Vermont Multifamily Baseline On-Site Report

FINAL

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Vermont Public Service Department

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ES Executive Summary

This report presents the findings of the multifamily on-sites conducted as part of the Vermont Residential Baseline Study. The NMR team conducted on-site inspections at 64 multifamily complexes in Vermont between April and August 2016 to assess the energy characteristics of multifamily buildings and provide baseline efficiency data regarding the multifamily market in Vermont. Consistent with both Vermont Residential Building Energy Standards (RBES) guidelines and the previous baseline study, this study defines residential multifamily buildings as those buildings with three or more housing units in buildings of three or fewer stories.

These complexes included 10 new construction and 54 existing sites. For the purposes of the study, we define existing multifamily buildings as those built prior to 2005, while newly constructed buildings include those built after October 1, 2011. For new complexes and existing Burlington Electric complexes, counts are provided in the tables rather than percentages due to the limited sample size. Because there is a lack of publicly available data on the multifamily market in Vermont, it is difficult to ascertain the extent to which the on-site samples are representative of the population. However, due to the difficulty in identifying and recruiting newly constructed non-program complexes (see Section 1.1) it appears that new program complexes may be overrepresented in our sample (see Section 1.4).

FINDINGS

Characteristics of Multifamily Complexes

- All ten of the newly constructed complexes are rental properties with an average size of 26 housing units each. Seven of ten new complexes offer both affordable housing (61% of all units) and market rate housing (39% of all units) (Table 1).
- The existing complexes provide a greater diversity of housing types, with 44% of the units being affordable housing, 28% market rate rentals, and 27% owner-occupied. The average size of the existing complexes is 33 housing units.
- In both new and existing complexes, heating and cooling costs are more likely to be included in the rent while electricity bills are more likely to be paid by the occupant.

Table 1: Summary of Multifamily Housing Unit Characteristics

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	*8*	*2*	*10*	*9*	*45*	*54*
Average Number of Units	22	42	26	66	26	33
Rental - Affordable	58%	67%	61%	41%	45%	44%
Rental - Market	42%	33%	39%	38%	24%	28%
Owned	--	--	--	21%	31%	27%

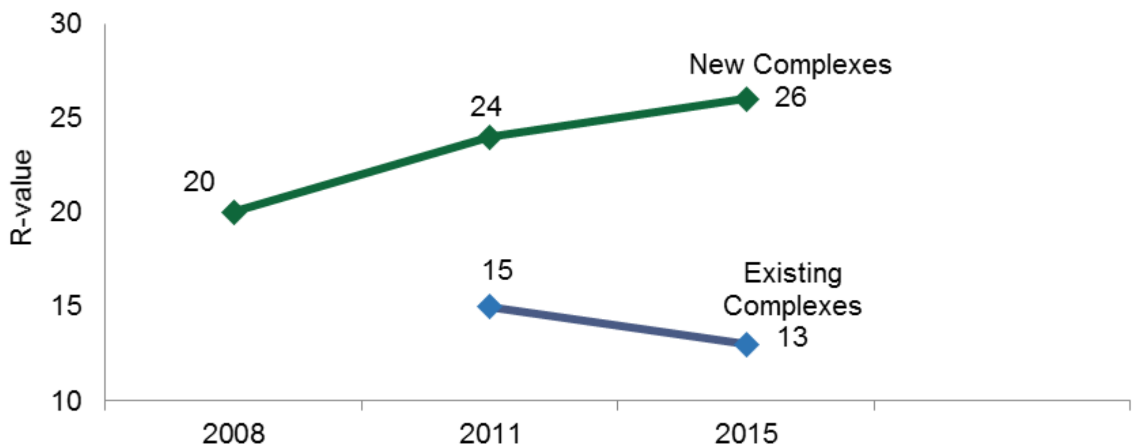
Common Area Lighting and Appliances

- Interior common area lighting in new buildings is split about equally between LEDs, CFLs, and fluorescent bulbs. Interior common area lighting in existing buildings is about one-half fluorescent, 30% CFL, and 15% LED, with the remainder being incandescent or halogen.
- CFLs and LEDs are the most common bulb types in exterior common areas (parking lots, walkways, etc.). Eight of ten exterior common areas in new buildings contain LEDs and 61% of exterior common areas in existing buildings contain CFLs.
- ENERGY STAR washers are present in the common areas of one-half of new complexes and slightly over one-half of existing complexes.

Above Grade Walls

- All new complexes have average wall R-values exceeding the 2011 RBES requirement of R-20, and the average conditioned to ambient wall R-value in new complexes is R-26. This R-value is an increase over the 2011 new construction study, where above grade walls averaged R-24 (Figure 1).
- In existing complexes, the average conditioned to ambient wall R-value is R-13, a drop from the 2011 study where walls averaged R-15. Thirteen existing complexes have fully uninsulated conditioned to ambient walls.

Figure 1: Wall R-value Trends

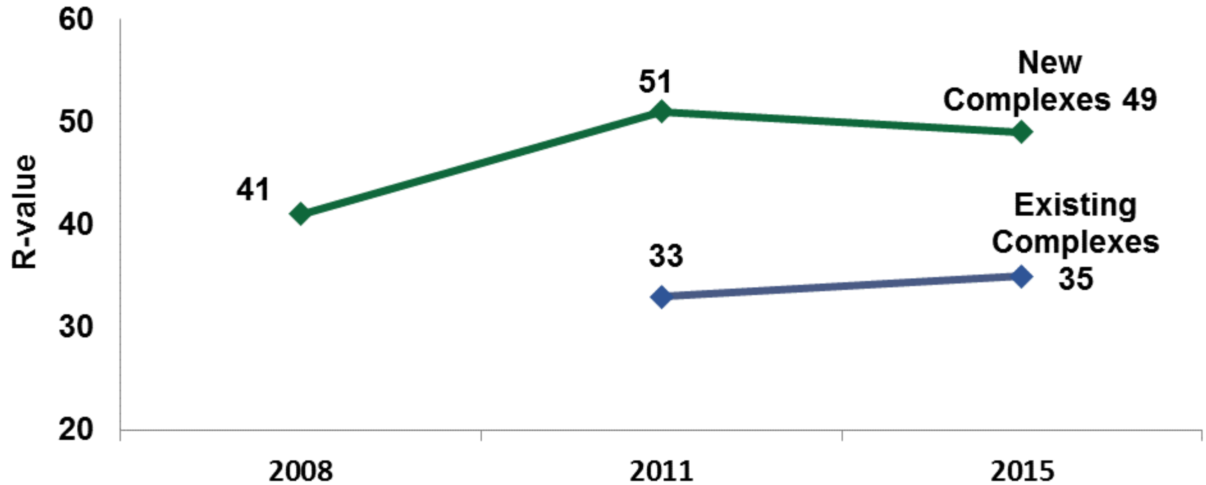


Flat and Vaulted Ceilings

- Flat ceiling insulation R-values decreased slightly to R-49 in new buildings in 2015 after a substantial increase between 2008 and 2011 (Figure 2). R-values in existing building flat ceilings increased slightly in 2015 to R-35.
- A relatively small fraction (14%) of ceiling area is uninsulated in existing buildings: 9% of flat ceiling area (including hatches) and 36% of vaulted ceiling area. Four existing

complexes have fully uninsulated flat ceiling assemblies, and two existing complexes have fully uninsulated vaulted assemblies.

Figure 2: Flat Ceiling R-value Trends



Frame Floors

- In existing buildings, the average R-value of framed floors over unconditioned or ambient space is R-10. While low, this is an improvement over the 2011 existing buildings sample, where floors averaged R-5. Twenty existing buildings have floors forming part of the thermal envelope that are uninsulated.
- Just two new buildings have floors forming part of the thermal envelope, one meets RBES prescriptive requirements at R-30 and the other falls short of code requirements at R-26.

Foundation Walls and Slabs

- Twenty-six percent of existing buildings have a basement thermal boundary (framed floor or foundation wall) that is fully insulated, while this boundary is uninsulated in 69% of buildings.
- Conditioned foundation walls are found in six new buildings and ten existing buildings. All conditioned foundation walls are insulated in new buildings and one-half are insulated in existing buildings, though no walls more than 50% above grade are insulated.
- In existing buildings, 78% of slab area with confirmed data is uninsulated. No slabs in existing buildings are insulated more than R-10, based on available information. In new buildings, most slabs with known insulation are insulated to R-15.

Glazing

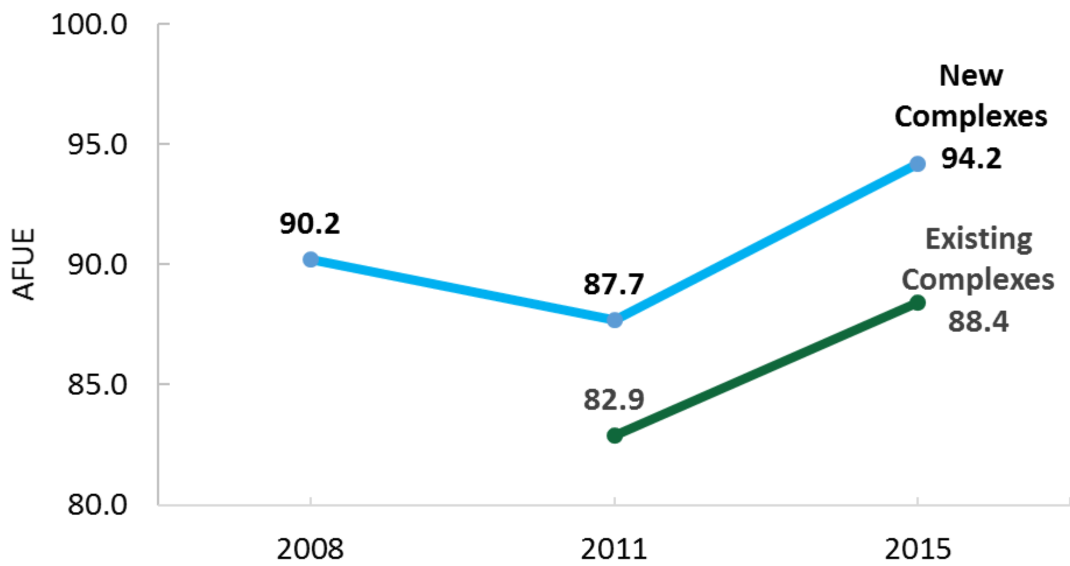
- All window area in new buildings is double pane, low-E glass; 8% of that window area uses argon gas. In existing homes, three-quarters of window area is clear (non-low-E) double pane glass, and another 11% of glazing area is single pane glass.

- Window glazing makes up 29% of exterior wall area in new complexes, almost double the percentage in 2011, when glazing made up 15% of exterior wall area.

Heating

- The average AFUE of boilers—the most common heating system type—has increased since 2011 in both new and existing complexes (Figure 3).
- Commercial-scale boilers are found in both new and existing complexes—the average thermal efficiency of commercial boilers in new complexes is 91.9 and in existing complexes is 88.3.

Figure 3: Boiler Efficiency Trends



Air Conditioning

- Six of the ten new complexes have central air conditioning systems installed and one complex uses room air conditioners. Nine percent of existing complexes have central air conditioners while an additional 30% have room air conditioners.
- All six of the central air conditioning systems in new complexes are heat pumps—two use central ducted air-source heat pumps, four use ductless mini-splits—while two existing complexes utilize ductless mini-splits.

Water Heating

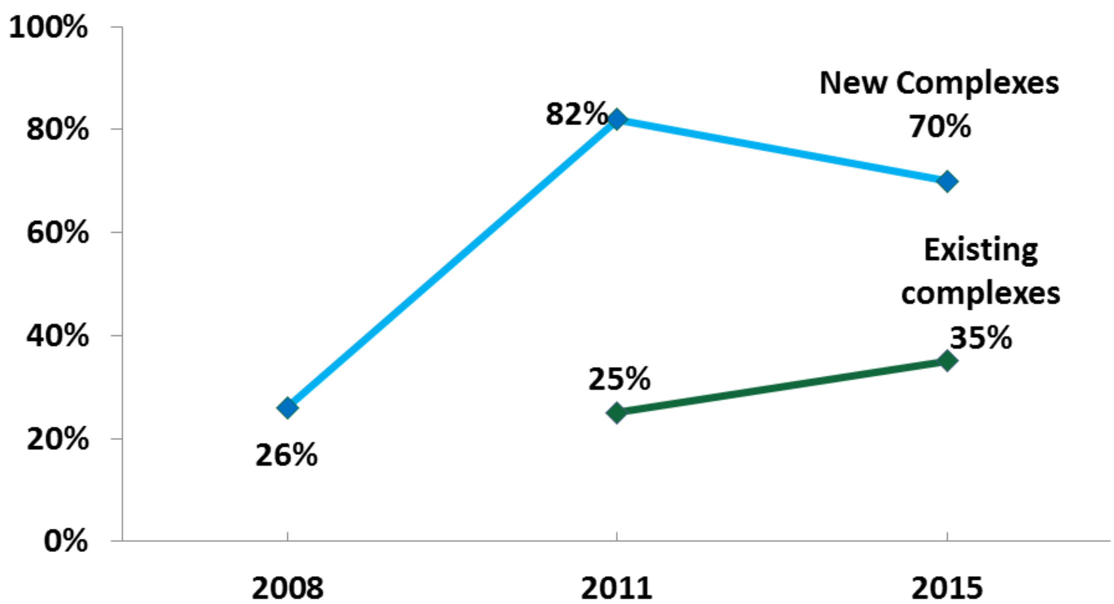
- Indirect water heaters are the most common type at both new and existing complexes, found at all ten new complexes and 63% of existing complexes. The remaining 37% of existing buildings use conventional storage systems.

- The average Energy Factor for indirect water heaters is 0.68 in new buildings and 0.66 in existing buildings. These numbers are improvements over 2011 average Energy Factors observed for indirect water heaters in both new and existing buildings.[1]

Appliances in Housing Units

- In existing housing units, 35% of refrigerators are ENERGY STAR, while seven of ten housing units in new complexes have an ENERGY STAR refrigerator.
- Fifty percent of clothes washers in existing housing units are ENERGY STAR, as are 19% of dishwashers. Two clothes washers and two dishwashers were present in new housing units—one washer was ENERGY STAR, as were both dishwashers.

Figure 4: ENERGY STAR Refrigerator Saturation in Housing Units



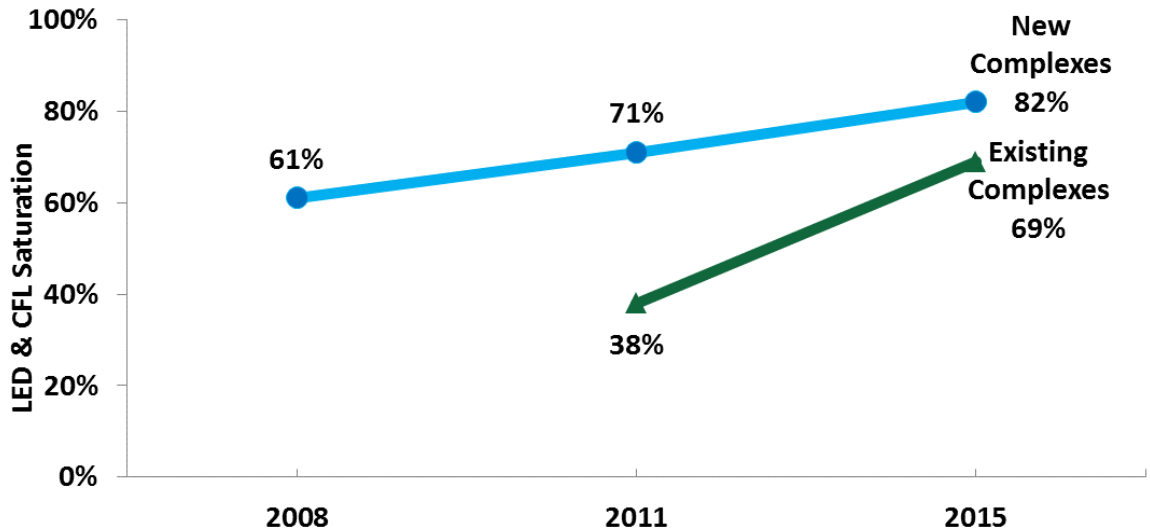
Lighting in Housing Units

- The proportion of newly constructed housing units with at least one LED increased from 5% to 60% since the 2011 study. Similarly, the proportion of existing housing units with at least one LED increased from 5% to 35%.
- CFLs represent 52% of sockets observed in existing housing units, incandescent bulbs fill 21%, fluorescents 14% and LEDs 11%. In newly constructed units, 36% of sockets contain LEDs, followed by CFLs at 30%, fluorescent bulbs at 21%, and incandescent or

[1] The energy factors of integrated (indirect) 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 AFUE, using Northeast Home Energy Rating System Alliance Manual 2007, Chapter 4: Technical Guidelines. Since 2015 Vermont has been following guidance from then-Architectural Energy that for indirect tanks off a boiler the Energy Factor equals 75% of the boiler AFUE. After applying the 92% method used in previous studies, the new and existing indirect Energy Factors equal 0.83 and 0.81, respectively, which reflect improvements over the 0.82 and 0.76 values from the previous study.

halogen bulbs at 13%. The saturation of CFLs and LEDs as a percent of all screw-based bulbs inside housing units has increased with each study (Figure 5).

Figure 5: Combined CFL and LED Saturation in Screw-based Sockets inside Housing Units[2]



Savings Opportunities

New buildings exhibit limited opportunities for savings, as the data show that most measures that impact building efficiency perform well compared to RBES requirements. In addition, new buildings in the current study outperform those from the 2011 study for most key measures. Existing buildings, on the other hand, show considerable savings opportunities, chief among them are insulation levels of the building shell.

- ***Newly constructed buildings in the study perform well in most key areas related to building efficiency.***

On average, most of the building shell area in newly constructed buildings is insulated to at least RBES requirements, with the exception of one site with a framed floor over unconditioned space. Ceilings and walls are all insulated to RBES requirements, as are conditioned foundation walls and slabs with known R-value data.

The efficiency of heating systems is high — the average AFUE of natural gas and propane boilers is 95% and the average thermal efficiency of commercial boilers is 92%. In addition, indirect water heaters are found at all ten new complexes with an average energy factor of 0.68.

[2] To match with the methodology of previous baseline studies, the numbers from 2015 do not include pin-based fluorescent tubular bulbs. Therefore, combined LED and CFL percentages will not match the values included in Section 6

Six of the ten new complexes use heat pumps for air conditioning and one complex uses room air conditioners.

All of the interior common area light bulbs are either LEDs, CFLs, or linear fluorescents. In addition, 87% of all sockets inside housing units contain either LEDs, CFLs, or fluorescent bulbs. Seven of the ten housing units have an ENERGY STAR refrigerator.

Given their newer vintage, auditors identified few opportunities for improving energy efficiency, though lighting efficiency could be improved at three of the ten sites.

Overall, these results indicate there is limited opportunities to improve the efficiency of newly-constructed multifamily buildings. However, as discussed earlier, due to the difficulty in identifying and recruiting newly constructed non-program complexes it appears that new program complexes may be overrepresented in our study sample.

