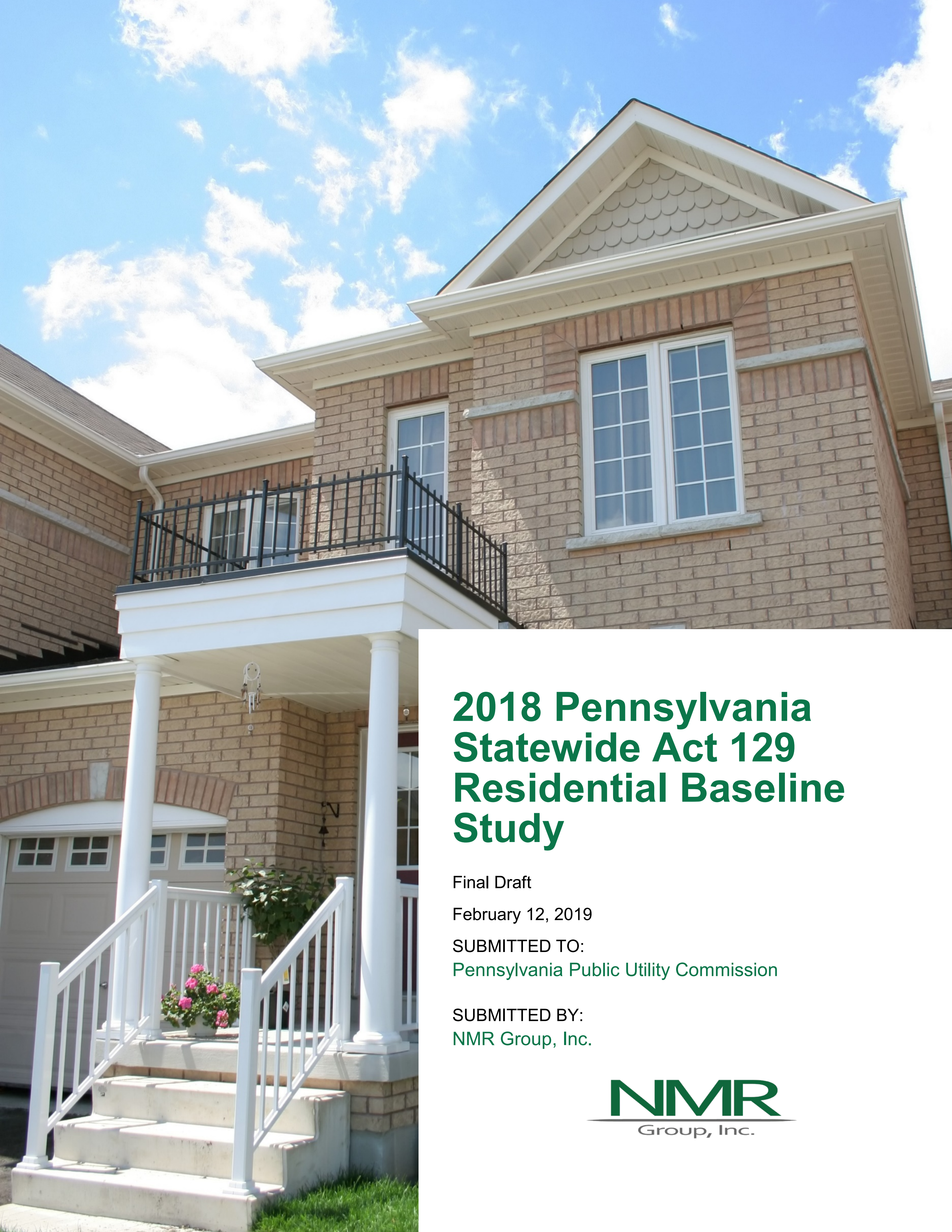


2018 Pennsylvania Statewide Act 129 Residential Baseline Study

Final Draft

February 12, 2019

SUBMITTED TO:
Pennsylvania Public Utility Commission

SUBMITTED BY:
NMR Group, Inc.

NMR Group, Inc.

Pennsylvania Residential Energy Efficiency Study

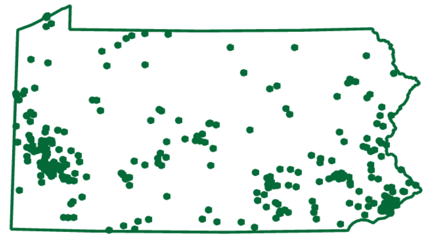
In 2018, Pennsylvania's Statewide Evaluator, led by NMR Group Inc, conducted a residential efficiency study in existing homes as required by the state's energy efficiency law, Act 129. Auditors inspected 289 randomly selected homes across the state to characterize the current baseline energy efficiency level of the housing stock. Auditors collected data on insulation, heating and cooling equipment, appliances, lighting, air leakage, duct leakage, and occupant's willingness to pay for upgrades. This study will be used to update the state's Technical Reference Manual and support the Phase IV energy efficiency market potential study.

145 Detached Single-family

48 Attached Single-family

26 Manufactured or Mobile

70 Multifamily homes



All over Pennsylvania

Key Findings

HERS Index Score[1]

132.3

Homes, regardless of vintage, are 61% less efficient than a home built to code in 2009.

Air Infiltration[1] (ACH50)

11.4

Homes have 63% more (worse) air infiltration than a home built to code in 2009.

Duct Leakage to Outside[1] (LTO CFM25/100 sq.ft.)

14.6

Duct systems have 83% more (worse) leakage than those in a home built to code in 2009.

Average Insulation

Vaulted Ceilings R-17.6

Flat Ceilings R-19.6

Walls R-8.6

Floors R-4.0

Walls, ceilings, and floors are between 48% and 87% less efficient than a home built to code in 2009.

1Based on a subset of 72 homes that received full energy modeling.

Averages

Age	Heating	Cooling	Water Heating	LED Saturation
65 Years	86.3 AFUE	13.1 SEER	0.78 UEF	20%

Saturation Over Time

The share of efficient equipment is increasing over time, but the shares of efficient refrigerators and freezers have plateaued.

		2011	2013	2018
	LED and CFL Bulbs	18%	24%*	40%*
ENERGY STAR	Refrigerators	20%	31%*	31%
ENERGY STAR	Freezers	7%	15%*	10%
ENERGY STAR	Clothes Washers	24%	26%	40%*
ENERGY STAR	Dishwashers	38%	44%	56%*
ENERGY STAR	Room ACs	21%	26%	33%

* Significantly different from the previous study at the 95% confidence level.

Lighting Highlights

27% PPL was the first EDC to stop incentivizing CFLs and exclusively support LEDs. As a result, PPL has a significantly higher saturation of LEDs than all other EDCs.

LED bulbs are replacing inefficient incandescent bulbs, while the share of CFL bulbs remains constant.

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Acknowledgements

The Act 129 Phase III Statewide Evaluation (SWE) Team thanks the staff of the seven electric distribution companies highlighted in this report. Their timely provision of data and their support during recruitment efforts proved immensely important for the success of this study. Specifically, the SWE would like to thank Nick DeDominicis and Kathy MacWilliams of PECO, Dirk Chiles and Peter Cleff of PPL, Dave Defide of Duquesne Light, and Christopher Siebens of FirstEnergy. Additionally, the SWE acknowledges the staff of the Pennsylvania Public Utility Commission's (PUC's) Bureau of Technical Utility Services (TUS) for their assistance and support in all aspects of the SWE's work during Phase III, including providing valuable guidance throughout this study and in the writing of this report

Acronyms

AC	Air Conditioner
ACH50	Air Changes per Hour with a 50 pascal pressure gradient
ACS	American Community Survey
AFUE	Annual Fuel Utilization Efficiency
ASHP	Air-Source Heat Pump
BTU	British Thermal Unit
BTUh	British Thermal Units per Hour
CAC	Central Air Conditioner
CFL	Compact Fluorescent Lamp
CFM25	Cubic Feet per Minute with a 25 pascal pressure gradient
CLG	Cooling
COP	Coefficient of Performance
DHW	Domestic Hot Water
ECM	Electronically Commutated Motor
EDC	Electric Distribution Company
EER	Energy Efficiency Ratio
EF	Energy Factor
EPS	Expanded Polystyrene
ERV	Energy Recovery Ventilation
EUI	Energy Use Intensity
FGB	Fiberglass Batt
GSHP	Ground Source Heat Pump
HERS	Home Energy Rating System
HRV	Heat Recovery Ventilation
HSPF	Heating Season Performance Factor
HTG	Heating
HVAC	Heating Ventilation and Air Conditioning
IECC	International Energy Conservation Code
kWh	Kilowatt Hour
LAP	Lights and Appliances
LED	Light-Emitting Diode
LTO	Leakage to Outside
MWh	Megawatt Hour
PTAC	Packaged Terminal Air Conditioner
PTHP	Packaged Terminal Heat Pump
PUC	Public Utility Commission
PV	Photovoltaic
REM/rate™	Residential Energy Modeling and Rating software by NORESCO

RESNET	Residential Energy Services Network
R-value	A measure of material's resistance to the flow of heat
SEER	Seasonal Energy Efficiency Ratio
SWE	Statewide Evaluator
TDL	Total Duct Leakage
TE	Thermal Efficiency
TRM	Technical Reference Manual
TUS	Technical Utility Services
UC	Unconditioned
UEF	Uniform Energy Factor
UFFI	Urea-formaldehyde
XPS	Extruded Polystyrene

Executive Summary

This report presents the results of a residential energy-efficiency baseline study conducted in 2018 in the service territories of the seven investor-owned utilities in Pennsylvania. The Pennsylvania Public Utility Commission (PUC) contracted with NMR Group, Inc., EcoMetric Consulting, Demand Side Analytics, Optimal Energy, and Abraxas Energy Consulting (collectively the Statewide Evaluation (SWE) team) to conduct this study as one element of the PUC's enforcement responsibilities under Act 129.

Act 129, enacted in 2008, requires each of the seven electric distribution companies (EDCs) with more than 100,000 customers to achieve a specified amount of energy savings over multi-year phases. Phase III started in June of 2016 and will end in May of 2021. The PUC is in the process of establishing the framework for Phase IV, which will begin in June 2021.

The study was designed to meet the following objectives:

1. Characterize the current baseline energy-efficiency levels of Pennsylvania's existing residential building stock
2. Compare current residential efficiency levels to the results of previous Act 129 baseline studies
3. Assess the current willingness-to-pay of electric customers for efficiency upgrades
4. Inform a market potential study for Phase IV of Act 129
5. Inform the update of the Technical Reference Manual (TRM) for Phase IV of Act 129

Auditors audited 289 homes to collect information on insulation, heating and cooling equipment, lighting, appliances, air leakage, and duct leakage. A sub-sample of 72 homes received diagnostic testing (i.e., air leakage and duct leakage to outside testing) and received full energy modeling, including the calculation of Home Energy Rating System (HERS) Index scores[1]. The SWE evenly spread the sample of 289 homes across all seven EDCs and designed it to match statewide mixes of home type and income status as estimated by the US Census American Community Survey.[2] Additionally, the SWE team sought a sample that was representative of the mix of home vintages statewide. The sample intentionally over-represented electrically heated homes to more clearly assess the degree and distribution of electric savings opportunities among single-family existing homes.

The recruiting process differed between single-family and multifamily homes. For single-family homes, the SWE selected a recruiting sample of customers from the full set of residential billing records provided by the EDCs and contacted occupants directly. Multifamily homes were more difficult to recruit because they required the participation of both tenants and owners or property

[1] The Home Energy Rating System (HERS), developed by the Residential Energy Services Network (RESNET) is a widely-used system to measure efficiency in homes. See https://www.resnet.us/hers-index-score-card.
[2] Statewide shares were estimated using the American Community Survey five-year Estimates for 2011-2015 https://www.census.gov/programs-surveys/acs/

managers. The SWE team employed multiple methods to generate multifamily contacts, including using billing data, internet searches, and EDC-supplied customer contacts.

STATEWIDE RESULTS FOR KEY MEASURES

Results for key measures are summarized below for each home type and statewide. The statewide values, in the last column, were weighted to estimate values for the entire housing stock of Pennsylvania.[3] The average HERS score of 132.3 indicates that the average single-family home in Pennsylvania, regardless of vintage, is about 61% less efficient than a home built to code in 2009.[4]

	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
Count	145	48	26	70	289
Average Age in Years	62	65	32	62	65
Average HERS Score*	134.8	110.6	150.4	NA	132.3
Average ACH50*	9.6	11.7	18.1	NA	11.4
Average Duct Leakage*	14.7	11.1	20.5	NA	14.6
Exterior Wall R-value	10.2	8.1	12.1	7.5	8.6
Flat Ceiling R-value	22.1	17.8	20.0	20.0	19.6
Vaulted Ceiling R-value	18.7	14.2	21.5	13.8	17.6
Floor Over Basement R-value	4.4	3.9	14.0	1.6	4.0
Cond. Bsmnt. Wall R-value	5.4	8.1	11.3	2.8	5.0
% of Prgm. Thermostats	53%	36%	46%	51%	47%
Heating System AFUE (systems with AFUE)	87.7	86.2	82.5	84.8	86.3
Cooling System SEER (systems with SEER)	13.1	13.2	11.5	12.7	13.1
Water Heating System UEF (systems with UEF)	0.78	0.70	0.99	0.79	0.78
% of Sockets with LED/CFL	36%	45%	46%	47%	40%

* Based on the 72 homes that received full energy modeling.

[3] The *Count* of homes in the sample is not weighted.

[4] A home built to 2009 IECC requirements would achieve a HERS score of 82. 2009 IECC was the code in effect at the time of the data collection for this study. The Pennsylvania Uniform Construction Code Review and Advisory Council adopted 2015 IECC standards in spring of 2018, to take effect in October 2018: https://www.dli.pa.gov/ucc/Documents/rac/UCC-RAC-2015-Code-Review-Report.pdf

Comparison to Previous Studies

Table 1 compares key measures from this study to the two other most recent studies: the 2013 baseline study[5] and the 2011 baseline study.[6] Comparisons were not made for average mechanical equipment efficiency, air leakage, duct leakage, or HERS score because such data was not reported in previous studies. Bold text indicates that the value is significantly different from another value in the table. Superscript letters identify the specific two values that are statistically different.

Note that this study improved on shell and lighting methods used in the previous studies by using methods more consistent with Residential Energy Services Network (RESNET) protocols and recent baseline studies in the Northeast.[7] Therefore, values reported elsewhere in this report are not comparable to the previous study. To facilitate comparisons, the SWE team re-calculated efficiency values for lighting and shell measures in Table 1 to match the methods used in the previous studies, as follows:

Lighting: Previous reports presented lighting data in a variety of ways, including adjusting socket counts by socket type and separating interior and exterior lighting. The SWE team kept the changes to the lighting marked in mind for this iteration of the report. These changes broadened the potential for LED[8] retrofits to most any socket type and location. Lighting tables include all socket types – screw based of varying sizes, pin-based, exterior – and include empty sockets in saturation tables as they represent opportunities for retrofits to LED bulbs as well. For comparison to previous reports, 2018 lighting data is separated by interior and exterior sockets to match previous methodology, but each category still includes all lighting technology and socket types.

