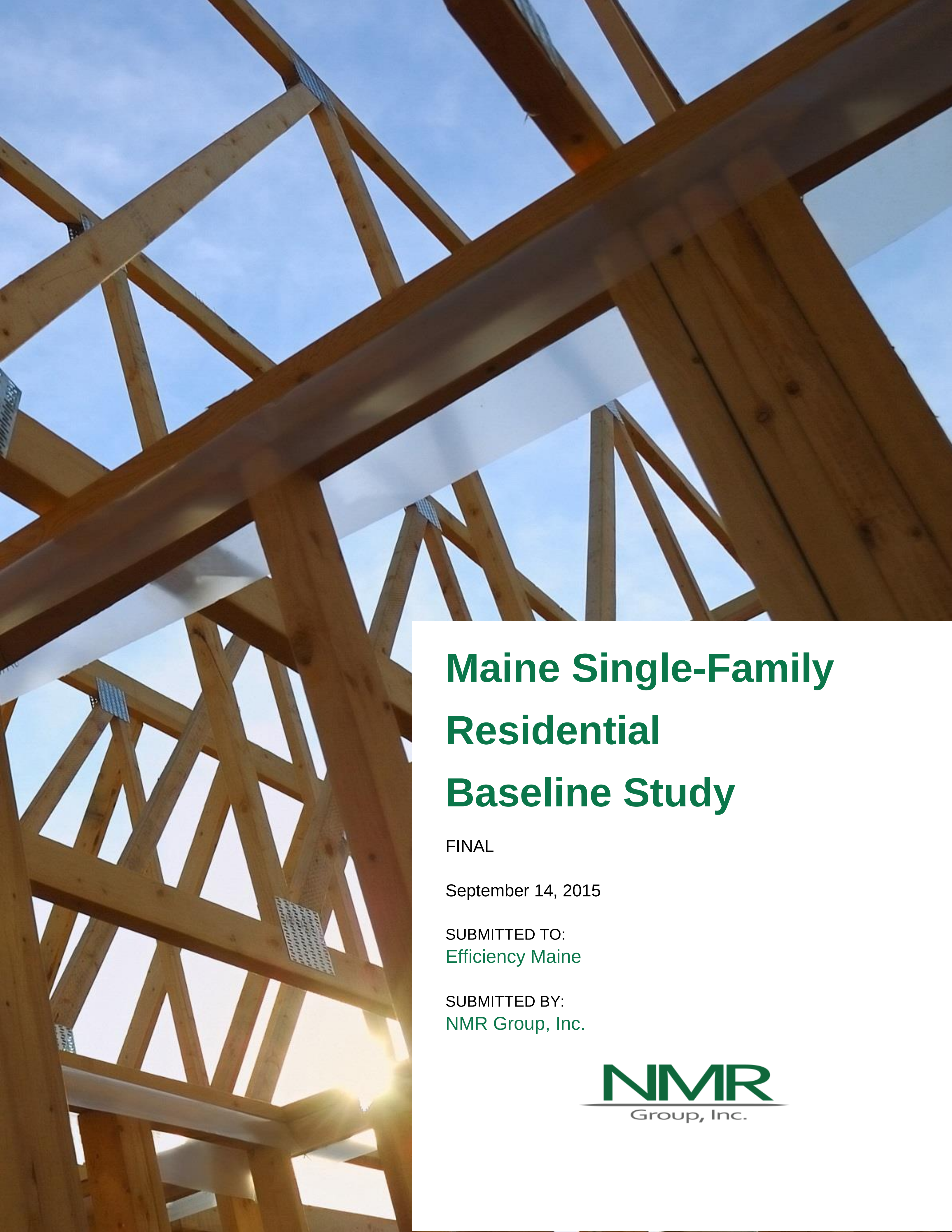


Maine Single-Family Residential Baseline Study

FINAL

September 14, 2015

SUBMITTED TO:
Efficiency Maine

SUBMITTED BY:
NMR Group, Inc.

Table of Contents

Figures

Tables

ES

Executive Summary

This report presents the findings from the Maine Single-Family Residential Baseline study. The objective of the study was to develop a representative baseline for single-family homes in the state of Maine. This analysis is based on 41 on-site audits of single-family homes throughout Maine, which NMR Group conducted between April and June of 2015. The study also included a telephone survey of 164 homeowners, analysis of Census Bureau data, and a review of other recent baseline studies.

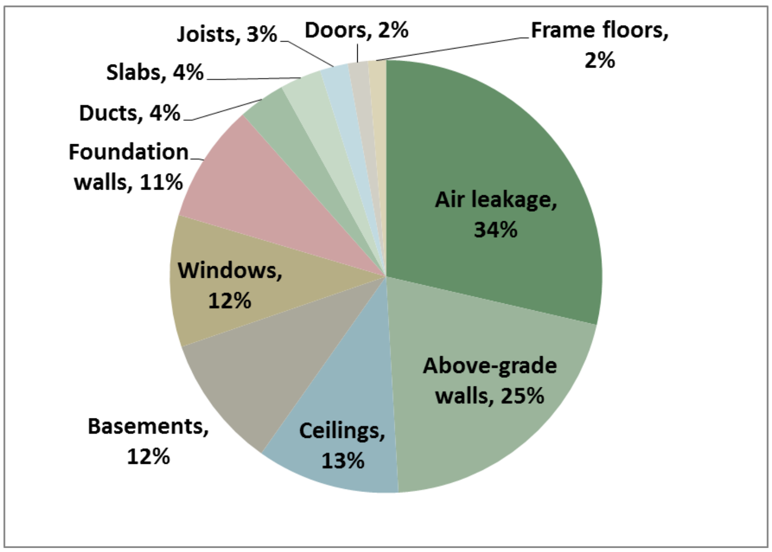
Key Findings

This section presents the key findings of the baseline assessment.

Areas of Greatest Heat Loss

- **Air leakage is the single greatest source of heat loss in Maine single-family homes.** Air infiltration through the home's thermal boundary accounts for over one-third (34%) of heat loss on average (Figure 1).
- **Above-grade walls account for substantial heat loss, more than ceilings.** Walls account for about 25% of all heat loss, while ceilings account for about 13%.
- **Basement components account for more than one quarter of all heat loss.** Basements, foundation walls, slab floors, and frame floors together account for about 28% of all heat loss.

Figure 1: Areas of Heat Loss



Air Leakage & Building Shell

- **The average air leakage rate in Maine is higher than in similar homes in nearby states.** Maine single-family homes have an average leakage rate of 11.2 ACH50, higher than the 10.4 figure for similar homes in Connecticut (measured in 2012) and the 7.6 figure for similar homes in Vermont (measured in 2011).
- **Exterior walls and vaulted ceilings are relatively well-insulated.** While walls represent a substantial source of heat loss, they appear to be relatively well insulated. The average insulation R-values for exterior walls and vaulted ceilings are R-13 and R-21 respectively, corresponding to roughly 4” and 7” of fiberglass batt insulation. The most common framing depths by area for these shell components are 4” and 6” respectively.
- **Open attics, frame floors, and foundation walls show potential for more insulation.** The average insulation R-value for open attics is R-29, and insulation in this shell component is not constrained by framing depth; attics in many homes could conceivably be insulated to the current code level of R-49. Floors over unconditioned basements have an average insulation R-value of R-3 and foundation walls in conditioned basements have an average of R-5, indicating an opportunity to reduce the heat loss from basements.
- **Most windows are double-pane, and most single-pane windows have storm windows installed.** Nearly 80% of all window area in Maine is double-pane, and 21% is single-pane. Of the single-pane window area, 91% has a storm window installed.

Mechanical Equipment

- **Most central heating equipment is oil-fired, but about one-sixth of those homes use another fuel source in lieu of oil.** Among the boilers and furnaces present in the study homes, 90% of units are oil-fired; 69% are oil boilers and 21% are oil furnaces. However, a smaller number of study homes—72%—identify oil as their sole primary heating fuel. Census data indicates that 72% of homes in Maine use fuel oil or kerosene as their primary heating fuel.
- **Central heating equipment has an average AFUE consistent with the current federal standard for oil boilers.** The boilers and furnaces have an average efficiency of about 83 AFUE, whereas the current federal standard for oil boilers is 82 AFUE for steam boilers and 84 AFUE for hot water boilers.
- **Supplemental heating equipment represents nearly one quarter of total installed capacity in the homes where it is present.** Stoves, fireplaces, space heaters, electric baseboard, and ductless mini-splits collectively represent 26% of installed heating capacity on average in the homes where they are present.
- **Most domestic water heating is oil-fired or electric.** Oil-fired models account for well over one-half of all water heaters (60%), split about evenly between indirect storage systems (32%) and tankless coil systems (28%). Electric models account for 30% of water heating systems.

Appliances & Lighting

- **Refrigerators in Maine use over 25% more energy annually on average than comparable ENERGY STAR models.** The average refrigerator efficiency in Maine is 588 kWh/year, while the parallel average ENERGY STAR efficiency is ≤472 kWh/year. However, 26% of refrigerators found on-site meet current ENERGY STAR standards.
- **Clothes washers meet ENERGY STAR criteria more often than other appliances.** Of the units for which efficiency information could be located, an estimated 32% of clothes washers, 18% of dishwashers, and 4% of clothes dryers in Maine meet current ENERGY STAR criteria.
- **Incandescents are still the most prevalent type of bulb.** Incandescents are installed in nearly half (46%) of all filled sockets found on-site. Together, CFLs (28%) and LEDs (9%) account for 37% of bulbs.

Other Findings

- **The most efficient homes are larger and newer than other homes.** The 20% of sampled homes categorized as 'most efficient'[1] have an average conditioned floor area of 3,349 ft^2 and an average age of 27 years, compared to an average of about 1,887 ft^2 and about 75 years among the remaining homes.
- **During the heating season, about one half of thermostats are maintained at a constant temperature for both day and night.** This may be related to the fact that 61% of thermostats found in the study homes are manually operated. There is a two-degree difference in the average daytime (66^o) and nighttime (64^o) heating season set points, however these averages capture vastly different occupant behaviors.
- **Faucets and showerheads generally do not meet EPA low-flow guidelines.** The average flow rate for sink faucets is 1.9 gpm compared to the EPA low-flow criteria of 1.5 gpm. Similarly, the average flow rate for showerheads is 2.5 gpm compared to the EPA low-flow criteria of 2.0 gpm.

[1] Measured in annual heating consumption in BTU per square foot of conditioned floor area.

2 Methodology

In order to develop a representative baseline of single-family homes in Maine, NMR conducted 164 telephone surveys and 41 on-site inspections of single-family homes. This section describes the methodology utilized to collect and analyze this data.

Telephone Survey

NMR Group conducted 164 computer-assisted telephone interview (CATI) surveys with occupants of single-family homes throughout Maine during April of 2015. Occupants of single-family attached, single-family detached, and mobile homes were included in the survey. Occupants of all other homes, including multi-family buildings, were screened out. The objectives of the survey were to:

- Assess awareness of, experience with, and interest in Efficiency Maine programs
- Assess key physical characteristics of the home, including house type, primary heating fuel, and vintage
- Identify occupant demographics, education history, and income status
- Identify geographic location
- Recruit for the on-site inspections

The survey utilized a dual sample frame of a random digit dial sample of landlines supplemented by a cell phone sample. Recent data indicate that about 31% of Maine households only use cell phones; therefore 51 of the 164 surveys (31%) were completed from the cell phone sample.

On-Site Data Collection and Analysis

This section describes the sampling, data collection, energy modeling, weighting, and analysis undertaken for the on-site effort.

In order to encourage respondents from the telephone survey to volunteer for the on-site visits, they were offered $100 at the time of the visit and later mailed an energy efficiency report that could be used as the assessment for eligible air sealing or insulation projects under the Home Energy Savings Program.

On-Site Sampling

NMR reviewed data for Maine from the U.S. Census Bureau to develop sampling targets based on house type and age. These two criteria were selected because it was expected that house type and age may be the two characteristics with the most substantial impact on energy usage.

The overall sample size of 41 sites achieves 10% relative precision at an 80% confidence level, with a coefficient of variation of 0.5 calculated based on annual heating consumption.

Table 1 describes the study's sampling plan and achieved sample. Older homes are slightly overrepresented in the final sample; a weight was applied during analysis to correct for this oversampling, as discussed later in this section.

Table 1: Sampling Plan

Segment	Maine Population Estimate per Census		Sample Size			
			Targeted		Achieved	
All single-family homes	583,483	100%	41	100%	41	100%
Single-family detached homes	*503,153*	*86%*	*35*	*85%*	*37*	*90%*
Single-family attached homes	*16,402*	*3%*	*1*	*2%*	*0*	*--*
Mobile homes	*63,928*	*11%*	*5*	*12%*	*4*	*10%*
1939 or earlier	*131,630*	*23%*	*9*	*22%*	*12*	*29%*
1940 to 1969	*119,176*	*20%*	*9*	*22%*	*10*	*24%*
1970 to 1989	*175,673*	*30%*	*12*	*29%*	*9*	*22%*
1990 or later	*155,414*	*27%*	*11*	*27%*	*10*	*24%*

While this sampling plan did not target homes on the basis of income level, NMR approached on-site recruitment cognizant of the sample bias that may result from under-sampling low-income homes, which are often challenging to recruit for studies. Based on Census data, approximately 18% of all single-family households in Maine are low-income. The final sample of 39 homes is 18% low-income.[2]

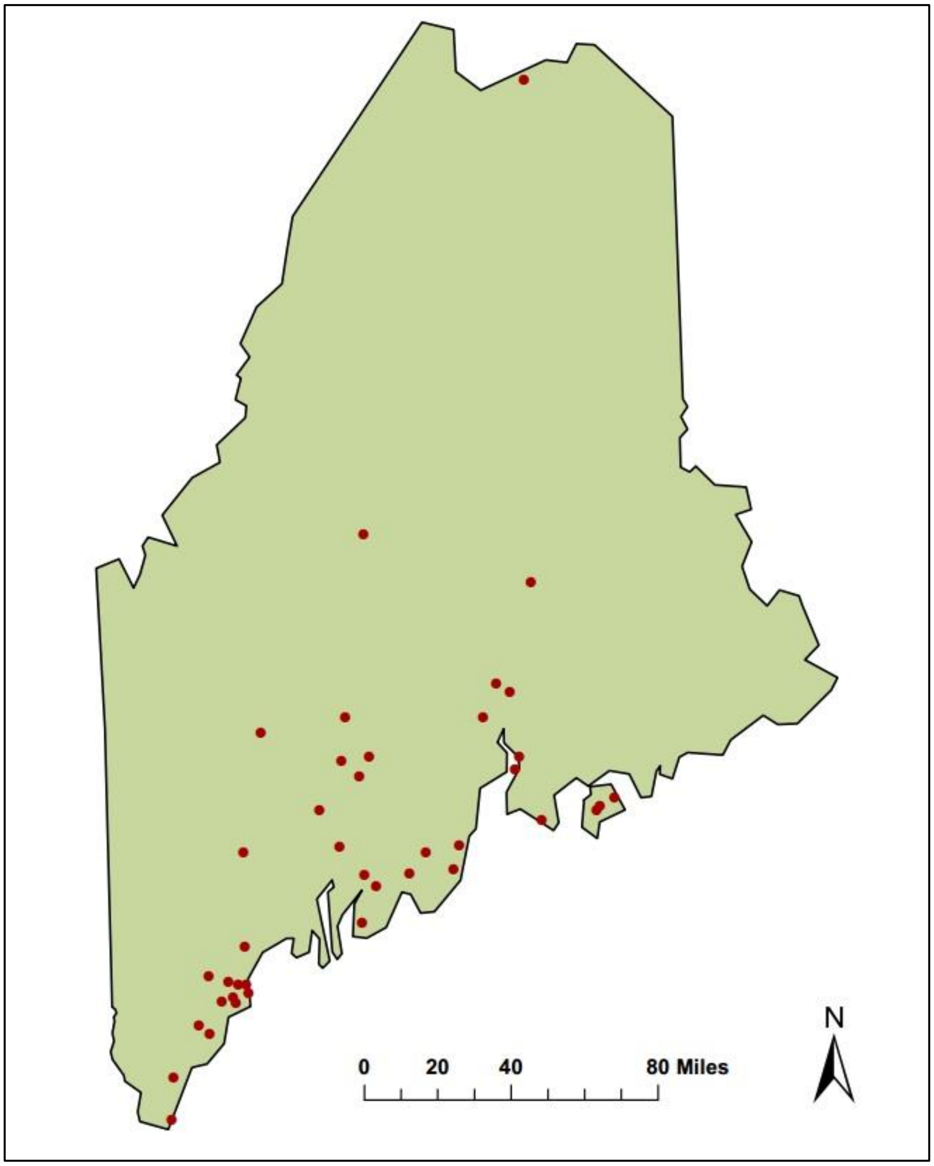
Additionally, Efficiency Maine screened the addresses of the on-site volunteers to identify past program participants in order to ensure that the on-sites accurately reflected the estimated proportion of homes that have participated in an Efficiency Maine residential program—in particular, the Home Energy Savings Program. In the final sample, one home out of the 41 had participated in the Efficiency Maine Home Energy Savings Program (2%), which is similar to the estimated participation rate of about 3% for the entire population.

Because we were unable to recruit a sufficient number of mobile homes for on-site visits from the pool of survey volunteers, three of the four mobile homes were recruited outside of the telephone survey using contacts from Efficiency Maine staff.

[2] This percentage is in reference to a total sample size of 39; income information is unknown for two of the mobile homes in the sample.

Figure 2 displays the locations of the 41 on-site visits conducted for this study.

Figure 2: Map of On-site Homes



On-Site Data Collection

The 41 on-site inspections conducted for this study took an average of about three hours each to complete. NMR auditors collected detailed data about all energy-related aspects of the homes, including:

- **Household characteristics** such as occupancy and square footage;
- **Building envelope characteristics** such as insulation type and R-value, air infiltration rates, and window material;

- **Heating and cooling system characteristics**, including type, make, model, fuel, rated output capacity, and efficiency;
- **Water heating system characteristics**, including type, tank volume, fuel, nameplate efficiency, and presence and flow rate of low-flow showerheads and faucet aerators;
- **Duct system characteristics**, including material, location, and insulation level;
- **Supplemental heating** count and fuel type, including wood stoves, fireplaces, portable space heaters, and heated mattress pads or blankets;
- Presence of a swimming pool or hot tub;
- Presence and size of solar photovoltaic systems or wind turbines.

Homes were visited between April and June of 2015. Upon the completion of the on-site inspections, NMR staff thoroughly reviewed each data collection form for reasonableness and consistency.

Basement Classification

Whether a home's basement is considered conditioned or unconditioned can substantially influence an auditor's assessment of the home's overall efficiency. The decision to include a basement or crawlspace within the home's thermal envelope can depend on a variety of factors, including (but not limited to):

- Whether the basement is finished;
- Whether there are duct vents, radiators, or baseboard present, indicating that the space is *intentionally* heated;
- Whether the basement is *unintentionally* heated to a substantial degree;
- If insulation is present, where it is located;
- How the homeowners themselves describe the space.

If the basement is finished and intentionally heated, this indicates that the homeowner considers it part of the home's living space, which would in turn suggest to an auditor that the home's thermal boundary should be set at the foundation walls and slab instead of the frame floor. Conversely, if the basement is unfinished and there is insulation in the frame floor cavities, this would be a strong indication that the home's thermal boundary lies at the frame floor.