- ***There are substantial savings opportunities in upgrading existing multifamily buildings.***

Table 2 displays statistics for several key efficiency measures found in the inspected existing multifamily buildings. The average R-values for key shell measures—above grade walls, flat and vaulted ceilings, and framed floors over unconditioned space—show that potential savings exist in upgrading the insulation.

- Twenty-six percent of existing buildings in the sample have above grade walls that are fully uninsulated, which contributes to the R-13 average.
- Fourteen percent of all ceiling area is uninsulated: 9% of flat ceiling area and 36% of vaulted ceiling area. These uninsulated areas contribute to an average of R-34 for flat ceilings and R-24 for vaulted ceilings.
- Eighty-five percent of existing buildings with below-grade foundation walls have entirely uninsulated walls. In addition, 61% of the existing buildings with framed floors are fully uninsulated, leading to an average of just R-10.
- Most of the slab area (78%) with confirmed data is uninsulated. No slabs in existing buildings are insulated more than R-10, based on available information.

There are also savings opportunities for mechanical equipment, appliances, and lighting.

- While the average AFUE (88%) of boilers is reasonably high, there are opportunities to upgrade boilers and furnaces that only achieve 80% efficiency. In addition, insulation on hot water piping is found in just 39% of hydronic heating systems.
- While common areas almost exclusively use efficient lamps, there is room for increasing the efficiency of lights and appliances inside housing units—21% of sockets use incandescent or halogen bulbs, and just 35% of refrigerators are ENERGY STAR rated.

Auditors identified energy efficiency opportunities at 42% of the existing multifamily complexes. Roughly one-quarter of these buildings offered opportunities for upgrading lights and windows, followed by basement insulation (17%) and furnace or boiler efficiency (15%).

Overall, these results indicate there are substantial opportunities to improve the efficiency of existing multifamily buildings, in particular for building shell insulation as well as for heating system efficiency, lighting, and appliances. While this study did not measure air infiltration at multifamily buildings, given the insulation deficiencies it's likely that air sealing also provides a good opportunity.

Table 2: Existing Building Opportunity Summary

Characteristic	Measurement	Statewide Value
n (buildings)		*54*
Above grade wall insulation	Average R-value	12.7
	Percent of area with no insulation	26%
	Percent of buildings with no insulation	24%
Flat ceiling insulation	Average R-value	34.3
	Percent of area with no insulation	9%
	Percent of buildings with no insulation	9%
Vaulted ceiling insulation	Average R-value	23.8
	Percent of area with no insulation	36%
	Percent of buildings with no insulation	15%
Framed floor insulation	Average R-value	9.7
	Percent of area with no insulation	30%
	Percent of buildings with no insulation	61%
Slab insulation	Percent of known area with no insulation	78%
Foundation wall insulation	Percent of buildings with uninsulated foundation walls	85%
Heating system efficiency	Average AFUE of boilers	88.4
	Average AFUE of furnaces	80.1
Hot water piping insulation	Percent of heating systems with pipe insulation	39%
Windows	Percent of window area with single pane glass	11%
Interior common area lighting	LED, CFL, and fluorescent saturation	94%
Housing unit lighting	LED, CFL, and fluorescent saturation	79%
Refrigerators	Percent ENERGY STAR	35%

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Section 1 Introduction

This report presents the findings from the multifamily on-sites conducted as part of the 2015 Vermont Residential Baseline Study. The NMR team conducted inspections at 64 multifamily complexes in Vermont between April 2016 and August 2016. These multifamily complexes included ten new construction and 54 existing sites. The objective of these inspections is to assess the energy characteristics of buildings and housing units to provide baseline data regarding the multifamily buildings market in Vermont.

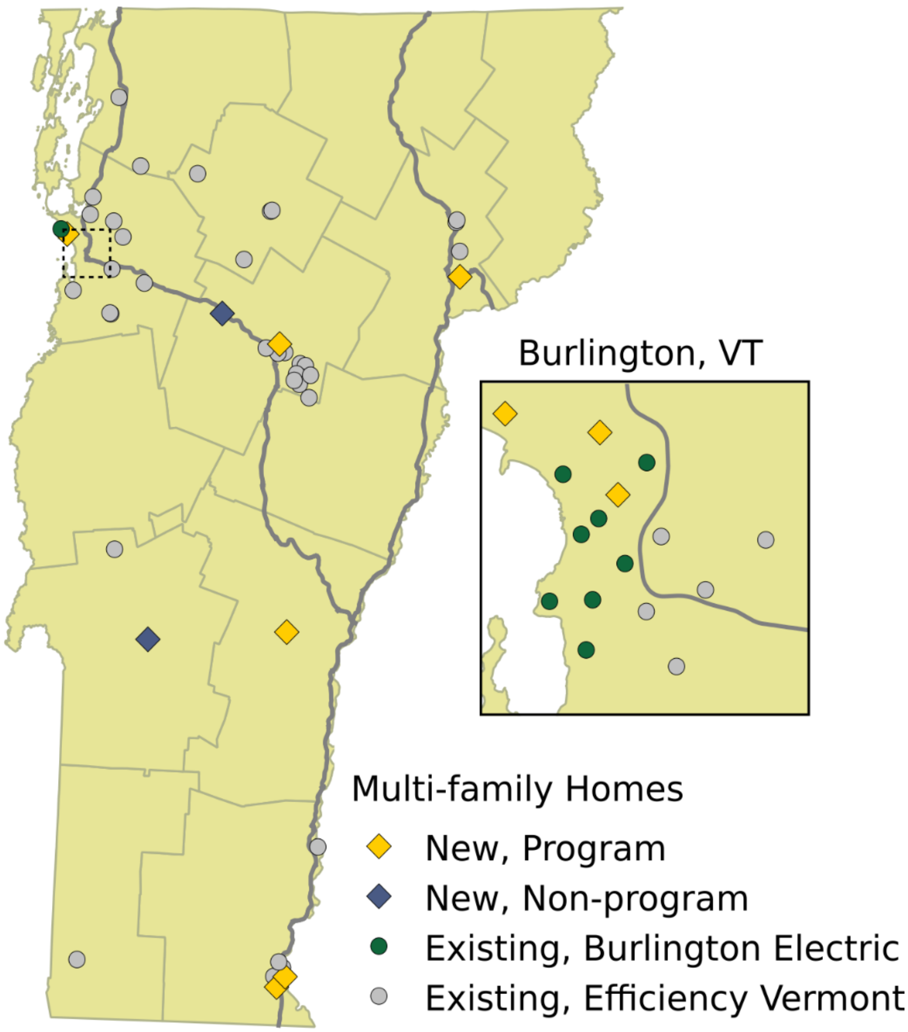
We define a multifamily complex to include building(s) located together under the same ownership or management. In each complex that consists of multiple buildings, a single building was chosen for a detailed inspection.

This baseline study − following RBES guidelines − defines residential multifamily buildings as those buildings with three or more housing units in buildings of three or fewer stories; this definition includes attached side-by-side homes with ground-to-roof walls separating units (if three or more units are attached). Following these criteria, our sample included the following types of complexes:

- Individual buildings with three or more units
- Three or more attached townhouses or row houses
- Complexes consisting of multiple two-unit buildings
- Market rate and low-income complexes

This definition excludes all hotels, motels, barracks, dormitories and nursing homes, which fall under a commercial classification and were included as potential sample for a separate commercial baseline study. Figure 6 shows the locations of the sites visited in the study. Not surprisingly, a bulk of the visits are concentrated in the Burlington area and surrounding suburbs, with smaller clusters around secondary population centers such as Montpelier and Brattleboro.

Figure 6: Geographic Distribution of Multifamily Site Visits



1.1 MULTIFAMILY MARKET

The 2013 American Community Survey (ACS) 5-year estimates indicate that there are 51,254 housing units located in buildings with three or more housing units in Vermont that meet the study definition of an existing structure (built prior to 2005). These units represent about 17% of the 310,737 housing units (both occupied and vacant) in the state. Based on census data, we estimate that there are approximately 15,283 existing multifamily buildings in Vermont. Small multifamily buildings with private owners are much more difficult to identify and recruit than larger properties, thus larger multifamily buildings are likely overrepresented in this study sample.

The Census also provides estimates[3] of new construction permits issued in Vermont, including for buildings with 3 to 4 units and buildings with 5 or more units (Table 3). From 2011 to 2014 the Census estimates that 168 buildings (representing 1,756 units) containing three or more units were built in Vermont. Because the cutoff for construction completion under the 2011 version of RBES occurs so early in 2015 (February 28), permit information for that year is excluded.

Table 3: Census Building Permit Data

Year	Building with 3 or 4 Units		Buildings with 5 or More Units	
	Units	Buildings*	Units	Buildings
2011	39	11	377	25
2012	26	7	336	27
2013	50	14	428	36
2014	29	8	471	40
Total	**144**	**40**	**1,612**	**128**

*Number of 3 to 4 unit buildings calculated by dividing number of units by 3.5.

Because these data can include buildings with more than three stories, which fall under the commercial designation, we used additional Census permit data to estimate that there were approximately 62 multifamily new construction projects built in 2013 and 2014 that are of three-story height or lower, representing roughly 591 units.

It is important to note that the ACS and Census definition of multifamily buildings differs from the definition employed by this study in two key ways. As previously mentioned, this baseline follows RBES guidelines and defines residential multifamily buildings as those buildings with three or more housing units in buildings of three or fewer stories; this definition includes attached side-by-side homes with ground-to-roof walls separating units (if three or more units are attached). However, the ACS and Census data categorize attached homes as individual single-family housing units, regardless of the number of units. The ACS estimates that there are an additional 10,607 single family attached units in the state (built prior to 2005), bringing the total estimate of potential existing multifamily units to 61,861 when combined with the 51,254 figure above. The other key difference is that the ACS and Census data include all buildings with three or more units, regardless of the number of stories.

1.2 Sampling and Recruitment

For the purposes of the study, we defined existing multifamily buildings as those built prior to 2005, while newly constructed buildings include those built after October 1, 2011. Generally, the team verified the age of the buildings through screening questions directed at the property manager or owner, though data from assessor's departments and other sources were also used. All newly constructed buildings included in the study were

[3] https://www.census.gov/construction/bps/stateannual.html

completed by February 28, 2015, therefore these buildings are required to comply with the 2011 version of RBES.

The team visited several buildings that recently underwent renovations. Due to the nature and extent of the renovation work performed on one building, it is classified here as new construction. The classification of a renovation project as new construction or as an existing building is often unclear; for the most part, renovation projects were classified as new construction if at least two of the three major building systems (building shell, lighting, or HVAC) were replaced.

1.2.1 Sample Sources & Selection

To identify multifamily buildings that met the eligibility criteria for this study, we utilized a variety of sources:

- Respondents who screened out of the single-family homeowner telephone surveys because they were tenants were asked to provide the name and phone number of their building manager or owner.
- Internet searches for eligible multifamily buildings: the team searched rental property listing sites such as craigslist.org and the sites of property management companies in Vermont.
- Vermont Directory of Affordable Housing[4].
- Utility service requests for new permanent residential electrical service.
- Observations from the field: while traveling for scheduled on-site visits, auditors looked for multifamily buildings meeting the study criteria. Complexes located this way were then contacted in-person or via phone or email if contact information could be found online.

Recruiting eligible multifamily properties proved to be a major challenge. Property managers were reluctant to devote the time necessary to join technicians onsite, and the initial incentive of $100 per site was largely ineffective. Shortly after the recruiting process began, the incentive was doubled to $200. Initially, the team capped recruitment at three separate properties per owner or property manager. Given the difficulties in recruiting eligible properties and the fact that contacts tended to manage diverse types of buildings, this cap was eventually relaxed to allow for up to five properties per person.

While raising the incentive amount and the number of sites per contact person were helpful, the multifamily market in Vermont remained challenging. Potential sites identified via the methods described above were contacted by phone, email, and/or mailings numerous times over the course of the study. New, non-program participant sites were the most difficult to recruit—despite sustained efforts, in the end they represented only 2 of the 10 new construction sites.

The team aimed to provide a mix of market-rate and affordable housing in the sample—using Census estimates that indicate a somewhat even split between low-income and non-low-income units in Vermont, we allowed for up to one-half of the sites included in the study

[4] http://www.housingdata.org/doarh/

to be affordable housing. In the end, less than one-quarter of the sample was strictly affordable housing, however due to the size of some sites and the presence of complexes with a mix of affordable and market-rate housing, affordable housing units comprise about 46% of the units at the sampled sites.

1.2.2 Sampling Error

A primary objective of this study is to document the current building and equipment status of new and existing multifamily buildings. The maximum coefficient of variation from the previous study (0.50) was used for sample design, however with the completion of this study we can calculate coefficients of variation and relative precision for key measures using actual site data.

Table 4 displays the coefficients of variation and relative precisions at the 90% confidence level for several key measures in new and existing buildings. Because of limited sample sizes and the high degree of diversity among sampled multifamily buildings, we only present relative precision values on a statewide basis.

Of the key measures in existing buildings, flat and vaulted ceiling R-values showed the most variability, with relative precision values of ±13% and ± 35%. In contrast, heating system efficiencies, cooling system efficiencies and conditioned to ambient wall R-values exhibit the least variability with precision values of ±7% or less. All key parameters in new buildings are less than ±14%.

Note that the sample size for each parameter is the total number of observations of that parameter in its respective sample rather than a per-building value. For example, there are 204 unique observations of conditioned to ambient above grade walls with different framing and assembly R-values from the 54 existing inspected buildings.

Table 4: Coefficients of Variation and Relative Precisions of Key Measures in New and Existing Buildings

Parameter	New Statewide			Existing Statewide		
	N	CV	Rel. Prec.	N	CV	Rel. Prec.
Conditioned/ambient wall R-value	51	0.14	±3.2%	204	0.61	±7.0%
Flat ceiling R-value	5	0.18	±13.5%	49	0.53	±12.5%
Vaulted ceiling R-value	9	0.21	±11.6%	13	0.78	±35.4%
AFUE of fossil fuel-fired heating systems	18	0.04	±1.7%	104	0.06	±0.9%
Cooling system SEER	17	0.27	±10.8%	10	0.12	± 6.2%

1.3 On-site Data Collection Procedures

At each multifamily complex, the NMR team collected data for one building and its common areas as well as the interior of one occupied housing unit. Technicians collected data using an electronic data collection form accessed through a tablet computer. Table 5 identifies the key inputs for the on-sites. Note that the visits did *not* include blower door tests or duct blaster testing, therefore we do not assess air infiltration or duct leakage in multifamily buildings.

Table 5: Data Collection Inputs

General Info	Multifamily	Shell Measures

• House type
• Conditioned Floor Area (CFA)
• Conditioned Volume (CV)
• Stories
• Bedrooms
• Thermostat type
• Faucet/shower flow rates
• Basement details
• Health and safety issues
• Home automation systems
	• Complex and inspected building details
	  ○ Size, age, number of units, management, program participation
	• Unit details
	  ○ Bedrooms, rental status, income
	• Common area laundry and lighting
		• Walls
		• Ceiling
		• Frame floors
		• Rim/band joists
		• Windows, doors, and skylights
		• Slab floors
		• Foundation walls
		• Mass walls
		• Sunspaces

Mechanical Equipment	**Customer Questions**	**In-Unit Lighting & Appliances**

• Central and single-unit heating and cooling equipment
• Central and single-unit water heating equipment
• Duct insulation
• Renewables
	• Heat Pump Water Heater presence/potential
	• HVAC Heat Pump presence and satisfaction
	• Homes Energy Management System presence
	• Energy savings opportunities
		• Lighting
		  ○ Fixture type, location, control
		• Electronics
		• Appliances
		  ○ Refrigerators and freezers
		  ○ Dishwashers
		  ○ Washers and dryers
		  ○ Ovens and ranges
		  ○ Dehumidifiers

Additional calculations and research on measures (e.g., looking up HVAC system efficiency) were performed as soon as possible after the site visit. The NMR team reviewed individual input forms as necessary and discussed resolution of inconsistencies with the auditor who conducted the onsite inspection. In addition, the NMR team reviewed data in each field for reasonableness and ensured all data are in consistent units.

1.4 Bias

Potential bias is a concern in this study, as it is with any sample based on voluntary participation. Several factors may influence a property manager's willingness to have their complex audited. Owners or managers who believe their complex is energy efficient may be more inclined to participate because they want to demonstrate the property's performance or, conversely, less willing because they feel that the audit would not be useful. Property managers who think their complex may not be energy efficient may be more interested to learn what they could do to improve its energy efficiency or, conversely, less interested because they have no plans to make additional investments in the property.

When recruiting new complexes for this study, prior participation in an energy efficiency program seemed to correspond to greater interest in participation. This, coupled with the lack of interest by non-program complexes, led to a high number of program buildings in the new construction sample.

Due to the various definitions of multifamily buildings (see Section 1.1) and the lack of publicly available data on the multifamily market, it is difficult to assess the extent to which the onsite samples represent their respective populations, particularly for the existing multifamily market.

1.5 Analysis

As discussed earlier, the team audited one building and one housing unit at each multifamily complex. Although the sampled complexes vary in terms of the number of buildings and housing units, we *do not* weight the housing unit data based on the number of units in each complex nor do we weight the building data by the number of buildings in each complex. We believe that unweighted data provide the clearest understanding of the results from the small sample of buildings visited for this study. Also, it is likely that some of the housing unit-level data collected during on-sites, such as lighting and electronics, will vary considerably between units, therefore having a single unit represent all units in a complex may be inappropriate.

Note that the sample sizes may vary between tables, depending on whether the feature is applicable to only some or all the buildings visited, or whether technicians could determine all characteristics of a feature. For example, auditors may be able to identify the type of insulation present but not inspect it closely enough to grade its installation quality.

Due to limited sample sizes (*n* of less than ten), counts are presented instead of percentages for newly constructed buildings, as well as existing buildings located in the Burlington Electric service territory.

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Section 2 Complex Characteristics

Among the ten sites visited for the new construction portion of the multifamily study, eight were program participants and two were not (

Table 6). Of the 54 existing sites visited, nine were in the Burlington Electric service area and 45 were in the Efficiency Vermont region. The 10 new complexes held a total of 261 housing units compared to 1,760 units in the 54 existing complexes. Details on the complexes included in the study are provided below—please note that in some tables, data refers only to the inspected building, as indicated in the table header.

Figure 7: Examples of Multifamily Buildings Visited

On average, new complexes had 26.1 units housed in 3.6 buildings. In existing complexes, there was an average of 32.6 units housed in 4.4 buildings. Existing Burlington Electric complexes had a much higher average number of units and buildings than any other region, driven in large part by a single complex with 53 buildings and 336 housing units. However, 60% of both new and existing complexes statewide were comprised of a single building.

Table 6: Size of Multifamily Complexes

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	*8*	*2*	*10*	*9*	*45*	*54*
Housing Units						
Total Number	178	83	261	595	1165	1760
Minimum	10	27	10	3	3	3
Maximum	34	56	56	336	185	336
Average	22.3	41.5	26.1	66.1	25.9	32.6
Median	23	42	26	15	12	12
Buildings						
One building	5	1	6	6	62%	63%
Two buildings	2	--	2	--	16%	13%
Three buildings	--	--	--	1	7%	7%
Four buildings	--	--	--	--	2%	2%
Five or more buildings	1	1	2	2	13%	15%
Average	2.6	7.5	3.6	10.4	3.2	4.4

New complexes visited for this study primarily contain a mix of affordable and market rate units (

Table 7). Two new construction complexes are exclusively affordable housing, and one is entirely market rate. In the existing sample, about 60% of complexes are market rate while roughly one-quarter are exclusively affordable housing.