LEDs replaced inefficient bulb types while the share of CFLs held constant

The saturation (i.e., the percent of bulbs that are a certain type) of efficient lighting has increased over time. While the saturation of CFLs[9] seems to have leveled off since 2013 at about 20%, the share of LEDs has increased from 2% to about 20%. This indicates that LEDs have been replacing inefficient bulbs and not CFLs. The increase in LEDs reflects the shift in programs to incentivize LEDs rather than CFLs. Figure 1 displays the increase in efficient lighting across all three studies. As the penetration (i.e., the percent of homes that have at least one bulb of a given type) of LEDs increased from 17% in 2013 to 74% in 2018, the saturation of LEDs increased from 2% to 20%. LED saturation in Pennsylvania is less than that of Rhode Island (33%) and Massachusetts (27%)

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[5] http://www.puc.pa.gov/Electric/pdf/Act129/SWE-2014_PA_Statewide_Act129_Residential_Baseline_Study.pdf
[6] http://www.puc.pa.gov/electric/pdf/Act129/PA_Residential_Baseline_Report2012.pdf
[7] Recent studies include studies in Massachusetts (http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC-17-2-Single-Family-New-Construction-Mini-Baseline-Study.pdf), Connecticut (https://www.energizect.com/sites/default/files/R1602-RNC%20Baseline%20Report-FINAL%2020180503_Revised.pdf), and Rhode Island (http://rieermc.ri.gov/wp-content/uploads/2018/03/ri-rnc-baseline-study_16jan2018_final.pdf)
[8] Light-emitting diodes (LEDs) are an efficient semiconductor lighting technology. See https://en.wikipedia.org/wiki/Light-emitting_diode.
[9] Compact Fluorescents (CFLs) are an efficient lighting technology. See https://en.wikipedia.org/wiki/Compact_fluorescent_lamp.

which have similar programs, but greater than that of New York (14%) which stopped incentivizing LEDs in 2014.[10],[11]

Appliances: The share of appliances that were ENERGY STAR qualified increased over time. Specifically, the shares of ENERGY STAR qualified clothes washers, dishwashers, and room air conditioners have increased since 2011. The shares of ENERGY STAR qualified refrigerators and freezers have plateaued since 2013. ENERGY STAR qualifications for dryers were only introduced recently and thus there were no ENERGY STAR dryers in previous studies. Additionally, the previous studies did not report on dehumidifier ENERGY STAR status.

Shell Measures: The previous reports included R-value[12] data in shell analyses only when insulation was present regardless of whether the insulation only comprised a small fraction of the building shell. This fails to properly consider the impact of uninsulated homes when trying to determine the average R-value of a shell measure in the sample. Additionally, the previous reports assigned a per-home R-value based on the insulation type and thickness installed in the majority of area in each measure for each home. This report follows the RESNET guidelines of calculating an area-weighted average R-value per-home. When comparing between reports, the 2018 results are still area-weighted R-values but exclude uninsulated cases to allow for a more direct comparison. Elsewhere in this report, uninsulated cases are included when calculating the average R-value per measure.

The average R-values of shell insulation have remained constant over time. This is not surprising since it is more difficult to upgrade insulation than appliances or light bulbs. The apparent but statistically insignificant reductions in R-value between 2013 and 2018 are likely the result of the 2018 study using the RESNET approved protocol for calculating R-value instead of just reporting nominal values.

[10] RI2311 National Grid Rhode Island Lighting Market Assessment. July 27, 2018. Submitted to National Grid Rhode Island by NMR Group, Inc. http://www.ripuc.org/eventsactions/docket/5.%20RI2311%20RASS%20Lighting%20Report%20Final%2027July2018.pdf

[11] A national estimate of LED penetration is not currently available.

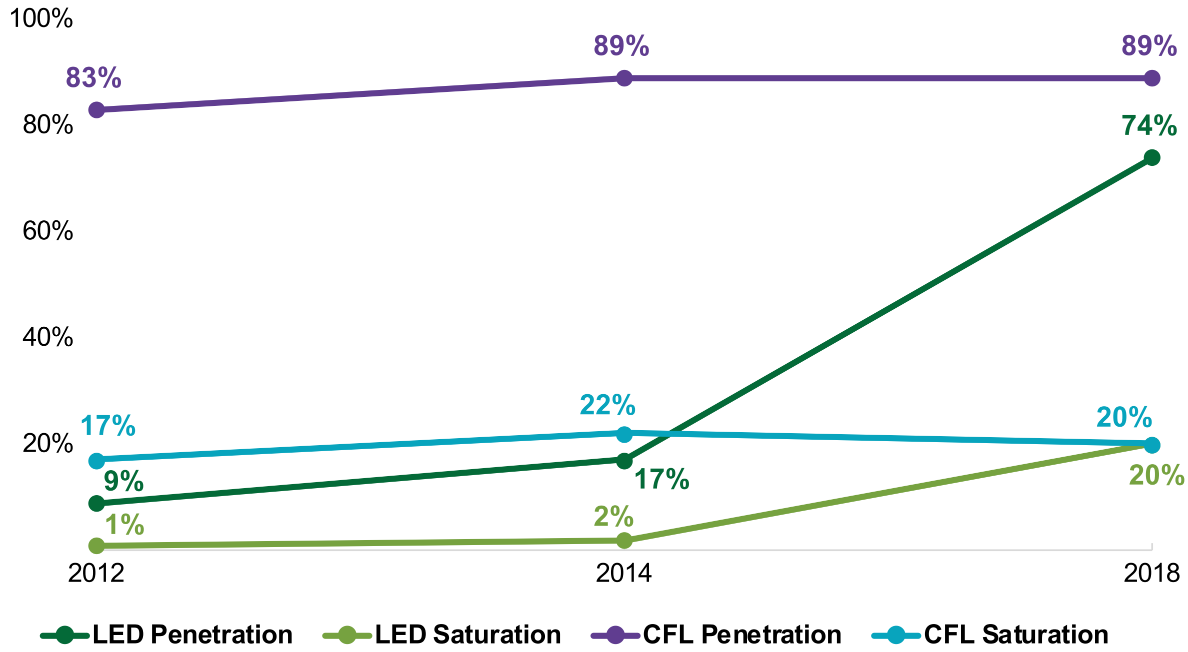
[12] R-value is a measure of the capacity of a material to resist heat flow. A material with a higher R-value is more insulating.

Table 1: Comparison of Efficiency Measures Across Studies

	2011	2013	2018
Lighting			
CFL Saturation (Interior)	**17%**	**22%**[a]	**20%**[a,b]
CFL Saturation (Exterior)	**12%**	**19%**[a]	**21%**[a]
LED Saturation (Interior)	**1%**	**2%**[a]	**20%**[a,b]
LED Saturation (Exterior)	**--**	**2%**[a]	**18%**[a,b]
LED Penetration (Interior)	**9%**	**17%**[a]	**74%**[a,b]
Appliances (Percent ENERGY STAR)			
Refrigerator	**20%**	**31%**[a]	**31%**[a]
Freezer	**7%**	**15%**[a]	**10%**[a]
Clothes Washer	**24%**	**26%**	**40%**[a,b]
Clothes Dryer	--	--	4%
Dishwasher	**38%**	**44%**	**57%**[a,b]
Dehumidifier	--	--	83%
Room AC	**21%**	26%	**33%**[a]
Shell (Average R-value)			
Flat Ceiling	R-24	R-25	R-23
Cathedral Ceiling	R-24	R-25	R-21
Ambient Walls	R-15	R-13	R-11
Frame Floor to UC Bsmt/ECS	R-16	R-19	R-12
Conditioned Foundation Wall	R-14	R-13	R-10

[a] Significantly different from the 2011 sample at the 95% confidence level.
[b] Significantly different from the 2013 sample at the 95% confidence level.

Figure 1: Efficient Lighting Across Studies



COMPARISONS BY EDC

Table 2 compares key measures across all EDCs. Results are unweighted. Again, bold text indicates that the value is significantly different from the value of another EDC. Superscript letters identify the specific two EDCs that are statistically different.

Throughout the rest of the report, results are primarily reported by home type since in some instances the sample sizes by EDC are small. For detailed results by EDC see Appendix D, Appendix F, Appendix G, and Appendix H.

LED bulb saturation in PPL homes was significantly higher than all other EDCs at 27%. This is believed to be because PPL switched to incentivizing LED bulbs in their programs sooner than the other EDCs. PECO and Penn Power had significantly lower LED saturation than the other EDCs at 15%. Met Ed homes displayed the highest rate of LED bulb penetration at 90% – all EDCs showed LED penetration rates of at least 71% outside of PECO, where LEDs were installed in 65% of homes.

Table 2: Comparison of Efficiency Measures by EDC

	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn
Lighting							
LED Saturation	**15%**	**27%[a]**	**21%[a,b]**	**20%[a,b]**	**20%[a,b]**	**15%[b,c,d,e]**	**20%[a,b,f]**
CFL Saturation	20%	20%	20%	20%	19%	19%	18%
Total Efficient Bulb Saturation[1]	**43%**	**54%[a]**	**52%[a]**	**53%[a]**	**50%[a,b,d]**	**41%[b,c,d,e]**	**53%[a,e,f]**
LED Penetration	**65%**	**82%[a]**	**73%**	**90%[a,c]**	**71%[d]**	81%	**74%[d]**
Appliances (Percent ENERGY STAR)							
Refrigerator	**26%**	**32%**	**25%**	**34%**	**28%**	**51%[abcde]**	**35%[f]**
Freezer	**--**	9%	13%	**--**	17%	11%	**29%[ad]**
Clothes Washer	**39%**	**36%**	**27%**	**50%[c]**	**16%[abd]**	**44%[e]**	**53%[ce]**
Clothes Dryer	**8%**	3%	**2%**	**2%**	**2%**	**--[a]**	**12%[adef]**
Dishwasher	**50%**	46%	31%	**48%**	**50%**	**26%[ad]**	**23%[ad]**
Dehumidifier	78%*	91%	67%	82%	100%	69%	77%
Room AC	28%	24%	26%	35%	**41%**	50%	**25%[e]**
Shell (Average R-value)							
Flat Ceiling	**15.2**	**23.9[a]**	**17.6[b]**	**21.9[a]**	**15.9[b]**	**27.2[a,c,e]**	**24.9[a,c,e]**
Cathedral Ceiling	18.2	**22.3**	17.7	16.1	**12.4[b]**	20.8	19.2
Ambient Walls	**6.1**	**11.1[a]**	**7.3[b]**	**9.7[a]**	**9.0[a]**	**12.2[a,c,e]**	**11.6[a,c]**
Frame Floor to UC Bsmt/ECS	3.9	**7.0**	**1.9[b]**	**8.3[c]**	4.1	1.4†	6.6
Conditioned Foundation Walls	**1.7**	**5.9[a]**	**2.5**	**6.6[a,c]**	**8.6[a,c]**	**6.5[a]**	**7.9[a,c]**
Mechanical Equipment Efficiency							
Heating (AFUE)[2]	84.2	85.3	87.8	86.4	85.0	88.9	89.2
Cooling (SEER)[3]	12.3	13.5	12.6	12.9	14.0	12.7	13.1
Water Heating (UEF)[4]	0.70	0.95	0.69	0.76	0.82	0.79	0.81

[a] Significantly different from the PECO sample at the 95% confidence level.
[b] Significantly different from the PPL sample at the 95% confidence level.
[c] Significantly different from the Duquesne sample at the 95% confidence level.
[d] Significantly different from the FE: Met-Ed sample at the 95% confidence level.
[e] Significantly different from the FE: Penelec sample at the 95% confidence level.
[f] Significantly different from the FE: Penn Power sample at the 95% confidence level.
†Sample size too low for significance testing.
[1] Includes LED, CFL, and fluorescent bulbs.
[2] Includes all systems with AFUE ratings
[3] Includes all systems with SEER ratings
[4] Includes all systems with UEF ratings and EF ratings converted to UEF.

Comparison of Findings by Income Status

The SWE team characterized each home as being above or below the low-income threshold based on the Pennsylvania Low-Income Home Energy Assistance Program income and household size criteria for 2016-2017. Table 3 compares results for key measures by income status excluding 15 homes for which the occupants declined to divulge income information. Efficient lighting and LED saturation was significantly higher in low-income homes than in non-low-income homes. Figure 2 shows bulb type saturation by income status in more detail. Non-low-income homes had significantly higher R-values in flat ceilings than low-income homes.[13] This could be the result of low-income homes having a larger share of row homes which frequently have flat roofs with little to no insulation. Additionally, non-low-income homes had a larger share of ENERGY STAR qualified freezers.[14]

Table 3: Comparison of Efficiency Measures by Income Status

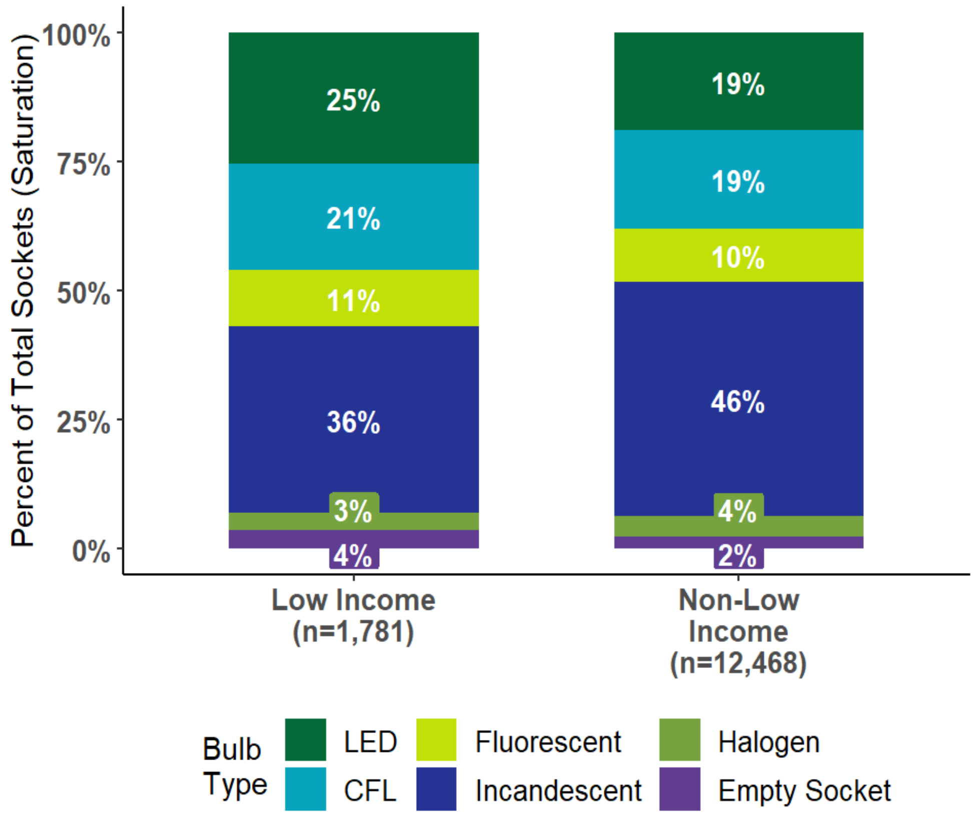
	Low-Income *(Sites=66)*	Non-Low-Income *(Sites=208)*
Lighting		
Efficient Lighting Saturation*	**57%**	**48%[a]**
CFL Saturation	21%	19%
LED Saturation	**25%**	**19%[a]**
Appliances (Percent ENERGY STAR)		
Refrigerator	38%	32%
Freezer	**--**	**15%[a]**
Clothes Washer	39%	42%
Clothes Dryer	8%	6%
Dishwasher	50%	38%
Dehumidifier	83%	80%
Room AC	22%	33%
Shell (Average R-value)		
Flat Ceiling	**17.6**	**22.3[a]**
Cathedral Ceiling	16.8	18.0
Ambient Walls	8.2	10.1
Frame Floor to UC Bsmt/ECS	5.6	4.8
Conditioned Foundation Walls	4.7	5.9
Mechanical Equipment Efficiency		
Heating Equipment (AFUE)[1]	**83.8**	**87.0[a]**
Cooling Equipment (SEER)[2]	13.1	12.9
Water Heating Equipment (UEF)[3]	0.88	0.78

[13] "Flat ceilings" refers to any ceiling with attic space above it or a completely horizontal flat roof commonly found in row homes.

