study: Volume 2- Final Report. Submitted to The Electric and Gas Program Administrators of Massachusetts. October 21, 2016.
[25] NMR Group, Inc. & Dorothy Conant. 2015-16 Massachusetts Single-Family Code Compliance/Baseline Study: Volume 3-Final Report. Submitted to The Electric and Gas Program Administrators of Massachusetts. February 13, 2017.
[26] NMR Group, Inc. R1602 Residential New Construction Program Baseline Study. Submitted to Connecticut EEB, Lisa Skumatz, Ralph Prahl, and Bob Wirtshafter, EEB Evaluation Administrators. December 5, 2017.
[27] NMR Group, Inc. Rhode Island Baseline Study of Single-Family Residential New Construction. Submitted to National Grid Rhode Island. January 16, 2018.
[28] NMR Group, Inc. MA RLPNC 17-2: 2017 Massachusetts Single-Family New Construction Mini-Baseline/Compliance Study Final. Submitted to The Massachusetts Electric and Gas Program

Administrators. January 3, 2018.

5 Section 5 Homeowner Questions – Single Family New Construction

Auditors asked homeowners a series of questions related to emerging technologies during the on-site inspections. Specifically, the questions focused on home energy management systems, solar panels, and heat pump water heaters.

5.1 Home Energy Management Systems

Auditors questioned homeowners with home energy management systems installed in their home about their level of satisfaction with the system and what the system controlled. There were 13 home energy management systems in the single-family new construction sample. Twelve of the thirteen systems controlled the homes' heating and cooling set points and one also controlled the in-home lighting. One system's capabilities were not clearly identified. Most homeowners with a home energy management system (69%) reported that they were either "very satisfied" or "satisfied" with the system. No homeowners with a home energy management system were unsatisfied.

5.2 Solar Net Metering

Homeowners were asked if they were members or owners of a solar net metering community. Additionally, the member/owners were asked how much of their annual utility bill was offset by energy produced by their solar net metering community. Only one homeowner was a member of a solar net metering community, and reported that 51-75% of their annual utility bill was offset.

5.3 HVAC Heat Pump

Owners of the 17 audited homes with heat pumps (air source, ground source, and ductless mini-splits) were asked to rate their satisfaction with the system(s). All but one homeowner responded with either "very satisfied" or "satisfied." One homeowner was "dissatisfied" with the heat pump/ductless mini split due to it being a "complicated system that breaks a lot and [is] too expensive."

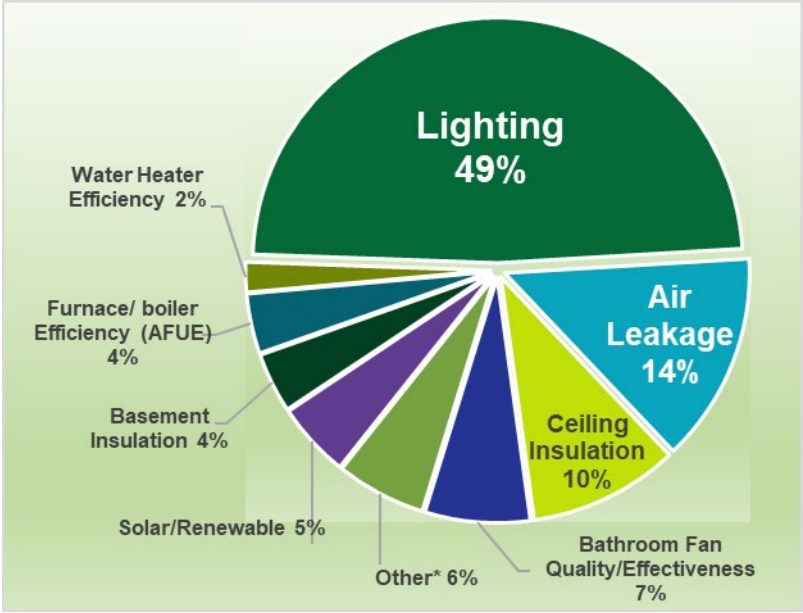
5.4 Heat Pump Water Heater

As part of the on-site inspections, auditors assessed the technical potential for heat pump water heater (HPWH) installation by identifying the features that are required to install a HPWH. Overall, 46% of homes meet all of the requirements to install a HPWH. That is they have sufficient space, ceiling height, temp. of at least 50 degrees, and a drain present. This percentage does not include the 9% of homes that already have a HPWH installed.