All new complexes included in the study were identified by the property contact as being owned by a private partnership. Among existing buildings, private partnerships (48%) and private single owners (43%) are the most common ownership structures, and the remaining 9% are public housing.

About one-half of all complexes are managed by the owner and one-half by a property management firm.

Table 7: Multifamily Property Characteristics

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	*8*	*2*	*10*	*9*	*45*	*54*
Property Type						
Affordable Housing	1	1	2	1	27%	24%
Market Rate	--	1	1	6	60%	61%
Combination	7	--	7	2	13%	15%
Property Ownership Type						
Private Single Owner	--	--	--	3	44%	43%
Public Housing	--	--	--	2	7%	9%
Private Partnership	8	2	10	4	49%	48%
REIT or Public Corporation	--	--	--	--	--	--
Other	--	--	--	--	--	--
Property Management Type						
By Owner or Agency	4	1	5	6	42%	46%
Through a Property Management Firm	4	1	5	3	58%	54%
Other	--	--	--	--	--	--

New multifamily buildings included in this study are exclusively rental properties, as are all units classified as “affordable” or “low-income” in existing complexes (44% of existing housing units). Market rate units in existing complexes are split about evenly between owner-occupied and rentals (Table 8). Existing housing units are more likely to be age-restricted (reserved for the elderly) than new units—26% compared to 18%.

Table 8: Owner-Occupied, Rental, and Age-Restricted Units

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Units in Complex)	178	83	261	595	1,165	1,760
Affordable	**103**	**56**	**159**	**243**	**524**	**767**
Owner-occupied	--	--	--	--	--	--
Rental	58%	67%	61%	41%	45%	44%
Market Rate	**75**	**27**	**102**	**352**	**641**	**993**
Owner-occupied	--	--	--	21%	31%	27%
Rental	42%	33%	39%	38%	24%	28%
Age-Restricted	**27%**	--	**18%**	**13%**	**33%**	**26%**

In both new and existing complexes, the majority of units are one or two bedrooms in size (Table 9).

Table 9: Housing Units by Number of Bedrooms

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Units in Complex)	178	83	261	595	1,165	1,760
Studio	7%	--	5%	3%	1%	2%
One Bedroom	54%	33%	47%	19%	47%	37%
Two Bedroom	35%	49%	39%	48%	39%	42%
Three Bedroom	4%	16%	8%	30%	13%	19%
Four or more Bedrooms	--	2%	1%	--	<1%	<1%

Most multifamily occupants do not pay for their heat but do pay for their electricity—68% of existing complexes have heating and cooling included in rent while 68% put responsibility for paying electric bills on the occupant. A similar pattern occurs in new complexes (Table 10).

Table 10: Utility Bill Responsibility

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	8	2	10	9	45	54
Heating and Cooling Paid by Occupant	2	--	2	5	27%	32%
Heating and Cooling Included in Rent	6	2	8	4	73%	68%
Electricity Paid by Occupant	6	2	8	7	67%	68%
Electricity Included in Rent	2	--	2	2	33%	32%

Most new complexes do not have someone on-site that monitors the energy usage of the complex (Table 11). In existing complexes, about one-half have a person on-site to monitor energy usage. A property manager at one site each in both the existing and new samples reported using the WegoWise[5] tool to remotely track energy usage at their complexes.

Table 11: Presence of On-Site Energy Monitor

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	8	2	10	9	45	54
Yes	2	1	3	4	51%	50%
No	5	1	6	5	47%	48%
Use WegoWise Tool	1	--	1	--	2%	2%

Aside from the new program complexes, there was limited self-reported participation in energy efficiency programs (

Table 12). Only 17% of existing complexes reported participating in programs sponsored by Burlington Electric, Vermont Gas, Efficiency Vermont and the Weatherization Assistance Program. Typical measures included lighting upgrades, insulation installation, weatherization, and boiler upgrades.

Table 12: Energy Efficiency Program Participation

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	8	2	10	9	45	54
Yes	8	--	8	2	16%	17%
No	--	2	2	7	84%	83%
Don't Know	--	--	--	--	--	--

[5] https://www.wegowise.com/

Buildings of three stories or less in height above grade were eligible for the study. All 10 new complexes were three stories in height (Table 13). In existing complexes, slightly more than one-half of the inspected buildings were three stories, while 41% were two stories.

Table 13: Inspected Building Height by Stories

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	8	2	10	9	45	54
1 Story	--	--	--	--	9%	7%
2 Stories	--	--	--	5	38%	41%
3 Stories	8	2	10	4	53%	52%

Existing multifamily buildings were most commonly built prior to 1939 (44%), with the next most common construction window being 1980-1999 (30%). Five of the 10 new complexes were built in 2012, two in 2014, and three in 2015 (Table 14). This includes one structure that was partially new construction, connected to an existing structure that was gut rehabilitated to the extent that it is considered new construction.

Table 14: Construction Date of Inspected Buildings

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	8	2	10	9	45	54
Before 1939	--	--	--	6	40%	44%
1940-1959	--	--	--	--	2%	2%
1960-1979	--	--	--	1	18%	17%
1980-1999	--	--	--	2	31%	30%
2000-2011	--	--	--	--	9%	7%
2011 or Later	8	2	10	--	--	--

With such a diversity of multifamily buildings visited during the study the square footage of conditioned floor area among inspected buildings varies widely, ranging from around 2,000 square feet up to almost 127,000 square feet (Table 15). On average, new buildings are larger than existing ones, with an average of 20,752 square feet for new buildings compared to 13,104 square feet in existing buildings.

Table 15: Square Footage of Inspected Buildings

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	8	2	10	9	45	54
Minimum	2,652	14,109	2,652	2,655	2,055	2,055
Maximum	38,000	32,583	38,000	43,713	126,620	126,620
Average	20,103	23,346	20,752	10,742	13,576	13,104
Median	17,969	23,346	17,969	6,612	7,447	7,261

Nearly 60% of existing inspected buildings had foundations entirely below grade, meaning the foundation consisted entirely of basement area with varying degrees of conditioning. Most of these were unconditioned basements. Conditioned basements contain either conditioned floor area or conditioned volume. A partially conditioned basement contains a combination of conditioned and unconditioned space. About one-quarter of existing buildings had slab on-grade foundations.

New complexes were more evenly split between below grade foundations, mixed grade foundations—where there is both a basement and an on-grade slab or crawlspace present—and buildings with no basements (Table 16). All basement areas in new buildings, whether part of a full basement or a mixed grade setup, were conditioned spaces. Three buildings, two new and one existing, had open-air parking garages underneath the buildings.

Table 16: Inspected Building Foundation Types

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	8	2	10	9	45	54
Below Grade						
Conditioned	2	1	3	1	11%	11%
Unconditioned	--	--	--	4	42%	43%
Partially Conditioned	--	--	--	1	2%	4%
Mixed Grade						
Conditioned	3	--	3	--	--	--
Unconditioned	--	--	--	2	4%	7%
Partially Conditioned	--	--	--	1	--	2%
No Basement						
Slab On-Grade	1	1	2	--	29%	24%
Crawl Space	--	--	--	--	9%	7%
Parking Garage	2	--	2	--	2%	2%

2.1 Common Areas

2.1.1 Interior Lighting

Interior common areas include laundry rooms, hallways, stairways and recreation rooms. Common areas in new buildings are lit with an almost even split of CFL, LED, and fluorescent bulbs (

Table 17). This is a large increase in the share of LEDs in new buildings compared to the previous report, where LEDs made up only 1% of common area lighting and fluorescents 69% (the proportion of CFLs remained about the same). Similar to the previous study, there were no incandescent or halogen bulbs in new common areas.

About one-half of common area bulbs in existing buildings are fluorescent and 30% are CFLs. In the previous study CFLs were almost one-half of bulbs and 30% were fluorescents. LED bulbs comprise 15% of lighting in existing common areas, up from 10% previously. The proportion of incandescent and halogen bulbs in existing common areas fell from 15% to 5%.

Table 17: Interior Common Area Lighting

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	7*	2	9*	9	45	54
Number of Bulbs	316	141	457	289	1,912	2,201
CFLs	49%	2%	34%	31%	29%	30%
LEDs	37%	16%	31%	26%	14%	15%
Incandescent	--	--	--	1%	1%	1%
Fluorescent	14%	82%	35%	40%	51%	49%
Halogen	--	--	--	1%	5%	4%

*Data unavailable for one New Program site.

2.1.2 Exterior Lighting

Exterior common areas—such as parking lots, walkways, porches, and building façades—used a more diverse selection of lighting types than interior common areas. Table 18 categorizes sites with a combination of CFLs and LEDs into the "Efficient" category and sites with a combination of incandescents and halogens into the "Inefficient" category. In addition, we aggregate a variety of less common lighting types, including metal halide, low pressure sodium, high pressure sodium, and various types of fluorescents, into the "Other" category.

Even simplified this way, illustrating the various lighting combinations yields an extensive list, as shown in the table below. Sixty-one percent of existing buildings used CFLs, while in new buildings LEDs were the most common bulb type. Despite the number of bulb combinations seen during site visits, exterior common areas in both new and existing buildings were more likely to be lit by CFLs or LEDs alone than any other type.

Table 18: Outdoor Common Area Lighting

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	8	2	10	9	44*	53*
CFL Only	--	--	--	3	21%	23%
LED Only	6	1	7	1	21%	19%
Inefficient Only	--	--	--	--	10%	8%
Other Only	--	--	--	--	5%	4%
CFL and LED Only	--	--	--	--	2%	2%
Both Efficient and Inefficient	1	--	1	4	31%	34%
Inefficient and Other					2%	2%
Efficient and Other	1	1	2	1	9%	10%
CFLs Present	**1**	**1**	**2**	**8**	**53%**	**61%**
LEDs Present	**7**	**1**	**8**	**3**	**37%**	**37%**
Incandescent Present	--	--	--	**1**	**18%**	**17%**
Halogens Present	**1**	--	**1**	**3**	**27%**	**29%**

*One Existing EVT building did not have exterior lighting.

2.1.3 Laundry Equipment

All new complexes visited during the study had common laundry facilities, while slightly over one-half of existing complexes did (Table 19). One-half of new complexes and slightly over one-half of existing complexes with laundry facilities have ENERGY STAR clothes washers installed. Machines in existing complexes are less likely to be in good condition than those in new complexes, though 68% of existing complex machines are still in good condition. No common area washers were listed as being in poor condition.

Table 19: Inspected Building Common Area Clothes Washers

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Buildings with Common Laundry Facility)	8	2	10	7	21	28
Number with ENERGY STAR Washers	4	1	5	4	11	15
Average Age (years)	2.3	3.0	2.4	10.7	8.1	8.8
Type						
Front Load	6	2	8	5	52%	57%
Top Load	2	--	2	2	48%	43%
Condition						
Good	8	2	10	3	76%	68%
Fair	--	--	--	4	24%	32%

Most common area clothes dryers in new complexes are electric. All were front load and all were found to be in good condition. In existing complexes, one-half of dryers were electric, with the rest using either propane or natural gas. Most dryers in existing complexes were front load machines and in good condition (Table 20).

Table 20: Inspected Building Common Area Clothes Dryers

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Buildings with Common Laundry)	8	2	10	7	21	28
Average Age (years)	2.3	3.0	2.4	10.7	8.5	9.1
Fuel Type						
Electric	6	1	7	3	52%	50%
Propane	1	1	2	--	24%	18%
Natural Gas	1	--	1	4	24%	32%
Dryer Type						
Air - Front Load	8	2	10	7	81%	86%
Air - Top Load	--	--	--	--	19%	14%
Dryer Condition						
Good	8	2	10	1	76%	61%
Fair	--	--	--	6	24%	39%

3

Section 3 Building Envelope

3.1 Shell Measure Data Collection

A building's envelope is formed by the walls, floors, and ceilings that separate conditioned space from unconditioned or ambient space, along with the buildings' windows and doors.[6] Data were collected on R-values, framing, insulation type, and installation grade for envelope measures, such as walls, ceiling and frame floors. Data were also collected on the level of insulation for foundation walls and slab floors in conditioned spaces, and the area, orientation, and frame material of windows.

The above grade walls section details walls between conditioned and ambient space, the ceiling section details flat and vaulted ceilings, and the frame floor section details floors over unconditioned basements. The foundation wall, slab floor, and window sections focus on measures found in conditioned space.

Verified and Assumed Values. Data for R-values, insulation type, and insulation grade can be difficult to confirm during post-construction audits in which visibility is limited. Data were verified using visual inspection or documentation. R-values were also verified based on confirmed insulation type and thickness. When data could not be verified, assumptions were made based on similar verified assemblies in the home. In rare cases in which an educated guess was impossible, the feature was marked as unknown. In the tables below, verified and assumed values are included while unknown values are either classified as unknown or excluded from the table altogether.

Primary Framing and Insulation. In each section below, tables report on primary framing and insulation. "Primary" refers to the framing or insulation that comprised the majority of the total area of the specific measure at that home. Ceilings, walls, or floors in homes may have multiple insulation or framing types, but the primary insulation type is that which comprises the largest area in each home. In instances where multiple insulation types were used over the entirety (or majority) of a shell assembly, the primary insulation type is reported as a combination. In instances where more than one insulation material was used in an assembly and the secondary type comprised insignificant areas, those secondary types are not reported in the insulation type tables, but are factored into R-value calculations.

3.2 Above Grade Walls

During on-sites, auditors collected data on the location, framing dimensions, and insulation type, grade, and R-value of above grade walls. Wall framing depth is determined by looking at the width of door or window frames or through probing the wall cavity by removing an electrical outlet cover. Insulation type can also be determined by probing wall cavities,

[6] Because doors are such a small portion of the building shell, information on doors was collected but ultimately not included in reporting.

visual inspection of wall assemblies where possible, and reviewing plans and blueprints. Above grade walls are recorded for a variety of locations, including:

- Walls between conditioned space and ambient conditions. These walls enclose the conditioned space of a building and represent the majority of wall area, therefore their thermal performance is key to determining the efficiency of the building shell.
- Walls between conditioned space and attic space, unconditioned basement, or garage. Together with ambient walls, these form most wall area between conditioned and unconditioned spaces.
- Walls between conditioned and adiabatic space. Walls connecting the inspected building to other conditioned spaces not part of, or accessible through, the conditioned space of the inspected building[7].

R-Values. Table 21 breaks down insulation R-value statistics for all above grade walls recorded during on-sites. The average R-value of above grade wall insulation in new buildings is R-26.0, well above the RBES requirement of R-20. All above grade walls in new buildings are insulated above RBES requirements. In existing buildings, the statewide average is R-12.7. The low average among existing buildings is due in part to several older multifamily buildings in the sample that were under-insulated or completely uninsulated. Fourteen existing buildings inspected during the study, including five of nine in the Burlington Electric service area, had entirely uninsulated above grade walls. The addition of insulation such as dense pack cellulose would be an obvious benefit to these buildings and provide an opportunity for savings through improved air sealing as well.

Table 21: Above Grade Wall R-value Statistics (All Wall Locations)

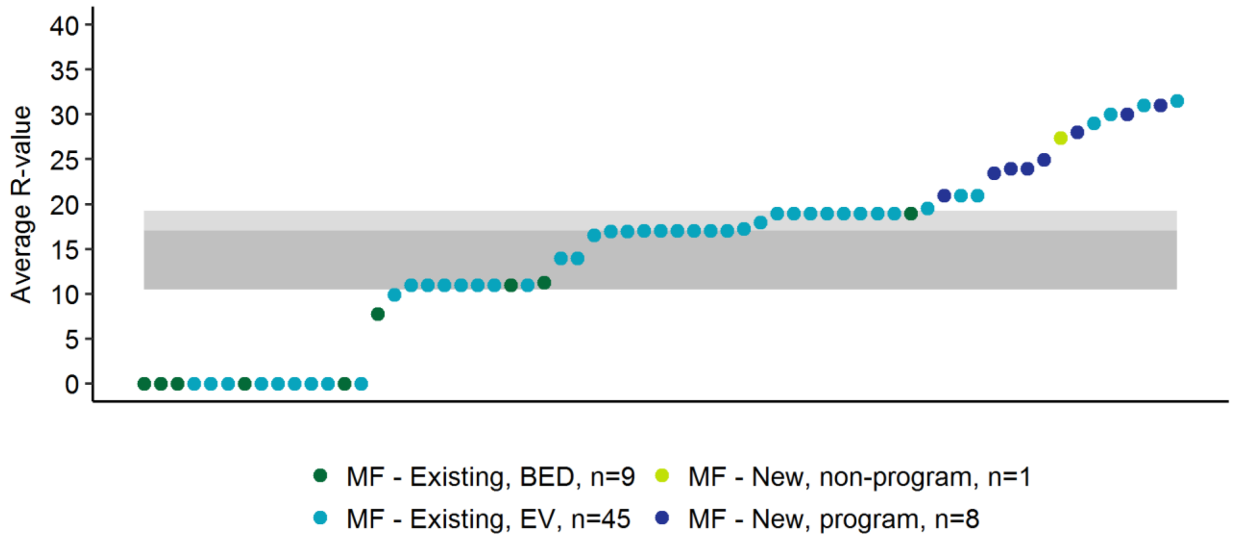
	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	8	1*	9	9	45	54
Minimum	21.0	27.4	21.0	0.0	0.0	0.0
Maximum	31.0	27.4	31.0	19.0	31.5	31.5
Average	25.8	27.4	26.0	5.4	14.2	12.7
Median	24.5	27.4	24.9	0.0	17.1	15.3

* Above grade wall data were not available for one new, non-program site.

[7] One site has a common wall with another building under different ownership with no access.

Figure 8 displays the range of average above grade wall R-values across the entire sample. The cluster of uninsulated existing buildings stands out on the bottom left, as does the dominance of new sites as the values rise on the right—no new buildings are insulated below R-21.

Figure 8: Average Above Grade Wall R-Values



3.2.1 Conditioned to Ambient Walls

Framing. In new buildings, above grade walls between conditioned space and ambient conditions are typically constructed with 2x6 framing, either 24” on-center (o.c.) or 16” o.c. (Table 22). In existing complexes, over one-half of sites (55%) are constructed with 2x6, 16 o.c. framing, while another 36% use 2x4, 16” o.c. framing. Two existing sites, one in the Burlington Electric territory and another in the Efficiency Vermont territory, did not have wood framed walls—one wall is brick, the other uses concrete masonry blocks.

Table 22: Primary Framing Types for Conditioned to Ambient Walls*

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	8	1**	9	9	44**	53
2×6, 16 o.c.	3	--	3	3	59%	55%
2×4, 16 o.c.	1	--	1	5	32%	36%
2×4, 24 o.c.	1	--	1	--	5%	4%
2×6, 24 o.c.	2	1	3	--	2%	2%
2×8, 24 o.c.	1	--	1	--	--	--
Brick	--	--	--	--	2%	2%
Concrete Masonry Unit (CMU)	--	--	--	1	--	2%

*Four buildings had a secondary framing type not included here.
**Data for conditioned to ambient walls were not available for one existing, EVT site and one new, non-program site.