[14] While freezers were located in a 30% of low-income homes and 37% of non-low-income homes, this difference was not statistically significant.

[a] Significantly different from the low-income sample at the 95% confidence level.
[1] Includes all systems with AFUE ratings
[2] Includes all systems with SEER ratings
[3] Includes all systems with UEF ratings and EF ratings converted to UEF.

Figure 2: Bulb Type Saturation by Income Level



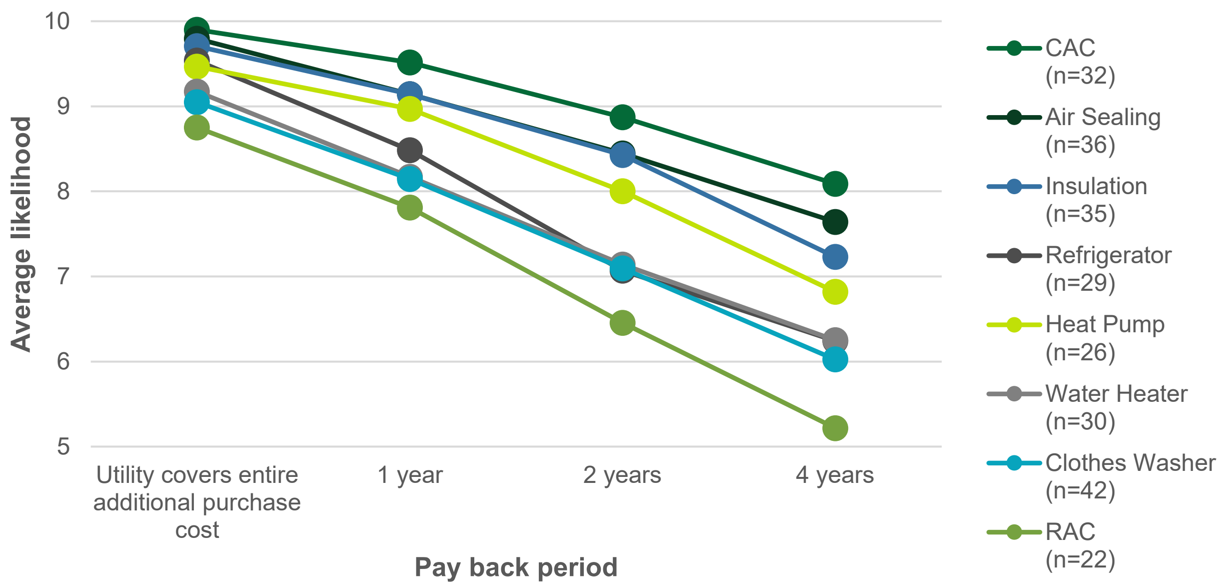
Willingness to Pay Findings

A willingness-to-pay survey was included in onsite data collection to provide insight into factors that are important to customers when deciding between standard and higher efficiency options, their likelihood to purchase higher efficiency options based on payback period, and the importance of service and program assistance that utilities can provide.

Respondents generally prioritized the performance of the new measure and electricity bill savings. For insulation and air sealing (especially insulation), respondents also prioritized receiving adequate information on the costs and savings; while for all other measures (especially heat pumps and water heaters) they prioritized the improved reliability and reduced maintenance costs of the new measure. Not surprisingly, respondents indicated a high likelihood of purchasing a higher efficiency option over a standard option if the utility were to cover the additional cost of the high-efficiency option.

Respondents were asked their likelihood to purchase efficient equipment given payback periods of four years, two years, one year, or if the utility covered the entire purchase cost up front. Central air conditioners (CAC), air sealing, insulation, and heat pumps had the highest purchase likelihoods for all payback periods. Room air conditioners (RAC) consistently had the lowest purchase likelihood (Figure 3).

Figure 3: Likelihood to Purchase Higher Efficiency Measures by Payback Period



When asked what utility services would be most important to them when considering upgrading to more efficient equipment, respondents not surprisingly said cash rebates would be the most attractive. Beyond that, they indicated interest in programs to ensure that contractors and retail stores offer high-efficiency options and competitive pricing, as well as offering free or low-cost energy audits.

Section 1 Introduction

This report presents the results of a residential energy-efficiency baseline study conducted in 2018 in the service territories of the seven major Electric Distribution Companies (EDCs) in Pennsylvania. The Pennsylvania Public Utility Commission (PUC) contracted with NMR Group, Inc., EcoMetric, Demand Side Analytics, Optimal Energy, and Abraxas Energy Consulting – collectively the SWE team – to conduct this study as one element of the PUC's enforcement responsibilities under Act 129. The study was designed to meet the following objectives:

1. Characterize the current baseline energy-efficiency levels of Pennsylvania's existing residential building stock
2. Compare current residential efficiency levels to the results of previous Act 129 baseline studies
3. Assess the current willingness-to-pay of electric customers for efficiency upgrades
4. Inform a market potential study for Phase IV of Act 129
5. Inform the update of the TRM for Phase IV of Act 129

For this study, the SWE conducted onsite energy-efficiency audits at 289 existing single-family and multifamily homes varying in vintage, heating fuel, and income status. The sites were located throughout the service territories of the following EDCs:

- PECO Energy Company (PECO)
- PPL Electric Utilities (PPL)
- Duquesne Light Company (Duquesne)
- First Energy: Metropolitan Edison Company (FE: Met-Ed)
- First Energy: Pennsylvania Electric Company (FE: Penelec)
- First Energy: Pennsylvania Power Company (FE: Penn Power)
- First Energy: West Penn Power Company (FE: West Penn)

The SWE designed the onsite data collection with the PUC to ensure comparability with the results of the previous baseline studies, conducted in 2011 and 2013. To provide a more detailed assessment of the energy features of single-family homes, this study also included energy modeling for a subset of 72 detached, attached, and mobile/manufactured single-family homes. These homes received full diagnostic testing, including the quantification of air leakage and duct leakage where possible. The SWE team generated HERS Index scores for each of these 72 homes.

1.1 Act 129 Background

Pennsylvania enacted Act 129 in October of 2008. Act 129 requires each of the seven EDCs to achieve a specified amount of energy savings in their respective service territories over multiyear phases. The Pennsylvania PUC sets the savings targets prior to the start of each phase. Phase III started on June 1, 2016 and will end on May 31, 2021. The PUC is establishing the framework for Phase IV, which will begin June 1, 2021.

The PUC will use an electric efficiency market potential study prepared by the SWE team to inform the savings targets. The residential baseline study is a key input into the market potential study, along with a commercial and industrial baseline study that the SWE team is conducting at the same time as the residential baseline study.

This residential baseline study will also supply several important inputs to the Phase IV update of the Act 129 TRM.[15] The TRM serves a variety of purposes for Act 129. In addition to providing measure savings protocols, the TRM ultimately seeks to facilitate the implementation and evaluation of Act 129 programs. The TRM serves as a common reference document for energy-efficiency measures and establishes standardized, statewide protocols to calculate energy and demand savings for measures.

[15] http://www.puc.pa.gov/filing_resources/issues_laws_regulations/act_129_information/technical_reference_manual.aspx

Section 2 Characterization of Electric Customers and Sales

Data from the U.S. Energy Information Administration (EIA) for 2017 show that sales to residential customers of the seven EDCs subject to Act 129 are 34% of the total sales statewide (Table 4). The average residential customer in the Act 129 EDC service territories uses 2.5 times less electricity per year than the average non-residential customer. However, there are more than seven times as many residential customers. The table is only meant to provide context about Act 129. It cannot be used to assess the effectiveness of Act 129 since multiple factors affect the energy consumption of any customer and those factors are not considered here.

Table 4: 2017 Electricity Sales in Pennsylvania[16]

	Sales (MWh)	Customers	Per Customer (kWh)
Pennsylvania	142,990,896	6,077,878	23,526
Act 129 EDCs	137,138,995 (96%)	5,690,268 (94%)	24,101
Residential Customers of Act 129 EDCs	48,353,538 (34%)	5,009,255 (82%)	9,653

Table 5 shows the trends in residential electricity consumption from 2012-2017, the period including the previous two baseline studies, for customers of the Act 129 EDCs. While the number of customers has increased each year since 2012, sales in 2017 were the lowest of the period and sales per customer are 6.4% less than their peak in 2013.[17] In 2012, PJM predicted average annual growth rates of more than 2% through 2017 for the Act 129 EDCs.[18] The actual annual growth rate only exceeded 2% in 2012-2013, and growth was negative for three of the five years. Going forward, the 2018 PJM load forecast predicts annual growth rates of less than 1% in Pennsylvania zones from 2018-2028.[19]

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[16] US Energy Information Administration (EIA), https://www.eia.gov/electricity/data.php. Accessed November 8, 2018.
[17] Note that these sales figures are not weather normalized. Weather changes from year to year will affect electricity demand for heating and cooling and other end uses. As shown in the Diagnostic section, nearly half of the electric consumption in the average single-family home goes to space heating or cooling.
[18] PJM Resource Adequacy Planning Department, PJM Load Forecast Report 2012. Table E-1: Annual Net Energy and Growth Rates for Each PJM Mid-Atlantic Zone and Geographic Region, 2012-2022. https://www.pjm.com/-/media/library/reports-notices/load-forecast/2012-pjm-load-report.ashx?la=en. Accessed December 2018.
[19] PJM Resource Adequacy Planning Department, PJM Load Forecast Report 2018. Table E-1: Annual Net Energy and Growth Rates for Each PJM Mid-Atlantic Zone and Geographic Region, 2018-2028. https://www.pjm.com/-/media/library/reports-notices/load-forecast/2018-load-forecast-report.ashx?la=en. Accessed November 2018.

Table 5: 2017 Electricity Sales in Pennsylvania[20]

Year	Sales (MWh)	Customers	Per Customer (kWh)
2012	49,567,215	4,918,750	10,077
2013	50,822,507	4,928,276	10,312
2014	50,726,906	4,944,568	10,259
2015	50,942,854	4,958,796	10,273
2016	50,443,722	4,987,885	10,113
2017	48,353,538	5,009,255	9,653

A primary goal of this report is to characterize how residential customers use electricity in their homes and how electricity consumption varies for different EDC service territories, home types, and heating fuels. These values are a primary input for the market potential study that will help the PUC and EDCs implement effective programs to save energy and meet the requirements of Act 129.

To achieve a reliable, fine-grained view of electricity use by EDC, home type, and heating fuel, the SWE team made use of the Census' Public Use Microdata Sample (PUMS) for the five-year averages of the American Community Survey (ACS) for 2012-2016.[21] This dataset is an anonymized version of the ACS that allows analysis of data that are not pre-tabulated by the Census at the level of the individual household. The PUMS includes a field for the monthly electric bill that, along with data on home type and fuel type, can be translated to consumption estimates for a non-Census geography, such as the EDC service territories. This data source is preferable to the residential billing data, which do not include reliable information about home type or heating fuel. Table 169 in Appendix A includes the full estimates of annual consumption for residential customers by EDC, home type, and heating fuel. The following summary tables show consumption and customer estimates by these categories individually. In Table 6, we see that Duquesne, an urban EDC with the lowest share of electrically heated homes, has the lowest consumption per customer.

[20] ibid.
[21] US Census American Community Survey PUMS Data. https://www.census.gov/programs-surveys/acs/technical-documentation/pums.html

Table 6: Electricity Consumption by EDC

EDC	Consumption (MWh)	Customers	Per Customer (kWh)
PECO	12,945,808 (27%)	1,463,018 (29%)	8,849
PPL	13,650,614 (28%)	1,246,636 (25%)	10,950
Duquesne	3,876,117 (8%)	532,920 (11%)	7,273
FE: Met-Ed	5,350,518 (11%)	499,192 (10%)	10,718
FE: Penelec	4,123,293 (9%)	498,288 (10%)	8,275
FE: Penn Power	1,590,587 (3%)	144,286 (3%)	11,024
FE: West Penn	6,816,601 (14%)	624,915 (12%)	10,908

Customers occupying detached single-family homes have the highest annual consumption whereas, customers residing in multifamily dwellings have the lowest, as shown in Table 7. This is likely influenced by the larger size of detached single-family homes compared to other home types.[22]

Table 7: Electricity Consumption by Home Type

Home Type	Consumption (MWh)	Customers	Per Customer (kWh)
Detached Single-family	31,794,384 (58%)	2,892,894 (66%)	10,991
Attached Single-family	8,316,509 (19%)	940,063 (17%)	8,847
Multifamily	6,596,807 (20%)	1,004,747 (14%)	6,567
Manuf./Mobile	1,645,838 (3%)	171,551 (3%)	9,594

Table 8 shows consumption by heating fuel. Customers with electric heat have the highest annual consumption, as expected. Natural gas customers have the lowest annual electricity use, though they make up the largest share of customers and total consumption. Natural gas service is commonly available only in more densely populated areas with higher shares of smaller, detached, and multifamily homes.