5.5 ENERGY EFFICIENCY OPPORTUNITIES

Auditors identified potential opportunities for energy efficiency improvements in the 47 inspected non-program homes. This was a qualitative assessment of the measures or areas that represent the largest savings opportunities in the opinion of the auditors. Figure 24 shows the most frequently cited opportunities address lighting, air leakage and ceiling insulation.

Figure 24: Energy Efficiency Opportunities by Category*



* Other category consists of: dedicated fresh air supply/woodstove, HVAC controls, kitchen range hood, ventilation systems - undersized, duct system insulation installation.

A Appendix A Comparisons to Earlier Vermont Baseline Studies

This appendix compares the results of five Vermont new residential construction baseline studies: the 1995, 2002, 2008, 2011 and 2015 studies. Construction practices have improved in almost all areas. Rows in the tables that show improvement are highlighted in yellow.

A.1 SUMMARY STATISTICS FOR KEY CHARACTERISTICS

Table 10: Summary Comparison of Vermont 1995, 2002, 2008, 2011 and 2015 Baseline Study Home Features

Characteristic	Vermont 1995 Baseline	Vermont 2002 Baseline	Vermont 2008 Baseline Weighted Data	Vermont 2011 Baseline Weighted Data	Vermont 2015 Baseline
Number of Homes	*151*	*158*	*106*	*97*	*70*
Water Heating Median Energy Factors					
Indirect Fired: Fossil Fuel	0.78	0.77	0.80	0.85	0.71
Stand Alone: Electric	0.82	0.88	0.90	0.92	0.92
Stand Alone: Fossil Fuel	0.52	0.60	0.59	0.63	0.61
Instantaneous	na	na	0.84	0.82	0.82
Flat Ceiling Insulation					
Average R-value	33	40	39	44	48
Cathedral Ceiling Insulation					
Average R-value	33	32	34	39	37
Conditioned/Ambient Wall Insulation					
Average R-value	19	20	21	22	23
Below Grade Foundation Wall Insulation					
Average R-value	7	8	11	12	16
Insulation in Floors Exposed to Outside Air					
Average R-value	30	30	28	26	33
Insulation in Floors Over Unconditioned Space					
Average R-value	30	30	3	11	1
Slab Insulation					
Average R-value	na	4	8	11	17
Air Changes per Hour					
Average ACH50	8.1	5.6	5.1	3.2	2.8

Characteristic	Vermont 1995 Baseline	Vermont 2002 Baseline	Vermont 2008 Baseline Weighted Data	Vermont 2011 Baseline Weighted Data	Vermont 2015 Baseline
Number of Homes	*151*	*158*	*106*	*97*	*70*
Average ACHnat	0.45	0.31	0.28	0.18	0.16
Boiler Heating System AFUE					
Average AFUE	na	84.8	87.4	91.2	92.5
Furnace Heating System AFUE					
Average AFUE	na	91.0	89.9	92.9	95.6
Screw-in or Pin-based CFL Bulbs					
Percent of Homes with Screw-in or Pin-based CFL Bulbs	About One-Third	47%	81%	94%	96%
Average Number of Screw-in or Pin-based CFLs per Home	na	3	14	27	23
LED Bulbs					
Percent of Homes with LED Bulbs	na	na	na	10%	87%
Average Number of LEDs Bulbs per Home	na	na	na	1	26
Percent ENERGY STAR Appliances					
ENERGY STAR Refrigerators*	na	27%	30%	62%	71%
ENERGY STAR Dishwashers*	na	36%	69%	66%	89%
ENERGY STAR Clothes Washers*	na	47%	48%	59%	88%
ENERGY STAR Separate Freezers*	na	na	12%	5%	14%

*Not all homes have these appliances. The percentages are the percentage of the individual appliances observed in homes that were ENERGY STAR qualified.