Insulation Type. A combination of dense pack cellulose in cavities and continuous foam board is the most common insulation method used in conditioned to ambient walls in new buildings, found in four of ten sites (Table 23). Seven new buildings utilized foam board to provide a continuous layer of insulation, either alone (one building) or in conjunction with cavity insulation. In existing buildings, fiberglass batt cavity insulation is the most common type, found in 56% of buildings. Another 24% of existing buildings are primarily uninsulated. Few existing buildings have continuous insulation installed on conditioned to ambient walls—just 13% of existing buildings utilize foam board to provide continuous insulation.

Auditors also grade insulation installations during on-sites, though this is often difficult when there is limited or no access to wall cavities. Insulation grade can be inferred from viewing other areas of the building, if photos are available of the construction process before wall cavities are sealed, and from the type of insulation installed[8]. In existing buildings, no insulation installs were given a Grade I—this is likely due to a combination of an inability to access wall cavities (RESNET standards caution against awarding a Grade I without being able to visually inspect the entire installation) and the absence of insulation types that would typically earn a Grade I such as closed cell spray foam. Grade II installations were the most common grade given in both new and existing buildings.

[8] Fiberglass batts are almost never given a grade I, for example, as it is difficult to install them in such a way to completely prevent gaps in the wall cavity.

Table 23: Primary Insulation Type and Grade for Conditioned to Ambient Walls*

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
Insulation Type						
n (Complexes)	*8*	***1*	*9*	*9*	*44***	*53*
Fiberglass batts	--	--	--	3	61%	56%
None	--	--	--	5	18%	24%
Fiberglass batts and foam board	2	--	2	--	14%	11%
Dense pack cellulose and foam board	3	1	4	--	--	--
Dense pack cellulose	1	--	1	1	2%	4%
Closed cell spray foam	2	--	2	--	2%	2%
Foam board only	--	--	--	--	2%	2%
Mineral wool batts	--	--	--		--	2%
Insulation Installation Grade						
n (Complexes)	8	1	9	6	36	42
Grade I Installation	2	--	2	--	--	--
Grade II Installation	5	1	6	5	75%	76%
Grade III Installation	1	--	1	1	25%	24%

*Eight buildings had a secondary insulation type not included here.
**Data for conditioned to ambient walls were not available for one existing, EVT site and one new, non-program site.

Table 24 shows the prevalence of the insulation types described in Table 23 (as well as secondary insulation) as a percent of total wall area. Because the size of the buildings in the sample varies greatly (See Table 15), there is some variation between the proportion of buildings with certain insulation types and the amount of wall area containing that insulation type. Buildings with no insulation are a good example—conditioned to ambient walls are uninsulated in about one-fifth of existing buildings, however uninsulated walls make up only one-tenth of total wall area. Fiberglass batts are found in conditioned to ambient walls at 59% of existing buildings, but make up the insulation in almost three-quarters (73%) of total wall area.

Table 24: Insulation Type as a Percent of Total Wall Area (All Wall Insulation)

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	*8*	***1*	*9*	*9*	*44***	*53*
Fiberglass batts	--	--	--	44%	76%	73%
None	--	--	--	38%	7%	10%
Fiberglass batts and foam board	36%	--	30%	--	10%	9%
Dense pack cellulose and foam board	32%	73%	39%	--	--	--
Dense pack cellulose	12%	--	10%	9%	4%	4%
Spray foam	21%	--	17%	--	2%	1%
Foam board only	--	--	--	--	1%	1%
Mineral wool batts	--	--	--	9%	--	1%
Dense pack cellulose and spray foam	--	27%	5%	--	--	--

**Data for conditioned to ambient walls were not available for one existing, EVT site and one new, non-program site.

R-Values. Table 25 displays R-value statistics for conditioned to ambient above grade wall assemblies recorded during on-sites. All conditioned to ambient walls in new sites are insulated to at least the R-20 RBES requirement, and the average R-value for walls in new sites is R-26. In existing sites, the average R-value drops to R-13. There were thirteen sites in the existing sample where walls to ambient are completely uninsulated, mostly older homes that have been repurposed into apartments.

Table 25: Conditioned to Ambient Wall R-value Statistics

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	*8*	*1**	*9**	*9*	*44**	*53*
Minimum	21.0	27.4	21.0	0.0	0.0	0.0
Maximum	31.0	27.4	31.0	19.0	31.5	31.5
Average	25.8	27.4	26.0	5.4	14.7	13.1
Median	24.6	27.4	25.1	0.0	17.1	17.0

**Data for conditioned to ambient walls were not available for one existing, EVT site and one new, non-program site.

3.3 CEILINGS

Auditors recorded insulation information on the following types of ceiling areas:

- Flat ceilings
  - This type of ceiling area separates conditioned space from unconditioned attic space, and can also be thought of as an attic floor.
- Vaulted ceilings
  - This type of ceiling area separates the conditioned area from ambient conditions; the insulated framing of the roof itself forms the thermal boundary. In such ceiling areas, there is no unconditioned attic space between the house and the ambient conditions, unlike with flat ceilings, where there is an unconditioned attic space above the conditioned space of the home.

Table 26 outlines the percentage of complexes in each region that have the types of ceilings listed, as well as what percentage of the total ceiling area is made up of vaulted ceilings, on average. Flat ceilings are present in 85% of existing complexes, but in only 4 of 10 new construction complexes. Statewide, vaulted ceilings make up 84% of the total ceiling area in new complexes versus 22% in existing buildings.

Table 26: Prevalence of Ceiling Types

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	*8*	*2*	*10*	*9*	*45*	*54*
Flat Only	3	--	4	7	76%	76%
Flat & Vaulted	--	1	--	--	11%	9%
Vaulted Only	5	1	6	2	13%	15%
Avg. % of total ceiling area that is vaulted	81%	98%	84%	48%	17%	22%

3.3.1 Flat Ceilings[9]

Framing. The predominant joist dimensions in flat ceilings are listed in Table 27. Most complexes with flat ceilings are framed with members that are 2×8 or larger (3 of 4 new construction sites, 52% of existing), and in most flat ceilings joists are spaced 16-inches apart.[10] Flat ceilings with multiple joist sizes are rare.

[9] Of all the complexes with flat ceilings, 21 (38%) had inaccessible attic spaces representing one-third (36%) of total flat ceiling area. In most cases (72% of inaccessible area, 17 complexes), insulation and framing characteristics were inferred from similar areas in the home, discussion with individuals on site, or from blueprints for some new complexes. The remaining ceilings were excluded from analysis.

[10] Statewide, flat ceilings in existing complexes are more likely to be framed with joists that are 24 inches on center than new construction (41% vs. 9%).

Table 27: Types of Construction for Flat Ceilings

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	*3*	*1*	*4*	*7*	*39*	*46*
2×4, 16 o.c.	--	--	--	2	3%	7%
2×4, 24 o.c.	--	--	--	--	13%	11%
2×6, 16 o.c.*	--	--	--	--	26%	22%
2×6, 18 o.c.	--	1	1	--	--	--
2×6, 24 o.c.	--	--	--	1	8%	9%
2×8, 16 o.c.*	1	--	1	--	28%	24%
2×8, 24 o.c.	1	--	1	1	--	2%
2×10, 16 o.c.	1	--	1	2	15%	17%
2×10, 24 o.c.	--	--	--	1	5%	7%
2×12, 24 o.c.	--	--	--	--	3%	2%

* Some complexes in this category have additional ceilings with a different framing type.

Insulation. In Table 28, Table 29, Table 30 and Table 31, an insulation type with a plus sign, as in—"Cellulose+Fiberglass"—indicates multiple types of insulation were present in the same ceiling assembly. In fact, 11% of existing complexes have attics with this layered combination.[11] Strictly cellulose insulation installations comprise the majority of ceiling insulation observed in both new (3 of 4 sites) and existing (57%) complexes statewide, perhaps due to the relative ease of installation compared to other materials.

Grade II insulation installations are present in one-half (49%) of flat ceilings, whereas Grade I installations comprise a mere 10% of installations statewide; grades for new construction were unavailable due to inaccessible spaces (Table 28).

Table 28: Type & Grade of Flat Ceiling Insulation by Percent of Complexes

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
Insulation Type						
n (Complexes)	*3*	*1*	*4*	*7*	*39*	*46*
Cellulose	3	--	3	6	51%	57%
Cellulose+Fiberglass	--	--	--	--	13%	11%
Fiberglass Batts	--	--	--	--	23%	20%
Rigid Foam Board	--	1	1	--	--	--
Spray Foam+Cellulose	--	--	--	--	3%	2%
Spray Foam+Fiberglass	--	--	--	--	3%	2%
None	--	--	--	1	8%	9%
Insulation Installation Grade						
n (Complexes)	*2*	*1*	*3*	*6*	*33*	*39*
Grade I Installation	Not available, from plans[9]			17%	9%	10%
Grade II Installation				50%	48%	49%
Grade III Installation				33%	42%	41%

[11] Of these complexes, 20% have fiberglass batts over cellulose, and 80% cellulose over fiberglass batts.

The breakdown of insulation by area in Table 29 reveals similar trends to those in Table 28, but it does more clearly highlight the higher prevalence of cellulose (98%) in new construction, and Grade II installations (69%) in existing complexes.

Table 29: Type & Grade of Flat Ceiling Insulation by Percent of Area

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
Insulation Type						
n (Complexes)	*3*	*1*	*4*	*7*	*39*	*46*
Cellulose	100%	--	98%	73%	54%	56%
Cellulose+Fiberglass	--	--	--	--	17%	15%
Fiberglass Batts	--	--	--	--	15%	13%
Rigid Foam Board	--	100%	2%	--	--	--
Spray Foam+Cellulose	--	--	--	--	2%	2%
Spray Foam+Fiberglass	--	--	--	--	6%	5%
None	--	--	--	27%	7%	9%
Insulation Installation Grade						
n (Complexes)	*2*	*1*	*3*	*6*	*33*	*39*
Grade I Installation	Not available, from plans[9]			16%	4%	6%
Grade II Installation				47%	66%	69%
Grade III Installation				37%	30%	33%

R-values. Four existing complexes—one Burlington Electric, three Efficiency Vermont—have completely uninsulated attics. As shown in Table 30, the average R-value for flat ceilings among sampled existing complexes is R-34.3 and for new complexes is R-46.8.

Table 30: R-value Statistics for Insulation in Flat Ceilings

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	*3*	*1*	*4*	*7*	*39*	*46*
Minimum	40.0	34.0	40.0	0.0	0.0	0.0
Maximum	60.0	34.0	60.0	64.0	74.0	74.0
Average	49.5	34.3	46.8	32.0	34.0	34.3
Median	53.0	34.0	46.0	34.0	30.0	34.0

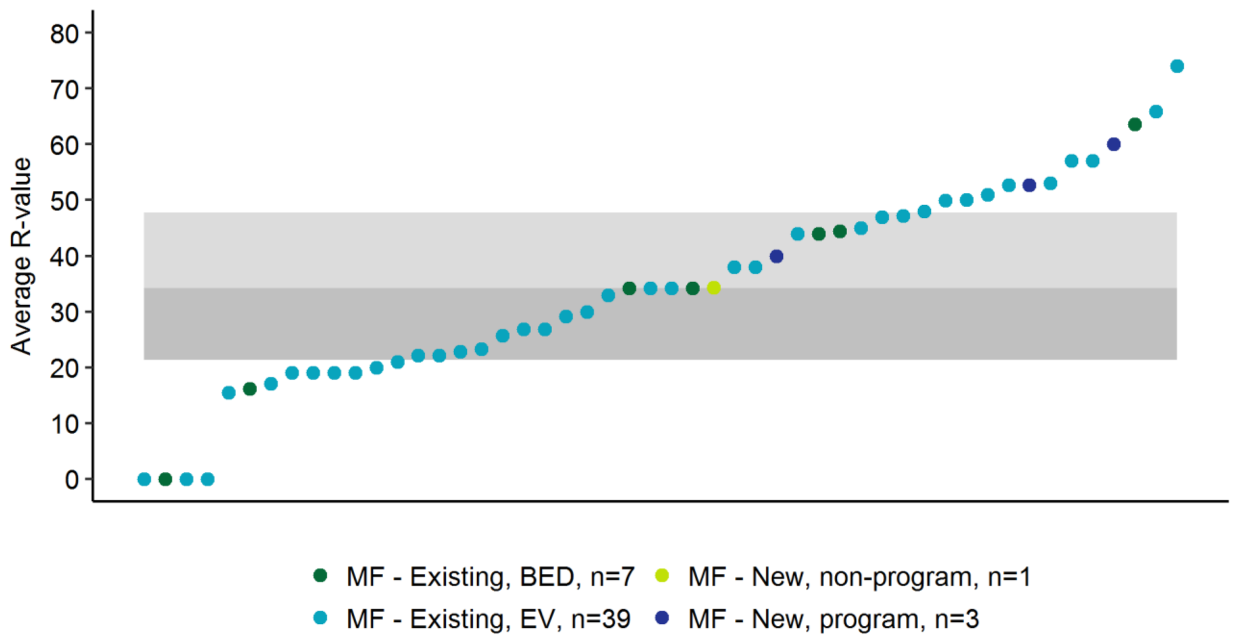
Every new complex and one-half of existing complexes (52%) with flat attics have some continuous insulation over ceiling joists, providing a thermal break from the cold attic air (Table 31).

Table 31: Covered Joists in Flat Ceilings

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	*3*	*1*	*4*	*7*	*39*	*46*
Covered Joists	3	1	4	4	51%	52%

Figure 9 displays the average R-values for each inspected building in the sample with flat ceilings. Four existing buildings, accounting for 9% of existing flat ceiling area, are uninsulated. The outlier on the right is an existing Efficiency Vermont site insulated to R-74.

Figure 9: Average R-values for All Flat Ceilings



3.3.2 Vaulted Ceilings[12]

Framing. Statewide, vaulted ceilings in existing complexes are more likely to be framed with 2×8 or larger members than new construction (62% vs. 3 of 6 respectively) as shown

[12] Given that vaulted ceilings are usually sealed and are frequently inaccessible, auditors are not always able to visually confirm the insulation materials as often as they can in flat attics. Twelve complexes with vaulted ceilings (60%) had inaccessible attic spaces representing one-half (53%) of total vaulted ceiling area. In 11 of these 12 complexes, insulation and framing characteristics were inferred from similar areas in the home,

in Table 32. This is the opposite of the relationship for flat ceilings, due in part to the use of 2×4 trusses in new construction.[13]

Table 32: Type of Construction for Vaulted Ceilings

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	*5*	*1*	*6*	*2*	*11*	*13*
2×4, 16 o.c.	1	--	1	--	--	--
2×4, 24 o.c.*	2	--	2	--	9%	8%
2×6, 16 o.c.	--	--	--	--	9%	8%
2×6, 24 o.c.	--	--	--	1	--	8%
2×8, 16 o.c.	2	--	2	--	27%	23%
2×10, 16 o.c.	--	--	--	--	27%	23%
2×10, 24 o.c.	--	--	--	--	9%	8%
2×12, 24 o.c.	--	--	--	--	9%	8%
2×12, unknown o.c.*	--	1	1	--	--	--
I-beams	--	--	--	1	--	8%

* Some complexes in this category have additional ceilings with a different framing type.

discussion with individuals on site, or from blueprints for some new complexes. The last complex was excluded from further analysis.

[13] As with flat ceilings, vaulted ceilings in existing complexes are more likely to be framed with 24-inch spacing than new construction (44% vs. 19%); however, the spacing is unknown for 33% and 14% of total vaulted ceiling area, respectively.

Insulation. Per Table 33, ceiling assemblies with either conventional fiberglass batts (46%) or cellulose (31%) represent the majority of insulation installations in existing complexes. Fiberglass batts and cellulose are not installed on their own in new complexes, rather these insulation types occur in combination with rigid foam board (RFB) as continuous insulation. Two of six complexes use a combination of fiberglass batts and foam board, while one uses cellulose and rigid foam board. Rigid foam board without cavity insulation accounts for another two complexes, making it the most common insulation type used in newly constructed vaulted ceilings.

Three-fifths of the insulation installations in existing vaulted ceilings are Grade Ⅲ, although as can be seen in Table 34 this represents less than one-half (47%) of ceiling area.

Table 33: Type & Grade of Vaulted Ceiling Insulation by Percent of Complexes

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
Insulation Type						
n (Complexes)	*5*	*1*	*6*	*2*	*11*	*13*
Cellulose	--	--	--	1	27%	31%
Cellulose+RFB	1	--	1	--	--	--
Fiberglass Batts	--	--	--	--	55%	46%
Fiberglass Batts+RFB	1	1	2	--	9%	8%
Rigid Foam Board	2	--	2	--	--	--
Spray Foam	1	--	1	--	--	--
None	--	--	--	1	9%	15%
Insulation Installation Grade						
n (Complexes)	*3*	*1*	*4*	*1*	*9*	*10*
Grade Ⅱ Installation	Not available, from plans[12]			--	4	40%
Grade Ⅲ Installation				1	5	60%

When comparing insulation by area in Table 34 to majority insulation by complex in Table 33, the uninsulated vaulted ceiling area in existing complexes doubles from 15% to 36%. As with above grade walls, the addition of insulation such as dense pack cellulose to these assemblies would likely improve air sealing; especially if, as the data suggest, larger buildings accounting for more ceiling area remain uninsulated.

Table 34: Type & Grade of Vaulted Ceiling Insulation by Percent of Area

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
Insulation Type						
n (Complexes)	*5*	*1*	*6*	*2*	*11*	*13*
Cellulose	--	--	--	3%	13%	10%
Cellulose+RFB	9%	--	8%	--	--	--
Fiberglass Batts	--	--	--	--	48%	31%
Fiberglass Batts+RFB	19%	72%	29%	--	34%	22%
Rigid Foam Board	45%	28%	42%	--	--	--
Spray Foam	26%	--	21%	--	--	--
None	--	--	--	97%	5%	36%
Insulation Installation Grade						
n (Complexes)	*3*	*1*	*4*	*1*	*9*	*10*
Grade Ⅱ Installation	Not available, from plans[12]			--	54%	53%
Grade Ⅲ Installation				100%	46%	47%

R-values. Statewide, the average new vaulted ceiling has more than twice as much insulation (R-49.7) as a ceiling in an existing complex (R-23.8). However, if we exclude the existing complex with the maximum R-value of 75, the median insulation level decreases from R-25 to R-23, and the average to R-20 (Table 35).