[22] As shown in Table 21, detached single-family homes have an average conditioned floor area of 2,295 sq. ft, followed by attached single-family homes at 1,778 sq. ft., manufactured/mobile homes at 1,166 sq. ft., and multifamily homes at 1,031 sq. ft.

Table 8: Electricity Consumption by Heating Fuel

Heating Fuel	Consumption (MWh)	Customers	Per Customer (kWh)
Utility Gas	21,744,062 (45%)	2,584,386 (52%)	8,413
Electricity	13,583,001 (28%)	1,115,198 (22%)	12,180
Fuel Oil, Kerosene, etc.	8,384,820 (17%)	862,479 (17%)	9,722
Bottled, Tank, or LP Gas	2,033,942 (4%)	196,763 (4%)	10,337
Wood	1,459,143 (3%)	134,111 (3%)	10,880
Coal or Coke	632,760 (1%)	64,207 (1%)	9,855
Other Fuel	353,195 (1%)	34,233 (1%)	10,317
No Fuel Used	142,654 (<1%)	16,132 (<1%)	8,843
Solar Energy	19,961 (<1%)	1,747 (<1%)	11,424

3

Section 3 Methods

The SWE conducted audits of a representative sample of homes to assess the energy efficiency of Pennsylvania's existing housing stock.[23] This is consistent with the approach that has historically been used in Pennsylvania under Act 129, including previous residential baseline studies conducted by the prior SWE team in 2011 and 2013. To provide greater detail and insight into the energy efficiency of single-family homes, the SWE performed diagnostic testing and generated energy models at a subset of sites. This chapter describes the methods used throughout the study, including sampling, recruiting, inspecting, and analysis.

3.1 Baseline Sampling

The study plan called for a sample of 287 energy audits comprised of 217 single-family homes and 70 multifamily housing units and/or buildings spread equally across all seven EDC service territories. The final sample had two more homes than planned, bringing the total sample size to 289.[24] Within the full sample, there are different home types and visit types that warrant specific presentation and analysis in the report.

- **Full sample** refers to the entire set of 289 sites.
- **Total single-family sample** refers to all 219 single-family homes. This includes detached, attached, and manufactured or mobile homes.
- **Diagnostic sub-sample** refers to the subset of 72 homes from the total single-family sample that received full energy modeling, including the calculation of HERS Index scores. This sub-sample intentionally included an over representation of electrically heated homes or homes with air conditioning. The energy modeling results are detailed in Section 5 Diagnostic Sub-Sample Results.
- **Multifamily sample** refers to the 70 multifamily housing units and/or buildings. This includes buildings with as few as two stacked units to as many as 289 units.

3.1.1 Full Sample Composition

The full sample is distributed across the seven EDCs with variations mainly driven by the multifamily sample (Table 9). The imbalance is due to the recruiting of more multifamily homes in the EDC service territories in or around large cities, such as PECO and Duquesne. For a detailed explanation of the multifamily sample and recruitment process, see section 3.2.2 Multifamily Recruitment.

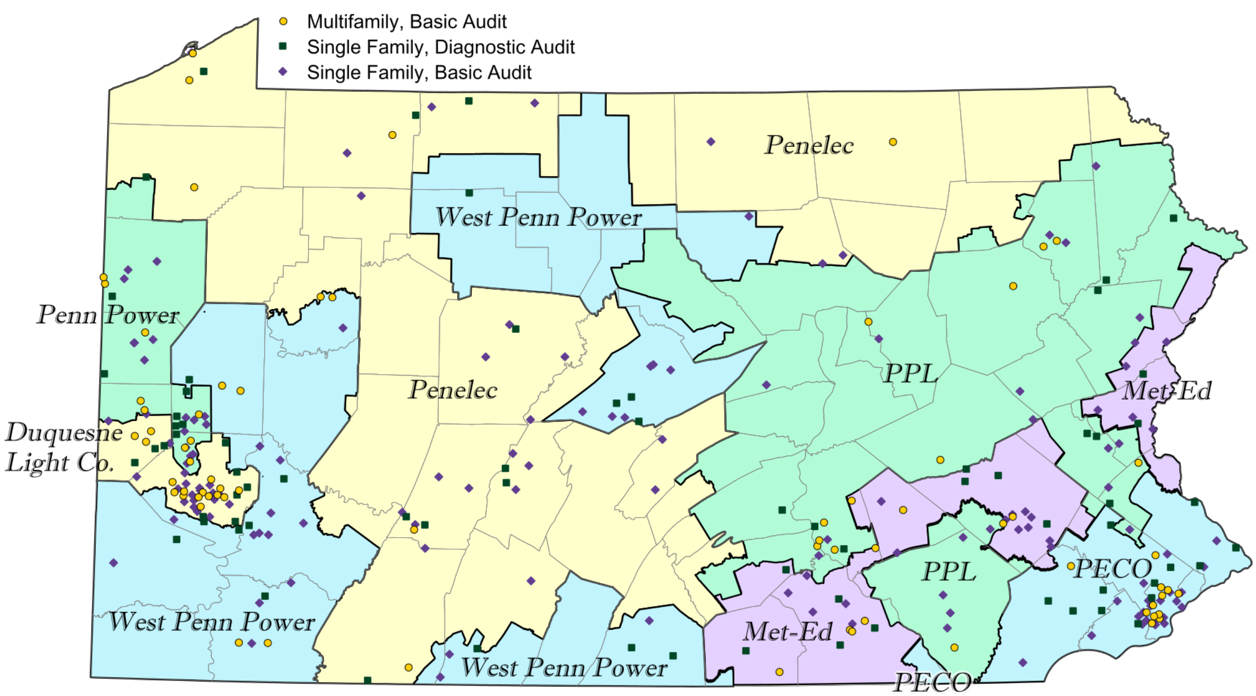
[23] Throughout the report *homes* refers to both houses and apartment units.
[24] Towards the end of the study, extra sites were scheduled in case occupants cancelled at the last minute. Few cancellations in the final month lead to two extra audits.

Table 9: Sample Composition by EDC

EDC	Total Single-family	Diagnostic Sub-sample	Multifamily Sample	Full Sample
PECO	34	11	12	46
PPL	32	11	12	44
Duquesne	33	10	18	51
FE: Met-Ed	31	10	8	39
FE: Penelec	31	10	7	38
FE: Penn Power	25	10	7	32
FE: West Penn	33	10	6	39
Statewide	**219**	**72**	**70**	**289**

Figure 4 maps the distribution of single-family basic audits (i.e., single-family homes that did *not* receive energy modeling), single-family diagnostic audits (i.e., homes that *did* receive energy modeling), and multifamily audits across the seven major EDC service territories.

Figure 4: Map of Sampled Homes



To facilitate the comparison of results, the 2018 study utilized the same housing types (single-family detached, single-family attached, mobile/manufactured home, and multifamily) as the prior baseline study. We used data from the American Community Survey (ACS) to estimate the proportion of housing types for all housing units in Pennsylvania and in turn develop targets by home type for our sample.[25] In addition, the SWE team categorized the homes as either above or

[25] American Community Survey Five-year Estimates for 2011-2015. https://www.census.gov/programs-surveys/acs/

below the low-income threshold based on the 2016-2017 Pennsylvania Low-Income Home Energy Assistance Program income and household size criteria.[26,27] Table 10 compares the full sample's mix of home types and income statuses to the sample plan targets. Overall, the final sample closely matched the sample plan. The final sample error at the 90% confidence level was ±5%, which matches the sample plan.

Table 10: Full Sample Composition – Home Type by Income Status

Home Type	Proportion	Non-low-income	Low-income	Don't Know/ Refused	Full Sample*
Detached Single-family	Target	43%	6%	--	49%
	Sample	45%	5%	--	50%
Attached Single-family	Target	13%	5%	--	17%
	Sample	11%	5%	1%	17%
Manufactured/ Mobile	Target	6%	3%	--	9%
	Sample	6%	3%	<1%	9%
Multifamily	Target	15%	9%	--	24%
	Sample	10%	10%	4%	24%
Full Sample	Target	76%	24%	--	100%
	Sample	72%	23%	5%	100%

* Rounding results in some rows not summing to the full sample value.

3.1.2 Total Single-family and Diagnostic Sub-Sample Targets

To account for variation in home efficiency due to vintage, the SWE team attempted to recruit a single-family sample with a vintage mix matching the statewide values for single-family homes. Within the diagnostic sub-sample, the SWE team purposefully oversampled electrically heated homes to more clearly assess the degree and distribution of electric savings opportunities among single-family existing homes. Table 11 and Table 12 summarize the mix of vintages and primary heating fuel for the total single-family sample and the diagnostic sub-sample.

26 http://www.dhs.pa.gov/citizens/heatingassistanceliheap/homeheatingassistanceliheapeligibility/

27 The LIHEAP program generally sets its income eligibility requirements at 150% of the federal poverty level except where 60% of the state medium income is higher. For Phase III, each EDC EE&C Plans must obtain at least 5.5% of its consumption reduction requirements from programs solely directed at low-income customers or low-income-verified participants in multifamily housing programs. Low-income customers are defined as households whose incomes are at or below 150% of the Federal Poverty Income Guideline.

Table 11: Total Single-family Sample Composition – Vintage

Year Built	Total Single-family (*n=219)*	Diagnostic Sub-sample (*n=72*)	ACS (*N*=3,945,837)
2010 or later	5%	6%	2%
2000-2009	8%	11%	9%
1980-1999	22%	32%	22%
1960-1979	21%	26%	23%
1940-1959	18%	13%	21%
Before 1940	27%	13%	23%

Table 12: Total Single-family Sample Composition – Primary Heating Fuel

Heating Fuel	Total Single-family (*n=219)*	Diagnostic Sub-sample (*n=72*)	ACS (*N*=3,978,999)
Natural Gas	57%	40%	52%
Electricity	20%	42%	17%
Oil or Kerosene	14%	10%	20%
Propane or Other Tank Gas	8%	8%	5%
Wood	1%	--	4%
Coal or Coke	<1%	--	2%
Solar	--	--	<1%
Other Fuel	--	--	1%
No Fuel Used	--	--	<1%

3.1.3 Multifamily Sample Targets

Within the sample target of 70 multifamily homes, the SWE attempted to match the mix of building sizes (in units) to the statewide distribution. The final sample somewhat over-represents larger buildings compared to 2-4 unit buildings (Table 13). These smaller properties proved more difficult to recruit than larger sites, as detailed in Section 3.1.4.

Table 13: Multifamily Sample Targets – Number of Units

Number of Units in Building	Multifamily (*n=70*)	ACS (N=974,669)
2 to 4	19%	41%
5 to 19	33%	29%
20 to 49	24%	10%
50 +	24%	20%

3.1.4 Program Participation

Whether a customer or multifamily building had participated in an EDC program was not a factor in selecting the sample. The SWE did, however, collect data on program participation from the customers in the sample and from the EDCs to explore two issues:

- Is the sample representative of program participation in the general population?
- To the extent that the sample is not representative, are the homes of program participants systematically different from those of non-participants in a way that could bias results?

Assessing Program Penetration. The SWE sought to identify the percentage of the sample that had participated in energy efficiency programs sponsored by their utility and compare that percentage to the program penetration across the state. The SWE used two methods to identify program participants in the sample: 1) Asking homeowners or residents onsite if they had ever participated in such a program and, if so, what the program entailed 2) Asking the EDCs to compare the sample addresses to their program records for all three phases of Act 129. The two methods produced quite different results – the self-reported program participation rate was 26%, while EDCs identified 62% of the sample addresses as participants.

Some homeowners who reported program participation were not matched by the EDCs to program records and some addresses identified by the EDCs as program participants did not self-report participation onsite. This highlights the difficulties in determining program participation: Individual residents may forget about prior participation, the resident present during the audit may differ from the resident who participated in the program, and changes in addresses and account numbers may complicate EDC record keeping. In addition, EDC records do not include participation in the EDCs' largest programs, upstream residential lighting programs, while study participants may be unaware they participated in an EDC program when purchasing EDC-sponsored lighting measures from participating retailers. The SWE chose to use the EDC reported participation rate of 60% due to its documentation and recommends that future studies use a mix of account numbers and addresses matched to EDC records to analyze or recruit for program participation.

Information on statewide program penetration rates for residential customers was not available for all EDCs. The First Energy companies provided estimated ratios of program participating accounts to active accounts in Phase II (31%) and Phase III (34%). Given that these figures exclude Phase I and also include an unknown share of customers that participated in more than one phase, it is difficult to make a definitive comparison with the sample. Fully estimating statewide program participation was outside the scope of this study. Given the available information, it is difficult to make a conclusion stronger than that a large share of both the sample and the general population has participated in energy efficiency programs.

Assessing Potential Bias. The SWE used a qualitative analysis of EDC records for the sample homes and a quantitative analysis of key measures to determine if the efficiency characteristics of program participants differ in important ways from homes of non-participants. Note that this analysis is not intended to assess the effectiveness of any particular program. Efficiency values were compared across participant and non-participant groups as a whole, though any individual participant home may have received only a single measure from the program. In addition, the SWE did not have participation records for the Low Income Usage Reduction Program (LIURP), which may affect the efficiency levels of the low-income sample.[28]

Table 14 shows the measures found in the EDC program records for the homes in the sample. Homes could have received more than one measure. The table displays the number of homes that received each measure and each measure's share of all measures received by the sample homes. Lighting measures were the most frequent, followed by low-flow aerators and shower heads, and furnace whistles. All three of those measures were included in "kits" for customers. Note that the "Whole Home" measure could include multiple measures, such as insulation, air sealing, HVAC equipment, or appliance rebates, but that detail was not available in the records.

Table 14: Program Participation Measure Mentions

Measure	# of Homes	% of Measures
Lighting	149	27%
Aerators and Showerheads	100	18%
Furnace Whistle	86	16%
Appliance Rebate	47	9%
Home audit	36	7%
HVAC Equipment	32	6%
Appliance Recycling	26	5%
Education	21	4%
Weatherization	18	3%
Whole Home	16	3%
Online Audit	12	2%
Smart Strip	4	1%
Water Heater Rebate	2	0%
Demand Response	2	0%

Table 15 compares key efficiency measures by program participation for low-income homes, non-low-income homes, and overall. Sixty percent of low-income homes were program participants compared to 63% of non-low-income homes.