A.2 COMPARISONS TO EARLIER VERMONT BASELINE STUDIES

The remainder of this appendix is tables from the 2011 Vermont report updated to include 2015 study results. Table 11 shows the average home size in the 2015 study is higher than in the 2011 study. Overall, the average home size across the five studies has ranged from 2,187 square feet in the 2011 study to 2,510 in the 2002 study. Some of the differences could be due, in at least part, to changes in the definition of conditioned floor area over the studies. However, the definitions of conditioned space in the most recent four studies, listed below, are very similar.

- 1995 study—finished living space
- 2002 and 2008 studies—intentionally heated space
- 2011 and 2015 studies—all finished space within the insulated envelope and intentionally heated unfinished space

Table 11: Vermont Studies—Home Size

Home Size (Heated Area) Square Feet	Vermont 1995 Baseline	Vermont 2002 Baseline	Vermont 2008 Baseline Weighted	Vermont 2011 Baseline Weighted	Vermont 2015 Baseline
Number of Homes	*151*	*158*	*106*	*97*	*70*
< 1,000	4%	0%	3%	3%	1%
1,000 to 1,499	12%	8%	12%	21%	10%
1,500 to 1,999	29%	25%	20%	28%	21%
2,000 to 2,499	21%	25%	25%	18%	29%
2,500 to 2,999	11%	19%	17%	13%	14%
3,000 to 3,499	10%	9%	10%	9%	10%
3,500 to 3,999	6%	8%	6%	3%	9%
4,000 to 4,499	4%	3%	5%	2%	0%
4,500 to 4,999	2%	2%	1%	0%	4%
5,000 or More	2%	2%	3%	1%	1%
Average Square Feet	**2,380**	**2,510**	**2,507**	**2,187**	**2,496**
Median Square Feet	2,130	2,390	2,352*	1,958*	2,324

*Not weighted.

Table 12 shows homeowners in the 2015 study continued the 1995 to 2011 trend to be less likely to heat with oil. Homeowners in 2015 are more likely to say they heat with natural gas or wood than in previous studies. Also, the percentage of homeowners in the Electric/Other/Combination category increased in the 2015 study, reflecting increased use of

heat pump heating systems. Air source heat pumps accounted for four percent and ductless mini-splits for three percent of primary heating systems in the 2015 study.

Table 12: Vermont Studies—Primary Heating Fuel

Primary Heating Fuel	Vermont 1995 Baseline	Vermont 2002 Baseline	Vermont 2008 Baseline Weighted	Vermont 2011 Baseline Weighted	Vermont 2015 Baseline
Number of Homes	*151*	*158*	*106*	*97*	*70*
Oil/Kerosene	60%	45%	34%	9%	4%
Natural Gas	6%	19%	11%	13%	23%
Propane	29%	29%	40%	57%	39%
Wood	0%	6%	14%	12%	17%
Electric/Other/Combination	5%	1%	1%	9%	17%

.

Table 13 shows that the current study is the first time no homes have a tankless coil water heater and the first time any inspected homes have heat pump water heaters. The percentage of homes with fossil fuel-fired integrated tank water heating continued to decline, the percentage of homes with instantaneous water heaters is roughly half of what it was in 2011, and the percentage of homes with combined appliance water heating is almost four times what it was in 2011.