Table 35: R-value Statistics for Insulation in Vaulted Ceilings

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	*5*	*1*	*6*	*2*	*11*	*13*
Minimum	38.0	51.0	38.0	0.0	0.0	0.0
Maximum	60.0	51.0	60.0	25.8	70.0	70.0
Average	49.5	50.6	49.7	12.5	25.9	23.8
Median	48.0	51.0	49.0	13.0	25.0	25.0

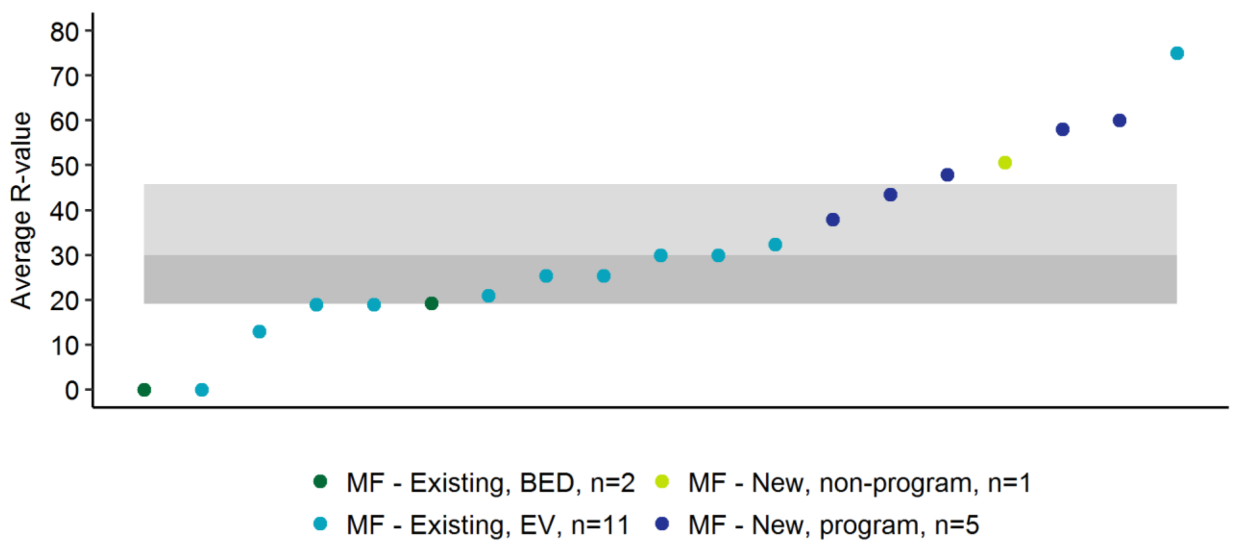
As previously noted, every new complex—except for one insulated with spray foam—had covered joists or rafters that were covered with rigid foam board, whereas only 15% of existing vaulted ceilings in Table 36 had continuous insulation.

Table 36: Covered Joists & Rafters in Vaulted Ceilings

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	*5*	*1*	*6*	*2*	*11*	*13*
Covered Joists	4	1	5	--	18%	15%

Figure 10 graphs the distribution of R-values seen in the vaulted ceilings of the sampled complexes. The outlier at R-75 is an existing apartment complex built in 2006.

Figure 10: Average R-values of Vaulted Ceilings



3.4 Frame Floors

Auditors recorded data on the insulation of frame floors over unconditioned spaces or ambient conditions that form part of the thermal boundary of the building. We report on the following types of floors:

- Floors over unconditioned basements, also referred to as basement ceilings
- Floors over unconditioned crawl spaces, also referred to as crawl space ceilings
- Conditioned floors over garages, also referred to as garage ceilings
- Conditioned floors over ambient (outdoor) conditions.
    - These areas are often small, as they are cantilevered out into space, either with or without support columns below, and can be referred to as bump-out floor area.

Two of the ten new buildings and 65% of existing buildings have floors over unconditioned space (Table 37). Both new buildings have insulation in floors over unconditioned space, while 43% of existing buildings have insulation.

Table 37: Framed Floor Location

	New Construction*		Existing		
	Program	Statewide	BED	EVT	Statewide
n (Buildings)	*8*	*10*	*9*	*45*	*54*
Buildings with Floors Over Unconditioned Space	2	2	8	60%	65%
Buildings with Floors Over Garages**	--	--	1	7%	7%
Buildings with Floors Over Ambient	1	1	--	4%	4%
Buildings with Insulated Floors over Unconditioned Space	2	2	2	48%	43%
Percent of Total Floor Area Over Unconditioned Space that is Insulated	100%	100%	18%	77%	70%

* The two new non-program buildings are not included in this table; both have no framed floor area over unconditioned space.
** Garages are also included in unconditioned space.

R-values. Table 38 shows the average building R-value of all envelope frame floors. For newly constructed buildings the average R-value is R-28.1, while existing homes have an average R-value of R-9.7. One new building has R-30 frame floors that meet the 2011 RBES requirement, while the other falls short of the R-30 requirement at R-26.3.

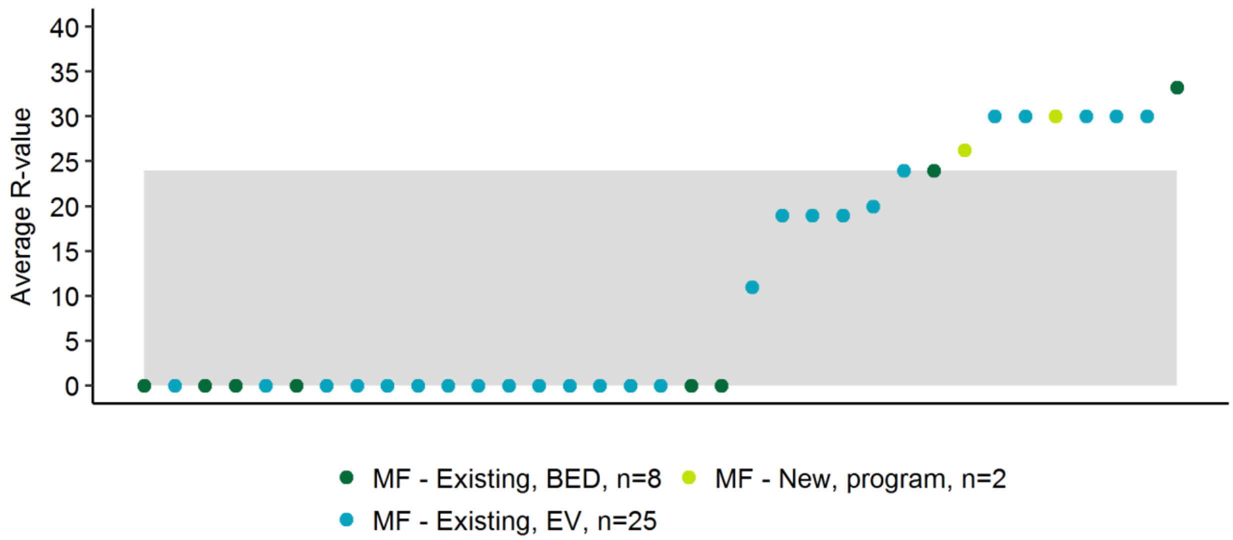
Table 38: Framed Floor R-Values

	New Construction*		Existing		
	Program	Statewide	BED	EVT	Statewide
n (Buildings with floors)	*2*	*2*	*8*	*25*	*33*
Minimum	26.3	26.3	0.0	0.0	0.0
Maximum	30.0	30.0	33.3	30.0	33.3
Mean	28.1	28.1	7.2	10.5	9.7
Median	28.1	28.1	0.0	0.0	0.0

* The two new non-program buildings are not included in this table; both have no framed floor area over unconditioned space.

Figure 11 shows the distribution of average R-values for frame floors across the sample. Immediately noticeable is the large collection of uninsulated frame floors in existing sites—a total of 20 existing sites have uninsulated envelope floors bordering unconditioned or ambient space. This contributes to the low average R-value for frame floors in existing sites. Of all shell measures observed during on-sites, framed floors demonstrate the clearest opportunity for air sealing opportunities. Unlike wall and vaulted ceiling cavities, framed floor cavities over unconditioned space are typically open, allowing for an easier application of high quality spray foam.

Figure 11: Average Frame Floor R-value by Site



3.5 Foundation Walls and Slabs

3.5.1 Foundation Walls

RBES requires foundation walls[14] enclosing conditioned space that are more than 50% above grade to be fully insulated. Just four multifamily buildings in our sample have foundation walls enclosing conditioned space that are more than 50% above grade—all are in existing buildings and uninsulated.

Most multifamily buildings in the sample (46 out of 64) contain below grade foundation walls, either in a basement or a crawlspace (

[14] Foundation walls are defined as concrete or masonry walls. Stud walls located on top of masonry/concrete wall (such as for a walkout basement) would be considered above grade walls and are included in Section 3.1.

Table 39). Walls are fully insulated in eight of forty existing sites with below grade walls, and walls are fully insulated in all six new buildings with below grade walls.

The basement areas of the six new buildings with below grade foundation walls are all conditioned. In the eight existing buildings with fully insulated below-grade foundation walls, five have conditioned basement space, while the remainder are unconditioned.

About 80% of existing buildings have unconditioned basements or crawl spaces; 84% of these basements have uninsulated foundation walls. In the 25% of existing complexes with conditioned basement space, below grade walls are uninsulated in one-half of the buildings.

Overall, 85% of existing buildings contain uninsulated below grade walls, 18% contain fully insulated walls, and 5% have partially insulated walls.

Table 39: Foundation Wall Insulation for Buildings with Below Grade Walls*

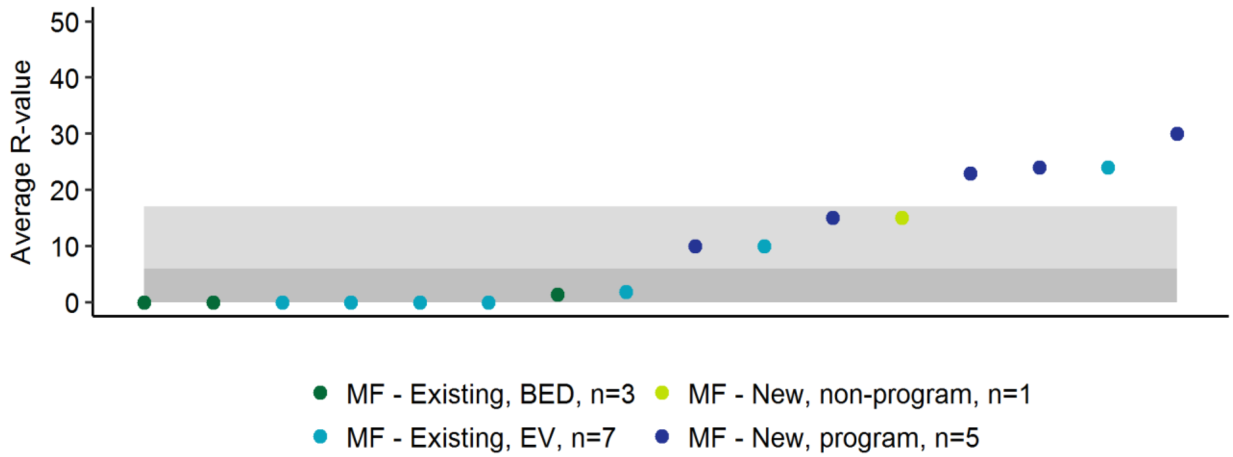
	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Buildings with Below Grade Foundation Walls)	5	1	6	9	31**	40
Fully Insulated Below Grade Foundation Walls	5	1	6	2	16%	18%
Partially Insulated Below Grade Foundation Walls	--	--	--	--	6%	5%
Fully Uninsulated Below Grade Foundation Walls	--	--	--	9	87%	85%
Homes with Unconditioned Foundation Walls	--	--	--	**7**	**81%**	**80%**
Fully Insulated Below Grade Foundation Walls	--	--	--	1	8%	10%
Partially Insulated Below Grade Foundation Walls	--	--	--	--	8%	6%
Fully Uninsulated Below Grade Foundation Walls	--	--	--	6	84%	84%
Homes with Conditioned Foundation Walls	**5**	**1**	**6**	**3**	**7**	**25%**
Fully Insulated Below Grade Foundation Walls	5	1	6	1	4	50%
Partially Insulated Below Grade Foundation Walls	--	--	--	--	--	--
Fully Uninsulated Below Grade Foundation Walls	--	--	--	2	3	50%

*Because of mixed basement conditioning and mixed insulation levels on foundation walls in some existing homes, numbers will sum to greater than 100% of *n*.

**There are 30 EVT homes with a basement or crawlspace, however there is one home with slab OG that also has below grade foundation walls due to location on a slope, those walls are included in this analysis.

Figure 12 displays the average R-values of foundation walls located between conditioned and unconditioned space. The left side of the graph is populated by uninsulated foundation walls in existing buildings leading to an average R-value of R-3.7. In new buildings, no conditioned foundation wall is insulated below R-10, and the average R-value is 19.5.

Figure 12: Average R-values of Conditioned Basement Walls



Among the 45 buildings that have at least a partial basement or crawl space making up their foundation, 27 have both foundation walls and framed floors that are completely uninsulated, all of which are existing complexes (Table 40). Here again we see the opportunity for energy savings through improved air sealing in existing buildings. Any building with either a fully insulated framed floor or fully insulated foundation walls (for buildings where the basement is brought into the conditioned volume) is considered to have a fully insulated basement thermal boundary. In the case of new complexes, as mentioned previously, all six sites containing basement space have fully insulated foundation walls.

Table 40: Basement Thermal Boundary Information

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Buildings with Basement or Crawl Space)	5	1	6	9	30	39
Both framed floor and foundation walls partially uninsulated	--	--	--	7	73%	74%
Both framed floor and foundation walls completely uninsulated.	--	--	--	7	67%	69%
Fully insulated basement thermal boundary	5	1	6	2	27%	26%

3.5.2 Slabs

Eight of ten new buildings have slab floors, with most either fully or partially below grade, with conditioned basements (Table 41). Existing buildings, on the other hand, have slabs primarily located on grade. New slabs are most commonly insulated to R-15—where insulation levels are known[15], with 64% of slab area insulated to that level. In existing buildings, almost 80% of slab area is uninsulated, and no insulation with confirmed R-values is insulated higher than R-10. The presence of insulation was unknown at two new sites and at 30% of existing sites[16].

Table 41: Slab floor Insulation

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Buildings with Slab Floors)	6	2	8	5	22	27
Slab On-Grade/ Slab Below Grade						
On Grade	1	1	2	3	64%	63%
Below Grade	2	1	3	1	23%	22%
On Grade and Below Grade	3	--	3	1	14%	15%
Slab Insulation R-value						
R-0	1	--	1	3	59%	59%
R-5	1	--	1	--	5%	4%
R-10	1	--	1	--	9%	7%
R-15	2	1	3	--	--	--
Unknown	1	1	2	2	27%	30%
R-value as a Percent of Area	**New Complexes**			**Existing Complexes**		
*Number of Buildings with Known Insulation**	*5*	*1*	*6*	*3*	*16*	*19*
R-0	11%			78%		
R-5	17%			7%		
R-10	8%			15%		
R-15	64%			--		

*Merged due to limited sample sizes.

[15] Typically, information on insulation R-values was derived from plans or other construction documents provided by the property management contact.

[16] Technicians generally assumed there was no slab insulation at older existing sites if there was no documentation or other evidence to prove otherwise. Sites classified as unknown are general newer sites where slab insulation could not be confirmed.

3.6 GLAZING

3.6.1 Windows

This section describes the characteristics of door and window glazing in conditioned walls. When documentation of glazing properties was unavailable, a reflection test—where a flashlight shone on the window surface will yield a reflection with a green hue in the presence of low-E treatment—was used to determine if the windows had a low-E coating. Similarly, the presence of injection plugs in the frame between the panes of glass was used to infer the presence of argon or similar insulating gas fills. Due to the imprecision of this method—manufacturing techniques vary—the proportion of argon windows may be under-reported.

Double pane, low-E windows are present in six of ten newly-constructed buildings (Table 1), while double pane, low-E argon windows are present in four new buildings. Among existing buildings, 70% have clear double pane windows; over one-quarter (28%) have low-E double pane windows, and over one-quarter (26%) have single pane windows. Only 4% of existing buildings have triple pane windows. Buildings had multiple window types, so counts may sum to more than the total sample size or 100%.

Table 42: Window Type

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Buildings)	*8*	*2*	*10*	*9*	*45*	*54*
Single Pane	--	--	--	6	13%	26%
Double Pane (clear)	--	--	--	7	51%	70%
Double Pane low-E	4	2	6	--	25%	28%
Double Pane low-E Argon	4	--	4	--	8%	9%
Triple Pane	--	--	--	--	3%	4%

Just over three-quarters (76%) of total window area in existing buildings is clear double pane glass, while single pane windows account for 11% of total glass area. All the windows in newly-constructed buildings are double pane, low-E though only 8% are argon-filled (Table 43).

Table 43: Window Area by Type

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Buildings)	*8*	*2*	*10*	*9*	*45*	*54*
Single Pane	--	--	--	34%	5%	11%
Double Pane (clear)	--	--	--	66%	78%	76%
Double Pane low-E	90%	100%	92%	--	11%	8%
Double Pane low-E Argon	10%	--	8%	--	4%	4%
Triple Pane	--	--	--	--	1%	1%

Wood-frame windows are the most common type found in existing buildings (61%) (Table 44). Vinyl-frame windows are the most common type in newly-constructed buildings (7 of 10), and the second most common type in existing buildings (56%). Metal frame windows are found in four newly-constructed buildings. Buildings had windows with multiple frame materials, so counts may sum to more than the total sample size or 100%.

Table 44: Window Frame Type

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Buildings)	*8*	*2*	*10*	*9*	*45*	*54*
Wood	--	1	1	8	56%	61%
Vinyl	6	1	7	2	62%	56%
Metal	3	1	4	1	9%	9%
Fiberglass	--	1	1	1	7%	7%

Table 45 displays the glazing percentage, which is the ratio of window-to-wall area following the approach outlined in the RBES manual. Overall, the average glazing percentage is 29% for new buildings, and 14% for existing buildings. The average glazing percentage for new buildings exceeds the 2011 RBES requirements, which caps glazing percentage at 20%.

Table 45: Glazing Percentage of Exterior Wall Area

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Buildings)	*8*	*2*	*10*	*9*	*45*	*54*
Min	16%	13%	13%	6%	6%	6%
Max	45%	33%	45%	28%	29%	29%
Average	30%	23%	29%	18%	14%	14%
Median	31%	23%	31%	23%	10%	11%

3.6.2 Skylights

One of the ten newly constructed buildings and seven percent of existing buildings have skylights (Table 46). The average area of the skylights is 8.8 square feet for existing buildings, and 8.0 square feet for the new buildings. All skylight glass is double pane.

Table 46: Skylights

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Buildings)	*8*	*2*	*10*	*9*	*45*	*54*
Buildings with skylights	--	1	1	--	9%	7%
Average area (s.f.)	--	8.0	8.0	--	8.8	8.8
Skylight Window Types (% Buildings)						
Single Pane	--	--	--	--	--	--
Double Pane	--	1	1	--	4 (100%)	4 (100%)
Triple Pane	--	--		--	--	--

4

Section 4 Mechanical Equipment

This section presents the findings for mechanical equipment that was identified during on-site inspections. The results cover heating, cooling, and water heating equipment. Data were collected on the type of equipment, fuel, capacity, and efficiency.

4.1 Heating Systems

Data were collected on all heating equipment observed during on-sites. Because of the diversity of building types present, the configurations of heating systems can vary significantly. Part of the data collection process included recording if a heating system served a single unit or multiple units and common areas. These different arrangements are reported separately below.