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[28] https://aese.psu.edu/research/centers/csis/liurp

There are no statistically significant differences between participants and non-participants for lighting measures even though lighting measures were the most frequently cited measure in the sample's program records. The only statistically significant difference between participants and non-participants overall was for ambient wall R-value in which participants had an average of 10.0 and non-participants had an average of 8.4. However, as shown in Table 14, only a relatively small number of records indicated that homes participated in programs that could have included wall insulation upgrades: "weatherization" and "whole home."

When looking at the sample by income groups, we do find some statistically significant differences between participants and non-participants. The differences, however, do not show participant homes to be consistently more efficient than non-participant homes. In low-income homes, there are statistically significant differences between participants and non-participants for the percent of ENERGY STAR clothes washers, flat ceiling R-value, and cathedral ceiling R-value. However, in all cases, the non-participant group has a *more* efficient value than the participant group.

In non-low-income homes, there are statistically significant differences between participants and non-participants for the percent of ENERGY STAR refrigerators, percent of ENERGY STAR room air conditioners, ambient wall R-value and frame floor R-value. In all cases, the participant group had more efficient values than the non-participant group.

In conclusion, the SWE finds no clear indication that the sample is unrepresentative of program participation levels in the general population, and also no evidence of systematic differences between participant and non-participant homes.

Table 15: Comparison of Efficiency Measures by Program Participation

Measure	Low-Income		Non-low-income		Overall[4]	
	Part.	Non-part.	Part.	Non-part.	Part.	Non-part.
Lighting						
Efficient Lighting Saturation	59%	59%	51%	50%	53%	52%
CFL Saturation	21%	26%	22%	21%	21%	22%
LED Saturation	27%	24%	19%	20%	21%	21%
Appliances (Percent ENERGY STAR)						
Refrigerator	32%	38%	**35%**	**21%**[a]	35%	25%
Freezer	--	--	11%	15%	9%	12%
Clothes Washer	**25%**	**52%**[a]	42%	42%	37%	46%
Clothes Dryer	--	3%	3%	4%	2%	4%
Dishwasher	46%	57%	58%	64%	57%	63%
Dehumidifier	100%	--	85%	68%	86%	65%
Room AC	20%	23%	**38%**	**18%**[a]	32%	19%
Shell (Average R-value)						
Flat Ceiling	**14.2**	**23.2**[a]	22.5	22.1	20.9	22.3
Cathedral Ceiling	**12.0**	**24.0**[a]	17.4	18.9	16.6	19.8
Ambient Walls	8.1	8.5	**11.1**	**8.4**[a]	**10.0**	**8.4** [a]
Frame Floor to UC Bsmt/ECS	4.6	8.8	**6.0**	**2.8**[a]	5.6	3.7
Conditioned Foundation Walls	6.0	3.2	6.4	4.5	6.4	4.2
Mechanical Equipment Efficiency						
Heating Equipment (AFUE)[1]	82.4	87.4	87.3	86.6	86.2	86.9
Cooling Equipment (SEER)[2]	12.1	13.9	13	12.6	12.3	12.9
Water Heating Equipment (UEF)[3]	0.84	0.81	0.81	0.73	0.81	0.75

[a] Significantly different from the participant group at the 95% confidence level.
[1] Includes all systems with AFUE ratings.
[2] Includes all systems with SEER ratings.
[3] Includes all systems with UEF ratings and EF ratings converted to UEF.
[4] Excludes homes that did not divulge income information

3.2 Recruiting

Onsite audits took place between February and August of 2018. The recruiting process differed between single-family and multifamily homes. For single-family homes, the SWE selected a recruiting sample of customers from the full set of residential billing records provided by the EDCs and contacted occupants directly. Multifamily sites required the participation of property managers and tenants to ensure access to heating and cooling equipment. This made multifamily properties more challenging to recruit. The SWE team employed multiple methods to acquire multifamily participants. The rest of this section provides greater detail on the recruiting process.

Figure 5: Recruiting Processes for Single-family and Multifamily

3.2.1 Single-family Recruitment

The SWE selected a random sample of 3,000 customers per EDC from the full set of residential billing records the EDCs provided. The SWE team developed a pre-recruitment letter that was then mailed to a sub-sample of 1,700 customers per EDC. The letters included the PUC logo, the appropriate EDC logo, and EDC-specific contact information so that recipients could verify the legitimacy of the study. The letters were sent in three waves to accommodate field staff availability and to proceed east to west across the state. After the first wave, which only included physical letters, the SWE added email invitations, which improved response rates.[29] The EDCs provided

[29] On March 12th, customers started receiving email invitations with links to complete the pre-recruitment survey in addition or in lieu of a physical letter. Before March 12th, only 10% of respondents completed the survey online while the rest completed the survey by phone. These online respondents had manually gone to a website using a link

customer email addresses after screening the sample for customers that had previously declined email communications.

The pre-recruitment letters notified recipients of the study and invited them to call or visit a website to complete a screening survey. Shortly after the mailings, a subcontracted survey firm began calling recipients who did not initiate the screening survey on their own.[30]

The purpose of the screening survey was to verify the customer's name and address, and to gather information relevant to the study recruiting targets, such as home type, heating fuel, heating equipment type, income, home vintage, tenure status, and occupant demographics. Eligible respondents were asked if they were interested in scheduling an onsite audit for a $150 incentive. The SWE team contacted interested respondents and scheduled the onsite audits at the customers' convenience. For the full screening survey, see Appendix K.

3.2.2 Multifamily Recruitment

Recruiting multifamily participants was far more challenging than single-family sites because we attempted to involve both tenants and property managers. The SWE initially used this approach to ensure that there would be access to common spaces and any central heating/ventilation/air conditioning (HVAC) or water heating equipment. The initial sample for multifamily recruitment was based on identifying potential multifamily properties from billing data provided to the SWE team. To confirm the status of these sites, and to supplement the sample base they provided, the SWE team employed three strategies: (1) internet research on billing data addresses (e.g., Google searches and Google Street View, where available), (2) internet searches for additional multifamily complexes not included in the billing data, (3) supplemental data provided by EDCs including contact information for property managers of sites in their service territories when available.

Property managers were frequently unresponsive to or unmoved by cold calls and emails, making recruitment a challenge. It was difficult to identify and secure contact information for the person onsite that would be the most knowledgeable or appropriate to meet with. In addition, property managers frequently refused when contact was made. They were reluctant to dedicate their or their employees' time when they saw no immediate benefit, and the $150 incentive was not attractive enough to sway them. However, it was enough to attract the interest of tenants, which led to an adjustment in the SWE team's recruitment efforts.

At the end of May, the SWE team contacted TUS staff to suggest an additional recruitment track where only tenants at multifamily sites were contacted for site visits. Because tenants had been more responsive than property managers to recruitment efforts, and because most key data points would still be accessible, the SWE team moved forward on that recruitment track, but continued to recruit property managers where possible.

The downside to this was that tenants were frequently less knowledgeable about the building than property managers when it came to things like general building characteristics or the presence

printed in their mailed letter. After the email invitations were sent on March 12th, 45% of respondents completed the survey online. Overall, 39% of respondents completed the survey online.

[30] Blackstone Group conducted the surveys over the phone and online.

and type of insulation. Also, without access to all common or central building locations, it was sometimes difficult to identify HVAC or domestic hot water (DHW) equipment when those systems were central rather than in-unit. In most cases, auditors were able to record some level of information on key data points, and the trade-off allowed the SWE team to accelerate multifamily recruitment.

Larger multifamily properties were overrepresented relative to small (2-4 unit) sites due to the nature of multifamily sample development. Smaller multifamily buildings are more difficult to identify by analyzing billing data or through online research than larger buildings, which were the SWE team's main methods for sample development. Also, if tenant contact information is not available in billing data for a site identified as a small multifamily, it is far more difficult to find online than the contact information for a management office at a larger multifamily site.

3.3 Data Collection

Data was collected onsite by trained technicians using a tablet-based digital data collection form developed by NMR Group, Inc. This section describes the inputs in our data collection form and the procedures that were used for onsite data collection and in-office data-cleaning procedures. The study involved three types of audits:

- **Single-family basic audits:** Audits were conducted by one auditor. They collected the basic energy-efficiency information of a home, including shell measures,[31] mechanical equipment, and inventories of lighting and appliances. Audits focused on key measures, such as exterior walls.[32]
- **Single-family diagnostic audits:** Audits were conducted by two technicians. They collected all the same information as with basic audits and any additional information required for energy modeling, such as air leakage and duct leakage testing and data for the entire thermal envelope. Certified HERS Raters led all diagnostic audits.
- **Multifamily audits**: Audits were conducted at multifamily properties. One unit in one building was audited at each property. The in-unit information collected at multifamily sites was similar to the information collected at single-family basic sites. In addition, auditors recorded details of the larger complex and energy features in common-areas, such as common area lighting, common laundry facilities, and HVAC or hot water systems serving multiple units.[33]

3.3.1 Data Collection Inputs

The electronic onsite data collection form contained all the inputs needed to assess the energy efficiency of a home. Auditors collected additional detail at the 72 diagnostic sites to create energy models. At multifamily properties, shell measures and mechanical equipment were collected at the building level, while fixtures and appliances were collected for the audited unit and common areas. Appendix B details the data collected at each of the three audit types: single-family diagnostic, single-family basic, and multifamily.

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[31] Shell measures include insulation and material data for a home's structural components, such as walls, ceilings, and floors.
[32] Exterior walls are a key component because they often comprise the majority of a home's thermal envelope (i.e., the boundary between conditioned space and ambient conditions).
[33] In a memo dated May 29, the SWE team requested permission from the PUC to alter the recruiting process in two ways to ensure the recruitment of 70 multifamily properties. Thirty-three sites had been recruited but the pace of recruiting had slowed significantly. The first change was to allow for the recruitment of occupants and tenants without property managers, which at times meant forgoing access to HVAC equipment. The second change was to allow for a larger share of low-income properties since they were easier to recruit. In the end, the final share of low-income properties in the sample (24%) nearly matched the target (23%).

3.3.2 Data Collection Procedures

One of the challenges of inspecting completed homes is that several building envelope components are commonly inaccessible. Specifically, exterior wall insulation, window U-factor and solar heat gain coefficient, vaulted ceiling insulation, exterior foundation wall insulation, slab insulation, and garage and cantilevered frame floor insulation can be difficult to visually inspect in an existing home. As part of the onsite data collection procedures, the SWE relied on the following key data sources.

Onsite visual verification of actual component. Actual observations in the field are the first and most important source of data. When direct access to the component was not possible, auditors examined the area around the component to gather whatever information they could. For example, when trying to determine exterior wall insulation, auditors might have removed an electrical outlet cover and probe to determine the presence of insulation.

Onsite visual verification of similar component. Once auditors exhausted opportunities to examine the actual component, they used similar locations to inform their assessment. For example, an auditor might have found visible/accessible above-grade wall insulation in an attic knee wall or a walkout basement that they would then have used to inform their assessment of the enclosed wall cavities.

Plans or other documentation. Home plans, documentation, or blueprints can provide valuable information for inaccessible insulation. When plans were available onsite, auditors first attempted to visually verify data inputs. Auditors would then use the plans to inform their assessment of the home. Typically, plans could be useful in determining insulation R-values and window U-values.

Knowledgeable homeowner recollection. If homeowners could demonstrate reliable knowledge about the building shell with the auditor, auditors could use homeowner recollection to inform their assessment. This would be particularly useful if the homeowner was present during construction or during a major renovation. Additionally, homeowner input could shed light on old appliances and mechanical equipment. For instance, homeowners could estimate the age of old appliances and systems that had missing or illegible name plates.

3.4 WEIGHTING

To account for sample bias, this report utilizes two separate weighting schemes: a full sample weighting scheme and a diagnostic sub-sample weighting scheme. The full sample weighting scheme matches the 2013 residential baseline study.[34] It weights the sample by home type and EDC to give more weight to data from larger EDCs. Since the EDCs were unable to provide data on the counts of each home type in their service areas, the SWE leveraged PUMS data from the US Census Bureau to match home type counts to service territories.[35] The sample was stratified by home type and EDC and compared to the count of home types by EDC of the population from the PUMS data. Weights were calculated to account for over and under sampling of home types

[34] http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-2014_PA_Statewide_Act129_Residential_Baseline_Study.pdf
[35] American Community Survey 2012-2016 ACS 5-year PUMS: https://www.census.gov/programs-surveys/acs/data/pums.html

by EDC in the full sample relative to the population. Table 16 shows the final weights for the full sample.

Table 16: Full Sample Statewide Weights

Home Type	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn
Detached Single-family	1.86	1.89	0.66	0.82	1.09	0.38	1.43
Attached Single-family	2.03	3.77	0.46	1.07	1.37	0.06	0.20
Multifamily	1.85	1.05	0.41	0.58	0.77	0.18	0.94
Manuf./Mobile	0.25	0.31	0.09	0.43	0.69	0.53	0.85

The diagnostic sub-sample required a separate weighting scheme because it purposefully overrepresented electrically heated homes. The SWE tested the explanatory power of various combinations of home type, heating fuel, and vintage on overall home consumption. The combination of home type and heating fuel (electrically heated or not) proved to best predict home consumption. Vintage proved a poor predictor as it was strongly correlated with heating fuel in our sample – the vast majority of electrically heated homes were built between 1960 and 1999. Likewise, testing by all heating fuel types did not add accuracy beyond that achieved by using a simple electric heat or non-electric heat indicator. Therefore, the weighting scheme for the diagnostic sub-sample is based on a stratification by home type and electric heat status (Table 17).

Table 17: Diagnostic Sub-Sample Statewide Weights

Primary Heating Fuel Type	Detached Single-family	Attached Single-family	Manufactured/ Mobile
Electric	0.38	0.55	0.09
Non-Electric	1.33	2.82	0.78

3.5 Significance Testing and Table Formats

Significance testing was conducted on key measures. Superscript letters and bolded text indicate that there is 95% probability that the compared results are truly different from each other, and only a 5% probability that observed differences happened by chance. Significance testing was only performed when both tested samples had sample sizes of at least ten. Throughout the report, the terms "significant" and "significantly" always refer to *statistical* significance at the 95% confidence level.

Table 18 shows an example of a statistical table. The "attached single-family" mean and the "manufactured or mobile" mean are both significantly different from the "detached single-family" mean as demonstrated by the "a" in superscript. The "manufactured or mobile" mean is also significantly different from the "attached single-family" mean as demonstrated by the "b" in superscript. The multifamily mean is not significantly different from any of the other groups. The "Statewide" represents the overall distribution for the table and is not tested for significance against any of the sub-groups.

Table 18: Example of Statistical Table Format

	Detached single-family	Attached single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*X*	*X*	*X*	*X*	*X*
Min	x	x	x	x	x
Max	x	x	x	x	x
Mean	**x**	**x**[a]	**x**[a,b]	**x**	**x**
Median	x	x	x	x	x
Sd.	x	x	x	x	x

[a] Significantly different from the detached single-family sample at the 95% confidence level.
[b] Significantly different from the attached single-family sample at the 95% confidence level.