Table 13: Vermont Studies—Water Heating Type and Energy Factor

Water Heating Type	Vermont 1995 Baseline		Vermont 2002 Baseline		Vermont 2008 Baseline Weighted Data		Vermont 2011 Baseline Weighted Data		Vermont 2015 Baseline	
	Percent of Homes	Median Energy Factor	Percent of Homes	Median Energy Factor	Percent of Homes	Median Energy Factor*	Percent of Homes	Median Energy Factor*	Percent of Homes	Median Energy Factor
Number of Homes	*151*	*na*	*137*	*na*	106	na	97	na	70	na
Tankless Coil	32%	0.50	3%	na	5%	0.40	1%	0.45	0%	na
Indirect Fired: Fossil Fuel	50%	0.78	83%	0.77	74%	0.80	58%	0.85	33%	0.70***
Stand Alone: Electric	8%	0.82	6%	0.88	3%	0.90	6%	0.92	16%	0.92
Stand Alone: Fossil Fuel	11%	0.52	11%	0.60	13%	0.59	10%	0.63	11%	0.61
Instantaneous	0%	na	0%	na	4%	0.84	20%	0.82	11%	0.82
Combined Appliance	na	na	na	na	na	na	5%	0.75	19%	0.75****
Heat Pump	na	na	na	na	na	na	na	na	9%	2.77
Other**	na	na	na	na	na	na	5%	na	1%	na

*Median Energy Factors not weighted.
**Other is one home with a solar assisted water heating system.
*** The energy factors of integrated systems were estimated using 75% of the boiler AFUE. In previous studies the Energy Factors of integrated systems were calculated as 92% of the boiler efficiency, using Northeast Home Energy Rating System Alliance Manual 2007, Chapter 4: NE HERS Rating Technical Guidelines. Since 2015 Vermont has been using guidance from then-Architectural Energy that for indirect tanks off a boiler the Energy Factor should be 75% of the boiler AFUE.
****In the 2015 study Vermont used the REM/Rate default Energy Factor of 0.75 for combined appliances if there was no documented Energy Factor available. Energy Factors were not available for any of the combined appliances so, to treat program and non-program homes consistently, all Energy Factors were assumed to be 0.75.

Table 14 shows the percentage of homes meeting or exceeding code for flat ceiling insulation (R-38) increased from 60% in 2011 to 83% in 2015 and the average R-value increased from R-44 in 2011 to R-48 in 2015.

Table 14: Vermont Studies—Flat Ceiling Insulation

Flat Ceiling Average R-value Minimum Requirement 2005 & 2011 RBES R-38	Vermont 1995 Baseline	Vermont 2002 Baseline	Vermont 2008 Baseline Weighted	Vermont 2011 Baseline Weighted	Vermont 2015 Baseline
Number of Homes	*na*	*141*	*94*	*80*	62
R-value Below Code	38%	28%	26%	40%	18%
R-value Meets or Exceeds Code	62%	68%	74%	60%	83%
R-value Statistics*					
Minimum R-value	na	15	19	19	18
Maximum R-value	na	83	100	110	111
Average R-value	**33**	**40**	**39**	**44**	**48**
Median R-value	na	38	38	38	49

*Only the average R-value is weighted for 2008 and 2011.

Table 15 shows that the percentage of homes meeting or exceeding code for cathedral ceiling insulation decreased from 90% in 2011 to 58% in 2015; this decrease in compliance with code likely reflects the change in the minimum requirement from R-30 in 2005 RBES to R-38 in 2011 RBES. However, the average R-value also decreased from R-39 to R-37 and the median decreased from R-39 to R-38.

Table 15: Vermont Studies—Cathedral Ceiling Insulation

Cathedral Ceiling Average R-value Minimum Requirement 2005 RBES R-30 2011 RBES R-38**	Vermont 1995 Baseline	Vermont 2002 Baseline	Vermont 2008 Baseline Weighted	Vermont 2011 Baseline Weighted	Vermont 2015 Baseline
Number of Homes	*na*	*141*	*55*	*51*	*36*
R-value Below Code	35%	36%	20%	10%	41%**
R-value Meets or Exceeds Code	65%	64%	80%	90%	58%
R-value Statistics*					
Minimum R-value	na	19	16	11	12
Maximum R-value	na	60	66	60	61
Average R-value	**33**	**32**	**34**	**39**	**37**
Median R-value	na	30	36	39	38

*Only the average R-value is weighted for 2008 and 2011.