In existing homes, however, the decision of how to classify a home's basement is rarely simple; there may be as many basement classifications as there are homes. For this study, NMR auditors assumed that if no insulation is present in the basement, the space is unfinished, and there is no intentional heating—a common basement configuration in existing homes—that basement is unconditioned. In such a space, unintentional space heating resulting from a heating system's operating or standby losses is regarded as heat loss taking place outside the home's thermal envelope, rather than as useful heat. The REM/Rate home energy modeling software which NMR used to assess areas of greatest heat loss, heating load, heating design load, and heating consumption take into account the location of heating equipment in modeling a home's energy efficiency.

REM/Rate Energy Modeling

NMR used REM/Rate[3] home energy rating software to model energy use for the 41 homes where on-sites were conducted. REM/Rate models assessed the following items:

- Annual energy consumption;
- Annual loads (in MMBtu/year) and design loads (in kBTU/h);
- Energy loss by component (e.g. walls, ceilings, air infiltration).

All homes in the sample were modeled exactly as they were found during on-site inspections,[4] with the exception of duct leakage inputs, which were assigned default values because duct leakage diagnostic tests were not performed during the inspections. Nine of the 41 homes in the sample have ducts.

On-Site Weighting

Analysis of energy usage data from the REM/Rate models showed that the difference in energy use intensity between older and newer homes—measured in BTU per square foot of conditioned floor area—is statistically significant. Additionally, older homes are overrepresented in the on-site sample, as illustrated in Table 1. For that reason, NMR applied weights based on home age in order to develop a representative baseline of the housing stock in Maine. Table 2 details the overall weights used in the analysis.

Table 2: Overall On-Site Weights

Weighting category	On-Sites		Population		Proportional Weight
	Count	Percent	Count	Percent	
Homes built before 1970	22	54%	250,806	43%	0.80
Homes built in 1970 or later	19	46%	331,087	57%	1.23
Overall	*41*	*100%*	*581,893*	*100%*	--

For parts of the analysis where either of the two weighting categories contained less than five sites, no weight was applied.

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[3] REM/Rate is residential energy analysis software that is commonly used to model the performance of residential buildings. The software is most notably used by the ENERGY STAR®™ Homes program, though not exclusively.
[4] For homes with multiple heating and/or cooling systems the NMR auditors used discussions with homeowners to assign a proportion of the load to each piece of equipment based on self-reported occupant behavior. These proportions are reflected in the REM/Rate models.

Analysis Splits

In order to illustrate the differences between homes with differing levels of energy efficiency, the analysis presents most results (where sample sizes are sufficient) for three energy efficiency categories, based on energy use intensities measured in annual heating consumption per square foot of floor area (BTU/ft^2):

- **Least efficient:** the 20% of homes (n=8) with the highest BTU/ft^2
- **Middle efficiency:** the 60% of homes (n=25, includes all four mobile homes) with middle BTU/ft^2
- **Most efficient:** the 20% of homes (n=8) with the lowest BTU/ft^2

3 General Home Characteristics

This section presents information on the general characteristics of the on-site homes and occupants.

Table 3 details the square footage of heated space, or conditioned floor area (CFA), of single-family homes in Maine. The statewide average size for homes in the baseline study is 2,245 ft^2. On average, the most efficient study homes are also the largest homes in terms of CFA. While these homes average 3,349 ft^2, homes in the middle and least efficient categories both average less than 2,000 ft^2. This can be partially explained by the fact that the ratio of building shell area to CFA is typically less for larger homes, which provides an advantage in calculating BTU/ft^2.

Table 3: Conditioned Floor Area

(Base: all homes)

Category	Efficiency Level in Heating BTU/ft^2/year[a]			Overall[b]
	Most Efficient	Middle Efficiency	Least Efficient	
N	*8*	*25*	*8*	*41*
Average	3,349	1,970	1,629	2,245
Median	3,035	1,840	1,739	1,998
Minimum	2,464	884	748	748
Maximum	5,292	4,504	2,256	5,292

[a] Unweighted
[b] Weighted

Maine homes are 58 years old on average, which corresponds to a 1957 year of construction (Table 4). The most efficient homes are much younger on average at 27 years (1988 year of construction) than the least efficient homes, which are over a century old on average (1898 year of construction). Homeowners' occupancy tenures are about 20 years on average.

Table 4: Home Age and Occupancy

(Base: all homes)

Category	Efficiency Level in Heating BTU/ft²/year[a]			Overall[b]
	Most Efficient	Middle Efficiency	Least Efficient	
N	*8*	*25*	*8*	*41*
Average age of home in years	27	61	117	58
Average occupancy tenure (years)	18	20	26	20

[a] Unweighted
[b] Weighted

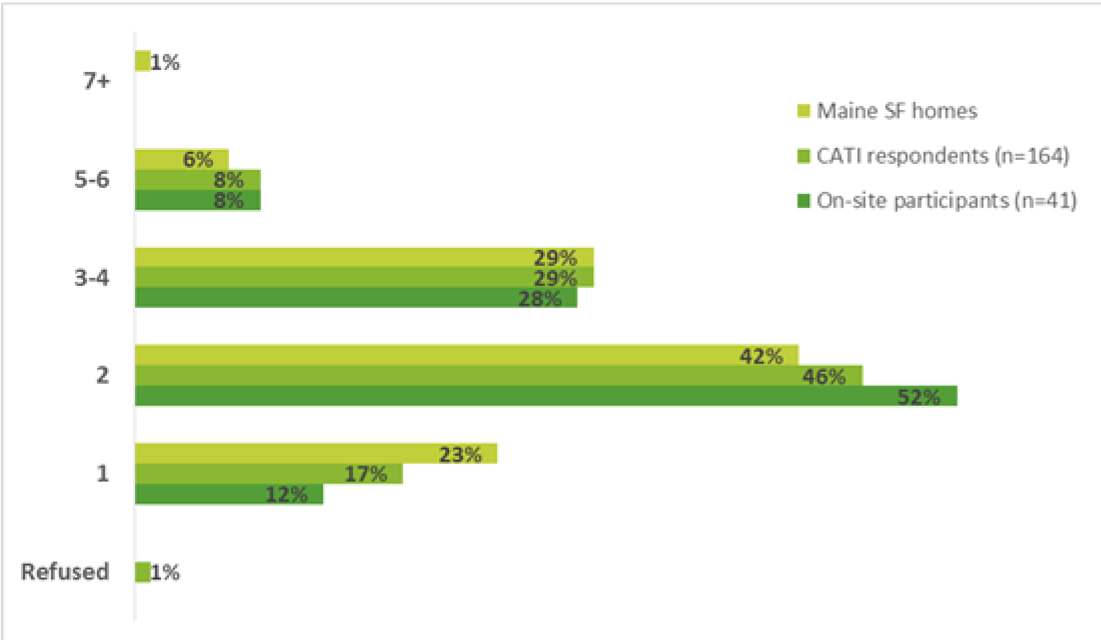
Figure 3 shows three examples of homes where NMR conducted energy audits.

Figure 3: Examples of Homes Visited

Auditors inspected homes for the presence of asbestos, mold, and vermiculite. These are extremely hazardous substances when airborne, and therefore preclude diagnostic tests—such as blower door tests—that rapidly circulate air in the home. Two of the study homes were found with vermiculite, and one of those was also found with asbestos and mold.

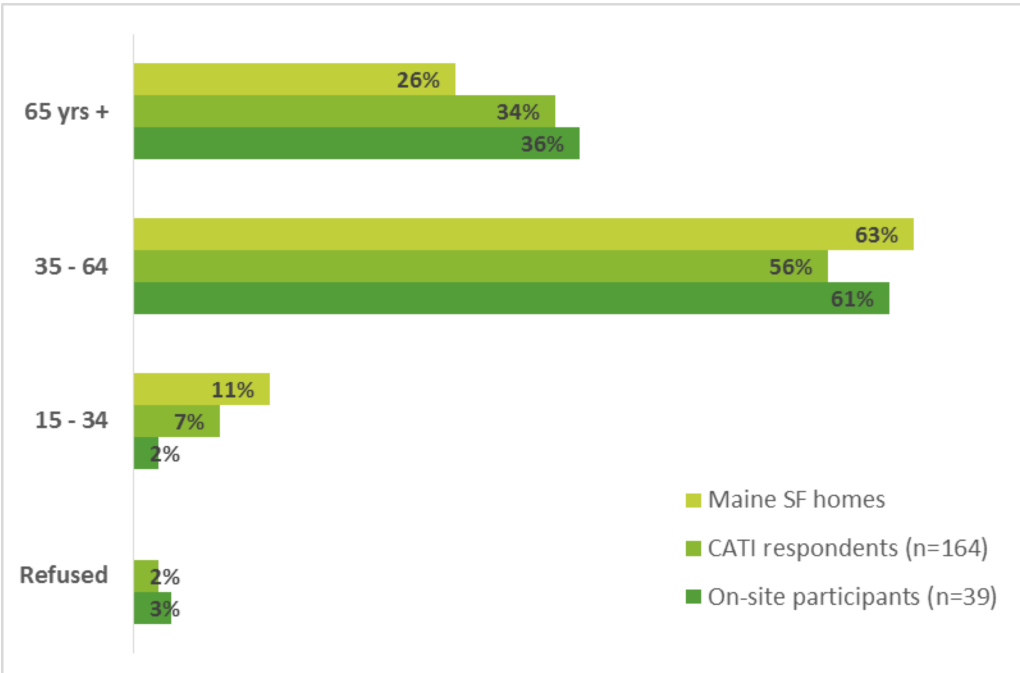
The proportion of on-site participants and telephone survey respondents that reside in three- or four-person households is similar to all single-family residents across Maine per the Census (Figure 4). On-site participants included fewer one-person households and more two-person households than both the Census and the telephone survey.

Figure 4: Household Size



Over one-half of on-site participants (61%) and telephone survey respondents (56%) are between the ages of 35 and 64, similar to the 63% figure for all single-family residents in Maine.[5] Figure 5 shows that on-site participants and survey respondents tend to be slightly older than all single-family residents in Maine, likely because the survey asked to speak with the person who is most knowledgeable about the home's characteristics and heating systems – typically the owner.

Figure 5: Respondent Age



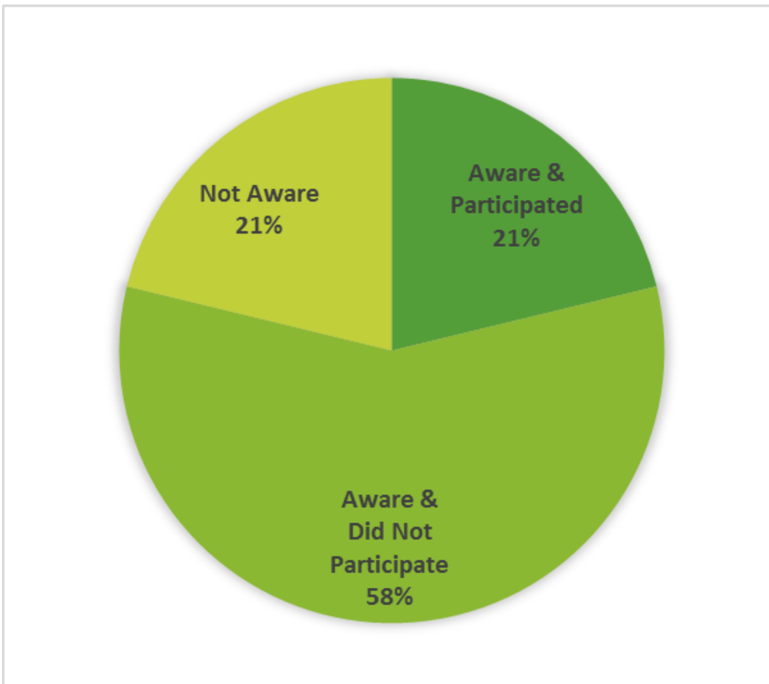
[5] Census data on the age of single-family householders excludes mobile homes. In this chart, Maine SF Homes includes only single-family detached and single-family attached householders.

EFFICIENCY MAINE

Nearly four out of five survey respondents (79%) had heard of Efficiency Maine (Figure 6). Respondents most often heard of Efficiency Maine through TV (39%), newspapers (29%), radio (12%), and online (10%).

Respondents who were aware of Efficiency Maine were asked to describe what the organization does. The most common response was that Efficiency Maine promotes energy efficiency (36%), followed by saves energy (18%), offers rebates for making homes more energy efficient (12%) and provides information/education about energy efficiency (11%). However, 16% of the aware respondents did not know what Efficiency Maine does.

Figure 6: Familiarity with Efficiency Maine



Over one-third (35%) of all respondents were unable to name or describe any Efficiency Maine programs. The Home Energy Savings program was the most commonly recognized program (30%), followed by the Retail Lighting program (12%), the Heat Pump Water Heater program (7%), and the Appliance Rebate program (6%).

Twenty-one percent of survey respondents reported participating in an Efficiency Maine program or receiving rebates for energy-efficiency equipment from Efficiency Maine (Figure 6). These respondents were most likely to have reported participating in the Appliance Rebate program (7%), followed by the Home Energy Savings program (5%), the Retail Lighting program (4%) and the Heat Pump Water Heater program (4%).

THERMOSTATS

The majority of the 41 sampled homes (61%) use only manual thermostats, while 39% use programmable thermostats; no home has both types present. The vast majority of homes have only one thermostat installed (86%); this is similar across efficiency categories. These thermostats are almost entirely for heating systems only. Just two homes have permanently installed cooling systems—central air split systems or ductless mini-splits—that operate via thermostats.

Table 5: Number and Type of Thermostats

(Base: all homes)

	Efficiency Level in Heating BTU/ft^2/year[a]			Overall[b]
	Most Efficient	Middle Efficiency	Least Efficient	
N	8	25	8	41
Types of thermostat				
Manual only	50%	64%	75%	61%
Programmable only	50%	36%	25%	39%
Number of thermostats				
One	88%	88%	88%	86%
Two	13%	8%	13%	11%
Three	0%	0%	0%	0%
Four	0%	4%	0%	3%

[a] Unweighted
[b] Weighted

Set Points

Auditors recorded the temperature set points for heating and cooling equipment in the study homes in order to better understand occupant behavior.

Across the 46 thermostats[6] in use for heating systems, about one-half (51%) are kept at a constant temperature during the day and night during the heating season.[7]

The average occupant-reported daytime set point is 66 degrees Fahrenheit, compared to 64 degrees at night. However, this average set back value includes vastly different occupant behaviors. For instance, on one end of the spectrum, a homeowner set their thermostat 15 degrees higher at night (from 50 to 65 degrees), while on the opposite end, another homeowner lowered the temperature at night by 10 degrees (from 70 to 60).

Table 6: Winter Thermostat Set Points

(Base: thermostats used for heating, degrees Fahrenheit)

	Efficiency Level in Heating BTU/ft^2/year[a]						Overall[b]	
	Most Efficient		Middle Efficiency		Least Efficient			
N	*9*		*29*		*8*		*46*	
Time of day	Day	Night	Day	Night	Day	Night	Day	Night
Average	64	63	69	65	66	62	66	64
Minimum	55	57	50	50	63	58	50	50
Maximum	68	68	72	72	68	68	72	72

[a] Unweighted
[b] Weighted

[6] There are two additional thermostats in the sampled homes, but they control supplemental heating systems that the owners do not use.
[7] This is a weighted percentage and represents 22 out of the 46 heating thermostats in sampled homes.

Only eight of the 21 total air conditioning systems have specific temperature set points, including room air conditioners with digital temperature controls. Six of those systems (77%[8]) are kept at a constant temperature day and night. One is lowered by four degrees at night, and one is only used at night.

Across the eight cooling systems with temperature set points, the average occupant-reported set points are 75 degrees Fahrenheit during the day and 73 degrees at night.

Table 7: Summer Thermostat Set Points[a]

(Base: thermostats used for cooling, degrees Fahrenheit)

	Efficiency Level in Heating BTU/ft²/year[b]						Overall[c]	
	Most Efficient		Middle Efficiency		Least Efficient			
N	*2*		*7*		*1*		*10*	
Time of day	Day	Night	Day	Night	Day	Night	Day	Night
Average	72	70	75	74	75	75	75	73
Minimum	72	68	70	70	75	75	70	68
Maximum	72	72	80	76	75	75	80	76

[a] Average set points include room air conditioners with digital temperature controls.
[b] Uneighted
[c] Weighted

[8] Percentage is weighted to account for oversampling of older homes.

4 Whole-House Efficiency, Consumption, and Loads

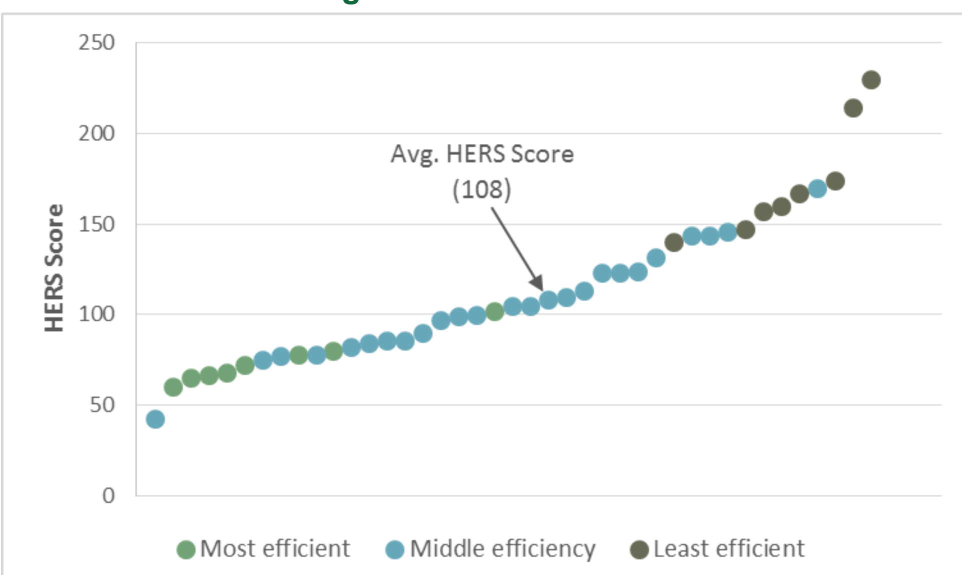
This section provides information on heating and cooling loads and energy consumption by end use in single-family homes in Maine. It also details which building components are most responsible for heating and cooling losses in the inspected homes. Annual loads and consumption were assessed at the home level using REM/Rate home energy rating software.

HERS Score

The REM/Rate energy modeling software rates a home's level of energy efficiency using a Home Energy Rating System (HERS) score[9], which compares the home's efficiency to that of a reference home meeting the 2004 International Energy Conservation Code (IECC) energy code. A HERS score of 100 indicates that the home exactly meets the prescriptive requirements of the 2004 IECC code; a score greater than 100 indicates a less efficient home, and a score less than 100 indicates a more efficient home.

Figure 7 shows the HERS scores of the 41 on-site homes, which range from a low of 43 to a high of 230.

Figure 7: HERS Scores



9 http://www.resnet.us/energy-rating

The statewide average HERS score for single-family homes in Maine is 108 (Table 8). The most efficient 20% of homes have a substantially lower score of 74 on average. For context, the Massachusetts stretch energy code requires newly-built homes of less than 3,000 ft^2 to achieve a HERS score of 70, and homes 3,000 ft^2 or greater to achieve a score of 65. The eight most efficient homes in our sample approach this benchmark. However, the average HERS score of 174 among the eight least efficient homes indicates significant room for improvement for those homes.