4.1.1 Primary Heating Fuel

Table 47 shows the primary heating fuel, defined as the fuel that serves most of the heating load for each complex. Natural gas is the most frequently used primary fuel for both new construction (3 of 10) and existing buildings (43%). As shown in Figure 6, many sampled complexes were found in and around Burlington, where piped natural gas networks are located, which may explain these numbers.

Oil is the primary fuel at two of the new construction complexes and one-third (35%) of existing sites. Propane has the same frequency as oil for new construction (2 sites) but is only the primary fuel at 13% of existing complexes.

Only twelve complexes have an additional fuel type used for supplemental space heating. In six primarily natural gas-fueled complexes, the supplemental fuel is electricity. In addition, one primarily oil-fueled complex has a supplemental propane space heater. Another complex uses natural gas in common spaces but electricity in the units. Electricity is considered the primary fuel in this case since the units comprise most of the CFA.

Supplemental fuels back up hydronic systems in four complexes. Two use pellets to back up a primarily oil fired hydronic system, one uses oil to back up a primarily pellet-fired hydronic system, and one uses a combination of oil and pellets to back up a primarily solar-powered hydronic system.

Table 47: Primary Heating Fuel

(Base: all complexes)

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	*8*	*2*	*10*	*9*	*45*	*54*
Natural Gas	3		3	9	31%	43%
Oil	2	--	2	--	42%	35%
Propane	1	1	2	--	16%	13%
Electric	1	--	1	--	4%	4%
Kerosene	--	--	--	--	2%	2%
Pellet	1	1	2	--	2%	2%
Solar	--	--	--	--	2%	2%

4.1.2 Counts of Heating Systems

During onsite inspections auditors recorded heating systems found in common areas and heating systems in one inspected unit. [17]

[17] Auditors recorded the types of heating systems present to the best of their abilities, given that they sometimes had limited access to mechanical areas and only inspected one unit consistently at each complex. Accordingly, it is possible that some of the buildings listed with single systems could have had an additional system whose presence the auditor could not confirm.

Table 48 through Table 51 split the systems into two groups: (1) systems that served multiple units and/or common space and (2) systems that served only individual units. For each group, we show the counts of systems per inspected building and by type. Note that we did not extrapolate heating equipment to match the number of units in the complex because such equipment could vary. Therefore, to remain consistent, we also exclude any equipment that served only a single unit outside of the inspected unit.

Systems Serving Multiple Units

Every new construction complex has at least one heating system that serves multiple units. Five of ten complexes have one such heating system and three have two systems. More than one-third of existing complexes (35%) do not have any heating systems serving more than one unit which means for those complexes, every unit has only its own heating system. A larger portion (37%) have one multi-unit system and more than one-tenth (13%) have two systems (

Table 48).

Table 48: Systems Serving Multiple Units or Common Space Per Complex

(Base: all complexes)

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	*8*	*2*	*10*	*9*	*45*	*54*
None	--	--		5	31%	35%
One	4	1	5	2	40%	37%
Two	2	1	3	1	13%	13%
Three	--	--	--	--	7%	6%
Four	1	--	1	1	2%	4%
Five	--	--	--	--	2%	2%
More than Five	1	--	1	--	4%	4%

Most systems that serve multiple units in both new and existing construction are forced hot water boilers (81% and 91%, respectively). Hydro-air boilers comprise 19% of new construction systems (all program complexes) but only 1% of existing systems. Furnaces are not present in any new construction complexes and make up only 7% of systems serving multiple units in existing complexes.

Table 49: Systems Serving Multiple Units or Common Space by Type

(Base: all multi-unit systems)

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Systems)	*18*	*3*	*21*	*8*	*68*	*76*
Boiler (forced hot water)	78%	3	81%	5	90%	88%
Furnace	--	--	--	2	4%	6%
Steam boiler	--	--	--	--	3%	3%
Boiler (hydro-air)	22%	--	19%	1	-	1%
Packaged RTU	--	--	--	--	1%	1%
Ductless mini-split	--	--	--	--	1%	1%

Systems Serving Single Units

As noted above, in addition to recording heating systems which served multiple units, auditors collected data on heating systems that served only the inspected unit in each complex. This includes supplemental heating systems such as electric baseboards. However, it does not include any systems that served a single unit other than the inspected unit.

Only two new construction complexes have systems that are solely dedicated to the inspected unit. Similarly, more than one-third (41%) of all existing complexes have heating systems that serve only the inspected unit (Table 50).

Table 50: Systems Serving Single Units

(Base: all complexes)

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	*8*	*2*	*10*	*9*	*45*	*54*
None	6	2	8	4	62%	59%
One	--	--	--	5	29%	33%
Two	2	--	2	--	4%	4%
Three	--	--	--	--	2%	2%
Four	--	--	--	--	2%	2%

Both new complexes that have single-unit heating systems have an air source heat pump and electric baseboards in the inspected unit. For existing complexes, 31% of systems are forced hot water boilers, 22% are electric baseboards, and 19% are direct vent wall furnaces.

Table 51: Systems Serving Single Units by Type

(Base: all single-unit systems)

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Systems)	*4*	*--*	*4*	*5*	*21*	*26*
Boiler (forced hot water)	--	--	--	3	24%	31%
Electric baseboard	2	--	2	--	28%	22%
Direct vent wall furnace	--	--	--	1	18%	19%
Ductless mini-split	--	--	--	--	5%	4%
Stove	--	--	--	--	10%	8%
Combined appliance	--	--	--	1	5%	8%
Steam boiler	--	--	--	--	5%	4%
Furnace	--	--	--	--	5%	4%
ASHP	2	--	2	--	--	--

4.1.3 Centralized Heating System Characteristics

This section characterizes centralized heating systems, here defined as systems that have a central heating component and a distribution system. This includes boilers, furnaces, ASHPs[18], ductless mini-splits[19], steam boilers, and packaged roof top units (RTUs).

Table 52 shows the location of centralized heating systems (excluding ductless mini-splits, which necessarily have an outdoor compressor and indoor heads in conditioned space). Three-quarters of new construction heating equipment is located in conditioned space, compared to 56% in existing buildings.

Table 52: Location of Heating Systems

(Base: All heating systems with distribution structures)

	New Construction			Existing		
	Program	Non-Program	Statewide	Program	Non-Program	Statewide
n (Systems)	*20*	*3*	*23*	*12*	*75*	*87*
Conditioned Space	76%	2	75%	58%	56%	56%
Unconditioned Space	24%	1	25%	42%	39%*	40%
Garage or open crawl	--	--	--	--	4%	3%
Ambient	--	--	--	--	1%	1%**

* Three boilers feed the same distribution system. It is primarily a solar hydronic system with pellet and oil boilers for back up.

** One complex had a packaged RTU on its roof.

[18] Every air source heat pump found during inspections had a duct distribution system.

[19] While ductless mini-splits fall into a slightly grey area when it comes to decentralized and centralized designations, we define them as centralized for this study because the ductless mini-splits found have a single "centralized" compressor with multiple indoor heads and a coolant distributed between them. They are capable of heating an entire home. However, we count the ductless mini-splits by compressor and not by indoor head.

Table 53 shows the year of manufacture for centralized heating systems. The “Boilers” group includes hydronic, hydro-air, steam, and combined systems. All boilers and ASHPs found in new construction were manufactured since 2010. Almost two-thirds (64%) of boilers and furnaces in existing construction are older than 2010. The manufacture date was undeterminable for eight boilers and two furnaces due to missing or covered serial numbers on the units, or because we could not determine the age of the equipment based on the serial number.

Table 53: Year of Manufacture of Centralized Heating Systems

(Base: Systems with age data)

	New Construction		Existing			
	Boilers	ASHP	Boilers	Furnaces	Packaged RTU	Ductless mini-split
n (Systems)	*21*	*2*	*80*	*6*	*1*	*1*
2015	14%	1	10%	--	1	--
2014	24%	1	13%	--	--	--
2013	5%	--	5%	--	--	--
2012	48%	--	4%	--	--	--
2011	10%	--	--	--	--	--
2006-2010	--	--	8%	--	--	1
2001-2005	--	--	21%	1	--	--
1996-2000	--	--	23%	1	--	--
1991-1995	--	--	13%	2	--	--
1986-1990	--	--	--	1	--	--
Don’t know	--	--	5%	1	--	--

Table 54 shows the qualitative assessments of piping insulation. As the R-values were rarely labeled on the insulation, R-values are not reported. The vast majority of systems (93%) in new, program complexes had piping that was “fully insulated” and the final 7% had “mostly insulated” pipes. Only one of three systems in new non-program complexes were “fully insulated” and two were “mostly uninsulated”. About one-third (39%) of systems in existing complexes are “fully insulated” and the same amount (39%) have no insulation.

Table 54: Hydronic Heat Piping Insulation

(Base: All hydronic heat systems)

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Systems)	*14*	*3*	*13*	*9*	*70*	*79*
Fully Insulated	93%	1	77%	4	39%	39%
Mostly Insulated	7%	--	8%	1	11%	11%
Mostly Uninsulated	--	2	15%	--	11%	10%
None	--	--	--	4	39%	39%

4.1.3.1 Centralized Heating System Efficiency

Fossil fuel-fired heating systems—mainly boilers—are the most common type of heating equipment in use at multifamily sites. Figure 13 displays the average efficiency (Annual Fuel Utilization Efficiency, or AFUE) of fossil fuel-fired boilers and furnaces at each site. Below, heating system efficiencies will be explored by specific type and fuel. The efficiencies of systems with capacities larger than 290,000 BTU/hr are summarized separately (in Table 58) because they are given “Thermal Efficiency” ratings rather than AFUE ratings.

Two ASHP and two ductless mini-split systems are not included because they are rated using an HSPF. The ASHPs have HSPF values of 10.6 and 12.5 and the ductless mini-splits have HSPF values of 9.3 and 10.6.

There were also two combi appliances present in the sample, both in existing complexes. A combi appliance is a tankless, instantaneous water heater that is configured to provide both domestic hot water and space heating via hydronic or hydro-air distribution. These units are rated in AFUE for space heating, their respective AFUEs were 95 and 92.5.

Figure 13: Average AFUE of Fossil Fuel Heating Systems

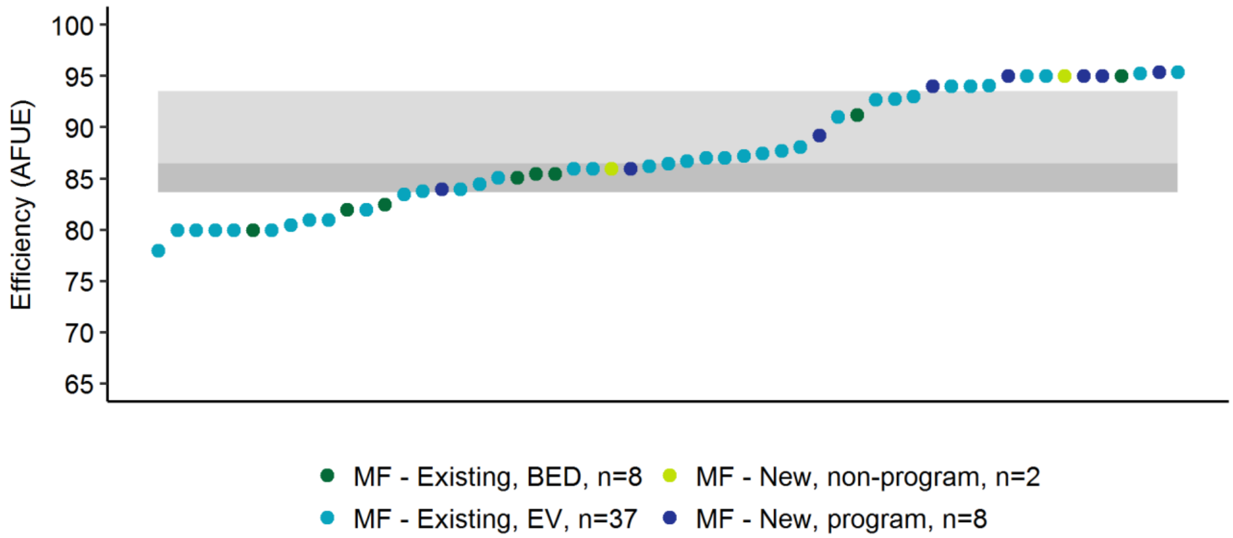


Table 56 shows the efficiency of boilers with AFUE ratings available. This includes both hydro-air and hydronic boilers. Two oil-fueled steam boilers are not included because AFUEs were not available. Additionally, one propane boiler by Fais and one oil boiler by Biasi did not have ascertainable efficiency information. Six pellet boilers are excluded because they did not have AFUE ratings. The average efficiency of the six pellet boilers is 87.6%.

The average AFUE for boilers in new construction complexes is 94.2 and the average for existing construction is 88.4.

Table 55: Boiler Efficiency (AFUE)

(Base: Boilers with efficiency data)

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Systems)	*9*	*2*	*11*	*4*	*50*	*54*
Minimum	86.0	95.0	86.0	81.6	80.0	80.0
Maximum	95.0	95.0	95.0	87.0	95.3	95.3
Mean	94.0	95.0	94.2	85.3	88.6	88.4
Median	95.0	95.0	95.0	86.3	87.0	87.0
Unknown (count)	--	--	--	--	2	2

Looking exclusively at natural gas and propane boilers, the average AFUE for new construction is 95.0 and the average for existing construction is 89.1 (Table 56).

Table 56: Natural Gas and Propane Boiler Efficiency (AFUE)

(Base: Natural gas and propane boilers with efficiency data)

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Systems)	*8*	*2*	*10*	*4*	*38*	*42*
Minimum	95.0	95.0	95.0	81.6	80.5	80.5
Maximum	95.0	95.0	95.0	87.0	95.3	95.3
Mean	95.0	95.0	95.0	85.3	89.4	89.1
Median	95.0	95.0	95.0	86.3	87.0	87.0
Unknown (count)	--	--	--	--	1	1

The single oil boiler found in a new construction complex had an AFUE of 86.0 and the oil boilers in existing complexes had an average AFUE of 86.2 (Table 57).

Table 57: Oil Boiler Efficiency (AFUE)

(Base: Oil boilers with efficiency data)

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Systems)	*1*	--	*1*	--	*13*	*13*
Minimum	86.0	--	86.0	--	80.0	80.0
Maximum	86.0	--	86.0	--	94.0	94.0
Mean	86.0	--	86.0	--	86.2	86.2
Median	86.0	--	86.0	--	86.0	86.0
Unknown (count)	--	--	--	--	1	1

The average thermal efficiency for commercial scale systems in new construction is 91.9%. The average for existing construction is 88.3%. There were no commercial scale systems at new non-program complexes (Table 58).

Table 58: Commercial Scale Boiler Efficiency (Thermal Efficiency)

(Base: Boilers with efficiency data)

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Systems)	*7*	*--*	*7*	*5*	*13*	*18*
Minimum	85.5	--	85.5	82.0	80.0	80.0
Maximum	95.4	--	95.4	91.2	95.4	95.4
Mean	91.9	--	91.9	89.4	87.9	88.3
Median	94.0	--	94.0	91.2	90.4	91.2
Unknown	--	--	--	--	1*	1*

* Efficiency data was not available for one commercial steam boiler.

Table 59 summarizes the efficiency of furnaces split by service territory and fuel. The average AFUE overall is 80.1. Oil furnaces have an average AFUE of 81.7 and natural gas furnaces have an average AFUE of 78.7. Note that the sample sizes are limited and that there are no furnaces in new construction complexes.

Table 59: Furnace Efficiency (AFUE) By Service Territory and Fuel

(Base: Furnaces with efficiency data)

	Existing			All Oil Furnaces	All Natural Gas Furnaces
	BED	EVT	Statewide		
n (Systems)	*2*	*4*	*6*	*3*	*3*
Minimum	78.0	78.0	78.0	80.0	78.0
Maximum	80.0	83.4	83.4	83.4	80.0
Mean	79.0	80.8	80.1	81.7	78.7
Median	79.0	80.8	80.0	81.7	78.0

4.1.4 Decentralized Heating System Characteristics

As mentioned above, auditors also collected information on decentralized heating systems during onsite inspections.[20] Decentralized systems include stoves, electric baseboards, and direct vent wall furnaces.

[20] NMR did not extrapolate to estimate the total number of decentralized systems in a complex. Only systems in the inspected unit of each complex and any common spaces were recorded.

Two complexes have stoves, both of which were natural gas fueled and located in existing buildings. Their efficiencies were rated at 75.7% and 80% by their manufacturers.

Auditors found direct vent wall furnaces at five complexes, all in the existing sample. The majority (3 of 5) were propane fueled. The average AFUE is 84.7 (Table 60).

Table 60: Direct Vent Wall Furnace Details

(Base: Direct vent wall furnaces)

	Existing		
Number of Units	BED	EVT	Statewide
n (Buildings)	*1*	*4*	*5*
Fuel Type			
Natural Gas	*1*	--	*1*
Propane	--	3	3
Kerosene	--	1	1
Equipment Efficiency (AFUE)			
Min	73.0	80.4	73.0
Max	73.0	95.0	95.0
Mean	73.0	87.6	84.7
Median	73.0	87.5	82.0

4.2 Cooling Systems

Auditors counted room air conditioners found in each inspected unit (Table 61).[21] The majority of both new and existing complexes had no room air conditioners (8 of 10 and 70%, respectively).

Table 61: Number of Room Air Conditioners Per Inspected Unit

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Buildings)	*8*	*2*	*10*	*9*	*45*	*54*
None	7	1	8	6	71%	70%
One	1	1	2	3	27%	28%
Two	--	--	--	--	2%	2%

[21] Auditors would have also recorded room air conditioners located in common space, however none were found.

Table 62 summarizes the Energy Efficiency Ratio (EER) data for room air conditioners. In the two new complexes the average EER is 9.1. In existing complexes, the average EER is 10.1.

Table 62: Efficiency of Room Air Conditioners (EER)

(Base: Room air conditioners with efficiency data)

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (systems)	*1*	*1*	*2*	*3*	*14*	*17*
Minimum	8.8	11.2	8.8	9.4	8.9	8.9
Maximum	8.8	11.2	11.2	10.0	11.3	11.3
Mean	8.8	11.2	9.1	9.7	10.1	10.1
Median	8.8	11.2	8.8	9.7	10.2	9.9
Unknown	--	--	--	1	4	5

Table 63 summarizes the average age, size, and efficiency of installed air conditioning systems. The average SEER for central air-split systems in existing construction is 14.8. The average SEER for ASHP systems in new construction is 24.6. Both new and existing construction have ductless mini-splits with average SEER ratings of 16.8 and 19.4, respectively.