** The RBES fast track prescriptive requirements for cathedral ceilings increased from R-30 in 2005 RBES to R-38 in 2011 RBES with an allowance for up to 20% of the total ceiling area (up to a maximum of 500 square feet) to be insulated with as little as R-30. The percentage of homes below code in the 2011 study (10%) includes only homes with cathedral ceilings with less than average R-30 insulation. The percentage of homes below code in the 2015 study (41%) includes homes with less than average R-30 insulation (19% of homes) and homes with more than 20% of the total ceiling area, up to a maximum of 500 square feet, less than R-38 (22% of homes).

Table 16 shows the percentage of homes meeting or exceeding code for wall insulation decreased from 91% in 2011 to 67% in 2015; this decrease in compliance with code likely reflects the change in the minimum requirement from R-19 in 2005 RBES to R-20 in 2011 RBES. At the same time, the average R-value of conditioned/ambient wall insulation increased from R-22 in 2011 to R-23 in 2015 and the median increased from R-19 to R-21.

Table 16: Vermont Studies—Conditioned/Ambient Wall Insulation

Conditioned/Ambient Walls Average R-value Minimum Requirement RBES 2005 R-19 RBES 2011 R-20	Vermont 1995 Baseline	Vermont 2002 Baseline	Vermont 2008 Baseline Weighted	Vermont 2011 Baseline Weighted	Vermont 2015 Baseline*
Number of Homes	*na*	*141*	*105*	*97*	*70*
R-value Below Code	na**	10%	5%	9%	33%
R-value Meets or Exceeds Code	na**	90%	95%	91%	67%
R-value Statistics*					
Minimum R-value	na	8	7	8	10
Maximum R-value	na	40	48	54	57
Average R-value	**19**	**20**	**21**	**22**	**23**
Median R-value	na	19	19	19	21

*Only the average R-value is weighted for 2008 and 2011.

**Previous baseline reports include multiple estimates of the percentage of homes meeting or exceeding R-19 wall insulation. Reported estimates range from 57% to 94%. Without knowing which estimate is consistent with the 2002 and 2008 data, this cell is not populated.

Table 17 shows the percentage of homes meeting or exceeding code requirements for below grade foundation wall insulation grew consistently from 48% in 1995 to 87% in 2011 and then dropped to 55% in 2015. Again, this reflects an increase in minimum code requirements from R-10 in 2005 RBES to R-15/20 (R-15 continuous insulated sheathing on the interior or exterior of the home or R-20 cavity insulation at the interior of the basement wall) in RBES 2011. The average R-value increased from R-12 in 2011 to R-16 in 2015 and the median increased from R-10 to R-15.

Table 17: Vermont Studies—Below Grade Foundation Wall Insulation

Below Grade Foundation Walls Average R-value Minimum Requirement 2005 RBES R-10 2011 RBES R-15/20**	Vermont 1995 Baseline	Vermont 2002 Baseline	Vermont 2008 Baseline Weighted	Vermont 2011 Baseline Weighted	Vermont 2015 Baseline
Number of Homes	*na*	*146*	*88*	*67*	*57*
R-value Below Code	52%	38%	27%	13%	40%
R-value Meets or Exceeds Code	48%	62%	73%	87%	55%
R-value Statistics*					
Minimum R-value	na	0	0	0	0
Maximum R-value	na	29	35	25.5	40
Average R-value	**7**	**8**	**11**	**12**	**16**
Median R-value	na	10	11	10	15

*Only the average R-value is weighted for 2008 and 2011

Table 18 shows that 58% of the 2015 audited homes meet the insulation code requirement of R-38 for floors exposed to outside air. This is up from 20% in 2011. The average R-value of insulation increased from R-26 in 2011 to R-33 in 2015 and the median increased from R-30 to R-38.