Table 19 shows an example of significance testing in a proportional table. The "total single-family" sample has a significantly different proportion of cases in "Category 3" than the "diagnostic sub-sample." The "diagnostic sub-sample" has a significantly different proportion of cases in "Category 2" than the multifamily sample. There is no significance testing with the "Statewide" column.

Table 19: Example of Proportional Table Format

Categories	Total Single-family (*n=XX*)	Diagnostic Sub-sample (*n=XX*)	Multifamily (*n=XX*)	Statewide (*n=XX*)
Category 1	x%	x%	x%	x%
Category 2	x%	**x%**	**x%**[b]	x%
Category 3	**x%**	**x%**[a]	x%	x%
Category 4	x%	x%	x%	x%

[a] Significantly different from the total single-family sample at the 95% confidence level.
[b] Significantly different from the diagnostic sub-sample at the 95% confidence level.

In statistical tables and proportional tables, the mean presented in the "Statewide" column is always a weighted mean unless otherwise noted. The "Statewide" column is the only column that ever displays weighted results. All other columns are unweighted.

In addition to statistical tables and proportional tables, this report frequently presents *penetration* and *saturation* results. *Penetration* is defined as the amount of homes that have at least one of the relevant measure. For example, the penetration of LED bulbs shows the percent of homes that have at least one LED bulb. *Saturation* is defined as the amount of a larger measure that are a specific subtype of that measure. For example, the saturation of LEDs refers to the percent of all light bulbs that are LED bulbs. Since a single home may have, for example, light bulbs of several different types, penetration tables may sum to more than 100%. Saturation and proportion tables sometimes do not sum to exactly 100% due to rounding error.

Section 4 General Characteristics

This section presents general characteristics of the sample of homes included in the residential baseline study, including average conditioned floor area, foundation type, thermostat type, and presence of pools and hot tubs. The sample included 145 detached single-family homes, 48 attached single-family homes, 26 manufactured or mobile homes, and 70 multifamily homes (Figure 6), defined below.

- **Detached single-family:** A single-residence structure that is not physically attached to any other structure. [36]
- **Attached single-family:** A single-residence that is separated from the adjacent units by a ground-to-roof wall and has its own heating and cooling systems and utilities.
- **Manufactured/Mobile:** A single-residence structure that is transportable in one or more sections and is built on a permanent chassis with or without a permanent foundation.[37]
- **Multifamily:** Any residential structure that has units on top or below other units or attached units with shared heating or cooling systems or utilities.

Figure 6: Examples of Audited Homes

Detached Single-Family | Attached Single-Family | Manufactured/Mobile | Multifamily

4.1 Home Characteristics

On average, homes were 65 years old (Table 20). Manufactured and mobile homes were significantly younger than other home types, reflecting the widespread introduction of manufactured homes in the 1970s.[38]

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[36] Detached and attached single-family home and multifamily definitions are based on the U.S. Census: https://www.census.gov/construction/chars/definitions/

[37] Based on HUD definitions. See CFR 3280.2.

[38] HUD started regulating and financing for manufactured homes in 1976. https://www.hud.gov/program_offices/housing/rmra/mhs/faqs

Table 20: Average Age of Audited Homes (Years)

	Detached Single-family	Attached Single-family	Manufactured/Mobile	Multifamily	Statewide
n	*145*	*48*	*26*	*70*	*289*
Years	62	65	32	62	65

Table 21 shows the average conditioned floor area (CFA) by home type.[39] The statewide weighted average CFA was 1,881 square feet. The average CFA was 2,048 square feet for all single-family homes and 1,031 square feet for multifamily units.

Table 21: Audited Home Conditioned Floor Area (Sq. Ft.)

	Detached Single-family	Attached Single-family	Manufactured/Mobile	Multifamily	Statewide
n	*145*	*48*	*26*	*70*	*289*
Min	480	960	621	417	417
Max	6,022	4,338	2,288	2,263	6,022
Mean	**2,295**	**1,778**	**1,166**	**1,031**	**1,881**
Median	2,032	1,646	954	952	1,584
Std. Dev.	1,041	675	441	364	984

Table 22 shows the foundation types of the homes in the sample.[40] Unconditioned basements were the most common (38%), followed by conditioned basements (24%), and then a mix of both conditioned and unconditioned basements (16%).

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[39] Auditors used RESNET protocols to define conditioned floor area in accordance with the method used for HERS ratings.

[40] Enclosed crawl spaces were grouped with unconditioned basements. Conditioned crawl spaces were grouped with conditioned basements. “Apt over cond. Space” refers to apartments that were entirely above either a garage or commercial property.

Table 22: Foundation Type

Foundation Types	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*145*	*48*	*26*	*70*	*289*
Unconditioned Basement	37%	42%	77%	24%	38%
Conditioned Basement	33%	25%	12%	16%	24%
Cond./Uncond. Mix	19%	4%	4%	11%	16%
On-grade Slab	1%	19%	--	41%	11%
Other	10%	10%	8%	8%	12%[1]

[1] Includes 8.2% that were a mix of unconditioned basement and on-grade slab, 2.7% that were a mix of conditioned basement and on-grade slab, and less than 1.0% that was open or over other conditioned space.

4.2 THERMOSTATS

Auditors recorded the types of thermostats at each home.[41] Table 23 shows the *penetration* of each thermostat type. Manual thermostats were present at 50% of homes. Programmable thermostats or a more advanced technology (e.g., *wi-fi* or *smart*) were present at 48% of homes.[42] Five percent of homes had no thermostat. These homes had heating systems with built-in controls or on-off switches, such as stoves, electric baseboards, or through-the-wall heat pumps. The previous studies did not report this metric and thus comparisons are not possible.

Table 23: Thermostat Penetration

Type	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide[1]
n	*143*	*47*	*25*	*65*	*280*
Manual	45%	64%	52%	40%	50%
Programmable	49%	32%	44%	38%	43%
Wi-fi	3%	4%	--	2%	2%
Smart	4%	2%	--	--	2%
None	1%	--	4%	20%	5%

[1] Since some homes have more than one thermostat, column totals can sum to more than 100%.

Table 24 shows the *saturation* of thermostat type across all thermostats observed during audits. Most thermostats (53%) were manual, which presents an opportunity for efficiency upgrades. Homes with electric baseboards were more likely to have manual thermostats than homes without electric baseboards: 61% of thermostats in homes with electric baseboards were manual

[41] Thermostats serving only common space in multifamily buildings were ignored since consistent collection was not feasible. Auditors were unable to acquire thermostat details at nine homes.

[42] The 48% value is the result of summing the programmable, wi-fi, and smart statewide values. Together the three types sum to 47.7%.

compared to 45% in the rest of homes. Programmable thermostats comprised the bulk of the remaining share (42%) and advanced technologies (i.e., wi-fi or smart thermostats) comprised only 5%. Fifty-eight percent of central cooling systems had programmable thermostats. This represents a slight increase from the previous report, which found that 54% of central cooling systems had programmable thermostats.

Table 24: Thermostat Saturation

Type	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*184*	*54*	*24*	*53*	*315*
Manual	47%	65%	54%	49%	53%
Programmable	46%	30%	46%	49%	42%
Wi-Fi	3%	4%	--	2%	3%
Smart	4%	2%	--	--	2%

4.3 Pools and Hot Tubs

Only 14 homes (5%) had either a pool or a hot tub. There were nine pools and five hot tubs in the sample. Two of the pools were heated. Table 25 shows the penetration of pools and hot tubs by home type.

Table 25: Pool and Hot Tub Penetration

Type	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*145*	*48*	*26*	*70*	*289*
Pool	5%	--	4%	1%	3%
Hot Tub	2%	2%	4%	--	2%
None	93%	98%	92%	99%	95%

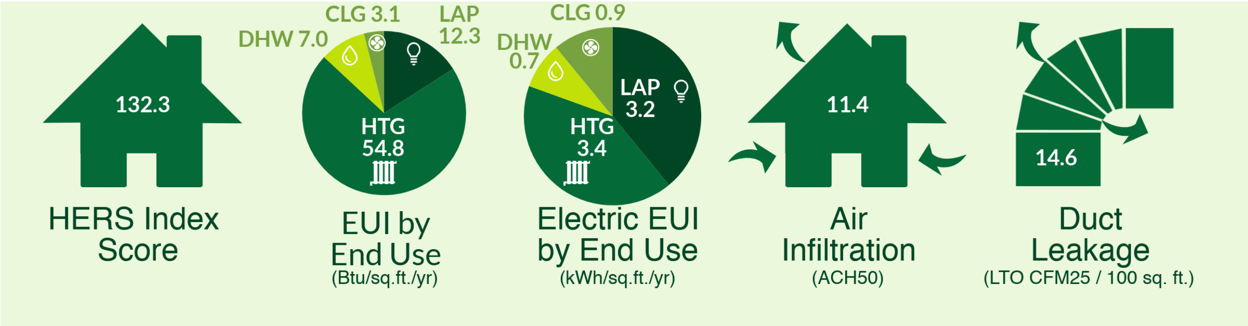
Section 5 Diagnostic Sub-Sample Results

The SWE team generated energy models for each of the 72 diagnostic sub-sample homes using REM/rate™ version 15.4.[43] The homes received full diagnostic testing, including air infiltration and duct leakage tests. Energy models were used to calculate HERS Index scores and energy use intensities (EUI) for various end uses including heating (HTG), cooling (CLG), domestic hot water (DHW), and lights and appliance (LAP). This chapter presents the results of the modeling, diagnostic testing.

For context, results of the diagnostic sub-sample are compared to the 2009 International Energy Conservation Code® (IECC). This is not to imply that homes in the sample *should* be built to the standards of 2009 IECC. Pennsylvania adopted 2009 IECC in December 2009 and those standards would only have applied to the four homes in the sample built after that time.[44] Still, the 2009 IECC provides a useful benchmark to compare the energy efficiency of the sampled homes to the performance of a new home built to the current code.

As discussed in the methods section above, the study used a different weighting scheme from the rest of the report when looking only at the diagnostic sub-sample. The weights used in this section are based on home type and whether homes used electricity as their primary heating fuel.

Figure 7: Diagnostic Results Highlights



Key Findings:

- The average weighted HERS Index score of 132.3 indicates that, statewide, the entire existing housing stock is 61% less efficient than homes built to 2009 IECC.[45]

[43] Version 15.4 was the most recent version of REM/rate at the time of the study.

[44] The Pennsylvania Uniform Construction Code Review and Advisory Council adopted 2015 IECC standards in spring of 2018, to take effect in October 2018: https://www.dli.pa.gov/ucc/Documents/rac/UCC-RAC-2015-Code-Review-Report.pdf Builders will be able to prove compliance by achieving a HERS Index value of 62 (for climate zone 4) or 61 (for climate zones 5 and 6).

[45] See Section 5.1 for a description of the HERS Index. A home built to 2006 IECC minimum standards would receive a HERS Index score of 100, and a home built to 2009 IECC minimum standards would receive a HERS Index score of 82.

- The average energy use intensity (EUI) of 77 Btu/sq.ft./yr is used mostly for space heating (54.8 Btu/sq.ft/yr or 71%) and lights and appliances (12.3 Btu/sq.ft./yr or 16%).[46]
- The average unweighted electric EUI was 40.9 Btu/sq.ft./yr for primarily electrically heated homes and 22.2 Btu/sq.ft./yr for primarily non-electrically heated homes.[47]
- Looking at all homes together regardless of heating fuel, the average weighted electric EUI was 28.0 Btu/sq.ft./yr. Space heating comprises 41% of the average electric EUI and lights and appliances 39%.
- The average weighted ACH50[48], a measure of air leakage, of 11.4 is above the 2009 IECC requirement of 7.0 but not unreasonable considering the statewide average age of homes sampled was 65.
- The average weighted duct leakage to the outside of 14.6 is higher than the 2009 IECC requirement of 8.0 but not unreasonable considering the age of the duct systems.

5.1 HERS Index Scores

This section summarizes the diagnostic sub-sample HERS Index scores. The HERS Index is based on the 2006 IECC, where a score of 100 equals a home built to 2006 prescriptive standards and a score of 0 represents a net-zero-energy home (i.e., a home that uses no more energy than it generates onsite). The SWE performed significance testing on subsamples where each group had a sample size of ten or greater.

The overall mean HERS Index score of 132.3 signifies that the average home in the sample is 32.3% less efficient than a home built to the 2006 IECC and 61% less efficient than a home built to 2009 IECC.[49] The majority of homes (67) have HERS Index scores that are higher (i.e., less efficient) than the 2009 IECC performance benchmark of 82.[50] This is not unreasonable given that the sample had homes dating back to 1900. Not surprisingly, older homes have higher HERS Index values (indicating lower energy efficiency) than newer homes (Table 26).[51]

[46] EUI is a measure of annual energy consumption per year normalized by area of a home.
[47] To convert to Btu, kWh values were multiplied by 3.412.
[48] ACH50 refers to air changes per hour at a pressure differential of 50 Pascals between the inside and outside of a home. It is a standard measure of air leakage in homes. RESNET protocols for measuring air leakage in homes: http://www.resnet.us/standards/DRAFT_Chapter_8_July_22.pdf.
[49] The HERS Index is benchmarked to the 2006 IECC. https://www.resnet.us/energy-rating
[50] Note that the 2009 IECC does not require homes to meet a certain HERS Index score of 82, rather a score of 82 has been found equivalent to 2009 IECC in climate zones 4 and 5. See http://www.resnet.us/uploads/documents/EnergyRatings_FactSheet6_Final.pdf.
[51] The home with a HERS Index of 355 had no insulation in the walls, a small amount of insulation in the ceiling, a furnace manufactured before 1970, high infiltration, and high duct leakage. Another home, which had a HERS Index of 311, had high infiltration, leaky ducts with *panning*, and an electric furnace. *Panning* refers to the use of open wall or floor cavities as ducts, typically with sheet metal attached to the studs.