Table 8: Average HERS Scores

(Base: all homes)

Efficiency Category	*Number of Homes*	Average HERS Score
Most efficient[a]	*8*	74
Middle efficiency[a]	*25*	106
Least efficient[a]	*8*	174
Overall[b]	*41*	*108*

[a] Unweighted
[b] Weighted

HEATING, COOLING, AND WATER HEATING CONSUMPTION

Table 9 shows annual MMBtu consumption for heating, cooling, and water heating. Unsurprisingly, the most efficient 20% of homes use the least energy for heating, while the least efficient 20% of homes use the most energy for heating. These least efficient homes also raise the statewide average heating consumption; homes in both the most efficient and middle efficiency categories use less energy for heating than average. Cooling represents a small proportion of energy consumption for the homes that possess air-conditioning equipment.

On average, homes in Maine use 114.3 MMBtu per year for heating. This is the equivalent of about 824 gallons of oil, 1,252 gallons of propane, or 1,115 ccf of natural gas.

Table 9: Average Annual Consumption by End Use in MMBtu/yr

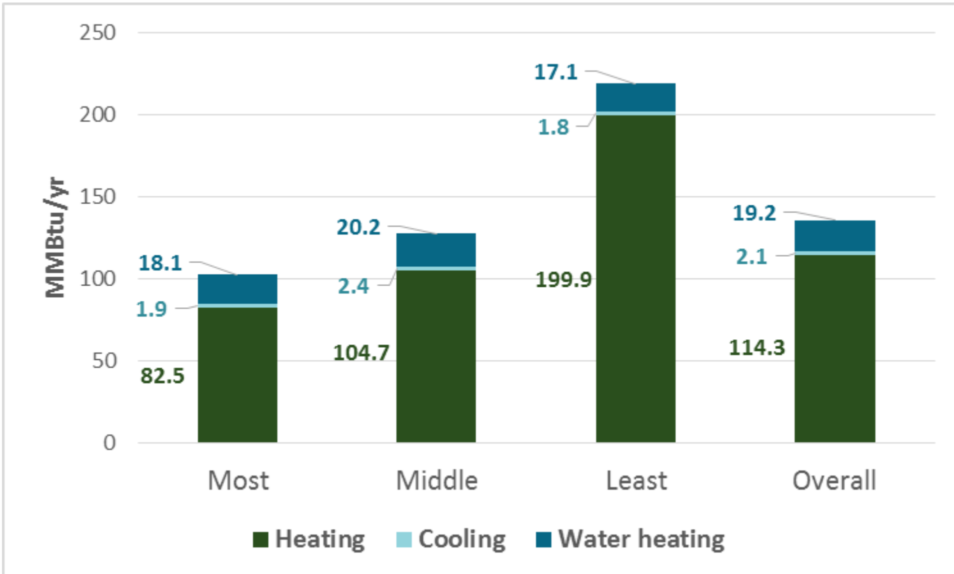
(Base: all homes)

End Use	*Number of Homes*	Efficiency Level in BTU/ft²/year[a]			Overall[b]
		Most Efficient	Middle Efficiency	Least Efficient	
Heating	*41*	82.5	104.7	199.9	114.3
Cooling	*13*	1.9	2.4	1.8	2.1
Water heating	*41*	18.1	20.2	17.1	19.2

[a] Unweighted
[b] Weighted

Figure 8 shows total annual energy consumption in MMBtu/yr by efficiency category and for the state overall. The primary difference in energy consumption is due to heating, as energy consumption for cooling and water heating is similar across all three efficiency categories.

Figure 8: Annual Consumption by Efficiency Category



HEATING AND COOLING LOADS

Table 10 details the average heating and cooling annual consumption, load, and design load for Maine single-family homes.

- **Consumption** describes the amount of energy that the home's heating and cooling equipment actually use over the course of a year. It is expressed in million BTUs per year (MMBtu/yr).
- **Load** describes the amount of energy that the home's heating and cooling equipment must provide to maintain a given temperature set point over the course of a year. It is expressed in MMBtu/yr. Load divided by consumption is equal to the system's efficiency.
- **Design load**—or sizing load—describes the amount of heating or cooling that the home's equipment must provide during the hottest or coldest hour of the year. It is expressed in thousand BTUs per hour (kBTU/h).

Table 10: Heating & Cooling Annual Consumption & Load[a]

(Base: all homes)

End Use	*N*	*Statistic*	Average Consumption (MMBtu/yr)	Average Load (MMBtu/yr)	Average Design Load (kBTU/h)
Heating	*41*	*Mean*	114.3	92.0	48.4
		Median	104.2	89.3	46.5
		Minimum	59.1	49.5	26.2
		Maximum	298.4	228.2	109.6
Cooling	*13*	*Mean*	2.1	6.4	17.0
		Median	1.9	5.8	17.8
		Minimum	0.8	3.7	11.4
		Maximum	3.9	11.2	21.3

[a] Weighted

The models[10] show that the average heating load of homes in Maine is 92.0 MMBtu/yr, with an average annual consumption of 114.3 MMBtu/yr. This suggests an average overall heating system efficiency of 80.5%, taking into account all heating equipment types.

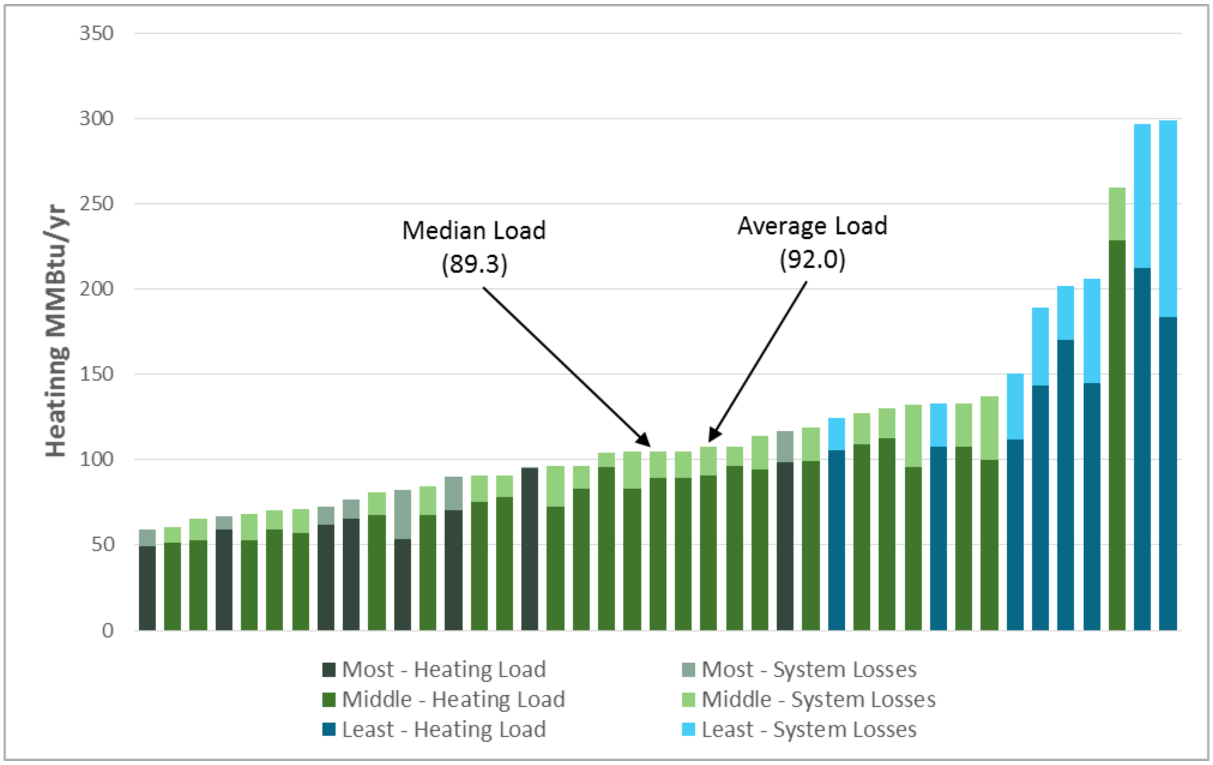
The modeling also shows that average design load for homes in Maine is about 48 kBTU/h. In other words, the optimal total rated output capacity of heating equipment in the average Maine home should be about 48 kBTU/h. The actual total rated output capacity in the sampled homes for central heating equipment is about 118 kBTU/h and for all heating equipment is about 145 kBTU/h, indicating that far more heating capacity than necessary is installed in the average home. For an average home, the capacity of central heating equipment is almost 2.5 times greater than the design load; including supplemental heating equipment increases the oversizing factor to about 3.0. This is due partially to oversized boilers and furnaces and partially to the preponderance of a variety of supplemental heating sources (i.e. electric baseboard, stoves, fireplaces, space heaters, and ductless mini-splits), at least one of which is present in 64% of homes and together account for an average of 26% of total heating capacity in homes where this supplemental equipment is present.[11]

[10] REM/Rate uses hundreds of complex, interrelated algorithms in calculating a home's annual consumption and loads. Variables accounted for in these algorithms include (but are not limited to) the percentage of total load accounted for by different pieces of equipment, the nameplate efficiency and rated output capacity of the equipment, the characteristics of building shell components, the efficiency of lighting and appliances, the size of the home, the location of the home, and the number of people living in the home.

[11] Percentages are weighted.

Figure 9 illustrates the range of heating loads and consumption in the sampled homes, organized by the study's three home efficiency categories—most efficient, mid-efficient, and least efficient. The entire bar represents the home's heating consumption in MMBtu/yr, with the darker portion representing load and the lighter portion representing heating system losses.[12] The weighted average and median heating loads are indicated with arrows.

Figure 9: Range of Heating Loads by Efficiency Category



Additionally, the models show that the average cooling load of homes in Maine where cooling equipment is present is 6.4 MMBtu/yr. This average reflects the cooling load only of the 13 homes where cooling equipment was found on-site. When sites with no cooling are included (i.e. sites with cooling loads equal to zero), the average cooling consumption and load are equal to 0.7 and 2.0 MMBtu/yr, respectively.

Central cooling systems were rare in the sample, with only one home out of 41 possessing a split-system central air conditioner. The remaining 12 sites with cooling equipment use either room air conditioners or ductless mini-splits, which in each case only serve part of the home. While the load reflects the amount of energy that cooling equipment would need to supply to keep the whole house at a given setpoint, the consumption describes the amount of energy that the smaller, partial-house equipment uses annually. Therefore, it would not be accurate to derive cooling system efficiency using these load and consumption figures.

[12] One bar in the "most efficient" category displays no system losses because the home uses entirely electric heating equipment, which is 100% efficient at the point of consumption.

Heating and Cooling Loss by Building Component

This section details the proportion of heating and cooling loads accounted for by various building components. Those components are:

- **The building envelope,** including above-grade walls, flat and vaulted ceilings, frame floors, rim and band joists, foundation walls, slab floors, basements and crawlspaces, windows, and doors.
- **Air leakage through the building envelope.**
- **Duct system leakage.** Duct blaster tests were not conducted during on-site inspections for this study; therefore, estimates of heating loss due to duct leakage are based on RESNET default leakage values.
- **Internal gains.** This refers to heat that is produced within the home by occupants, lighting, appliances and other plug loads, and processes such as cooking.
- **Mechanical ventilation.** This refers to fans that automatically and continuously exchange inside air with outside air. Bathroom fans are not included in this category because turning them on and off generally requires human intervention. Balanced ventilation such as that provided by heat recovery ventilators is included in this category.
- **Natural ventilation.** This refers to ventilation that occurs naturally without any ventilation equipment, for example from open windows in the summer.

Table 11 lists the average percentage of Maine homes' annual heating and cooling loss accounted for by various building components. The losses and gains presented in the table are from the perspective of the heating or cooling system, rather than the house. For this reason, internal heat gains—which translate into a lower load for heating systems—are expressed as negative losses.

Table 11: Heating & Cooling Loss by Building Component[a]

(Base: all homes)

Component	Percent of Loss	
	Heating	Cooling
Air leakage	34.2%	- 51.7%
Above-grade walls	24.5%	- 15.5%
Internal gains	- 19.6%	183.7%
Ceilings	12.8%	4.7%
Basements & crawlspaces	11.9%	- 15.5%
Windows	11.8%	100.6%
Foundation walls	10.6%	- 27.6%
Ducts	4.2%	--
Slabs	3.7%	- 15.7%
Joists	2.5%	- 4.5%
Doors	1.8%	- 2.6%
Frame floors	1.6%	- 1.2%
Mechanical ventilation	< 0.1%	- 0.1%
Natural ventilation	--	- 54.6%
Total percent of load	100%	100%
Total average load (MMBtu/yr)	92.0	6.4

[a] Weighted

Air leakage is the primary cause of heat loss in Maine homes, accounting for 34% of heating load on average. Walls and ceilings, which comprise most of nearly every home's thermal boundary, account for about 25% and 13% of load respectively. Together, air leakage, walls, and ceilings account for 72% of heat loss. Internal gains from lighting, appliances, and the presence of people reduce heating load in Maine homes by about 20% annually on average. Unconditioned basements and crawlspaces, windows, and foundation walls in conditioned space also each account for greater than 10% of a home's heat loss on average. Windows are responsible for some solar heat gain as well as loss.

Cooling load-by-component percentages are given as a negative number if the component stops heat from entering the house, and as a positive number if the component directly contributes warm air which must be cooled. Put another way, total cooling load is perhaps best understood as “negative heating” or “heat removal load.” Some components serve to add heat, and some components effectively subtract it; for this reason, expressed as percentages, some values in the cooling load-by-component analysis are greater than ±100% either by themselves or together with other component values. The cooling load-by-component values in Table 11 add up to 100%.

In the 13 homes in the sample with cooling equipment, internal gains generate heat during the cooling season that accounts for +184% of cooling load, the equivalent of 11.8 MMBtu of heat per year. Windows and ceilings also generate heat through solar heat gain which the cooling system must offset; this heat is equivalent to +101% and +4.7% of cooling load respectively, or 6.5 and 0.3 MMBtu/year. Air leakage through the building envelope and natural ventilation together account for the equivalent of more than -106% of annual cooling load, the equivalent of removing 6.8 MMBtu of heat from the house over the course of a year.

5 Building Envelope

This section describes the insulation and framing characteristics of building shell components as they were found on-site. All insulation R-values provided in this section take into account only the R-value of the cavity or continuous insulation itself, as opposed to the total R-value of the building shell components. While other shell component layers—e.g. exterior finish, gypsum board, or cladding—also provide some insulating value, the total collective R-value of these features is only about R-3 on average, and these shell component layers generally are not added or subtracted for insulating effect.[13]

The shell components discussed in this section include:

- Exterior walls
- Open attics
- Vaulted ceilings
- Exterior joists
- Floors over unheated basements
- Foundation walls in heated space

Calculating Average R-value

We calculated equivalent R-values for shell components using the following U-value Area (UA) equation:

$$Ravg = \frac{\left(\frac{1}{R1} * A1 + \frac{1}{R2} * A2 + \cdots \frac{1}{Rx} * Ax\right)}{A1 + A2 + \cdots Ax}$$

This approach is necessitated by the fact that while R-values can be added, they cannot be averaged without first converting them to U-values. Unlike simply taking the mean of all R-values observed for a given shell component in a given house, the UA equation takes into account the surface areas of components insulated to different levels and in this way corrects for the fact that heat transfer follows the path of least resistance.

For example, a house with walls that contain R-19 insulation in 75% of the area and R-11 insulation in 25% of the area would have an area-weighted average R-value of R-17, however the same assembly using the UA formula would have R-12 wall insulation, on average. The UA approach is standard practice in the building science industry when calculating average R-values.

[13] The REM/Rate assumptions for the collective R-value of all building shell component layers aside from insulation are R-3.0 for frame floors, R-4.3 for exterior walls, R-2.3 for flat attics, and R-3.6 for vaulted ceilings.

Building Shell Component Summary

Table 12 provides a summary of area-weighted insulation R-values and most common framing types for each shell component.

The average R-value of insulation in open attics is about R-29. Because the potential R-value of open attic insulation is not constrained by framing depth like that of other shell components, this average indicates an opportunity. The current Maine residential building energy code for newly constructed homes is equivalent to 2009 IECC; it requires R-49 ceiling insulation in both of Maine's climate zones. This difference between the average attic R-value in existing Maine homes and the current code is equivalent to about six inches of blown-in cellulose, which is technically achievable in most homes.

Table 12: Summary of Common Building Shell Component Characteristics

(Base: all homes)

Shell component	*Number of Homes*	Average Cavity + Continuous[14] Insulation R-value[a]	Most Common Framing Type by Area[a]
Exterior walls	*41*	R-13	2 x 4 x 16" o.c.
Open attics	*40*	R-29	2 x 6 x 16" o.c.
Exterior joists	*32*	R-12	2 x 8 x 16" o.c.
Frame floors over unheated basements	*24*	R-3	2 x 8 x 16" o.c.
Vaulted ceilings	*21*	R-21	2 x 6 x 16" o.c.
Foundation walls in heated space	*19*	R-5	No studs

[a] Weighted

[14] The "cavity and continuous" insulation R-value reflects only the insulation added to the building shell, and does not include the insulating value of the gypsum board, cladding, wood floor, etc. The term "continuous" refers to insulation that is present on either the inside or outside surface of the shell component and covers the entire surface of the component, including framing members. Continuous insulation helps to guard against thermal bridging, which occurs when studs conduct heat faster than the insulation in the cavities between them. Among the study homes, 6 have exterior walls, 26 have open attics, 2 have vaulted ceilings, 2 have floors over unheated basements, and 6 have foundation walls in heated space featuring continuous insulation. For every shell component except open attics, continuous insulation is most often polyisocyanurate or rigid foam. In open attics, it is generally blown-in cellulose or fiberglass that is deep enough to cover the studs.

DETAILED SHELL COMPONENT CHARACTERISTICS

This section includes more detailed information regarding the insulation R-values and framing types of common building shell components in Maine homes.

Exterior Walls

Figure 10 shows the range in exterior wall insulation R-value among the study homes. As the figure demonstrates, R-11 and R-19 are the most common single R-values because standard fiberglass batt insulation in a 2 x 4" wall cavity is usually rated R-11, and the same insulation in a 2 x 6" cavity is generally rated R-19. The red line shown at the R-20 level reflects the current code for newly constructed homes built in Maine (IECC 2009 Zone 6); note that existing homes with smaller sized framing (i.e. 2"x4") would be unable to meet this requirement using only cavity insulation.