Table 63: Characteristics of Installed Air Conditioning

(Base: direct vent wall furnaces)

	New Construction		Existing		
	ASHP-split	Ductless Mini-split	Central Air-split	Ductless Mini-split	Central Air-packaged
n (Complexes)	*2*	*4*	*2*	*2*	*1*
Number of Systems	*2*	*4*	*2*	*8*	*1*
Average age (years)	2	3	10	5	1
Average size (tons)	1	3.9	4.4	1.5	7.5
Average efficiency	24.6 SEER	16.8 SEER	14.8 SEER	19.4 SEER	12 EER

4.3 Water Heating

4.3.1 Water Heater Characteristics

Table 64 shows the counts of water heaters by type in each complex. Note, just as with heating and cooling, only systems that provided hot water to the inspected unit, or to multiple units at the complex were counted. Any water heater that provided hot water only to a single unit separate from the inspected unit was not counted. The table is split into two sections: complexes that had only one water heater (Single DHW Complexes) and complexes that had multiple water heaters (Multiple DHW Complexes). All 10 new construction complexes use at least one indirect tank for hot water; five of which have multiple indirect tanks, two have an indirect tank and a solar storage system, and three have just a single indirect tank providing hot water for the entire complex.

Among existing complexes, 31% use just a single indirect tank for hot water, 26% use multiple indirect tanks, and 19% use just a single conventional storage water heater.

Table 64: Types of DHW Systems

(Base: All buildings)

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	*8*	*2*	*10*	*9*	*45*	*54*
Single DHW Complexes						
Indirect w/ storage tank	3	--	3	4	29%	31%
Conventional Storage Tank	--	--	--	1	20%	19%
Instantaneous	--	--	--	--	7%	6%
Combined appliance	--	--	--	1	2%	4%
Multiple DHW Complexes						
Indirect w/ storage tanks	4	1	5	2	27%	26%
Conventional Storage Tanks	--	--	--	1	7%	7%
Indirect w/ storage tank and Conventional Storage Tank	--	--	--	--	4%	4%
Heat pump and Conventional Storage	--	--	--	--	2%	2%
Indirect w/ storage tank and Solar Storage	1	1	2	--	2%	2%

Table 65 summarizes the fuels used for hot water in each complex. In new construction, four of ten complexes use natural gas, two use oil, and one each use propane, pellets, propane plus solar, and solar plus pellets. In existing homes, natural gas is again used by the largest share of complexes for hot water (39%, including one that also uses solar). There are electric water heaters at 22% of existing complexes but not at any new complexes. Oil is used at 26% of existing complexes and solar is used at 15% of existing complexes.

Table 65: DHW Fuel

(Base: All buildings)

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	*8*	*2*	*10*	*9*	*45*	*54*
Natural Gas	4	--	4	8	27%	37%
Electric	--	--	--	1	20%	19%
Oil	2	--	2	--	18%	15%
Propane	1	--	1	--	11%	9%
Pellet	--	1	1	--	2%	2%
Natural gas and solar	--	--	--	--	2%	2%
Electric and Solar	--	--	--	--	2%	2%
Oil and Solar	--	--	--	--	9%	7%
Propane and Solar	--	1	1	--	2%	2%
Propane and Electric	--	--	--	--	2%	2%
Solar and Pellet	1	--	1	--	--	--
Oil and Electric	--	--	--	--	2%	2%
Solar, Oil and Pellet	--	--	--	--	2%	2%

Table 66 summarizes the location of water heaters in new and existing construction. Two-thirds (66%) of water heaters in new construction are located in conditioned space and 35% in unconditioned space. Almost one-half (45%) of water heaters in existing complexes are located in conditioned space, and nearly the same share (43%) are in unconditioned space. The remaining 12% of water heaters in existing complexes are located in garages or open crawl spaces and were almost all from one complex that had indirect water heaters located in the garage and serving multiple units.

Table 66: Location of Water Heaters

(Base: All water heaters)

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Systems)	*20*	*9*	*29*	*12*	*95*	*107*
Conditioned Area	80%	3	66%	33%	46%	45%
Unconditioned Space	20%	6	35%	67%	40%	43%
Garage or open crawl	--	--	--	--	14%	12%

Table 67 summarizes the age of every water heater for which the serial number or any other age documentation was available. Every water heater located in new construction complexes was manufactured after 2010. Only 28% of water heaters in existing complexes were manufactured since 2010 and 52% were built between 2001 and 2010.

Table 67: Age of Water Heaters

(Base: All water heaters)

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Systems)	*20*	*9*	*29*	*12*	*95*	*107*
2015	15%	--	10%	--	4%	4%
2014	10%	5	24%	17%	2%	4%
2013	20%	--	14%	8%	8%	8%
2012	35%	4	38%	--	11%	9%
2011	20%	--	14%	--	3%	3%
2006-2010	--	--	--	33%	23%	24%
2001-2005	--	--	--	25%	28%	28%
1996-2000	--	--	--	--	3%	3%
1991-1995	--	--	--	--	6%	6%
1981-1985	--	--	--	--	1%	1%
Don't Know	--	--	--	17%	9%	10%

Only 7% of water heaters and 8% of complexes with tanks had external tank wrap. The average nominal R-value for tank wrap in new construction was 3.2. The average for existing buildings was 3.4 (Table 68).

Table 68: Tank Wrap R Value

(Base: Boilers with efficiency data)

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Systems with tank wrap)	*5*	*--*	*5*	*--*	*13*	*13*
Minimum	3.0	--	3.0	--	3.0	3.0
Maximum	4.0	--	4.0	--	8.0	8.0
Mean	3.2	--	3.2	--	3.4	3.4
Median	3.0	--	3.0	--	3.0	3.0

Because the R-values of piping insulation was rarely available in documentation or on the insulation itself, Table 69 provides a qualitative summary of the extent to which hydronic heat piping was insulated. Every system in new construction complexes had fully insulated piping. Only 42% of systems in existing buildings were fully insulated and 39% had no insulation.

Table 69: Hydronic Heat Piping Insulation

(Base: All hydronic heat systems)

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Systems)	*20*	*9*	*29*	*12*	*95*	*107*
Fully Insulated	100%	9	100%	25%	44%	42%
Mostly Insulated	--	--	--	8%	14%	13%
Mostly Uninsulated	--	--	--	--	6%	6%
None	--	--	--	67%	36%	39%

4.3.2 Water Heater Efficiency

Table 70 through Table 74 summarize the energy factors of water heaters found during onsite inspections. There was a single heat pump water heater present with an energy factor of 3.26 that is excluded from the tables. Additionally, systems for which energy factors were not available from either the AHRI database, the manufacturer, or online are listed in each table as “Unknown”.

The average energy factor for indirect water heaters is similar for both new and existing construction (0.68 and 0.66 respectively)[22].

Table 70: Indirect DHW Energy Factor

(Base: Boilers with efficiency data)

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Systems)	*17*	*5*	*22*	*8*	*42*	*50*
Minimum	0.64	0.65	0.65	0.51	0.51	0.51
Maximum	0.72	0.65	0.72	0.68	0.75	0.75
Mean	0.69	0.65	0.68	0.62	0.67	0.66
Median	0.71	0.65	0.71	0.65	0.68	0.68
Unknowns	--	--	--	--	1	1

[22] The energy factors of integrated (indirect) 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 AFUE, using Northeast Home Energy Rating System Alliance Manual 2007, Chapter 4: Technical Guidelines. Since 2015 Vermont has been following guidance from then-Architectural Energy that for indirect tanks off a boiler the Energy Factor equals 75% of the boiler AFUE. After applying the 92% method used in previous studies, the new and existing indirect Energy Factors equal 0.83 and 0.81, respectively, which reflect improvements over the 0.82 and 0.76 values from the previous study.

The average energy factor for gas powered indirect water heaters in new construction is 0.71 compared to 0.67 in existing construction (Table 71).

Table 71: Natural Gas and Propane Indirect DHW Energy Factor

(Base: Boilers with efficiency data)

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Systems)	*12*	*--*	*12*	*8*	*29*	*37*
Minimum	0.71	--	0.71	0.51	0.51	0.51
Maximum	0.72	--	0.72	0.68	0.75	0.75
Mean	0.71	--	0.71	0.62	0.68	0.67
Median	0.71	--	0.71	0.65	0.69	0.68
Unknowns	--	--	--	--	--	--

The average energy factor for oil fueled indirect systems is slightly lower than gas fired systems--0.65 for new construction and 0.64 for existing construction (Table 72).

Table 72: Oil Indirect DHW Energy Factor

(Base: Boilers with efficiency data)

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Systems)	*4*	*--*	*4*	*--*	*12*	*12*
Minimum	0.65	--	0.65	--	0.60	0.60
Maximum	0.65	--	0.65	--	0.71	0.71
Mean	0.65	--	0.65	--	0.64	0.64
Median	0.65	--	0.65	--	0.61	0.61
Unknowns	--	--	--	--	1	1

Turning towards conventional storage water heaters, the average energy factor is 0.57 for fossil fuel systems and 0.93 for electric systems (Table 73).

Table 73: Conventional Standalone Storage System Energy Factors*

(Base: Storage systems with efficiency data)

	Existing		
	BED	EVT	Statewide
Fossil fuel-fired conventional systems			
n (Systems)	*1*	*5*	*6*
Minimum	0.59	0.56	0.56
Maximum	0.59	0.58	0.59
Mean	0.59	0.57	0.57
Median	0.59	0.56	0.57
Unknowns	--	--	--
Electric conventional systems			
n (Systems)	*2*	*20*	*22*
Minimum	0.95	0.85	0.85
Maximum	0.95	0.95	0.95
Mean	0.95	0.93	0.93
Median	0.95	0.94	0.94
Unknowns	--	2	2

*There were no new complexes with conventional standalone storage systems.

Table 74 shows the energy factors of the instantaneous and combined appliance systems excluding one electric Tempra brand water heater with an energy factor of 0.99. The average energy factor of fossil fueled instantaneous systems (0.97) is higher than that of storage systems.

Table 74: Instantaneous and Combined Appliance Energy Factor

(Base: Instantaneous systems with efficiency data)

	Existing		
	BED	EVT	Statewide
n (Systems)	*1*	*3*	*4*
Minimum	0.97	0.82	0.82
Maximum	0.97	0.93	0.97
Mean	0.97	0.86	0.88
Median	0.97	0.82	0.88
Unknowns (count)	--	--	--

Auditors came across water heaters fueled by solar arrays at several new and existing sites. Where data were available, these indirect, solar-fueled water heaters were 119 gallon models manufactured by HTP. The documented Solar Energy Factors are listed as 2.4[23].

4.3.3 Renewables

There was only one solar photovoltaic system present in the multifamily sample that was not providing hot water or space heating. The unit was in a new, program complex and had an area of 680 square feet and a peak power output of 9kW.

[23] http://www.htproducts.com/literature/SSC-SBCERTIFICATION.pdf

5

Section 5 Appliances in Housing Units

This section provides information on the appliances and electronics located inside housing units. Information regarding the shared clothes washers and clothes dryers located in common areas is provided in Section 2.1. While scheduling visits at sampled complexes, the property management contact was asked to provide access to an occupied housing unit somewhere in the complex. In a few instances, auditors were only allowed to examine an unoccupied housing unit which typically include hard-wired lighting fixtures, kitchen appliances, and laundry appliances but not occupant-provided products such as plug-in lighting fixtures and electronics.

All the units visited have at least one refrigerator, and all but one unit has an oven/range (Table 75). Almost one-third of existing building units have clothes washers, clothes dryers, and dishwashers, while only two of ten new building units have these appliances. Separate freezers and dehumidifiers are rarely found in housing units.

Table 75: Appliance Saturation Levels

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	*8*	*2*	*10*	*9*	*45*	*54*
Refrigerator	8	2	10	9	100%	100%
Oven / Range	8	2	10	8	100%	98%
Clothes washer	2	--	2	3	29%	30%
Clothes dryer	2	--	2	3	29%	30%
Dishwasher	2	--	2	2	31%	30%
Separate freezer	--	--	--	--	4%	4%
Dehumidifier	--	--	--	--	4%	4%

5.1 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, 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; older models that met the ENERGY STAR criteria in effect when they were manufactured would not be listed if they do not meet the current criteria. Therefore, the estimated penetration of ENERGY STAR appliances is likely a conservative estimate.

In newly constructed housing units, seven of ten refrigerators are ENERGY STAR qualified (Table 2). In existing housing units, one-half of the clothes washers and over one-third (35%) of refrigerators are ENERGY STAR qualified.

Table 76: ENERGY STAR Appliances

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	*8*	*2*	*10*	*9*	*45*	*54*
Refrigerators	*8*	*2*	*10*	*9*	*45*	*54*
ENERGY STAR	6	1	7	2	38%	35%
Clothes washers	*2*	--	*2*	*3*	*13*	*16*
ENERGY STAR	1	--	1	1	54%	50%
Dishwashers	*2*	--	*2*	*2*	*14*	*16*
ENERGY STAR	2	--	2	--	21%	19%
Dehumidifiers	--	--	--	--	*2*	*2*
ENERGY STAR	--	--	--	--	2	2

5.2 Refrigerators

Most refrigerators (nine of ten) in new construction units were manufactured since 2010, compared to one-third of refrigerators found in existing units (Table 77). Thirty-eight percent of refrigerators in existing building units were manufactured prior to 2006.

Table 77: Refrigerator Year of Manufacture

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (refrigerators)	*8*	*2*	*10*	*9*	*45*	*54*
1986-1990	--	--	--	--	4%	4%
1991-1995	--	--	--	--	4%	4%
1996-2000	--	--	--	--	13%	11%
2001-2005	--	--	--	3	16%	19%
2006-2010	--	1	1	--	24%	20%
2011	--	--	--	--	2%	2%
2012	3	--	3	--	9%	7%
2013	--	--	--	--	7%	6%
2014	1	--	1	2	4%	7%
2015	3	1	4	1	11%	11%
Don’t know	1	--	1	3	4%	9%

Eight of ten refrigerators in new construction units are between 15 and 20 cubic feet in size, compared to fifty-nine percent in existing building units (Table 78). Over one-quarter (26%) of refrigerators in existing building units are less than 15 cubic feet in size.

Table 78: Refrigerator Size

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Refrigerators)	*8*	*2*	*10*	*9*	*45*	*54*
Less than 15 cubic feet	1	--	1	--	24%	26%
15-20 cubic feet	6	2	8	3	58%	59%
More than 20 cubic feet	--	--	--	6	7%	6%
Don't know	1	--	1	--	11%	9%

Top-freezer refrigerator models comprise all ten refrigerators in newly-constructed units and 87% in existing units (Table 79).

Table 79: Refrigerator Type

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Refrigerators)	*8*	*2*	*10*	*9*	*45*	*54*
Top Freezer	8	2	10	7	89%	87%
Bottom Freezer	--	--	--	1	4%	6%
Side by Side	--	--	--	--	7%	6%
Single Door	--	--	--	1	--	2%

5.3 Separate Freezers

The two separate chest freezers were found in existing Efficiency Vermont units. One of the freezers is 7.2 cubic feet and was manufactured between 2001-2005. The other freezer is 9 cubic feet and was manufactured in 2013.

5.4 Clothes Washers

The two clothes washers in newly constructed units were manufactured in 2014 and 2015 (Table 80). Sixty-nine percent of clothes washers in existing units were manufactured before 2011.

Table 80: Washer Age

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Washers)	*2*	*--*	*2*	*3*	*13*	*16*
1976-1980	--	--	--	--	8%	6%
2001-2005	--	--	--	1	23%	25%
2006-2010	--	--	--	1	39%	38%
2012	--	--	--	1	--	6%
2013	--	--	--	--	15%	13%
2014	1	--	1	--	--	--
2015	1	--	1	--	--	--
Don’t Know	--	--	--	--	8%	13%

One of the clothes washers found in newly constructed units is top-loading and the other is front-loading (Table 81). In existing units, almost two-thirds (63%) of clothes washers are top-loading, while over one-third (38%) are front loading.

Table 81: Washer Type

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Washers)	*2*	*--*	*2*	*3*	*13*	*16*
Front Load	1	--	1	1	39%	38%
Top Load	1	--	1	2	62%	63%

5.5 Clothes Dryers

The two clothes dryers in newly constructed units were manufactured in 2014 and 2015 (Table 82). Three-quarters of clothes dryers found in existing units were manufactured before 2011.

Table 82: Dryer Age

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Dryers)	*2*	*--*	*2*	*3*	*13*	*16*
1976-1980	--	--	--	--	8%	6%
1991-1995	--	--	--	--	15%	13%
2001-2005	--	--	--	2	15%	25%
2006-2010	--	--	--	--	39%	31%
2011	--	--	--	1	--	6%
2013	--	--	--	--	15%	13%
2014	1	--	1	--	--	--
2015	1	--	1	--	--	--
Don't know	--	--	--	--	8%	6%

The two clothes dryers in newly constructed units use natural gas as a fuel source (Table 83). Clothes dryer fuel in existing units is predominantly electricity (94%).

Table 83: Dryer Fuel

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Dryers)	*2*	*--*	*2*	*3*	*13*	*16*
Electric	--	--	--	2	100%	94%
Natural Gas	2	--	2	1	--	6%

5.6 Ranges and Ovens

All ten newly constructed units have oven/ranges that were manufactured after 2011 (Table 84). Sixty percent of existing units have oven/ranges that were manufactured before 2011, though the manufacture date is unknown for 30%.

Table 84: Oven/Range Age

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Ranges)	*8*	*2*	*10*	*8*	*45*	*53*
1976-1980	--	--	--	--	2%	2%
1981-1985	--	--	--	--	4%	4%
1986-1990	--	--	--	--	4%	4%
1991-1995	--	--	--	2	11%	13%
1996-2000	--	--	--	1	11%	11%
2001-2005	--	--	--	--	11%	9%
2006-2010	--	--	--	--	20%	17%
2012	4	1	5	--	--	--
2014	1	1	2	--	2%	2%
2015	3	--	3	--	11%	9%
Don’t know	--	--	--	5	24%	30%

Ranges in both newly constructed units and existing units are primarily electric (nine of ten and 87%, respectively).

Table 85: Range Fuel

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Ranges)	*8*	*2*	*10*	*8*	*45*	*53*
Electric	7	2	9	5	91%	87%
Natural Gas	1	--	1	3	4%	9%
Propane	--	--	--	--	4%	4%

Similarly, ovens in both newly constructed units and existing units are primarily electric (nine of ten and 89%, respectively) (Table 86).

Table 86: Oven Fuel

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Ovens)	*8*	*2*	*10*	*8*	*45*	*53*
Electric	7	2	9	5	93%	89%
Natural Gas	1	--	1	3	2%	8%
Propane	--	--	--	--	4%	4%

5.7 Dehumidifiers

The two dehumidifiers were both found in existing Efficiency Vermont units, both are ENERGY Star, one was manufactured in 2015 while the other dehumidifier's age is unknown.

5.8 Televisions and Peripherals

Eighty-percent of housing units in both new and existing buildings have at least one TV set. One-third of existing units have two or more TVs, while seven of ten new construction units have only one TV (Table 87).

Table 87: TV Saturation

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	*8*	*2*	*10*	*9*	*45*	*54*
None	2	--	2	3	18%	20%
One	5	2	7	5	44%	46%
Two	1	--	1	1	27%	24%
Three or More	--	--	--	--	11%	9%

Over one-half of TV sets (51%) in existing units are liquid crystal display (LCD) models, while forty percent are light emitting diode (LED) models (Table 88). Five of nine TV sets in newly-constructed units are LED models, and three of nine are LCD models.