Table 26: HERS Index Scores by Vintage

	Before 1940	1940-1959	1960-1979	1980-1999	2000-2009	2010 or later	Total
n	*9*	*9*	*19*	*23*	*8*	*4*	*72*
Min	103.0	106.0	76.0	85.0	75.0	68.0	68.0
Max	222.0	193.0	355.0	249.0	118.0	93.0	355.0
Mean	**159.1**	**138.1**	**147.6**	**133.1**	**90.1**	**85.8**	**132.3**
Median	149.0	121.0	126.0	119.0	88.5	91.0	119.5
Std. Dev.	41.8	32.2	64.8	44.6	13.8	11.9	50.0

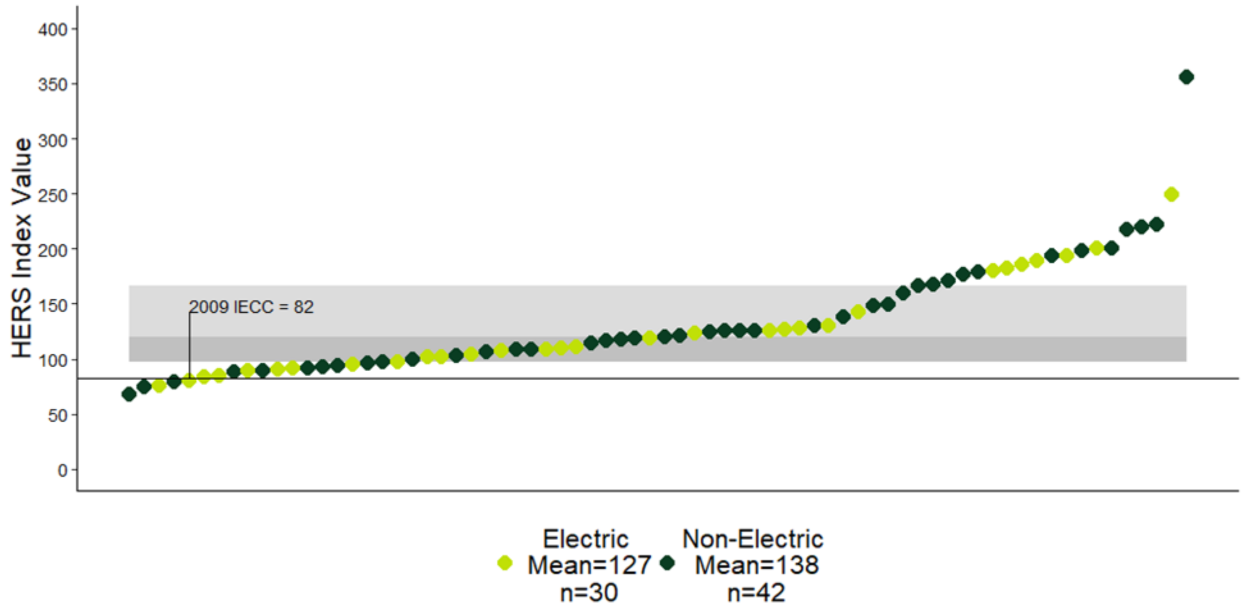
Attached single-family homes had lower HERS Index values than detached homes (Table 27). This is an expected result since heat loss is lower in attached homes due to the common walls. Additionally, detached homes were generally older than attached homes in the sample. Manufactured and mobile homes have the highest mean score, which is also expected due to the typical construction features in these homes and is likely driven by high air leakage and duct leakage rates reported below.

Table 27: HERS Index Scores by Home Type

	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Total
n	*53*	*10*	*9*	*72*
Min	75.0	68.0	100.0	68.0
Max	355.0	180.0	220.0	355.0
Mean	**134.8**	**110.6**	**150.4**	**132.3**
Median	119.0	94.0	130.0	119.5
Std. Dev.	52.5	36.1	42.8	50.0

Figure 8 displays HERS Index scores of homes with and without electric primary heat. The plot displays the values in increasing order and shows the interquartile range for the entire sample as a dark grey and light grey bar. The border between them represents the median. As noted above, the majority of homes (67) have HERS Index scores that are higher (i.e., less efficient) than the 2009 IECC performance benchmark of 82. There was no statistically significant difference between electrically heated and non-electrically heated homes.

Figure 8: HERS Index Value with and Without Electric Primary Heat



There were no significant differences in HERS Index scores by primary heating fuel or income status. See Appendix C Detailed Diagnostic Results for detailed HERS Index score results by primary heating fuel, income status, and EDC.

5.2 Energy Consumption and Loads

The REM/rate energy models produced detailed information on modeled energy consumption for each home. To facilitate comparisons within the sample, results are binned by home efficiency relative to a home built to 2009 IECC standards (Table 28). To comply with this standard, a home built under the 2009 IECC performance path must achieve a HERS Index score of 82 or less.[52] Homes that had HERS Index scores below 82 are more efficient than the 2009 IECC, and homes with HERS Index scores above 82 are less efficient. The efficiency categories in Table 28 are used for the rest of the energy consumption analysis.

Table 28: HERS Index Value Comparison to 2009 IECC

Efficiency Category	Number of Homes	Average HERS
Better than 2009 IECC	5	75.6
Up to 25% Less Efficient	18	93.8
Between 25% and 100% Less Efficient	30	123.1
More than 100% Less Efficient	19	202.4
Statewide (Weighted)	72	132.3

[52] See 2009 IECC performance path requirements for climate zones 4 and 5: http://www.resnet.us/uploads/documents/EnergyRatings_FactSheet6_Final.pdf

Figure 9 shows the average EUI by end use (i.e., heating, cooling, water heating, and lighting and appliances) for each efficiency category. EUI is a measure of energy consumption per year normalized by the area of the home. As expected for Pennsylvania, the largest share of the EUI for each efficiency category comes from heating, followed by lighting and appliances. Statewide, the weighted average total EUI is 77.13 Btu/sq.ft./year.

Figure 9: Energy Use Intensity by End Use (Btu/sq.ft./year)

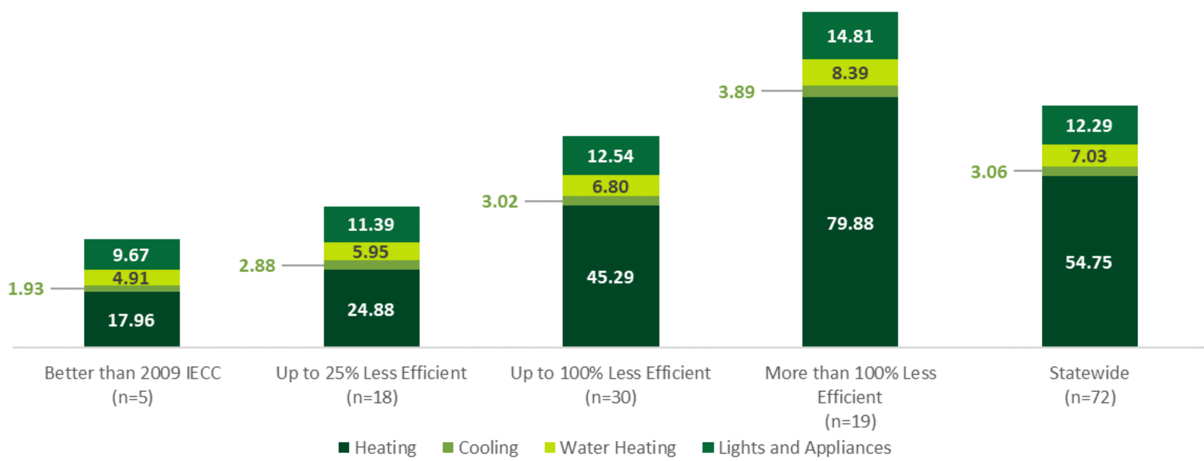


Figure 10 shows the unweighted electric EUI by end use for homes with primarily electric heat and homes with primarily non-electric heat. Note, that the primarily non-electrically heated homes could still use supplemental electric heat. Primarily electrically heated homes had an average electric EUI of 12.0 while primarily non-electrically heated homes had an average electric EUI of 6.5. Primarily electrically heated homes had an EUI of 6.4 for heating while primarily non-electrically heated homes had an EUI of only 1.8 for heating.

Figure 10: Average Electric EUI by End Use by Heating Fuel (kWh/sq.ft./year)

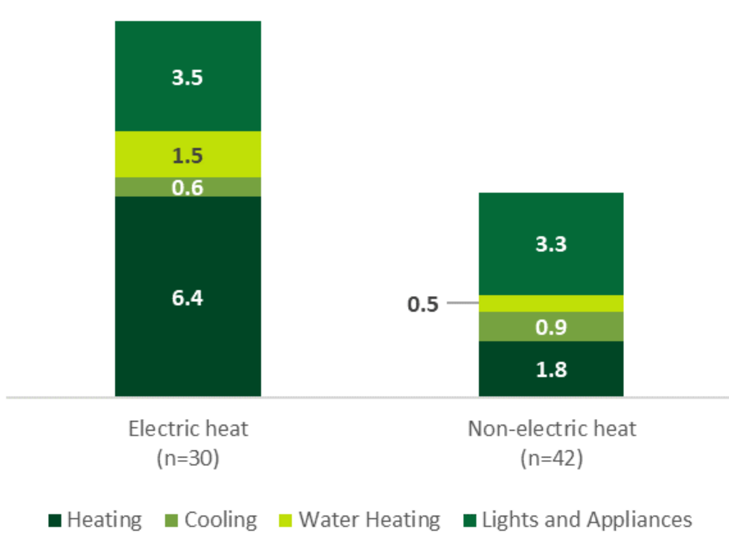


Figure 11 and Figure 12 specifically look at the electric consumption for all 72 homes, regardless of whether the home is electrically heated. Onsite consumption of electricity is split by end use. Note that the SWE team purposefully oversampled electrically heated homes. This results in an overestimate of average electric consumption for water heating since electrically heated homes are more likely to have electric water heaters. To account for this oversampling, the weighting scheme used for the statewide results discounted electrically heated homes. Therefore, the statewide results show less electric consumption than the unweighted results. In Figure 11 and Figure 12, the statewide results are weighted, while all other results are not.

The average modeled electric consumption of the 72 homes in the diagnostic sample was 14,973 kWh/year. Lighting and appliances make up the largest share, followed closely by heating (Figure 11). In efficient homes, lights and appliances make up the biggest share of electric consumption. In inefficient homes, heating makes up the biggest share of electric consumption.

Figure 11: Average Electric Consumption by End Use (kWh/year)

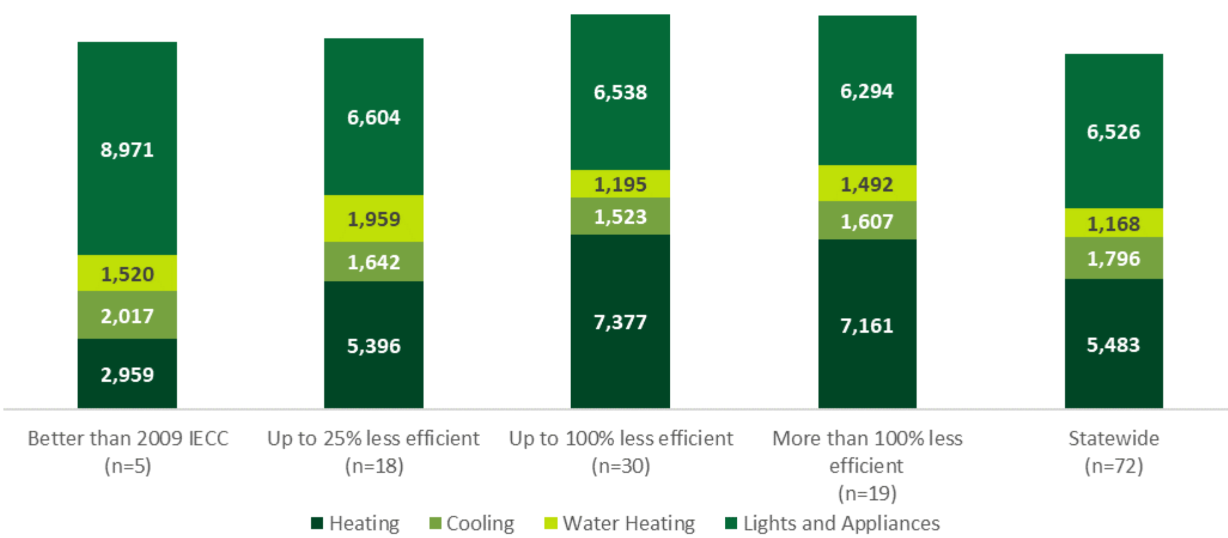
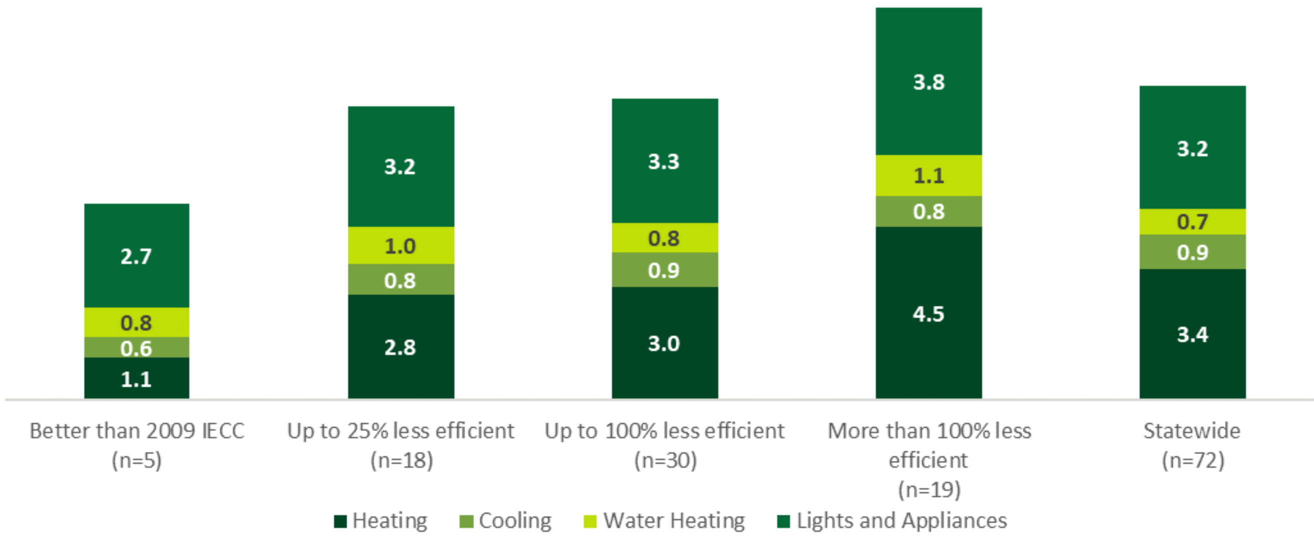


Figure 12 shows the average electric EUI by end use. Statewide, the average electric EUI is 8.2 kWh/sq.ft./year. Space heating comprises the largest share followed by lights and appliances.

Figure 12: Average Electric EUI by End Use (kWh/sq.ft./year)



5.3 Air Infiltration

Field technicians conducted blower door tests at all 72 diagnostic visits. Table 29 through Table 31 summarize the ACH50 results split by vintage, home type, and low-income status.[53] The average ACH50 for the entire sample was 11.4. This is less efficient than the 2009 IECC requirement of 7, but as mentioned above, the majority of homes when built were not subject to this requirement at the time they were constructed. As expected, newer homes had lower (i.e., more efficient) ACH50 values than older homes (Table 29).