Figure 10: Exterior Wall Insulation R-values (Cavity + Continuous)

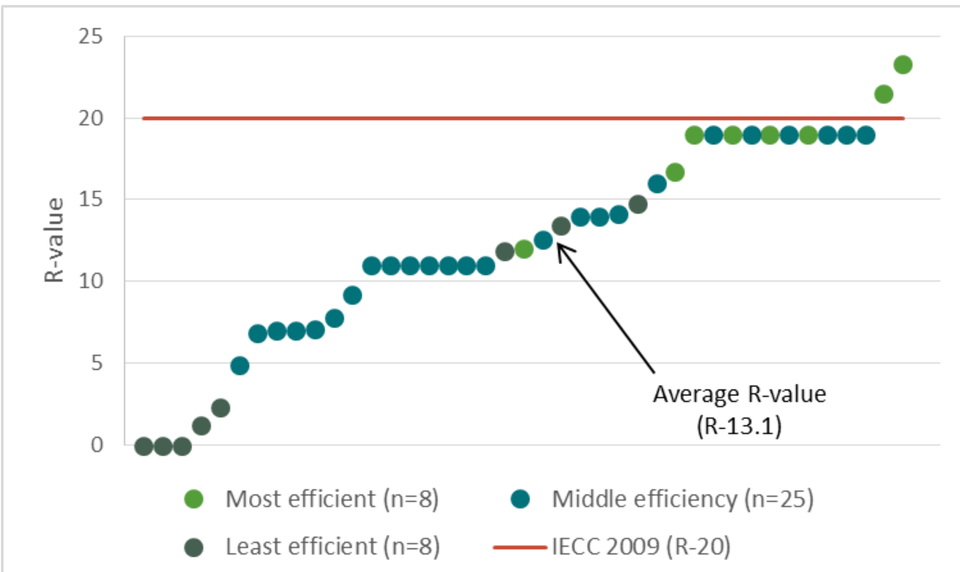


Table 13 provides more details regarding the characteristics of exterior walls. The most efficient 20% of homes in Maine have exterior walls containing more insulation (about an additional R-6) than the statewide average of R-13. Correspondingly, these efficient homes are more likely to feature 6” wall cavity depths, although 4”-deep wall cavities remain the most prevalent by area in all efficiency categories.

Table 13: Exterior Wall Detailed Characteristics

(Base: all homes)

Characteristic	Efficiency Level in BTU/ft²/year[a]			Overall[b]
	Most Efficient	Middle Efficiency	Least Efficient	
N	*8*	*25*	*8*	*41*
Average insulation R-value	R-19	R-13	R-6	R-13
Count of uninsulated homes	--	--	*3*	*3*
Construction by percent of wall area				
2 x 4 x 16” o.c.	59%	87%	74%	79%
2 x 6 x 16” o.c.	41%	10%	--	13%
2 x 4 x 24” o.c.	--	2%	26%	7%
2 x 8 x 16” o.c.	--	< 1%	--	< 1%

Ceilings

Auditors assessed the characteristics of two ceiling types on-site: open attics (or flat ceilings) and vaulted ceilings.

There is substantial variation in the R-value of insulation in open attics. This can be partially explained by the fact that open attic insulation is often not constrained by framing cavity depth like insulation in other shell components. For this reason, the average insulation R-value of R-29 in open attics (Figure 11) represents an opportunity. Current Maine energy code requires R-49 open attic insulation in new homes (see red line in chart), a level that would be technically possible in most attics in existing homes.

Figure 11: Open Attic Insulation R-values (Cavity + Continuous)

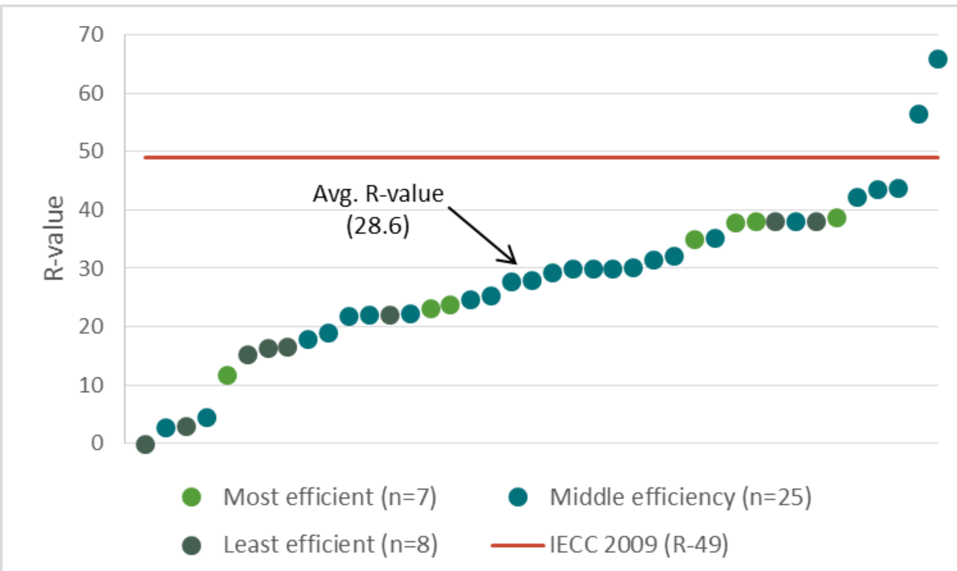


Table 14 provides more detailed characteristics of open attics in Maine. Open attics in the most efficient and middle efficiency homes are insulated to about the same level, but there is substantially less open attic insulation in the least efficient homes. The least efficient homes have an average of about R-19, which suggests that insulation in these homes is cavity-only, without added continuous insulation on top.

Table 14: Open Attic Detailed Characteristics

(Base: homes with open attics)

Characteristic	Efficiency Level in BTU/ft^2/year[a]			Overall[b]
	Most Efficient	Middle Efficiency	Least Efficient	
N	*7*	*25*	*8*	*40*
Average insulation R-value	R-30	R-30	R-19	R-29
Count of uninsulated homes	--	--	*1*	*1*
Construction by percent of ceiling area				
2 x 6 x 16” o.c.	18%	48%	50%	42%
2 x 8 x 16” o.c.	25%	14%	31%	18%
2 x 4 x 16” o.c.	15%	20%	--	17%
2 x 12 x 16” o.c.	--	7%	--	5%
2 x 10 x 16” o.c.	13%	2%	--	5%
2 x 6 x 24” o.c.	14%	2%	< 1%	4%
2 x 4 x 24” o.c.	15%	< 1%	--	4%
2 x 8 x 24” o.c.	--	2%	19%	3%
Other	< 1%	6%	< 1%	< 1%

[a] Unweighted
[b] Weighted

Insulation in vaulted ceilings, which is constrained by cavity depth, has an average R-value of R-21 in the 52% of homes with vaulted ceilings (Figure 12). Like open attic insulation, vaulted ceiling insulation R-values range substantially. The red line shown at the R-30 level reflects the current code for newly constructed homes built in Maine (IECC 2009 Zone 6); note that existing homes with smaller sized framing (i.e. 2”x6”) would be unable to meet this requirement using only cavity insulation.

Figure 12: Vaulted Ceiling Cavity Insulation R-values (Cavity + Continuous)

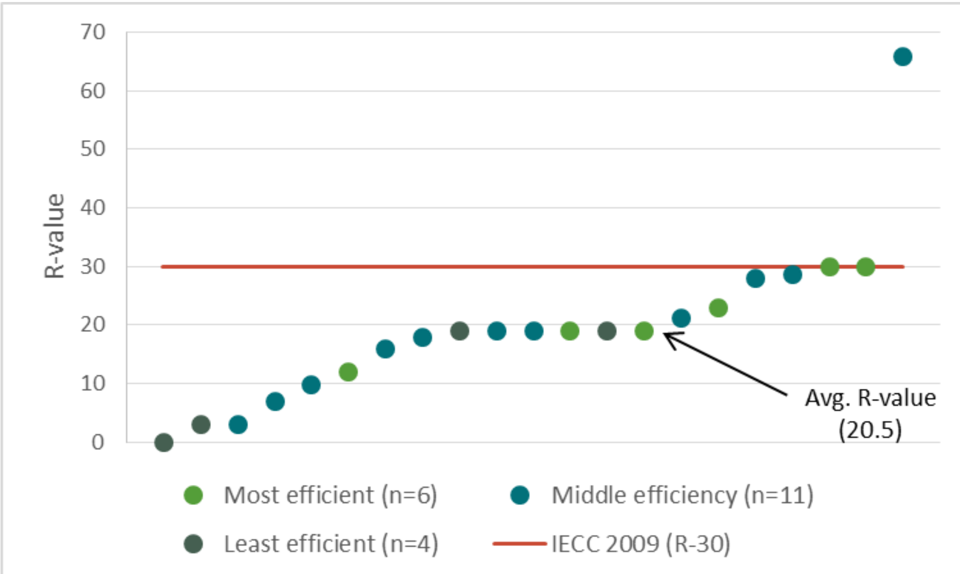


Table 15 provides detailed information regarding the characteristics of vaulted ceilings. Like open attic insulation, vaulted ceiling insulation levels are about the same in the most efficient and middle efficiency homes, while homes in the least efficient category have vaulted ceilings insulated to a lesser degree.

Cavity depths of 8” or 10” are most common in middle and most efficient homes respectively, while 6” cavity depths are most common in the least efficient homes. However, up to R-20 insulation can comfortably fit in a 6”-deep vaulted ceiling cavity, suggesting that this disparity in framing depth does not entirely explain the disparity in R-value.

Table 15: Vaulted Ceiling Detailed Characteristics

(Base: homes with vaulted ceilings)

Characteristic	Efficiency Level in BTU/ft^2/year[a]			Overall[b]
	Most Efficient	Middle Efficiency	Least Efficient	
N	*6*	*11*	*4*	*21*
Average insulation R-value	R-22	R-22	R-11	R-21
Count of uninsulated homes	--	--	*1*	*1*
Construction by percent of ceiling area				
2 x 6 x 16” o.c.	43%	33%	80%	46%
2 x 8 x 16” o.c.	6%	59%	--	26%
2 x 10 x 16” o.c.	51%	--	--	23%
2 x 6 x 24” o.c.	--	--	20%	--
Other	--	8%	--	2%

[a] Unweighted
[b] Weighted

Frame Floors over Unconditioned Basements

Figure 13 demonstrates the average R-values of floors over unconditioned basements in the 59% of homes that have these floors. As the figure demonstrates, the majority of floors over unconditioned basements are uninsulated. Because of this, insulation on these floors has a negligible average of about R-3.

It is very common for central heating equipment (i.e. boilers and furnaces) to be located in a home's basement. As Figure 13 shows, all but one of the unconditioned basements in the 24 homes contains heating equipment. This means that while these spaces may not be intentionally or even substantially heated, there is some residual heat produced by the heating system operation and standby losses present in these spaces. The red line shown at the R-30 level reflects the current code for newly constructed homes built in Maine (IECC 2009 Zone 6).

Figure 13: Floor Over Unconditioned Basement Insulation R-values (Cavity + Continuous)

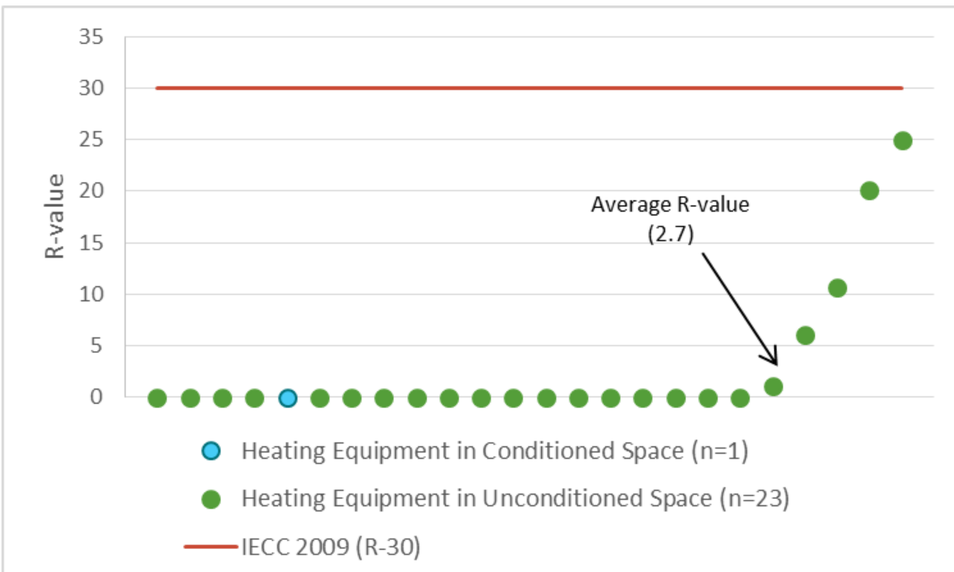


Table 16 provides more details about the characteristics of floors over unconditioned basements. These floors are most common in the middle efficiency category, where 15 of 25 homes have them (60%). However, 11 of those 15 basements (73%) are completely uninsulated. This represents an opportunity to insulate either frame floors or foundation walls in order to more clearly delineate the thermal boundaries.

Table 16: Floor Over Unconditioned Basement Detailed Characteristics

(Base: homes with unconditioned basements)

Characteristic	Efficiency Level in BTU/ft²/year[a]			Overall[b]
	Most Efficient	Middle Efficiency	Least Efficient	
N	*2*	*15*	*7*	*24*
Average insulation R-value	R-4	R-5	R-0	R-3
Count of uninsulated homes	*1*	*11*	*7*	*18*
Construction by percent of floor area				
2 x 8 x 16" o.c.	64%	68%	35%	50%
2 x 10 x 16" o.c.	36%	16%	--	31%
2 x 6 x 24" o.c.	--	6%	34%	9%
2 x 8 x 18" o.c.	--	4%	17%	5%
2 x 6 x 16" o.c.	--	6%	--	--
2 x 8 x 24" o.c.	--	--	14%	--

[a] Unweighted
[b] Weighted

Foundation Walls in Conditioned Space

Nineteen of the 41 study homes (46%) feature foundation walls in conditioned space (Figure 14). The average R-value of insulation installed on these foundation walls is about R-5, the equivalent of about one inch of polyisocyanurate or two inches of compressed fiberglass batt. Along with floors over unheated basements, these foundation walls represent an opportunity to more clearly delineate and insulate basement thermal boundaries. The red line shown at the R-15 level reflects the current code for newly constructed homes built in Maine (IECC 2009 Zone 6).

Figure 14: Foundation Walls in Conditioned Space Insulation R-values (Interior + Exterior)

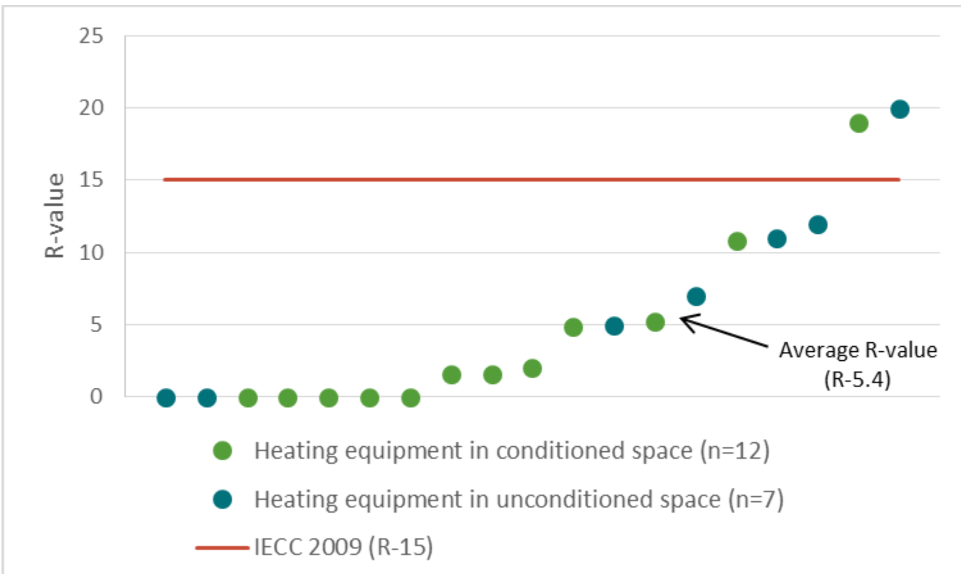


Table 17 provides more details regarding the characteristics of foundation walls in heated space. The thermal boundaries for homes in the least efficient group more often lie at the frame floor, while homes in the most efficient group generally have conditioned basements. The average R-value of foundation wall insulation in the most efficient homes is higher than the average above-grade exterior wall R-value in the least efficient homes (see Table 13). The 10 mid-efficiency homes with foundation walls in heated space have insulation on those walls with a low average of R-3.

Table 17: Foundation Walls in Conditioned Space Detailed Characteristics

(Base: homes with conditioned basements)

Characteristic	Efficiency Level in BTU/ft^2/year[a]			Overall[b]
	Most Efficient	Middle Efficiency	Least Efficient	
N	*8*	*10*	*1*	*19*
Average insulation R-value	R-9	R-3	R-0	R-5
Count of uninsulated homes	*1*	*5*	*1*	*7*
Construction by percent of foundation wall area				
2 x 4 x 16” o.c.	19%	20%	--	20%
2 x 6 x 16” o.c.	17%	--	--	10%
No studs	64%	80%	100%	70%

[a] Unweighted
[b] Weighted

Exterior Rim and Band Joists

Joists are structural framing members that support floors and ceilings. Exterior joists are on the same vertical plane as exterior walls, but because they separate the floors of a house, they are not always insulated in the same manner as wall cavities.

Figure 15 demonstrates the R-value of exterior joist insulation in Maine homes. On average, these joists are insulated to R-12, only slightly less than the R-13 of exterior walls. The disparity is mainly due to some uninsulated joists adjacent to heated basements.

Figure 15: Rim & Band Joist Insulation R-values (Cavity + Continuous)

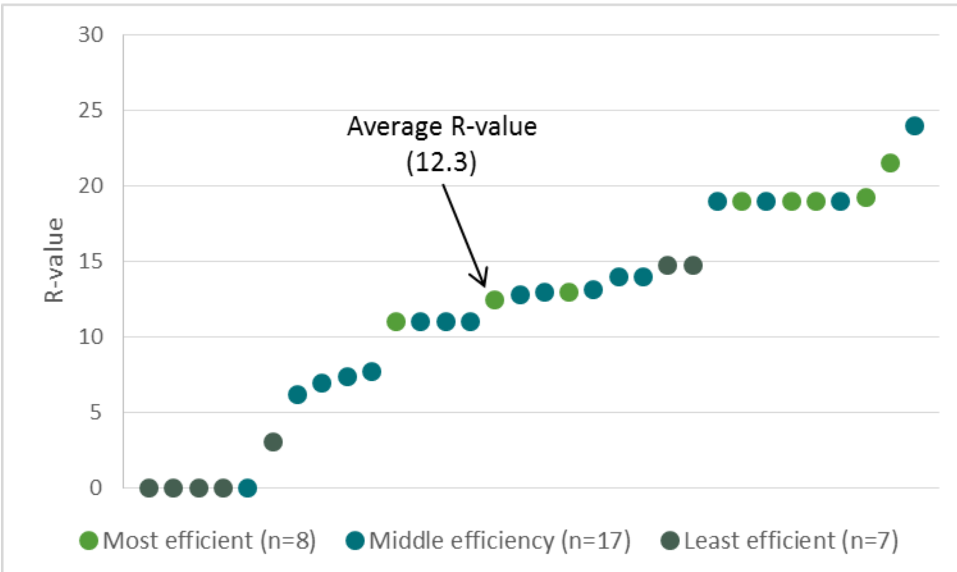


Table 18 provides more details regarding the characteristics of exterior joists. The average R-value of joist insulation hews closely to that of exterior wall insulation for all home efficiency categories: R-17 vs. R-19 for walls in the most efficient group, and R-5 vs. R-6 for walls in the least efficient group. For the middle efficiency group, the R-values are nearly the same (R-13 for walls, R-12 for joists).

Joist framing size is most often 2 x 8” or 2 x 10” (73% of homes statewide). Possibly due to their age, there is more variety in joist framing among homes in the least efficient group.