Table 88: Type of TV

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (TVs)	*7*	*2*	*9*	*7*	*60*	*67*
LCD	2	1	3	4	50%	51%
LED	4	1	5	3	40%	40%
CRT	1	--	1	--	5%	5%
Plasma	--	--	--	--	3%	3%
Projection	--	--	--	--	2%	2%

Almost two-thirds (63%) of TV sets in existing units and in eight of nine TV sets in newly-constructed buildings are between 31 and 50 inches in size (as measured diagonally) (Table 89).

Table 89: TV Set Screen Size

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (TVs)	*7*	*2*	*9*	*7*	*60*	*67*
20 inches or less	1	--	1	--	8%	8%
21 to 30 inches	--	--	--	2	12%	13%
31 to 40 inches	2	2	4	3	42%	42%
41 to 50 inches	4	--	4	1	22%	21%
51 to 60 inches	--	--	--	1	17%	16%

Over one-half (52%) of TVs in existing units and in eight of nine newly-constructed units do not have a TV peripheral (Table 90). One-third of TVs in existing units have a DVD player.

Table 90: TV Peripherals

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (TVs)	*7*	*2*	*9*	*7*	*60*	*67*
DVD	--	--	--	3	32%	33%
Game Console	--	--	--	--	12%	10%
VCR	1	--	1	--	5%	5%
None	6	2	8	4	52%	52%

Cable is the most prevalent form of TV set top box found in the inspected units; it is present in four of nine newly constructed units and 45% of existing units (Table 91).

Table 91: TV Set-top Boxes

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (TVs)	*7*	*2*	*9*	*7*	*60*	*67*
Cable	4	--	4	4	43%	45%
Satellite	3	--	3	--	10%	9%
Streaming Device	1	--	1	3	7%	10%
None	--	2	2	--	40%	36%

Over one-half (54%) of existing units and three out of ten newly-constructed units have at least one computer (Table 92). Tablets were not included in our computer count because it is likely at least some tablets would not be in the home at the time of the audit or not visible.

Table 92: Computer Saturation

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	*8*	*2*	*10*	*9*	*45*	*54*
None	6	1	7	1	53%	46%
One	2	1	3	6	42%	46%
Two	--	--	--	--	2%	2%
Three or More	--	--	--	2	2%	6%

Thirty percent of existing units and one out of ten newly-constructed units have a printer (Table 93).

Table 93: Printer Saturation

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	*8*	*2*	*10*	*9*	*45*	*54*
None	7	2	9	6	71%	70%
One	1	--	1	3	29%	30%

Two out of the three computers in newly-constructed buildings are desktops (Table 94). About one-half of the computers in existing buildings are laptops and the other one-half are desktops.

Table 94: Computer Type

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Computers)	*2*	*1*	*3*	*13*	*24*	*37*
Desktop	1	1	2	62%	46%	51%
Laptop	1	--	1	39%	54%	49%

Computer monitors are predominantly of the liquid-crystal display (LCD) variety--79% of monitors in existing housing units are LCD as is the single monitor in new housing units. (Table 95).

Table 95: Computer Monitor Type

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Computer Monitors)	--	*1*	*1*	*4*	*10*	*14*
LCD	--	1	1	3	8	79%
LED	--	--	--	1	2	21%

Almost two-thirds of computer monitors (64%) in existing homes are in the 16 to 20 inch size range (Table 96).

Table 96: Computer Monitor Size

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Computer Monitors)	--	*1*	*1*	*4*	*10*	*14*
16 to 20 inches	--	1	1	3	6	64%
21 to 25 inches	--	--	--	--	2	14%
Over 25 inches	--	--	--	1	2	21%

5.9 Home Offices

There was one home office in sampled housing units, a 137-sq. ft. office located in an existing building in the Burlington Electric service territory.

6

Section 6 Lighting in Housing Units

This section covers lighting data for the housing units inspected at each complex. Interior and exterior common area lighting data are reported in Section 2.1. As mentioned in the previous section, a few inspected units were unoccupied and as a result may have lower lighting counts relative to occupied units, which would be more likely to have portable fixtures installed in addition to the permanent fixtures.

CFL bulbs are present in 87% of existing housing units, compared to 70% in the previous study. The number of existing housing units with LEDs installed increased from 5% in the last study to 35% in the current study. Incandescent bulbs are found in 69% of existing units, a decrease of 7%, while fluorescent bulbs saw an increase of a similar percentage, up to 54%.

While all new construction housing units inspected in 2008 had CFLs installed, this figure dropped to 86% in 2011 and to 70% (seven of ten) in 2015. At the same time, the number of housing units with LEDs increased from one in 2011 to six in 2015, even with the number of inspected units halved.

Table 97: Bulb Type Penetration in Housing Units

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Housing units)	8	2	10	9	45	54
CFL	6	1	7	9	84%	87%
LED	6	--	6	3	36%	35%
Incandescent	4	1	5	7	67%	69%
Halogen	2	--	2	2	13%	15%
Fluorescents	5	2	7	4	56%	54%
Dimmable Bulbs	--	--	--	--	9%	7%

LED bulbs make up more than one-half of all bulbs in just 6% of units in existing complexes. In contrast, four of ten new units have more than one-half LEDs. However, both new non-program units have no LEDs installed and two units in new program buildings have no LEDs installed.

Table 98: LED Saturation

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Housing units)	8	2	10	9	45	54
None	2	2	4	6	64%	65%
1% to 10%	1	--	1	2	7%	9%
11% to 25%	--	--	--	1	16%	15%
26% to 50%	1	--	1	--	7%	6%
51% to 100%	4	--	4	--	7%	6%

Slightly over one-half of existing housing units have CFLs installed in at least 50% of sockets — an increase of 14% from the 2013 report. Three of ten units in new complexes do not use CFLs, while another three use CFLs in at least 50% of sockets.

Table 99: CFL Saturation

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Housing units)	8	2	10	9	45	54
None	2	1	3	--	16%	13%
1% to 10%	2	--	2	--	2%	2%
11% to 25%	1	--	1	--	9%	7%
26% to 50%	1	--	1	3	24%	26%
51% to 100%	2	1	3	6	49%	52%

CFLs make up slightly over one-half of all bulbs recorded in existing housing units, up from 37% in the previous study. Incandescent bulbs are installed in 21% of sockets in existing units down from 62% in the previous study. LED bulbs, installed in just 1% of existing unit sockets previously, are now found in 11% of sockets. New housing units have LED bulbs installed in 36% of sockets compared to 30% with CFLs. This is a departure from the previous study, where new units had 67% CFL saturation and 4% LED saturation.

Table 100: Bulb Saturation by Type

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Housing units)	8	2	10	9	45	54
Number of Bulbs	105	41	146	148	813	961
Average Number of Bulbs	13.1	20.5	14.6	16.4	18.1	17.8
CFL	30%	30%	30%	61%	50%	52%
LED	44%	--	36%	4%	12%	11%
Incandescent	7%	21%	10%	18%	22%	21%
Halogen	4%	--	3%	4%	2%	2%
Fluorescent	14%	49%	21%	12%	14%	14%
Empty socket	--	--	--	2%	<1%	<1%

7 Section 7 Homeowner Questions – Multifamily

Auditors asked owners and property managers a series of questions related to emerging technologies during on-site inspections. Specifically, the questions focused on home energy management systems, solar net metering, heat pumps, and heat pump water heaters.

There were no home energy management systems recorded during the multifamily site visits. Also, none of the owner or property manager contacts reported being part of a group net metered solar facility (also called shared or community solar).

7.1 Heat Pumps

At sites with heat pumps installed (air source, ground source, and ductless mini-splits), property management contacts were asked to rate their satisfaction with the system(s). Four multifamily sites had heat pumps installed for heating and/or cooling, though ground source heat pumps were absent in the sample.

At each of these four sites, the contact indicated that the heat pump was used as the primary source of heating (two sites) and cooling (four sites). Three contacts reported that they were very satisfied with their heat pumps and the fourth said they were satisfied.

7.2 Heat Pump Water Heaters

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. HPWH’s require sufficient area and ceiling height, a minimum temperature of 50 degrees, and a drain. Because of the diversity in buildings types observed during on-sites, this assessment was not relevant for all buildings included in the study, but for smaller multifamily sites—including condominiums/townhomes and homes divided into separate housing units—assessing the potential for heat pumps was appropriate.

Table 101 shows the breakdown of the required HPWH features that were present at inspected sites where data were available. There were two HPWHs installed in existing Efficiency Vermont complexes though none in existing Burlington Electric or new complexes. The majority of existing and new complexes met the requirements of having sufficient space, ceiling height, and temperature for a HPWH. Most new complexes also had a drain in the area near their mechanical equipment, though only about 40% of existing complexes did. Three existing complexes did not meet any of the requirements necessary to install a HPWH.

Table 101: HPWH Capabilities

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Buildings)	8	1*	9*	9	37*	46*
Sufficient ceiling height (6.5') in basement/utility room	7	1	8	7	84%	86%
Sufficient space (>750 cu ft.) in basement/utility room	7	1	8	9	73%	78%
Temp. at least 50 degrees in the winter	6	1	7	7	84%	83%
Drain present	6	--	6	4	38%	39%
HPWH already installed	--	--	--	--	5%	4%
No Conditions Met	--	--	--	--	8%	7%

*Data were unavailable for 8 existing EVT homes and 1 new, non-program home.

7.3 Energy Efficiency Opportunities

Auditors were asked to identify potential opportunities for energy efficiency improvements in the multifamily complexes assessed in this study.

Auditors identified specific opportunities (e.g., ceiling air leakage, wall insulation R-values, etc.) that were then aggregated for reporting purposes. It should be noted that these opportunities are not meant to encompass all the potential savings in each home. Instead, these represent a qualitative assessment of the measures or areas that represent the largest savings opportunities in the opinion of the auditors.

Table 102 presents a summary of the opportunities identified during inspections. These are general categories created to aggregate similar opportunities into larger, more general groups. For example, the wall insulation category includes homes where there is no insulation in wall cavities as well as those deemed to have low R-values. Roughly one-quarter of existing buildings were identified as having opportunities to improve energy efficiency via upgrading lights and windows. The next most common energy efficiency improvements identified in existing buildings were basement insulation (17%) and furnace or boiler AFUE (15%). Predictably, given their ages, new complexes had fewer opportunities identified, though according to auditors three sites had room for efficiency improvements in lighting.

Table 102: Energy Efficiency Opportunities in Multifamily Buildings

	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	8	2	10	9	45	54
Lighting	3	--	3	1	27%	24%
Windows	--	--	--	3	22%	24%
Basement Insulation	1	--	1	3	13%	17%
Furnace/boiler AFUE	1	--	1	3	11%	15%
Ceiling Insulation	--	--	--	1	9%	9%
Wall Insulation	--	--	--	1	7%	7%
Basement air Leakage	1	--	1	--	2%	2%

Table 103 shows the number of energy efficiency opportunities that were identified by auditors at each complex. At least one opportunity was identified at 42% of existing buildings. Of the three new sites where opportunities were identified, two were solely based on interior lighting and another included interior lighting along with other areas.

Table 103: Energy Efficiency Opportunities per Building

Number of Opportunities per Complex	New Construction			Existing		
	Program	Non-Program	Statewide	BED	EVT	Statewide
n (Complexes)	8	2	10	9	45	54
0	5	2	7	5	58%	58%
1	2	--	2	--	13%	11%
2	--	--	--	1	7%	7%
3	--	--	--	1	4%	5%
4	1	--	1	1	11%	11%
5	--	--	--	--	4%	4%
6	--	--	--	--	2%	2%
8	--	--	--	1	0%	2%

A

Appendix A Major Renovations and Additions

In this appendix, we describe buildings that underwent gut rehabilitations or renovations after October 1st, 2011, and assess whether the work done complies with the 2011 RBES requirements. Existing structures that underwent gut rehabilitations —where at least two of the three major building systems (HVAC, building shell, and lighting) were removed or replaced—would be sufficiently altered to be classified as new construction. No new construction complexes were solely gut rehabilitated existing structures—one new complex was 80% new construction on top of a demolished building with the remaining 20% an existing structure that had been salvaged and gutted. However, five existing complexes underwent repairs and renovations to the building shell, specifically walls and ceilings, that included adding new insulation.

It should be noted that in many instances, without documentation it is impossible to assess compliance for certain measures such as fenestration U-factor for windows that were installed after the effective date of 2011 RBES. This section will address measures where we could verify compliance.

A.1 New construction

One new construction building is a mix of new construction and a gut rehabilitation of a portion of an existing building salvaged after serious flooding caused by the remnants of Hurricane Irene. Eighty percent of the building was demolished and rebuilt as completely new construction. Plans for this structure, along with visual inspections where possible, show that insulation levels in the building shell exceed RBES requirements. In the gut-rehabilitated portion of the building, wall R-values exceed code requirements as well. However, based on plans, the vaulted ceiling is R-42 over the entirety of its area, which exceeds the 500-sq. ft. cap that code allows for vaulted ceilings under R-49.

A.2 Existing Construction

There are five existing complexes where auditors could confirm that renovations had taken place after RBES 2011 became effective, all of which involved renovations and repairs to walls and ceilings that included the addition of insulation. In four of the five complexes, the added insulation was confirmed to meet code requirements where it could be observed. These sites also had windows replaced—though auditors can confirm with visual inspection the type and number of panes in these windows, they were not able to confirm documented U-factors. The fifth existing complex had repairs of the above grade walls, during which closed cell spray foam was added to the cavities. Where this could be observed, the thickness of the application did not appear sufficient to bring the walls up to the R-20 code requirement.

Table 104 displays the minimum requirements of the four prescriptive packages offered under the Fast-Track compliance method of 2011 RBES for single family homes and multifamily homes under three stories in height.

Table 104: 2011 RBES Package Requirements for Fast-Track Compliance Method[24]

Component	Package 1	Package 2	Package 3	Package 4
Ceiling R-Value	R-49	R-38	R-38 or R-30+10 Cont.	R-28 Cont.
Above-Grade Wall R-value	R-20 or R-13+5 Cont.	R-20+5 Cont. or R-13+7.5	R-20 or R-13+5	R-21 Cont.
Floors over Unconditioned Spaces R-value	R-30	R-30	R-30	R-30
Conditioned Basement Walls/Crawl Space (full height) R-value	R-15 Cont. or R-20 Cavity	R-15 Cont. or R-20 Cavity	R-20 Cont.	R-15 Cont. or R-20 Cavity
Slab Edge R-value	R-15, 4 ft.	R-15, 4 ft.	R-15, 4 ft.	R-15, 4 ft.
Window and Door U-value	0.32	0.32	0.30	0.32
Skylight U-value	0.55	0.55	0.55	0.55
Glazing Percentage	≤20%	≤20%	≤20%	≤20%

[24] RBES Residential Handbook: http://publicservice.vermont.gov/sites/dps/files/documents/Energy_Efficiency/2011%20VT%20Energy%20Code%20Handbook%20V.2.1%20FINAL.pdf

B

Appendix B Insulation Grades

The Residential Energy Services Network (RESNET) provides guidelines and definitions for defining the quality of insulation installation. RESNET has specified three grades for designating the quality of insulation installation; the grades range from Grade I (the best) to Grade III (the worst). The RESNET definitions of Grade I, Grade II, and Grade III installation are provided below[25].

Grade I: "Grade I" shall be used to describe insulation that is generally installed per manufacturer's instructions and/or industry standards. A "Grade I" installation requires that the insulation material uniformly fills each cavity side-to-side and top-to-bottom, without substantial gaps or voids around obstructions (such as blocking or bridging), and is split, installed, and/or fitted tightly around wiring and other services in the cavity...To attain a rating of "Grade I", wall insulation shall be enclosed on all six sides, and shall be in substantial contact with the sheathing material on at least one side (interior or exterior) of the cavity…Occasional very small gaps are acceptable for "Grade I"… Compression or incomplete fill amounting to 2% or less, if the empty spaces are less than 30% of the intended fill thickness, are acceptable for "Grade I".

Grade II: "Grade II" shall be used to describe an installation with moderate to frequent installation defects: gaps around wiring, electrical outlets, plumbing and other intrusions; rounded edges or "shoulders"; or incomplete fill amounting to less than 10% of the area with 70% or more of the intended thickness (i.e., 30% compressed); or gaps and spaces running clear through the insulation amounting to no more than 2% of the total surface area covered by the insulation."

Grade III: "Grade III" shall be used to describe an installation with substantial gaps and voids, with missing insulation amounting to greater than 2% of the area, but less than 5% of the surface area is intended to occupy. More than 5% missing insulation shall be measured and modeled as separate, uninsulated surfaces…"

Below are examples of insulation installation and the corresponding grade applied by auditors. A brief description of the reasoning behind the grade designation is described for each example. Please note that these photographs were not all taken during the site visits for this study, and they are not meant to show the good and bad building practices observed during the site visits. Rather, these pictures are meant to provide visual examples of common insulation installation grades.

Figure 14 shows a conditioned attic with closed cell spray foam applied to the walls. This installation received a Grade I installation as the closed cell spray foam has little to no gaps, has no compression, and the cavity is enclosed on all six sides.[26] Grade I installs are typically reserved

[25] https://www.resnet.us/uploads/documents/conference/2012/pdfs/Cottrell-RESNET_Insulation_Grading_Criteria.pdf
[26] In the case of spray foam, a cavity may be open to the attic and still receive a Grade I installation because the spray foam itself is an air barrier.

for spray foam or blown insulation that can be applied in such a way to prevent any kind of air gaps or other imperfections that degrade insulating performance.

Figure 14: Grade I Closed Cell Spray Foam—Exterior Walls in Newly Constructed Home

Figure 15 shows a Grade II install of un-faced fiberglass batts in a conditioned basement.[27] The insulation has gaps in the corners of certain bays and there is some compression—though minor compression overall. The insulation is enclosed on all six sides (in most places), warranting a Grade II designation.

Figure 15: Grade II Fiberglass Batts—Basement Walls in Newly Constructed Home

Figure 16 shows R-21 fiberglass batts in a 2x4 wall cavity. This installation automatically receives a Grade III designation because the insulation is not enclosed on the vented attic side. Per the

[27] The basement in this case was considered conditioned volume, not conditioned floor area.

RESNET standards on Grade III installation, “This designation shall include wall insulation that is not in substantial contact with the sheathing on at least one side of the cavity, or wall insulation in a wall that is open (unsheathed) on one side and exposed to the exterior, ambient conditions or a vented attic or crawlspace.”

Figure 16: Grade III Fiberglass Batts—Attic Kneewalls in Newly Constructed Home

Figure 17 shows a Grade II installation of fiberglass batts in a frame floor cavity. While the insulation has a fair amount of compression the gaps are minimal. The primary reason for the Grade II designation is that the fiberglass batts are in consistent contact with the subfloor, eliminating the presence of air gaps that degrade the insulating properties of the batts. This example shows an installation that is right on the boundary of Grade II and Grade III installation.

Figure 17: Grade II Fiberglass Batts—Frame Floor in Newly Constructed Home

Figure 18 shows frame floor insulation receiving a Grade III designation. The insulation has gaps, as well as a mix of compression and sagging over its area. The sagging insulation creates an air gap between the insulation and the subfloor, which diminishes the insulating characteristics of the fiberglass batts.

Figure 18: Grade III Fiberglass Batts—Frame Floor in Newly Constructed Home