Table 18: Vermont Studies—Insulation in Floors Exposed to Outside Air

Floors Over Outside Air Average R-value Minimum Requirement RBES 2005 & 2011 R-38	Vermont 1995 Baseline	Vermont 2002 Baseline	Vermont 2008 Baseline Raw Data	Vermont 2011 Baseline Raw Data	Vermont 2015 Baseline
Number of Homes	na	26	4	15	7
R-value Below Code	na	73%	75%	80%	43%
R-value Meets or Exceeds Code	na	23%	25%	20%	58%
R-value Statistics					
Minimum R-value	na	8	19	0	15
Maximum R-value	na	43	50	38	40
Average R-value	**30**	**30**	**28**	**26**	**33**
Median R-value	na	30	22	30	38

Table 19 shows that 15% of the homes in the 2011 study met the code requirement of R-30 insulation in floors over unconditioned space and none of the six homes with floors over unconditioned space in the 2015 study met code. Five of the six homes had no insulation.

Table 19: Vermont Studies—Insulation in Floors Over Unconditioned Space

Floors Over Unconditioned Space Average R-value Minimum Requirement RBES 2005 & 2011 R-30	Vermont 1995 Baseline	Vermont 2002 Baseline	Vermont 2008* Baseline Weighted	Vermont 2011* Baseline Weighted	Vermont 2015 Baseline
Number of Homes	*na*	*26*	*11*	*20*	*6*
R-value Below Code	na	73%	100%	85%	100%
R-value Meets or Exceeds Code	na	23%	0%	15%	0%
R-value Statistics**					
Minimum R-value	na	8	0	0	0
Maximum R-value	na	43	21	38	4
Average R-value	**30**	**30**	**3**	**11**	**1**
Median R-value	na	30	0	0	0

*2008, 2011 and 2015 data based on floors over fully unconditioned basements.
**Only the average R-value is weighted for 2008 and 2011.

Table 20 shows that homes in the 2015 study are less likely to meet code requirements for slab insulation than in the 2011 study. However, the average R-value of slab insulation increased to R-17, up from R-11 in the 2011 study.

Table 20: Vermont Studies—Slab Insulation

Basement Slab Average R-value Minimum RBES Requirement R-10	Vermont 1995 Baseline	Vermont 2002 Baseline (n=63)	Vermont 2008 Baseline				Vermont 2011 Baseline	Vermont 2015 Baseline
			On-Grade Slab* Raw Data	Below Grade Slab* Weighted Data	Mix (on/below) Grade Slab* Raw Data	All Slabs** Weighted Data	All Slabs Requiring Insulation***	Known Slab Insulation RBES Compliance
Number of Homes	*na*	*na*	*19*	*51*	*17*	*82*	*24*	*15*
R-value Below Code	na	63%	21%	56%	38%	46%	16%	33%
R-value Meets or Exceeds Code	na	37%	79%	44%	62%	54%	84%	67%
R-value Statistics**								
Minimum R-value	na	0	0	0	0	0	0	0
Maximum R-value	na	11	28	14	16	30	20	60
Average R-value	**na**	**4**	**12**	**6**	**8**	**8**	**11**	**17**
Median R-value	na	0	14	8	10	10	10	15

*All homes with known slab insulation location and R-value.
**All homes with known slab insulation R-value.
***Only includes homes required by code to have slab insulation.

Table 21 shows that the percentage of homes with less than 10% glazing peaked in 2008 at 27% and then fell to 14% in 2011 and to 3% in 2015. Over the same period, the percentage of homes with more than 20% glazing grew from seven percent in 2008 to 27% in 2011 and 26% in 2015. The average glazing percentage increased from 15% in 2011 to 18% in 2015.