Table 18: Exterior Rim & Band Joist Detailed Characteristics

(Base: homes with conditioned to ambient joists)

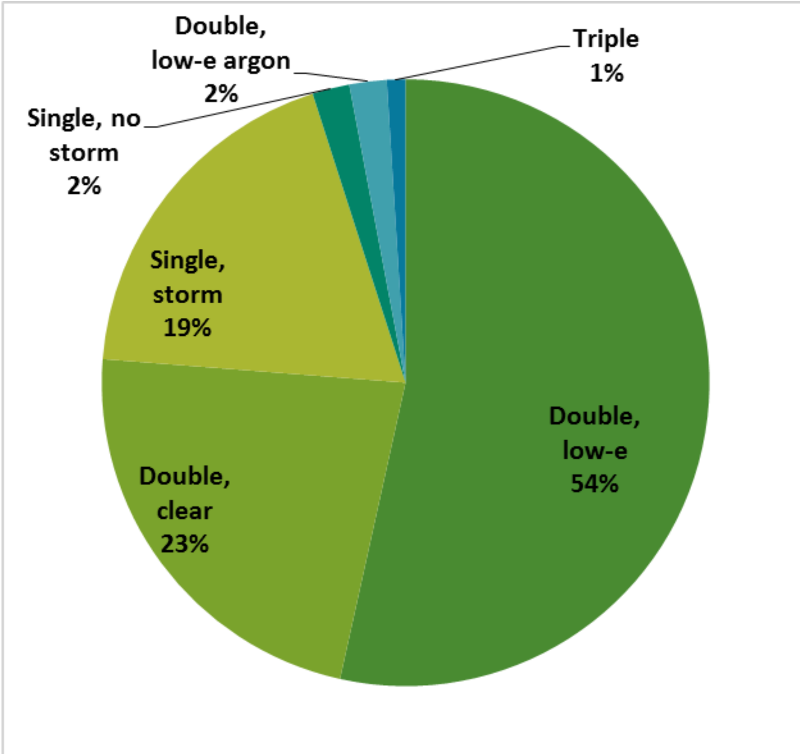
Characteristic	Efficiency Level in BTU/ft^2/year[a]			Overall[b]
	Most Efficient	Middle Efficiency	Least Efficient	
N	*8*	*17*	*7*	*32*
Average insulation R-value	R-17	R-12	R-5	R-12
Count of uninsulated homes	--	*1*	*4*	*5*
Construction by percent of joist area				
2 x 8 x 16” o.c.	42%	56%	34%	46%
2 x 10 x 16” o.c.	53%	7%	--	27%
2 x 4 x 16” o.c.	--	12%	29%	9%
2 x 12 x 16” o.c.	--	13%	--	7%
2 x 6 x 16” o.c.	5%	8%	--	6%
2 x 4 x 24” o.c.	--	4%	24%	5%
2 x 6 x 24” o.c.	--	--	14%	--

[a] Unweighted
[b] Weighted

WINDOWS

Figure 16 demonstrates the window glazing types that are most common as a percentage of total window area. Nearly 80% of window area in the state is double or triple pane. Twenty-one percent of window area is single-pane, but 91% of single-pane window area also features storm windows.[15]

Figure 16: Window Glazing Type by Percent of Total Area



[15] Storm windows can also be found on double-pane clear windows (representing 8% of double-pane window area, and 2% of total window area), and they are also found on double-pane low-E windows (on 11% of double-pane low-E window area, and 6% of total window area).

Table 19 presents window glazing types in more detail. The windows in the least efficient homes are more often single-pane than are the windows in the other efficiency categories—57% of the window area is single-pane. Double-pane, low-e glazing makes up 91% of window area among the most efficient homes.

Table 19: Window Glazing Type by Percent of Total Area

(Base: all homes)

Glazing type	Efficiency Level in Heating BTU/ft^2/year[a]			Overall[b]
	Most Efficient	Middle Efficiency	Least Efficient	
Number of homes	*8*	*25*	*8*	*41*
Avg. area per home (ft^2)	*290*	*229*	*226*	*240*
Single pane	**--**	**24%**	**57%**	**21%**
Percent of single pane area with storm windows	--	*88%*	*98%*	*91%*
Double pane	**98%**	**76%**	**43%**	**79%**
Clear	*7%*	*36%*	*11%*	*23%*
Low-e coating	*91%*	*36%*	*32%*	*54%*
Low-e coating & argon	--	*4%*	--	*2%*
Triple pane	**2%**	**--**	**--**	**1%**
Glass block	--	< 1%	--	< 1%

[a] Unweighted

[b] Weighted

Most windows in Maine are framed using either wood (52%) or vinyl (45%) (Table 20). Wood frames are most common in both the most (60%) and least efficient (76%) homes, while vinyl windows are most common in the middle efficiency category.

Table 20: Window Frame Material by Percent of Glazing Area

(Base: all homes)

Frame material	Efficiency Level in Heating BTU/ft^2/year[a]			Overall[b]
	Most Efficient	Middle Efficiency	Least Efficient	
Number of homes	*8*	*25*	*8*	*41*
Avg. area per home (ft^2)	*290*	*229*	*226*	*240*
Wood	60%	42%	76%	52%
Vinyl	40%	52%	20%	45%
Metal	--	5%	3%	3%
Fiberglass	--	< 1%	< 1%	< 1%
Other	--	< 1%	--	< 1%

[a] Unweighted
[b] Weighted

6

Mechanical Equipment & Ducts

This section describes the characteristics of heating, cooling, and water heating equipment in Maine single-family homes, as well as of their associated ductwork. NMR auditors collected detailed information regarding the type, fuel, make, model, efficiency, and output capacity of all mechanical information found in the study homes.

HEATING EQUIPMENT

This section describes the characteristics of heating equipment present in Maine single-family homes.

Primary Heating Fuel & System Type

During on-site inspections, homeowners were asked to estimate the proportion of their total heating needs that each piece of heating equipment present in the home provides. Figure 17 describes the fuel types that correspond to the heating equipment that homeowners reported using most often. Nearly three-quarters (72%) of homeowners reported using oil as their primary heating fuel, and another 12% reported using half oil and half wood, wood pellets, or electric. All other primary fuel types together only account for 16% of homes.

Figure 17: Primary Heating Fuel

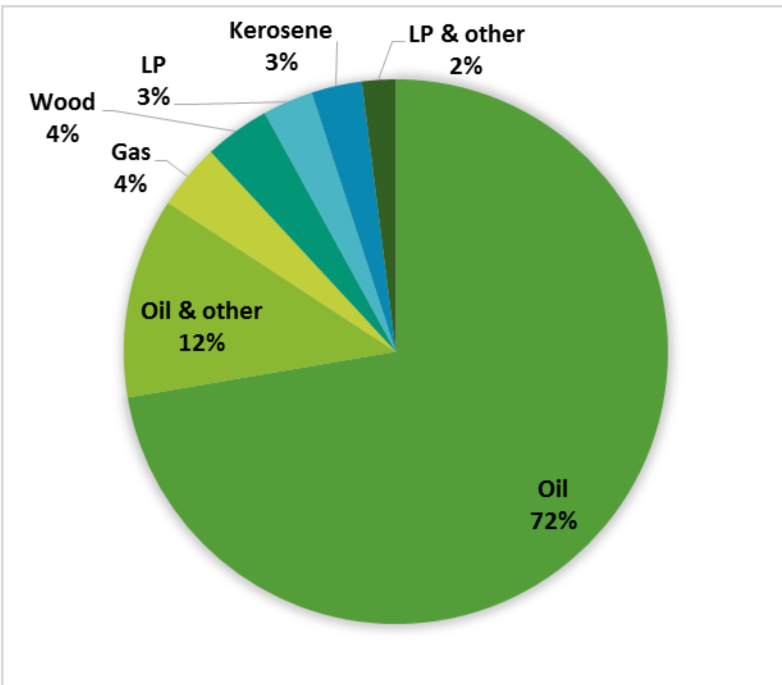


Table 21 provides more detail regarding the primary heating fuel of the on-site homes compared to the telephone survey conducted as part of this baseline study as well as the Census. Three quarters of on-site homes (75%) reportedly use oil or kerosene as their sole primary heating fuel, compared to the Census estimate of 72%. The on-site sample underrepresents homes that primarily use wood for heat; however, within the 14% of homes that use either oil or LP for half their heating needs, 10% use wood or wood pellets for the other half. Therefore, 14% of the on-site homes use wood or wood pellets for at least half of their heating needs, compared to the 16% estimated by the Census.

Table 21: Primary Heating Fuel Comparisons

<table>
<tr><th>Primary heating fuel</th><th>On-site Homes[b]</th><th>Telephone Survey</th><th>Census Bureau</th></tr>
<tr><td>N</td><td>41</td><td>164</td><td>250,806</td></tr>
<tr><td>Fuel oil or kerosene</td><td>75%</td><td rowspan="2">68%</td><td rowspan="2">72%</td></tr>
<tr><td>Fuel oil & other[a]</td><td>12%</td></tr>
<tr><td>Natural gas</td><td>4%</td><td>4%</td><td>2%</td></tr>
<tr><td>Wood</td><td>4%</td><td>17%</td><td>16%</td></tr>
<tr><td>LP</td><td>3%</td><td rowspan="2">6%</td><td rowspan="2">7%</td></tr>
<tr><td>LP & other[a]</td><td>2%</td></tr>
<tr><td>Electricity</td><td>--</td><td>1%</td><td>2%</td></tr>
<tr><td>Other</td><td>--</td><td>3%</td><td>2%</td></tr>
</table>

[a] Denotes a home that reported using oil or LP for half their heating needs and another fuel for the other half.
[b] Weighted.

As Figure 18 shows, the most common primary heating equipment type in Maine is boilers, which account for 62% of homes' primary heating systems. An additional 12% of homes use a boiler for half their heating needs and either a stove or space heaters for the other half. Furnaces account for 20% of primary heating systems, and stoves account for 6%.

Figure 18: Primary Heating Equipment Type

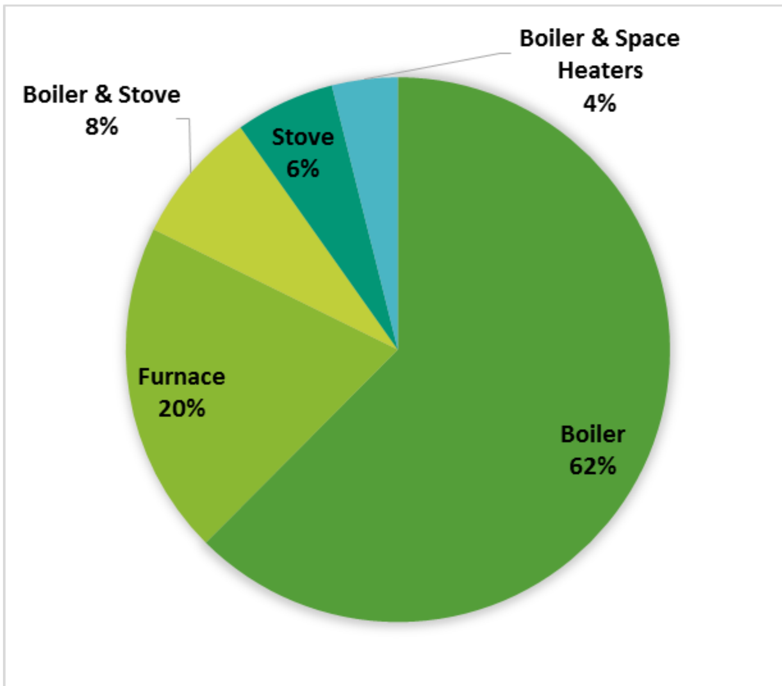


Table 22 shows the efficiency of primary heating systems which homeowners indicated accounted for 50% or more of their homes' heating needs. Boilers, the most common primary heating system type, are also the most efficient on average, with an average annual fuel utilization efficiency (AFUE)[16] of 83%. Stoves, which are the primary heating equipment in 6% of homes, are less efficient than the overall average (74% vs. 81%), while furnaces have the same average efficiency as the overall average (81%).

Table 22: Primary Heating System Efficiency

Primary heating equipment type	Fuel	Number of Systems	Efficiency Unit	Average Efficiency[a]
Boilers	Oil	27	AFUE	83%
	Gas	2		83%
	Propane	1		86%
	Pellet	1		90%
	All boilers	*31*		*83%*
Furnaces	Oil	7	AFUE	81%
	Kerosene	1		80%
	All furnaces	*8*		*81%*
Stoves	Wood	2	% Efficient	72%
	Pellet	1		74%
	Propane	1		79%
	All stoves	*4*		*74%*
Space heaters	Electric	8	COP	1.0
	Propane	1	% Efficient	70%
All non-electric primary heating equipment[17]	Non-electric	39	AFUE	83%
		5	% Efficient	73%
		44	*Overall*	*81%*

[a] Weighted.

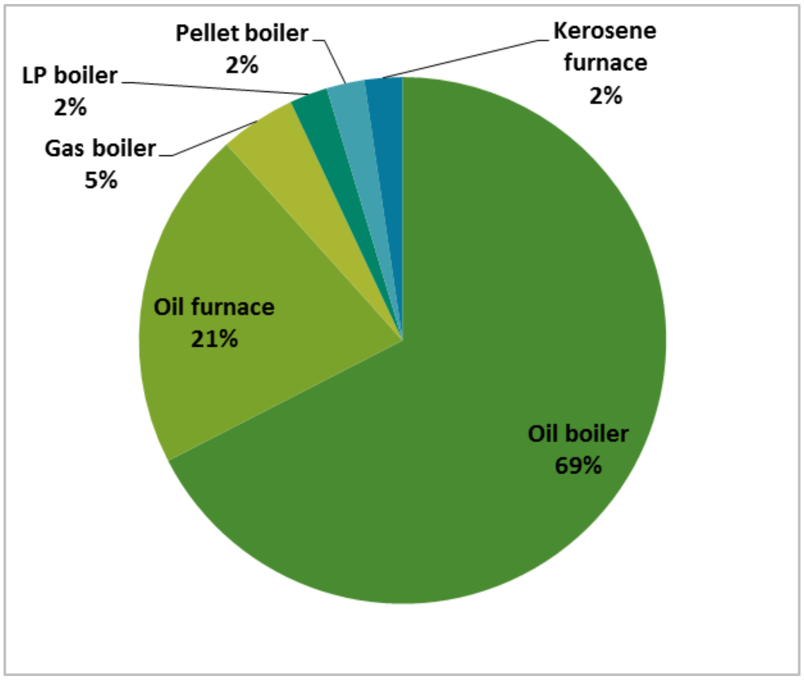
[16] AFUE stands for "annual fuel utilization efficiency." It is a measure of the efficiency of fuel-fired heating equipment like boilers and furnaces. It is expressed as a percentage.

[17] This count of equipment is higher than the count of study homes because five homes use both a boiler and another type of equipment, each accounting for half the home's heating needs.

Central Heating Equipment

Figure 19 shows the breakdown of central[18] heating system types in Maine single-family homes. Over two-thirds of central heating systems in Maine are oil boilers; a further 21% are oil furnaces. In total, 90% of boilers and furnaces in Maine are oil-fired.

Figure 19: Central Heating Equipment Types



[18] For the purposes of this study, the central heating system refers to either a boiler or furnace. While the home's occupant might report primarily using space heaters or a wood stove for heat, there is nearly always a boiler or furnace present in the home, and that equipment generally has the largest heating capacity in kBTUh. Additionally, should the house change hands, another homeowner might choose to use this more conventional method rather than rely on supplemental heating equipment. While the "primary" and "central" heating systems are the same system in most homes, they differ when the homeowner reports that supplemental equipment supplies more heating to their home than the central system.

The average nameplate AFUE of fuel-fired central heating equipment in Maine is about 83% (Table 23). This corresponds roughly to the current federal minimum efficiency standard for oil boilers,[19] the most common central heating system type found on site.

Table 23: Average Central Heating System Efficiency

(Base: all homes)

Central heating system type	N	Average Efficiency[a]
Boilers (AFUE)	**32**	**83%**
Fuel oil	*27*	*83%*
Natural gas	*2*	*83%*
Propane	*1*	*86%*
Wood pellet	*1*	*90%*
Furnaces (AFUE)	**10**	**81%**
Fuel oil	*9*	*81%*
Kerosene	*1*	*80%*
All fuel-fired central heating equipment	**42**[20]	**83%**

[a] Weighted

[19] The current federal minimum efficiency standard is 84% AFUE for oil hot water boilers and 82% AFUE for oil steam boilers. These standards can be found at: http://www.appliance-standards.org/national

[20] One home has both an oil boiler and a pellet boiler.

Table 24 shows the age of central heating systems. About two-fifths (43%) of all central heating equipment was manufactured in 1995 or earlier. The approximate[21] average age of this equipment is 17 years for boilers and 24 for furnaces. Overall, central heating systems in Maine homes are about 19 years old on average.

Table 24: Age of Central Heating Systems[a]

(Base: all homes)

Year of manufacture	Boilers	Furnaces	All Central Heating
N	*32*	*10*	*42*
1995 or earlier	28%	90%	43%
Approximate age in years			
Average	17	24	19
Minimum	2	17	2
Maximum	> 45	37	> 45

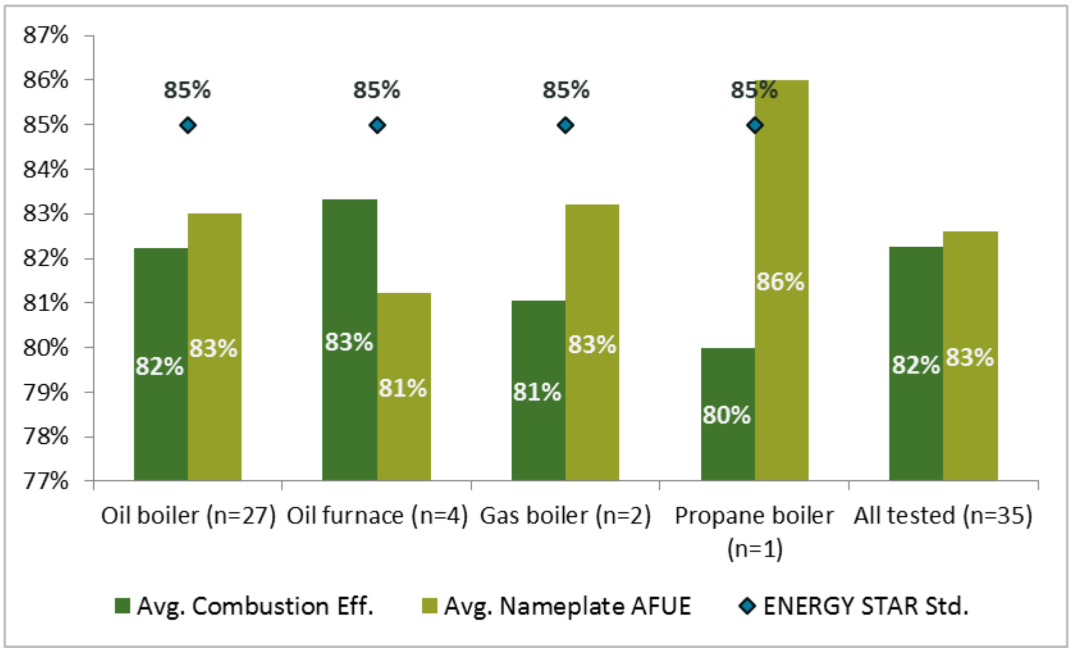
[a] Weighted

[21] NMR gathered data on heating equipment age in five year increments, with the exception of equipment that was manufactured in the last five years. Therefore, the average ages provided in Table 24 are approximate. For example, a boiler which NMR found to have been manufactured between 2006 and 2010 was given an age of 7 years, corresponding to the year 2008, for the purposes of calculating the average.

While on site, NMR auditors performed combustion efficiency testing on all boilers and furnaces upon which testing was possible. Figure 20 compares the measured combustion efficiency[22] and nameplate AFUE of primary heating systems in Maine. On average, the two measures do not diverge substantially from one another—among all fuel-fired primary heating systems, the average combustion efficiency was 82% and the average AFUE was 83%.

Because the ENERGY STAR™ product criteria for all boilers and oil-fired furnaces are not particularly stringent at 85% AFUE, the average efficiencies for these types of equipment do not differ substantially from the efficiency of an ENERGY STAR version of the same equipment (Figure 20).

Figure 20: Measured Combustion Efficiency vs. Nameplate AFUE



[22] Combustion efficiency and AFUE are not directly comparable despite being similar measures. While combustion efficiency describes the equipment's steady-state efficiency at a single point in time, AFUE is a seasonal rating that takes into account standby losses. However, the combustion efficiency and AFUE for any one piece of equipment are unlikely to be substantially different from one another.

On average, fuel-fired boilers and furnaces have an output capacity of about 118 kBTUh. Boilers tend to be larger than furnaces (124 vs. 93 kBTUh).

Table 25: Average Output Capacity of Central Heating Equipment

(Base: units of heating equipment)

Heating system type	N	Average kBTUh Capacity[a]
Average heating design load	41	48
Boilers	**32**	**124**
Fuel oil	*27*	*129*
Natural gas	*2*	*109*
Propane	*1*	*106*
Wood pellet	*1*	*54*
Furnaces	**10**	**93**
Fuel oil	*9*	*97*
Kerosene	*1*	*68*
All fuel-fired central heating equipment	**42**	**118**

[a] Weighted

Supplemental Heating Equipment

This section describes the size and efficiency of the several types of non-central, or supplemental, heating equipment found on-site. Supplemental heating equipment, for the purposes of this study, is defined as smaller equipment that is only capable of providing heat to part of a house.[23] Types of supplemental heating equipment include stoves, fireplaces, space heaters, electric baseboard, and ductless mini-splits.

Nearly two-thirds of single-family homes in Maine feature some kind of supplemental heating equipment, the most common types being wood stoves and electric space heaters. This supplemental equipment accounts for over one quarter (26%) of the total installed heating capacity[24] (measured in kBTUh) in the homes in which it is present. On average, non-electric supplemental heating equipment is less efficient than primary heating equipment (69% vs. 83%)[25] (Table 26).

Three air-source heat pumps (ASHPs) found at two sites (5% of sites) have an average heating season performance factor (HSPF) of 11.1. All three of these units are ductless mini-splits with heating efficiencies well above the ENERGY STAR standard HSPF of 8.2.

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23 While the "supplemental" and "primary" heating systems are different systems in most homes, they would be the same system when the homeowner reports that their supplemental equipment supplies more heating to their home than the central system.

24 Total installed capacity was calculated by taking the sum of the rated capacities of all primary and supplemental equipment providing heat in each home.

25 Electric resistance heating equipment has a coefficient of performance (COP) of 1.0 because it is 100% efficient at the point of consumption. This increases the overall average efficiency of supplemental heating equipment.

Table 26: Supplemental Heating Efficiency & Capacity by Home[a]

(Base: homes with supplemental heating equipment)

Equipment type	*Percent of Homes with Equip.*	*Fuel*	*Count of Units*	*Efficiency Measure-ment*	Average Efficiency	Avg % of Installed Capacity in homes with Suppl. Equip.	Avg Capacity Installed in homes with Suppl. Equip (kBTUh)
Stoves	*44%*	*Wood*	*11*	*%*	67%	23%	32.7
		Pellet	*6*		78%		
		Propane	*2*		79%		
		All stoves	*19*		72%		
Fireplaces	*13%*	*Propane*	*4*	*%*	60%	15%	25.7
		Wood	*1*		56%		
		All fireplaces	*5*		59%		
Space heaters	*32%*	*Electric*	*26*	*COP*	1.0	9%	13.6
		Propane	*2*	*%*	70%		
Electric baseboard	*10%*	*Electric*	*4*	*COP*	1.0	14%	26.3
Ductless mini-splits	*6%*	*Electric*	*3*	*HSPF*	11.1	14%	29.3
All non-electric supplemental heating equipment	*57%*	--	*26*	*%*	*69%*	21%	*31.4*
All supplemental heating equipment	*64%*	--	*59*	--	--	26%	*40.3*

[a] Weighted

Non-electric supplemental heating equipment has an average efficiency of 69%, taking all equipment types into account. Stoves—the majority (89%) of which are wood-fired—are the most common type of supplemental heating, and have an average efficiency of 72% (Table 27).

Table 27: Average Efficiency of Non-Electric Supplemental Heating Equipment by Unit

(Base: units of non-electric supplemental heating equipment)

Equipment type	*Number of Units*	Efficiency Level in Heating BTU/ft^2/year[a]			Overall[b]
		Most Efficient	Middle Efficiency	Least Efficient	
N	--	*4*	*14*	*7*	*25*
Stoves	*19*	67%	78%	65%	72%
Fireplaces	*5*	56%	62%	--	59%
Space heaters	*1*	--	70%	--	70%
Overall	*25*	*64%*	*73%*	*65%*	*69%*

[a] Unweighted
[b] Weighted

Stoves and space heaters, the two most common types of supplemental heating equipment, have average output capacities of 31 kBTUh and 7 kBTUh per unit respectively (Table 28). This suggests that the average stove would account for about two-thirds (65%) of the average home's design load, while it would take about seven space heaters to match the design load of an average home.

Table 28: Output Capacity of Supplemental Heating Equipment by Unit (kBTUh)

(Base: units of supplemental heating equipment)

Equipment type	*Number of Units*	Efficiency Level in Heating BTU/ft²/year[a]			Overall[b]
		Most Efficient	Middle Efficiency	Least Efficient	
N	--	*8*	*42*	*9*	*59*
Stoves	*19*	27	35	25	31
Fireplaces	*5*	20	28	--	26
Space heaters	*27*	5	8	5	7
Electric baseboard	*4*	--	29	13	26
Ductless mini-splits	*3*	22	15	--	20
Supplemental heating equipment	*59*	*20*	*17*	*22*	*19*
Primary heating equipment	*42*	*127*	*112*	*121*	*118*
Average heating design load	*41*	*44*	*44*	*72*	*48*

[a] Unweighted
[b] Weighted

Table 29 describes the approximate average age of all non-central heating equipment found on-site.[26] Stoves tend to be the oldest of these equipment types, at an average age of about 16 years. Fireplaces (14 years) and electric baseboard (12 years) have the next highest average ages. Space heaters and ASHPs have the lowest average ages among non-central heating equipment types.

Table 29: Supplemental Heating Equipment Ages[a]

(Base: all homes with supplemental heating equipment)

Year of manufacture	Space Heaters	Stoves	Electric Baseboard	Fireplaces	ASHPs
N	*22*	*15*	*8*	*5*	*3*
1995 or earlier	5%	40%	0%	20%	0%
Approximate average age					
Average	6	16	12	14	2
Minimum	1	1	12	7	1
Maximum	22	37	12	27	3

[a] Weighted

Heating Pads & Electric Blankets

Auditors asked homeowners if they use electric blankets or heating pads for additional warmth in the winter. Five homeowners reported using these blankets or pads (15% of homes[27]). In total, auditors found eight electric blankets or heating pads in these five homes—three homeowners had one each, one homeowner had two, and one had three.

[26] NMR gathered data on heating equipment age in five year increments, with the exception of equipment that was manufactured in the last five years. Therefore, the average ages provided in Table 29 are approximate. For example, a stove which NMR found to have been manufactured between 2006 and 2010 was given an age of 7 years, corresponding to the year 2008, for the purposes of calculating the average.

[27] Percentage is weighted to account for oversampling of older homes.

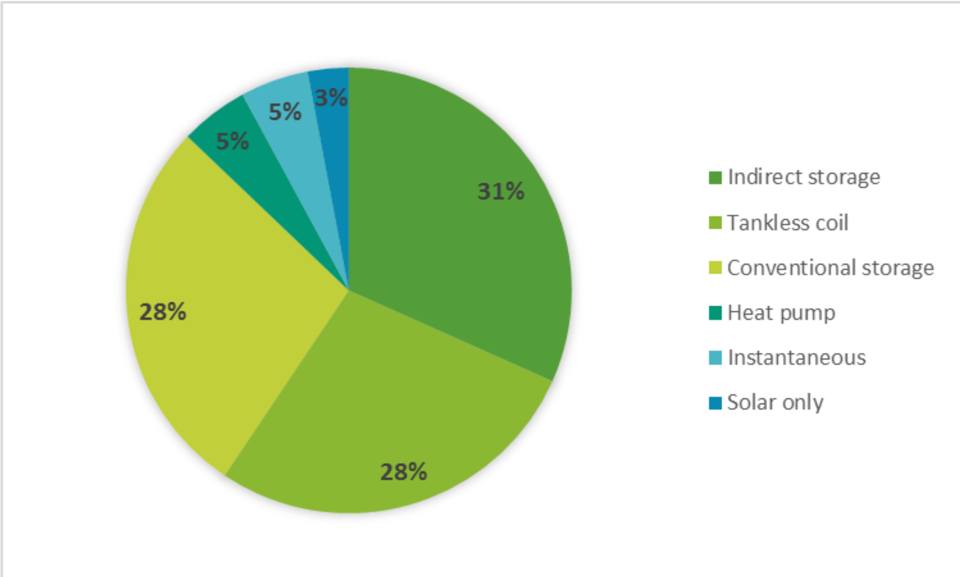
Water Heating Equipment

This section describes the characteristics of the domestic hot water (DHW) systems found on site.

DHW System Type and Age

Of the 44 water heaters inspected,[28] indirect storage tanks connected to the home's boiler are the most common (31% of systems). Boilers with tankless coil water heating and conventional storage tanks are the next most common, each comprising about 28% of DHW systems. Heat pump water heaters and instantaneous water heaters are less common, each representing 5% of systems. Additionally, there is one solar DHW system present in the sample.

Figure 21: Water Heater System Types



[28] Most homes (38 of 41, or 85%) have just one water heater. Three homes have two water heaters each.

Table 30 provides additional detail on the DHW system types found on-site. Indirect tanks make up the largest share of systems in homes in the most efficient category, while conventional storage tanks are most common in the least efficient homes. Overall, indirect tanks, conventional tanks, and tankless coil systems each make up slightly less than one third of all systems statewide.

Table 30: Water Heater System Types

(Base: all homes)

System Type	*Number of Systems*	Efficiency Level in Heating BTU/ft^2/year[a]			Overall[b]
		Most Efficient	Middle Efficiency	Least Efficient	
N	--	*10*	*26*	*8*	*44*
Indirect storage	*14*	4	8	2	32%
Tankless coil	*13*	2	10	1	28%
Conventional storage	*12*	1	7	4	28%
Heat pump	*2*	1	1	--	5%
Instantaneous	*2*	1	--	1	5%
Solar only	*1*	1	--	--	3%

[a] Unweighted
[b] Weighted

The age of water heaters in Maine homes, unsurprisingly, varies by system type (Table 31).[29] On average, tankless coil systems are the oldest, with an average age of 21 years (the same age as the associated boilers). Instantaneous and heat pump water heaters, being newer technologies, have the lowest average ages at 7 years and 1 year respectively, although these systems also are the least common in the study homes. Indirect storage and conventional storage systems are both 12 years old on average.

Table 31: Water Heater Ages[a]

(Base: all homes)

<table>
<tr><th>Equipment age</th><th>Indirect</th><th>Conven-tional</th><th>Tankless Coil</th><th>Instant</th><th>Heat Pump</th><th>Solar Only</th></tr>
<tr><td>N</td><td>14</td><td>12</td><td>13</td><td>2</td><td>2</td><td>1</td></tr>
<tr><td>Manufactured in 2005 or earlier</td><td>73%</td><td>42%</td><td>80%</td><td>--</td><td>--</td><td>--</td></tr>
<tr><td colspan="7">Approximate average age in years</td></tr>
<tr><td>Average</td><td>12</td><td>12</td><td>21</td><td rowspan="3">7</td><td>1</td><td rowspan="3">12</td></tr>
<tr><td>Minimum</td><td>7</td><td>1</td><td>2</td><td>1</td></tr>
<tr><td>Maximum</td><td>17</td><td>37</td><td>50</td><td>2</td></tr>
</table>

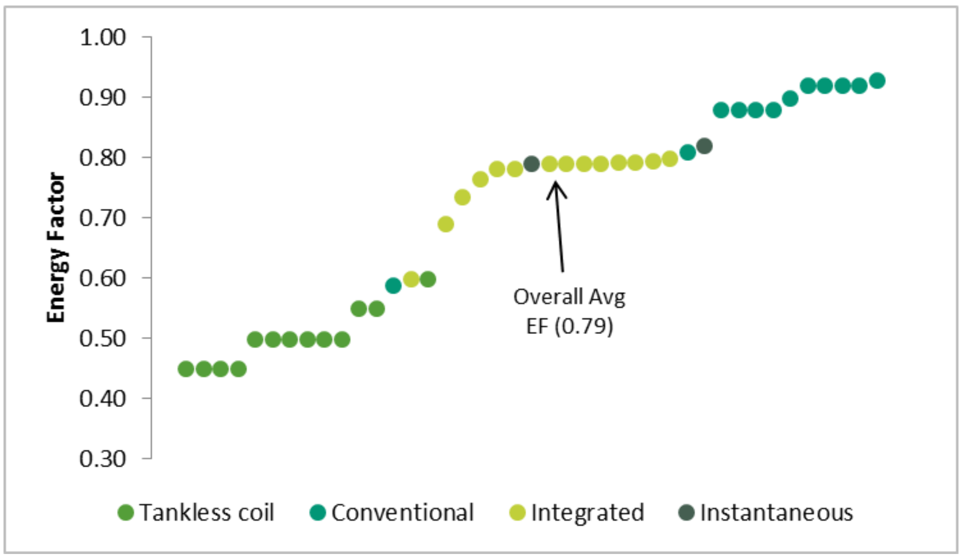
[a] Weighted

[29] NMR gathered data on equipment age in five year increments, with the exception of equipment that was manufactured in the last five years. Therefore, the average ages provided in Table 31 are approximate. For example, a water heater which NMR found to have been manufactured between 2006 and 2010 was given an age of 7 years, corresponding to the year 2008, for the purposes of calculating the average.

DHW Efficiency and Fuel

The efficiency of water heating systems in Maine varies widely, and as Figure 22 demonstrates, this is largely a function of system type. Conventional storage tank water heaters, which in the study homes are mostly electric, have the highest Energy Factors among non-heat pump systems.[30] Integrated tank systems, which have no combustion unit of their own and rely on a boiler to heat water, are next most efficient. Tankless coil systems—in which the boiler provides domestic hot water directly with no storage tank—become more efficient with greater hot water usage, but are still less efficient than other types.

Figure 22: Water Heater Energy Factors—Non-Heat Pump Models



[30] Two heat pump water heaters are not included in Figure 22 because their high Energy Factors make it difficult to distinguish the differences in efficiency between the other system types.

As Figure 23 demonstrates, the Energy Factors of the two heat pump water heaters in the sample are each more than double the highest Energy Factor from among non-heat pump water heaters.

Figure 23: Water Heater Energy Factors—All Water Heaters

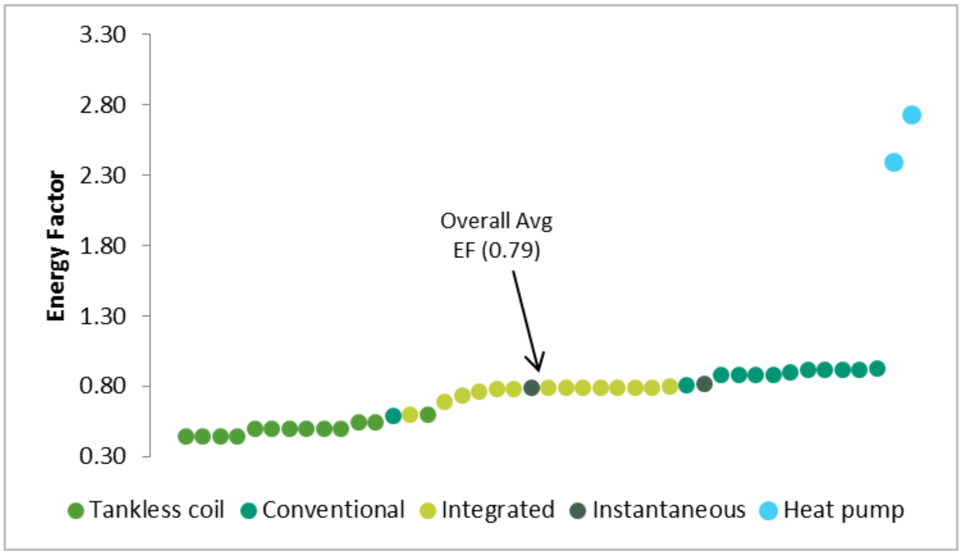


Table 32 shows the efficiency of water heating systems by system and fuel type. Among fuel-fired water heaters, instantaneous and indirect systems have the highest Energy Factors on average. Electric water heaters have the highest Energy Factors overall.

Table 32: Water Heater Energy Factor (EF) by System & Fuel Type[a]
(Base: all homes)

System type	Oil		Natural Gas		Propane		Electric	
	Count	EF	Count	EF	Count	EF	Count	EF
N	*26*		*2*		*2*		*13*	
Indirect storage	14	0.76	--	--	--	--	--	--
Tankless coil[31]	12	0.51	1	0.45	--	--	--	--
Conventional storage	--	--	1	0.59	--	--	11	0.90
Heat pump	--	--	--	--	--	--	2	2.57
Instantaneous	--	--	--	--	2	0.81	--	--

[a] Unweighted

[31] Consistent with the New England Home Energy Rating System (NEHERS) manual and other baseline studies, the Energy Factor for tankless coil water heating systems is estimated based on the potential occupancy of the home (number of bedrooms plus one). Specific Energy Factors by occupancy can be found in Appendix A.

Faucet Aerators & Low-Flow Showerheads

Auditors used calibrated tools to measure the actual flow rates of sink faucets and showerheads, and recorded nominal values where testing was not possible.[32] The average flow rate of sink faucets in Maine is about 1.9 gallons per minute (gpm), and 90% have aerators installed (Table 33). Despite this high incidence of aerators on Maine faucets, just 38%[33] of all faucets were found to meet the EPA's low-flow specification of 1.5 gpm.[34]

Bathroom and kitchen sinks are similar in terms of flow rate and presence of aerators. There are substantially fewer aerators used in the least efficient homes (70% of faucets) than in either the most efficient or mid-efficiency homes (91% and 93% respectively).