Table 21: Vermont Studies—Glazing Percentage

Glazing Area Window to Wall Area Ratio	Vermont 1995 Baseline	Vermont 2002 Baseline	Vermont 2008 Baseline Weighted	Vermont 2011 Baseline Weighted	Vermont 2015 Baseline
Number of Homes	*151*	*139*	*105*	*97*	*70*
Less than 10%	23%	10%	27%	14%	**3%**
10 to 12%	32%	29%	16%	8%	9%
>12 to 15%	30%	26%	28%	28%	24%
>15 to 20%	9%	19%	22%	22%	38%
More than 20%	6%	16%	7%	27%	26%
Glazing Percentage Statistics*					
Minimum Glazing %	na	6%	5%	3%	5%
Maximum Glazing %	na	27%	30%	26%	33%
Average Glazing %	**na**	**14%**	**13%**	**15%**	**18%**
Median Glazing %	na	13%	13%	15%	17%

*Only the average is weighted for 2008 and 2011.

Table 22 shows that homes in the 2015 study are tighter, on average, than homes in the 2008 and 2002 studies. Table 23 shows that average ACH50 has steady improved over the last three baseline studies from 5.1 in 2008 to 2.8 in 2015.

Table 22: Vermont Studies—Natural Air Changes per Hour

Natural Air Changes per Hour (ACHnat)	Vermont 1995 Baseline	Vermont 2002 Baseline	Vermont 2008 Baseline Weighted	Vermont 2011 Baseline Weighted	Vermont 2015 Baseline
Number of Homes	*151*	*156*	*82*	*55*	*69*
Less than 0.31	na	70%	60%	90%	91%
0.31 to 0.50	na	24%	32%	10%	6%
Over 0.50	na	6%	8%	0%	3%
ACHnat Statistics*					
Minimum ACHnat	na	na	0.04	0.05	0.03
Maximum ACHnat	na	na	0.65	0.40	0.79
Average ACHnat	**0.45**	**0.31**	**0.28**	**0.18**	**0.16**
Median ACHnat	na	na	0.26	0.13	0.12

*Only the average is weighted for 2008 and 2011.

Table 23: Vermont Studies—Air Changes per Hour at 50 Pascals (ACH50)

Air Changes per Hour (ACH50)	Vermont 1995 Baseline	Vermont 2002 Baseline	Vermont 2008 Baseline Weighted	Vermont 2011 Baseline Weighted	Vermont 2015 Baseline
Number of Homes	*151*	*156*	*82*	*55*	*69*
Less than or Equal to 1 ACH50	na	na	1%	4%	14%
>1 to 3 ACH50	na	na	21%	58%	60%
>3 to 5 ACH50	na	na	32%	27%	17%
Over 5 ACH50	na	na	46%	11%	9%
ACHnat Statistics*					
Minimum ACH50	na	na	**0.8**	0.8	0.5
Maximum ACH50	na	na	**11.7**	7.1	14.2
Average ACH50	**8.1**	**5.6**	**5.1**	**3.2**	**2.8**
Median ACH50	na	na	**4.8**	2.4	2.1

Table 24 shows the average boiler AFUE continues to rise, increasing from 91.2 in 2011 to 92.5 in 2015. Similarly, the median AFUE increased from 92.3 in 2011 to 94.0 in 2015.

Table 24: Vermont Studies—Boiler Heating System AFUE

Heating System AFUE Boilers	Vermont 1995 Baseline	Vermont 2002 Baseline	Vermont 2008 Baseline Weighted	Vermont 2011 Baseline Weighted	Vermont 2015 Baseline
Number of Boilers	*na*	*120*	*86*	*70*	41
AFUE Statistics*					
Federal Minimum Standard	80.0	80.0	80.0	80.0	Gas Water 82 Gas Steam 80 Oil Water 84 Oil Steam 82
ENERGY STAR Minimum	85.0	85.0	85.0	85.0	Gas Boilers 90 Oil Boilers 87
Minimum AFUE	na	80.2	80.5	85.0	85.0
Maximum AFUE	na	89.0	95.2	96.0	96.5
Average AFUE	**na**	**84.8**	**87.4**	**91.2**	**92.5**
Median AFUE	na	85.0	86.6	92.3	94.0

*Only the averages for 2008 and 2011 are weighted.

Table 25 shows that both the average and median furnace AFUEs are higher in 2015 than they were in 2011.

Table 25: Vermont Studies—Furnace Heating System AFUE

Heating System AFUE Furnaces	Vermont 1995 Baseline	Vermont 2002 Baseline	Vermont 2008 Baseline Weighted	Vermont 2011 Baseline Weighted	Vermont 2015 Baseline
Number of Furnaces	*na*	*20*	*15*	*19*	*14*
AFUE Statistics					
Federal Minimum Standard AFUE	78.0	78.0	78.0	78.0	Gas 80
ENERGY STAR Minimum AFUE [29]	90.0	90.0	90.0	90.0	Gas 95.0 Oil 85.0
Minimum AFUE	na	78.0	80.0	80.0	92.1
Maximum AFUE	na	93.0	93.5	97.5	97.7
Average AFUE	**na**	**91.0**	**89.9**	**92.9**	**95.6**
Median AFUE	na	86.5	92.5	95.5	96.0

*Only the averages for 2008 and 2011 are weighted

Table 26 presents the CFL and LED bulb results from the previous Vermont baseline studies and the current study. As shown, the percentage of homes with CFL bulbs installed has continued to increase over time with 96% of homes having CFLs in 2015 and the average number of screw-in or pin-based CFL bulbs per home is 23. The biggest change in lighting since the 2011 study is the growth in LED lighting. In the 2015 study, 87% of homes have LED bulbs and the average number of LED bulbs per home is 26, which is higher than the average number of CFL bulbs per home.

Table 26: Vermont Studies—CFL & LED Bulbs

Screw-in or Pin-based CFL Bulbs	Vermont 1995 Baseline	Vermont 2002 Baseline	Vermont 2008 Baseline Weighted	Vermont 2011 Baseline Weighted	Vermont 2015 Baseline
Number of Homes	*na*	*158*	*105*	*97*	*70*
Percent of Homes with Screw-in or Pin-based CFL Bulbs	About one-third	47%	81%	94%	96%
Average Number of Screw-in or Pin-based CFLs per Home	na	3.0	14.2	27.4	23
Percent of Homes with LED Bulbs	na	na	na	10%	87%
Average Number of LED Bulbs per Home	na	na	na	1	26

[29] ENERGY STAR minimum AFUE requirement is 90 for gas and 85 for oil furnace through the 2011 study.

Table 27 compares the saturation of appliances in the current study to previous studies. As shown, the saturations of all but primary refrigerators (100%) increased relative to 2011. The biggest increases between the 2011 and 2015 studies are increases in the saturation of separate freezers (21% to 50%), secondary refrigerators (12% to 33%), and central air conditioners (9% to 35%).

Table 27: Vermont Studies—Appliance Saturation

Percent of Homes with …	Vermont 2002 Baseline	Vermont 2008 Baseline Weighted	Vermont 2011 Baseline Weighted	Vermont 2015 Baseline
Number of Homes	*159*	*105*	*97*	*70*
Primary Refrigerators	100%	100%	100%	100%
Clothes Washer	98%	97%	97%	99%
Clothes Dryer	96%	94%	95%	97%
Dishwashers	90%	92%	87%	94%
Separate Freezer	na	33%	21%	50%
Secondary Refrigerators	12%	19%	12%	33%
Room Air Conditioner	15%	20%	9%	13%
Central Air Conditioner	6%	10%	9%	35%

Table 28 shows the percentages of homes with ENERGY STAR refrigerators, dishwashers, clothes washers, and separate freezers are all higher than in 2011.

Table 28: Vermont Studies—ENERGY STAR Appliances

Percent of Homes with …	Vermont 2002 Baseline	Vermont 2008 Baseline Weighted	Vermont 2011 Baseline Weighted	Vermont 2015 Baseline
ENERGY STAR Dishwashers	36%	69%	66%	89%
ENERGY STAR Refrigerators	27%	30%	62%	71%
ENERGY STAR Clothes Washers	47%	48%	59%	88%
ENERGY STAR Separate Freezers	na	12%	5%	14%