Table 33: Sink Faucet Flow Rates and Aerators

(Base: sink faucets)

Statistic	Efficiency Level in Heating BTU/ft^2/year[a]			Overall[b]
	Most Efficient	Middle Efficiency	Least Efficient	
N	*33*	*81*	*20*	*134*
Percent of faucets with aerators	91%	93%	70%	90%
Percent meeting EPA low-flow specification of 1.5 gpm	39%	35%	40%	38%
Flow rate in gallons per minute				
Average gpm	1.8	1.8	2.2	1.9
Minimum gpm	0.7	0.8	0.5	0.5
Maximum gpm	3.8	4.5	5.5	5.5

[a] Unweighted

[b] Weighted

[32] Relying on nominal values was a rare occurrence, and was typically limited to a small number of showerheads that were too large to work with the measurement tools.

[33] Percentage is weighted to account for oversampling of older homes.

[34] Low-flow faucet specification available here: http://www.epa.gov/WaterSense/products/bathroom_sink_faucets.html

The average showerhead flow rate is 2.5 gallons per minute (Table 34). This flow rate is greater than the EPA low-flow specification of 2.0 gpm[35]—16%[36] of showerheads found on-site meet this requirement. Average flow rates do not diverge substantially between the home efficiency categories.

Table 34: Showerhead Flow Rates

(Base: showerheads)

Statistic	Efficiency Level in Heating BTU/ft^2/year[a]			Overall[b]
	Most Efficient	Middle Efficiency	Least Efficient	
Number of showerheads	*14*	*36*	*8*	*58*
Percent meeting EPA low-flow specification of 2.0 gpm	*21%*	*14%*	*13%*	*16%*
Average GPM	2.5	2.5	2.7	2.5
Minimum GPM	1.5	1.5	1.9	1.5
Maximum GPM	5.0	4.8	4.6	5.0

[a] Unweighted

[b] Weighted

[35] Low-flow showerhead specification available here: http://www.epa.gov/WaterSense/products/showerheads.html

[36] Percentage is weighted to account for oversampling of older homes.

Cooling Equipment

Thirteen out of the 41 on-site homes (31%) were found with cooling equipment. Most of the cooling equipment found on site consisted of room air conditioners. The average efficiency of these units is 10.1 EER,[37] which corresponds roughly to the current federal minimum efficiency standard for this equipment.[38]

Only one central air conditioner was found on site with an efficiency of 10 SEER,[39] well below both the current federal standard of 13 SEER[40] and the ENERGY STAR criteria of 14.5 SEER. The three ductless mini-splits found on site have an average SEER of 21.5, well above the ENERGY STAR criteria.

Table 35: Average Cooling System Efficiency[a]

(Base: homes with cooling equipment)

Cooling system type	*Number of Units*	Average EER	Average SEER	ENERGY STAR Criteria
Room air conditioners	*17*	10.1	--	≥ 11.3 EER[41]
Ductless mini-splits	*3*	--	21.5	≥ 14.5 SEER[42]
Central air conditioners	*1*	--	10.0	

[a] Weighted

[37] EER stands for "energy efficiency ratio," a ratio of cooling output in BTU to electrical input in Watt-hours at a single point in time.

[38] Room air conditioner efficiency standards can be found on the Department of Energy website at this URL: http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41

[39] SEER stands for "seasonal energy efficiency ratio." SEER, like EER, describes a ratio of cooling output to electrical input, but over the course of a season rather than at a single point.

[40] Central air conditioner and heat pump efficiency standards can be found on the Department of Energy website at this URL: http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75

[41] Detailed ENERGY STAR criteria for room air conditioners can be found at: https://www.energystar.gov/index.cfm?c=roomac.pr_crit_room_ac

[42] Detailed ENERGY STAR criteria for ductless mini-splits (air source heat pumps) and central air conditioners can be found at: https://www.energystar.gov/index.cfm?c=airsrc_heat.pr_crit_as_heat_pumps

Age information is available for 11 of the 17 room air conditioners and all three ductless mini-splits found on-site, but not for the central air conditioner. Of the room air conditioners for which age information is known, nearly half (48%) are more than 10 years old. The average age of the mini-splits is 2 years.[43]

Table 36: Cooling Equipment Ages[a]

Statistic	Room AC	Ductless Mini-Split
N	*11*	*3*
Manufactured in 2005 or earlier	48%	--
Approximate average age in years		
Average	10	2
Minimum	7	1
Maximum	17	3

[a] Weighted

[43] NMR gathered data on equipment age in five year increments, with the exception of equipment that was manufactured in the last five years. Therefore, the average ages provided in Table 36 are approximate. For example, an air conditioner which NMR found to have been manufactured between 2006 and 2010 was given an age of 7 years, corresponding to the year 2008, for the purposes of calculating the average.

Ducts

Nine of the 41 study homes (22%) have ducts, and eight of those have ducts in unconditioned space (Table 37). The average R-value of duct insulation in these eight homes is about R-2 for supply and R-1 for return ductwork. Three homes have duct systems that are entirely uninsulated.

Table 37: R-value of Ducts in Unconditioned Space

(Base: homes with ducts)

R-value statistic	Efficiency Level in Heating BTU/ft^2/year				Overall[a]	
	Middle Efficiency		Least Efficient			
Homes with ducts in u.c. space	5		3		8	
Duct type	Supply	Return	Supply	Return	Supply	Return
Average R-value	3	2	1	1	2	1
Minimum R-value	0	0	0	0	0	0
Maximum R-value	6	6	4	4	6	6

[a] Unweighted due to low sample size.

7 Appliances & Lighting

This section provides details regarding the number and efficiency of appliances present in the study homes. Auditors collected data on refrigerators, freezers, dishwashers, clothes washers, clothes dryers, and dehumidifiers.

Appliance Efficiency Summary

Table 38 provides a summary of appliance saturation and efficiencies in Maine.

Table 38: Appliance Saturation and Efficiencies

(Base: all homes)

Appliance type	Percent of Homes with Appliance[b]	*Number of Units[c]*	Efficiency Measurement	Average Nameplate Efficiency[b]	ENERGY STAR Standard[a,b]	ENERGY STAR Standard Effective Date
Refrigerators	100%	*43*	kWh/yr	588	≤ 472	September 2014[44]
Freezers	57%	*24*	kWh/yr	574	≤ 252	
Dishwashers	54%	*23*	kWh/yr	408	≤ 295	January 2012[45]
Clothes washers	52%	*26*	kWh/yr	363	--	March 2015[46]
		22	MEF	1.78	≥ 2.13	
Clothes dryers	35%	*14*	EF	3.17	≥ 3.91	January 2015[47]
Dehumidifiers	28%	*5*	L/kWh	1.79	≥ 1.85	October 2012[48]

[a] ENERGY STAR criteria vary by appliance type and volume. NMR calculated ENERGY STAR efficiencies based on the characteristics of each appliance found on-site. This table provides the weighted average of those calculated values.

[b] Weighted to account for oversampling of older homes.

[c] This count includes only the units for which efficiency information is available.

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[44] The ENERGY STAR specification for residential refrigerators and freezers can be found at: http://www.energystar.gov/products/spec/residential_refrigerators_and_freezers_specification_version_5_0_pd

[45] The ENERGY STAR specification for residential dishwashers can be found at: https://www.energystar.gov/index.cfm?c=revisions.residential_dishwashers

[46] The ENERGY STAR specification for clothes washers can be found at: http://www.energystar.gov/products/spec/clothes_washers_specification_version_7_0_pd

[47] The ENERGY STAR specification for clothes dryers can be found at: http://www.energystar.gov/products/spec/clothes_dryers_specification_version_1_0_pd

[48] The ENERGY STAR specification for dehumidifiers can be found at: https://www.energystar.gov/index.cfm?c=revisions.dehumid_spec

Table 39 describes the ages of the appliances found on-site.[49] The oldest appliances by far are freezers, 80% of which were manufactured prior to 2005 and which are 21 years old on average. Refrigerators, dishwashers, clothes washers, and dryers are each about 10 years old on average. About one-half (46%) to three-fifths (59%) of these appliances were manufactured in 2005 or earlier. Dehumidifiers are generally newer, with an average age of five years.

Table 39: Appliance Ages[a]

(Base: all appliances)

Appliance type	*Number of Units[b]*	Percent Manufactured in 2005 or Earlier	Appliance Age		
			Average	Minimum	Maximum
Refrigerators	*45*	59%	11	2	32
Freezers	*25*	80%	21	2	47
Dishwashers	*26*	57%	10	1	27
Clothes washers	*42*	56%	11	1	32
Clothes dryers	*41*	46%	11	1	37
Dehumidifiers	*11*	--	5	2	7

[a] Weighted.

[b] This count includes only the units for which age information was available.

Detailed Appliance Characteristics

The charts in this section show the efficiency of appliances in the state relative to their ENERGY STAR standard. ENERGY STAR efficiencies are dependent on the volume or configuration of a product and were calculated for each unit found on-site. The charts' ENERGY STAR reference lines reflect a weighted average of these individual calculated standards. This method of identifying compliance with ENERGY STAR specifications is preferable due to a lack of data describing the ENERGY STAR status of appliance models at the time of their manufacture.

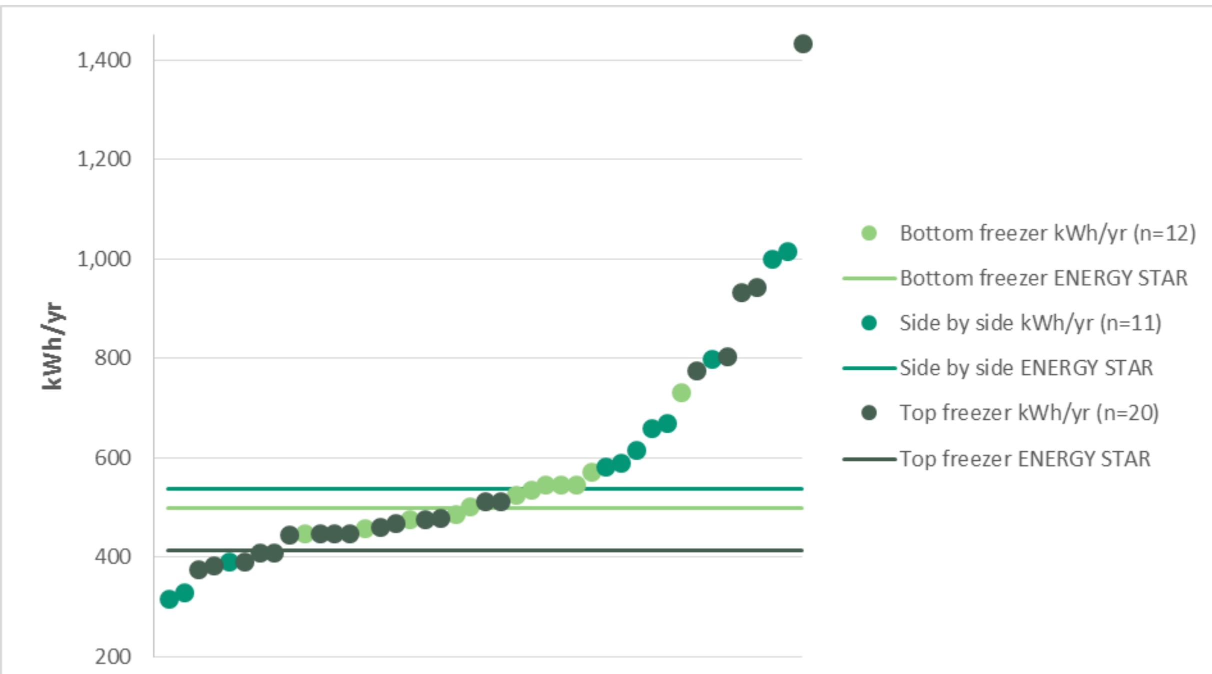
[49] NMR gathered data on equipment age in five year increments, with the exception of equipment that was manufactured in the last five years. Therefore, the average ages provided in Table 36 are approximate. For example, a refrigerator which NMR found to have been manufactured between 2006 and 2010 was given an age of 7 years, corresponding to the year 2008, for the purposes of calculating the average.

Refrigerators & Freezers

For refrigerators to meet ENERGY STAR standards, they must use 10% less annual kWh than would be required under federal minimum efficiency standards. Federal standards vary by refrigerator configuration and volume. Figure 24 shows the efficiency of refrigerators in Maine homes relative to the average ENERGY STAR standard for each refrigerator configuration.

Only 26%[50] of refrigerators (12 of 43 models) in Maine meet current ENERGY STAR criteria, which became effective in September 2014. Slightly more bottom freezer refrigerators meet current ENERGY STAR criteria (4 out of 12, or 35%[51]) than top freezer (5 out of 20, or 21%[52]) or side by side (3 out of 11, or 28%[53]).

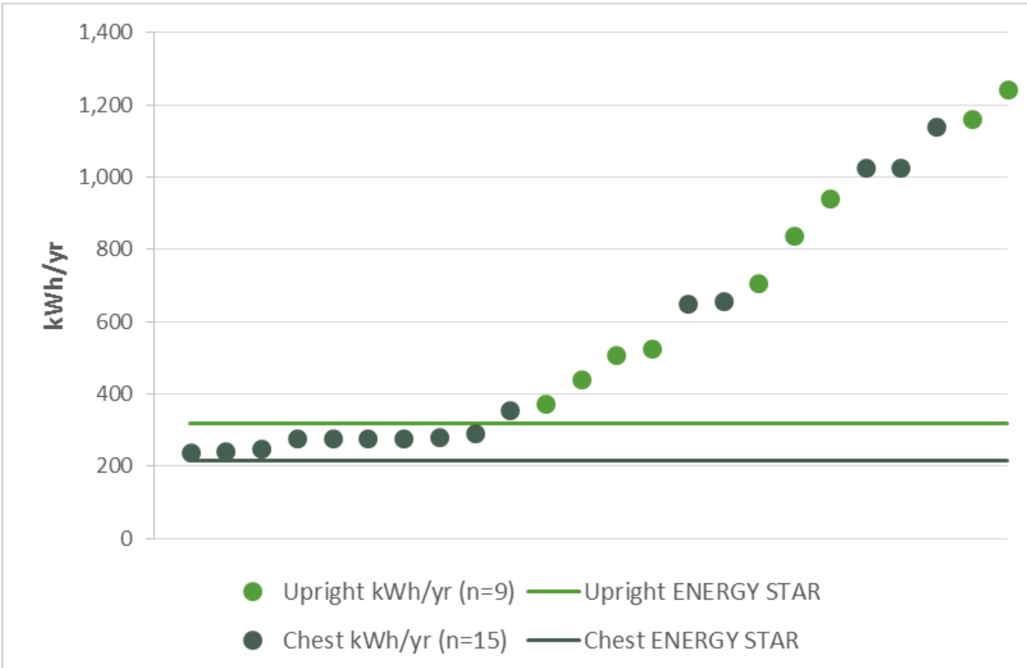
Figure 24: Maine Refrigerator Efficiency vs. ENERGY STAR Criteria



[50] Percentage is weighted to account for oversampling of older homes.
[51] Weighted.
[52] Weighted.
[53] Weighted.

Figure 25 demonstrates the efficiency of freezers in Maine relative to average ENERGY STAR efficiency—like refrigerators, the exact ENERGY STAR standard for freezers depends on the unit's volume and configuration. None of the 24 freezers found in the study homes meet current ENERGY STAR criteria.

Figure 25: Maine Freezer Efficiency vs. ENERGY STAR Criteria

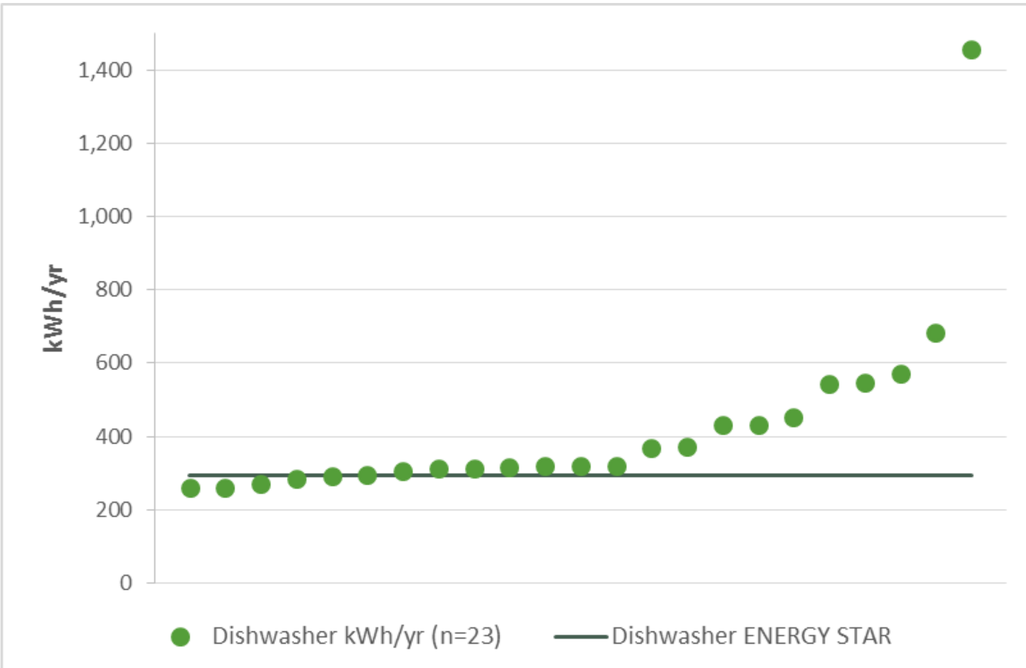


Washing Products

This section details the efficiency of dishwashers, clothes washers, and clothes dryers found in the study homes with reference to their respective ENERGY STAR standards.

Figure 26 shows the efficiency of Maine dishwashers in kWh/year. Of the 23 dishwashers for which efficiency information could be found, five meet current ENERGY STAR criteria (18%[54]).

Figure 26: Maine Dishwasher Efficiency vs. ENERGY STAR Criteria

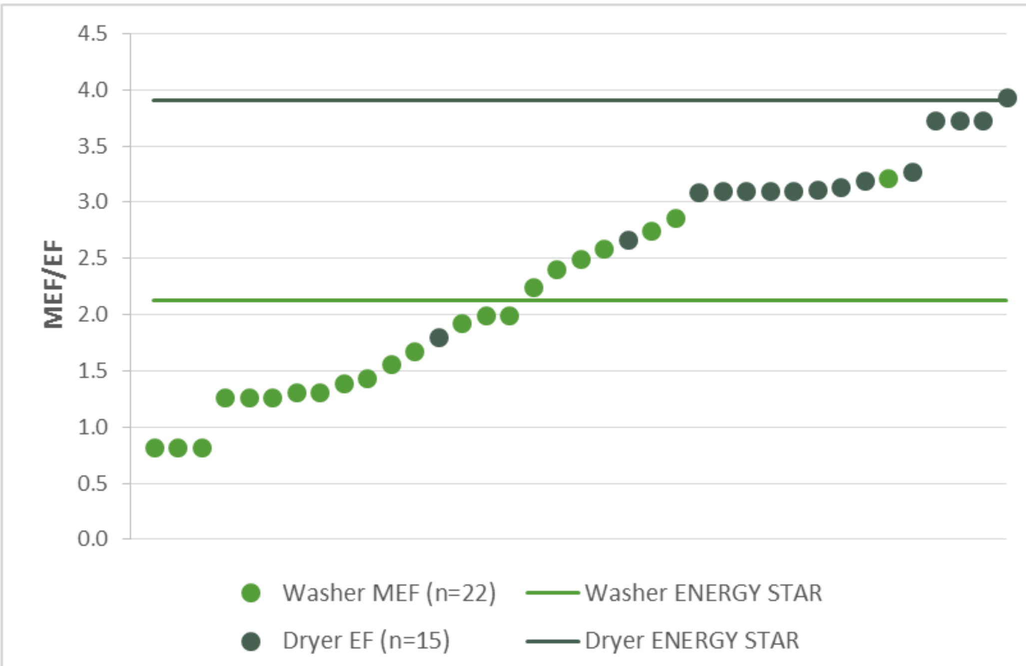


[54] Percentage is weighted to account for oversampling of older homes.

Figure 27 shows clothes washer MEF and clothes dryer EF for the units for which this information could be found. A higher MEF/EF indicates a more efficient machine. Just one dryer out of 15 (4%[55]) found on-site meets current ENERGY STAR criteria for dryers. This may be due to the fact that the first ENERGY STAR standard for clothes dryers had only been in effect for three months at the start of the on-site inspections, having gone into effect in January of 2015.

Clothes washers are generally more efficient, with 7 out of 22 (32%) meeting current ENERGY STAR criteria. The current ENERGY STAR specification for clothes washers took effect in March 2015, just a month prior to the start of on-site inspections; under the previous version of the specification,[56] 9 out of the 22 washers (46%[57]) meet ENERGY STAR criteria.

Figure 27: Maine Washer & Dryer Efficiency vs. ENERGY STAR Criteria



Dehumidifiers

Twelve dehumidifiers were found in eleven homes during the on-site inspections. Of these 12 units, six featured an ENERGY STAR label. Specific efficiency information was available for five of these—on average, they collect about 51 pints of water per day and their Energy

55 Percentage is weighted to account for oversampling of older homes.
56 The ENERGY STAR v. 6 specification for residential clothes washers requires an MEF ≥ 2.0 for all configurations. Available here: https://www.energystar.gov/ia/partners/prod_development/revisions/downloads/commercial_clothes_washers/ENERGY_STAR_Final_Version_6_Clothes_Washer_Specification.pdf
57 Percentage is weighted to account for oversampling of older homes.

Factor in liters/kWh is 1.79. Three of these five units meet the current ENERGY STAR specification of 1.85 liters/kWh.

LIGHTING

Figure 28 displays the breakdown of bulb types in the baseline study homes, excluding empty sockets. Traditional incandescent bulbs are installed in 46% of filled sockets, with CFLs (28%) and LEDs (9%) together representing another 37% of bulbs.

All 41 homes had at least one CFL bulb installed and 46% of homes had at least one LED bulb installed.

Figure 28: Socket Saturation

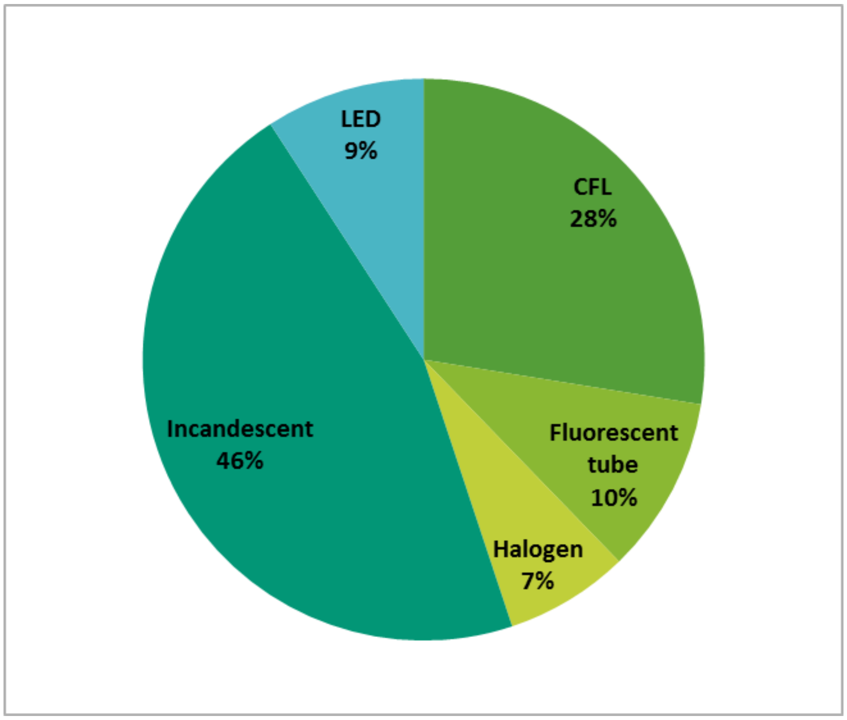


Table 40 compares the bulb types found in the 41 study homes to socket saturation estimates from the recent Retail Lighting program evaluation.[58] As Table 40 shows, the baseline study found a higher share of incandescents (46% vs. 41%) and LEDs (9% vs. 3%) though fewer CFLs (28% vs. 34%) installed in the state's sockets, likely because the Lighting evaluation data was collected only at homes that reported using CFLs. Nonetheless, the proportion of all sockets in which either a CFL or an LED was installed is the same in both the Retail Lighting evaluation and the baseline study at 37%.

Among the baseline study homes, CFLs were installed in the same proportion of sockets in the middle efficiency group as in the most efficient group (29%). Unsurprisingly, incandescents are most common in the least efficient homes (69%), and LEDs are most common in the most efficient homes (14%).

Table 40: Lighting Socket Saturation

Bulb type	Efficiency Level in Heating BTU/ft^2/year[a]			Overall[b]	Retail Lighting Program Evaluation Dec. 2013
	Most Efficient	Middle Efficiency	Least Efficient		
Number of homes	*8*	*25*	*8*	*41*	*67*
Number of bulbs	*747*	*1,500*	*306*	*2,553*	*4,648*
Incandescent	33%	48%	70%	46%	41%
CFL	29%	28%	19%	28%	34%
Fluorescent tube	16%	9%	3%	11%	12%
LED	14%	8%	4%	9%	3%
Halogen	8%	7%	5%	7%	7%
Other	--	< 1%	--	--	3%
CFL or LED	*43%*	*37%*	*23%*	*37%*	*37%*

[a] Unweighted
[b] Weighted

[58] NMR Group, Inc. *Efficiency Maine Retail Lighting Program Overall Evaluation Report.* Submitted to Efficiency Maine on April 16, 2015. Section 2.6.1: Socket Saturations, p. 29.

8 Air Infiltration & Ventilation

This section details the air infiltration rates and ventilation equipment characteristics of Maine homes.

NMR auditors measured air infiltration on-site using blower door tests, where a home is pressurized using a fan mounted in the front door and air leakage is assessed by a manometer (pressure gauge). Blower door tests were conducted at 39 of 41 sites in the sample. At two sites, the presence of asbestos or vermiculite in the home precluded performing the test.

Table 41 details the average air infiltration rates, given in air changes per hour at 50 Pascals (ACH50), within the three efficiency categories and for the state of Maine overall. There are substantial disparities between the three efficiency categories in air leakage rates—while some homes in the most efficient category demonstrate air leakage in a range that would meet new home requirements under the 2009 IECC energy code, air leakage in the eight least efficient homes is very high at about 23 ACH50 on average.

Table 41: Average Air Infiltration Rates

(Base: all homes where testing was possible)

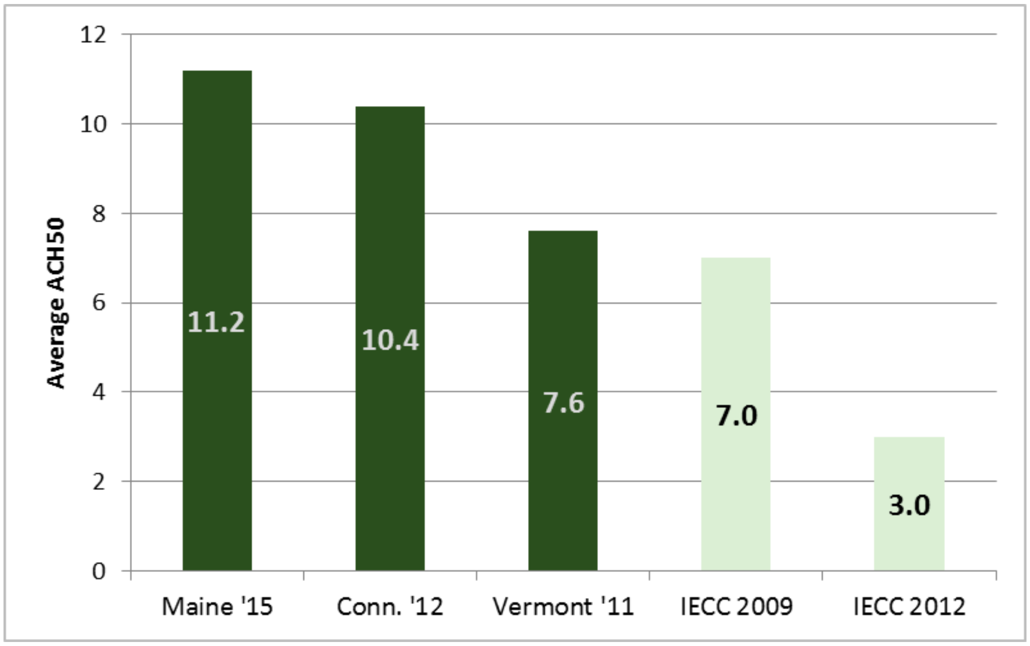
Category	*N*	Average ACH50
Most efficient[a]	*8*	5.6
Middle efficiency[a]	*24*	10.8
Least efficient[a]	*7*	23.5
Overall[b]	***39***	**11.2**

[a] Unweighted

[b] Weighted

Figure 29 compares the average air infiltration rate of existing single-family homes in Maine with that of similar homes in nearby states. Maine's average ACH50 of 11.2 is higher than both the 10.4 ACH50 measured in Connecticut in 2012[59] and the 7.6 ACH50 measured in Vermont in 2011.[60] For context, the 2009 and 2012 IECC energy codes require 7 ACH50 and 3 ACH50 respectively for newly constructed homes.

Figure 29: Air Leakage State Comparisons

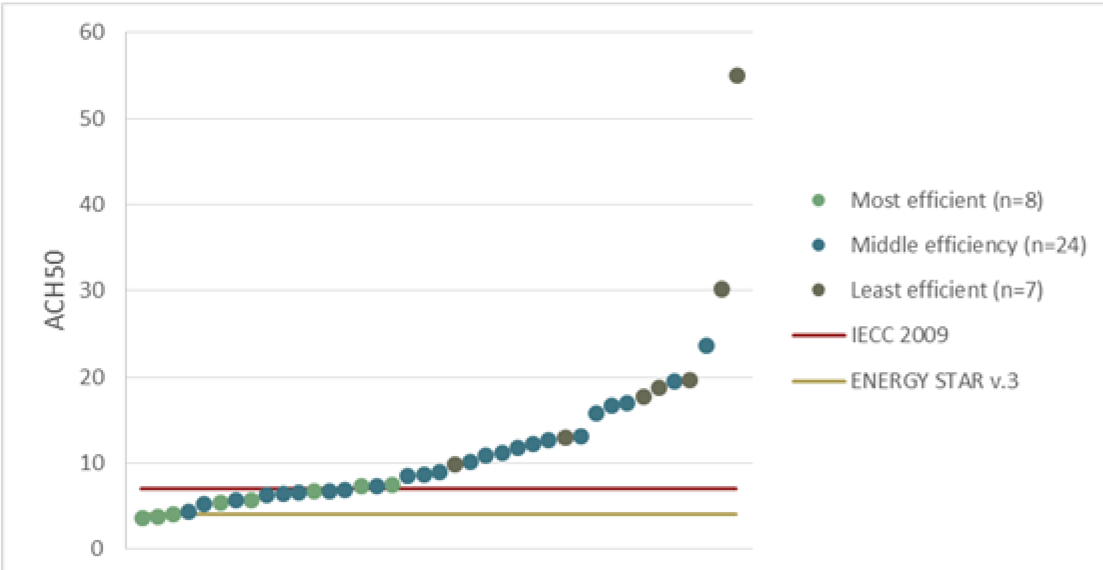


[59] http://www.energizect.com/sites/default/files/R5-Connecticut%20Weatherization%20Baseline%20Assessment-FINAL%2006-04-14.pdf

[60] http://publicservice.vermont.gov/sites/psd/files/Topics/Energy_Efficiency/EVT_Performance_Eval/VT%20SF%20Existing%20Homes%20Onsite%20Report%20-%20final%20021513.pdf

Just two homes out of 39 (5%) meet the current air leakage requirements of the ENERGY STAR Homes Program, while 14 (36%) meet the requirements of the IECC 2009 energy code. It is important to note that these standards apply only to newly constructed homes, and therefore represent a high benchmark for existing homes.

Figure 30: Air Leakage Standard Comparisons



9 Renewables

This section provides information regarding the renewable energy installations found during the on-site inspections. Two homes in the sample feature renewable energy equipment—one has a solar photovoltaic (PV) array, and the other has a solar-assisted hot water (solar thermal) system. The former home falls in the middle efficiency category, and the latter is in the most efficient category of homes.

Solar PV Array

Only one sampled home (3%[61]) has an installed solar photovoltaic array. The array has an area of 405 square feet, a peak power rating of 8,066 watts, and uses an inverter operating with a peak efficiency of 98.3%.

Solar Thermal System

Only one sampled home (3%[62]) has a solar-assisted water heating system, and it was used to heat water for both domestic hot water and space heating purposes. The 45-square foot collector is double glazed, flat black in color, and uses an indirect liquid-based collector loop (using a heat exchanger). Solar-heated water is stored in a 110-gallon tank that could provide heated water to the oil-fired boiler or the indirect storage water heating system.

[61] This is a weighted percentage of the sample.
[62] This is a weighted percentage of the sample.

A

Appendix A Default Efficiency Values

This appendix provides more detail regarding age-based default efficiency values for heating, cooling, and water heating equipment; REM/Rate default R-values for non-insulation building shell component layers; and insulation R-value per inch assumptions by insulation material.[63,64]

[63] Default efficiency values and R-values can be found in the Northeast Home Energy Rating System (NEHERS) Alliance Manual, which is available for purchase at: https://www.nehers.org/store/manual.aspx
[64] REM/Rate default R-values for non-insulation building shell layers were taken directly from the REM/Rate software itself.

Heating, Cooling, and DHW Age-Based Default Efficiencies

Table 42 describes the age-based default mechanical efficiency values which NMR assigned to equipment where no efficiency information was available. This was most often the case when no nameplate—and therefore no model or serial number—was present on the equipment.

Table 42: Heating, Cooling, and Water Heating Age-Based Default Efficiency Values by Equipment Type

Heating system type	Unit	Year of Equipment Manufacture						
		Pre-1960	1960 to 1969	1970 to 1974	1975 to 1983	1984 to 1987	1988 to 1991	1992 Or Later[a]
Heating age-based default efficiency values								
Gas furnaces	AFUE	60	60	65	68	68	76	78
Gas boilers	AFUE	60	60	65	65	70	77	80
Oil furnaces or boilers	AFUE	60	65	72	75	80	80	80
Air-source heat pumps	HSPF	4.5	4.5	4.7	5.5	6.3	6.8	6.8
Cooling age-based default efficiency values								
Central air conditioners	SEER	5.0	6.1	6.5	7.4	8.7	9.4	10.0
Room air conditioners	EER	5.0	6.1	6.1	6.7	7.7	8.1	8.5
Air-source heat pumps	SEER	5.0	6.1	6.5	7.4	8.7	9.4	10.0
Water heating age-based default efficiency values								
Storage gas	EF	0.47	0.47	0.47	0.49	0.55	0.56	0.56
Storage oil	EF	0.47	0.47	0.47	0.48	0.49	0.54	0.56
Storage electric	EF	0.79	0.80	0.80	0.81	0.83	0.87	0.88

[a] Efficiency information is nearly always available for equipment manufactured recently.

Table 43 shows the default Energy Factors assigned to tankless coil water heating systems. These Energy Factors are based on home occupancy[65].

Table 43: Tankless Coil Default Energy Factors

Number of occupants[a]	Energy Factor
Three or fewer	0.45
Four	0.5
Five	0.55
Six	0.6
Seven or more	0.65

[a] Assumed to be the number of bedrooms in the home plus one.

Table 44 describes the default efficiency values for solid-fuel stoves. NMR only applied these values to units for which no identifying information was available. These units tended to be older or in disrepair.

Table 44: Default Seasonal Efficiencies for Solid-Fuel Space Heating

Stove type	Location	Percent Efficiency
EPA-listed stove	Conditioned	Varies[a]
	Unconditioned	85% of EPA listing
Unlisted EPA stove	Conditioned	60%
	Unconditioned	50%
EPA-listed stove insert	Enclosed, such as in fireplace	EPA listing minus 10%
Non-EPA stove	Conditioned	50%
	Unconditioned	40%
Biomass furnace or boiler with distribution system	Conditioned	50%
	Unconditioned	40%
	Outside	30%

[a] Contained in the publication "List of EPA Certified Wood Stoves" available here: http://www2.epa.gov/compliance/list-epa-certified-wood-stoves

[65] Default energy factors from the Northeast Home Energy Rating System Alliance Manual, which is available for purchase at: https://www.nehers.org/store/manual.aspx

Insulation R-value Assumptions

Table 45 details the assumptions auditors used to assess insulation R-value in the absence of kraft facing or another R-value label.

Table 45: R-value per Inch Assumptions by Insulation Material

Insulation material	R-value per Inch
Fiberglass batts, normal	3.1
Fiberglass batts, high-density	3.7
New blown-in fiberglass, open attics	2.5
New blown-in fiberglass, enclosed cavities	3.1
Old blown-in fiberglass or rock wool	1.8
Mineral wool board or batt	4.0
Vermiculite	2.2
Cellulose, loose-fill	3.7
Cellulose, dense-pack	3.5
Polyisocyanurate	6.0
Closed-cell spray foam	6.0
Open-cell spray foam	3.6
Extruded rigid foam	5.0
Expanded rigid foam	4.0

REM/Rate Default Building Shell Component Layer R-values

In modeling heat transfer through the building envelope, REM/Rate assumes the R-values outlined in Table 46 for building shell component layers aside from insulation. The average R-value of all non-insulation layers across component types is about R-2.8.

Table 46: REM/Rate Default Building Shell Component Layer R-values

Component layer	Walls	Floors	Flat Ceilings	Vaulted Ceilings
Inside air film	0.82	0.86	0.86	0.86
Outside air film	0.28	0.46	0.86	0.86
Gypsum board	0.45	--	0.45	0.45
Air gap[a]	0.97	--	--	--
Exterior finish or shingles	0.94	--	--	0.40
Plywood or subfloor	--	0.82	--	0.93
Total R-value	3.46	2.14	2.17	3.50

[a] Not present in every wall assembly. Value based on a 2” gap.

Terms

- **Inside air film.**[66] A layer of still air adjacent to the building’s inside surface that provides some thermal resistance.
- **Outside air film.** A layer of still air adjacent to the building’s outside surface that provides some thermal resistance.
- **Gypsum board.** Used to finish interior walls and ceilings; also known as drywall.
- **Air gap.** The gap that occurs when cavity insulation does not fill the entire depth of the wall cavity.
- **Exterior finish.** The home’s siding.
- **Subfloor.** The structural floor underneath a cosmetic or “finished” floor of hardwood, laminate, or tile.

[66] http://www.energy.ca.gov/glossary/glossary-a.html