Table 29: ACH50 by Vintage

	Before 1940	1940-1959	1960-1979	1980-1999	2000-2009	2010 or later	Total
n	*9*	*9*	*19*	*23*	*8*	*4*	*72*
Min	11.7	5.1	2.7	3.1	2.5	2.1	2.1
Max	31.9	12.0	46.5	19.5	10.8	7.1	46.5
Mean	**18.7**	**8.7**	**13.6**	**9.6**	**5.7**	**5.1**	**11.4**
Median	17.3	8.4	11.1	7.9	4.3	5.5	9.4
Std. Dev.	6.6	2.6	9.7	4.6	3.0	2.1	7.3

[53] ACH50 is the air changes per hour with a pressure of 50 pascals between indoors and outdoors.

There were no statistically significant differences in ACH50 between different home types, though mobile/manufactured homes had the highest mean and maximum ACH50 values (Table 30).

Table 30: ACH50 by Home Type

	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Total
n	*53*	*10*	*9*	*72*
Min	2.1	4.4	4.9	2.1
Max	25.9	31.9	46.5	46.5
Mean	**9.6**	**11.7**	**18.1**	**11.4**
Median	8.4	8.3	16.2	9.4
Std. Dev.	5.0	9.2	11.8	7.3

Low-income homes had significantly higher (i.e., less efficient) ACH50 values than non-low-income homes (9.9 compared to 15.9; Table 31).

Table 31: ACH50 by Low-income Status

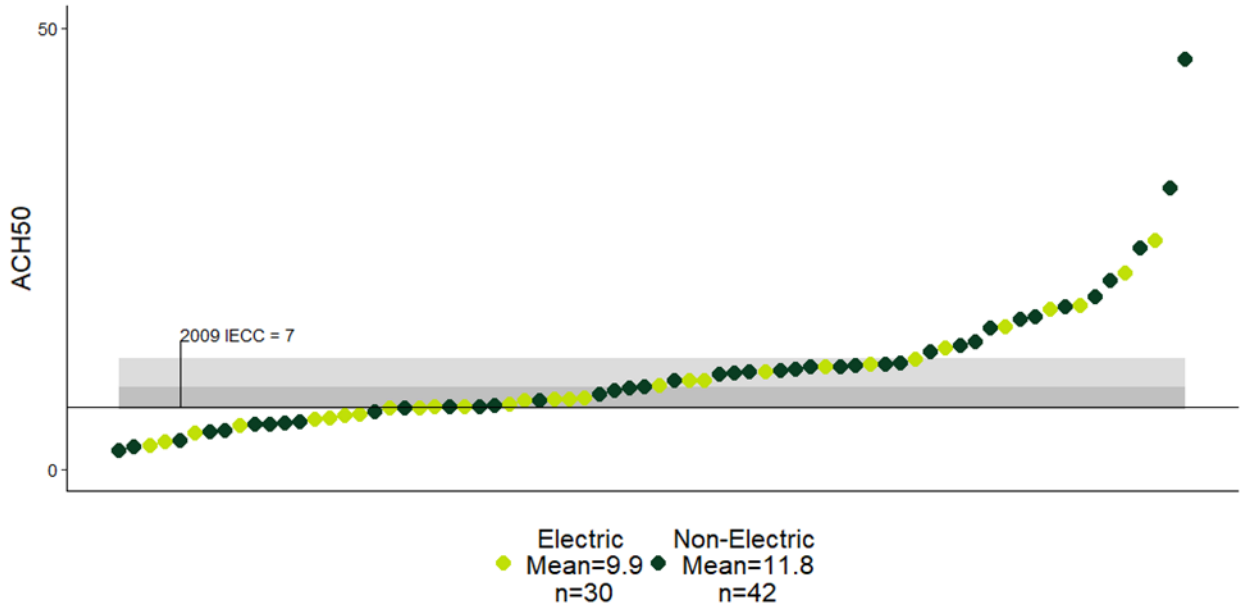
	No	Yes	Refused	Total
n	*60*	*11*	*1*	*72*
Min	2.1	6.2	25.1	2.1
Max	46.5	31.9	25.1	46.5
Mean	**9.9**	**15.9**[a]	**25.1**	**11.4**
Median	8.6	16.2	25.1	9.4
Std. Dev.	6.5	8.3	NA	7.3

[a] Significantly different from the “No” column at the 95% confidence level.

Figure 13 shows that 22 (31%) homes meet the 2009 IECC requirement. There was no statistically significant difference between homes with and without primary electric heat.[54]

[54] Of the two homes with the highest ACH50 values, one was a home built in the 1920’s that had limited insulation, visible cracks through the floor, and the homeowner conducted retrofits that further compromised the shell. The other was a manufactured home that had floors damaged by animals.

Figure 13: ACH50 by Electric Primary Heat



For detailed ACH50 results by primary heating fuel and EDC, see Appendix C Detailed Diagnostic Results.

5.4 Duct Leakage To Outside

Ducts were present at 60 diagnostic sites, and there were 67 duct systems in total. Technicians attempted to test the duct leakage of every system, but at times were unable to get a reliable measurement. This was due to systems being too leaky to reach test pressure or the home having inaccessible duct registers.[55] Table 32 summarizes the completion rates of total duct leakage (TDL) and leakage to outside (LTO) tests by vintage. Overall, LTO tests were completed for 39 systems in 35 homes. This report focuses on LTO tests instead of TDL tests because LTO reflects a loss of energy.

[55] Extremely leaky duct systems often had *panning* (i.e., a metal sheet nailed to an open wall or floor cavity to turn the cavity into a *duct*) or large holes in unconditioned space. Additionally, some had inaccessible registers that could not be sealed during testing.

Table 32: Duct Leakage Tests by Vintage

(Base = Systems)

Result	Before 1940	1940-1959	1960-1979	1980-1999	2000-2009	2010 or later	Total
LTO and TDL Completed	6	5	8	8	9	3	39
Unsuccessful LTO/TDL Tests	3	5	6	7	0	1	22
Inaccessible Registers	0	1	1	4	0	0	6

For the 28 systems that were too leaky to test, the SWE team estimated LTO using an algorithm for duct leakage in unsealed duct systems from the Manual J protocols. [56] The estimate is based on duct system supply and return surface area. The average system-level LTO is 14.6 CFM25/100 sq. ft when considering both estimated and tested (i.e., actual) values (Table 33).[57] The average estimated LTO of the systems that were too leaky to test (18.6) is higher (i.e., more leaky) than the average of tested systems (12.3). This result is unsurprising since results were only obtainable for systems that were tight enough to test.

To assess the accuracy of the Manual J estimation method, the SWE team also compared the estimated leakage values against the actual values for the 39 tested systems. On average, the calculated estimates were 37% higher than the actual values. This is reasonable given that the estimation method assumes a leaky, unsealed duct system, whereas the sample includes sealed duct systems.

Table 33: Duct Leakage to Outside (CFM25/100 sq.ft.)

(Base = Systems)

	Estimated	Tested	Statewide
n	*28*	*39*	*67*
Min	6.2	0.0	0.0
Max	27.0	43.4	43.4
Mean	**18.6**	**12.3**	**14.6**
Median	20.2	9.8	16.0
Std. Dev.	4.8	11.4	9.7

As expected, newer homes tend to have less duct leakage than older homes (Table 34). Manufactured or mobile homes have much higher duct leakage to outside (20.5 CFM25) than attached single-family homes (11.1 CFM25) and detached single-family homes (14.7 CFM25). This could be the result of manufactured or mobile homes having ducts exposed to ambient

[56] Manual J is the standard set by the Air Conditioning Contractors of America for sizing residential heating and cooling equipment. Manual J sets default leakage rates for unsealed systems in units of CFM25/Sq. Ft duct surface area as 0.35 times supply surface area for supply-side leakage and 0.7 times return surface area for return leakage. See Manual J Residential Load Calculation, 8th Edition, page 19, Figure 3-6.

[57] CFM25/100 sq. ft stands for cubic feet per minute at a pressure difference of 25 pascals between the inside and outside of the home per 100 square feet of conditioned floor area. The 2009 IECC standard specifies a maximum leakage to outside value of 8 CFM25/100 sq. ft.

conditions in crawl spaces. However, the sample sizes are too small for significance testing (Table 35, Figure 14).

Table 34: Duct Leakage to Outside by Vintage (CFM25/100 sq. ft.)

(Base = Systems)

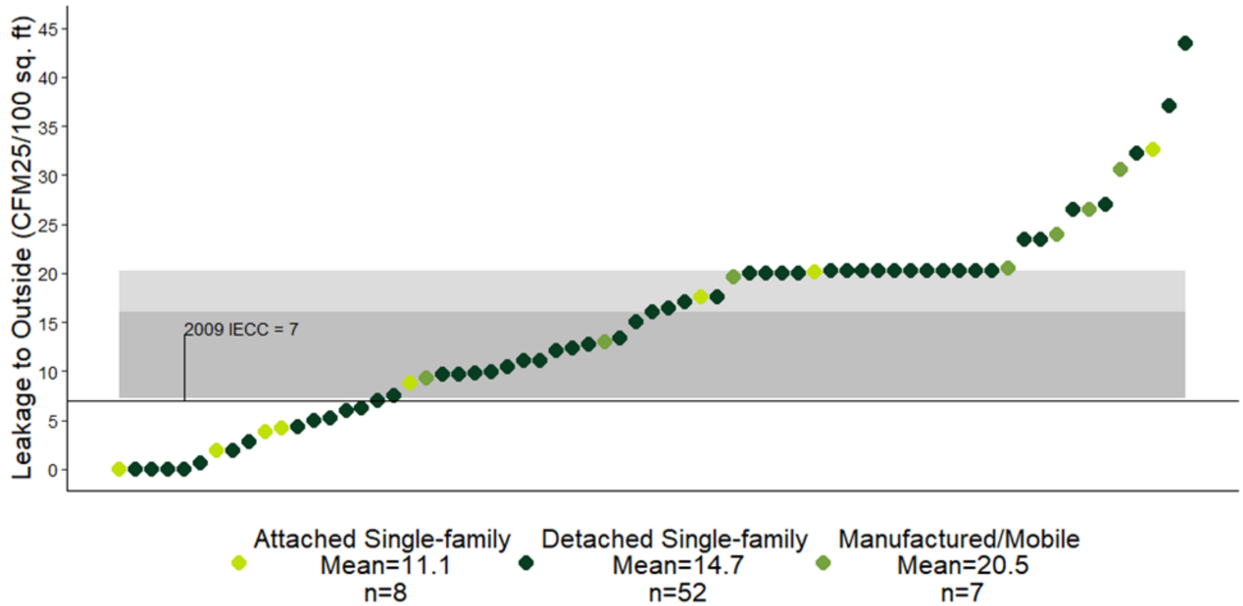
	Before 1940	1940-1959	1960-1979	1980-1999	2000-2009	2010 or later	Total
n	*9*	*11*	*15*	*19*	*9*	*4*	*67*
Min	4.9	0.0	0.6	1.8	0.0	1.8	0.0
Max	37.1	43.4	24.0	30.6	20.4	27.0	43.4
Mean	**20.0**	**14.1**	**15.1**	**17.5**	**7.6**	**9.2**	**14.6**
Median	20.2	9.8	17.6	20.0	8.8	4.0	16.0
Std. Dev.	11.7	13.0	7.0	7.2	6.8	11.9	9.7

Table 35: Duct Leakage to Outside by Home Type (CFM25/100 sq.ft.)

(Base = Systems)

	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Total
n	*52*	*8*	*7*	*67*
Min	0.0	0.0	9.2	0.0
Max	43.4	32.6	30.6	43.4
Mean	**14.7**	**11.1**	**20.5**	**14.6**
Median	15.5	6.5	20.4	16.0
Std. Dev.	9.5	11.4	7.5	9.7

Figure 14: Duct Leakage to Outside by Home Type

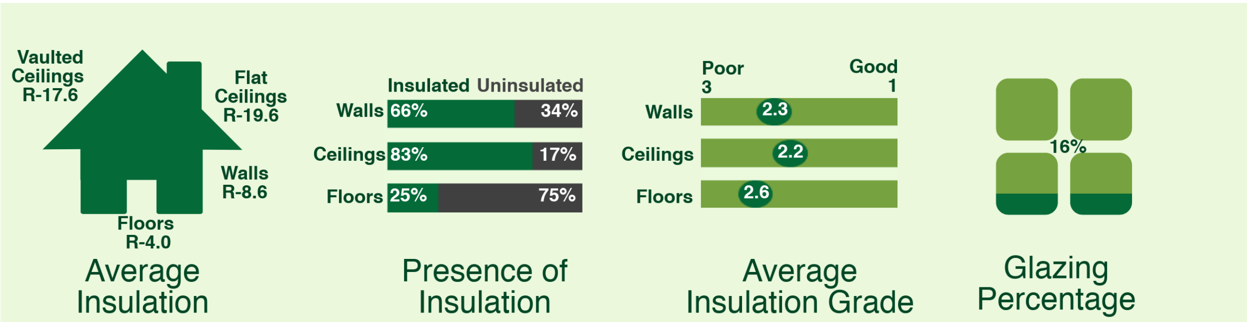


For detailed results split by heating fuel, income status, and EDC, see Appendix C Detailed Diagnostic Results.

Section 6 Building Envelope

This section describes efficiency features of the building shell (i.e., building envelope) of all homes in the sample. These features included above grade walls, ceilings, foundation walls, slab floors, and windows.

Figure 15: Building Envelope Results Highlights



Key Findings:

- Homes in the sample demonstrate significant potential for efficiency improvements through upgrading insulation in the building shell. Exterior walls are primarily uninsulated in 34% of homes, ceilings are primarily uninsulated in 17% of homes, and frame floors over unconditioned basements are primarily uninsulated in 75% of homes.
- The average R-value of exterior walls is R-8.6. The average R-value of walls in mobile or manufactured homes (12.1) is significantly higher than all other home types.
- Flat ceilings in the sample have an average R-value of 19.6, while vaulted ceilings average 17.6.
- Almost 50% of foundation walls enclosing conditioned space are uninsulated, and the average R-value is just 5.0.
- Windows comprise 16% of external wall area. Seventy percent of window area is made up of plain double pane glazing, and 21% of window area had confirmed low-emissivity coatings.

6.1 Shell Measure Data Collection

A building's thermal envelope is formed by the walls, floors, ceilings, and fenestration (i.e., windows and doors) that separate conditioned space from unconditioned or ambient space.[58] For this study, auditors gathered data on thermal resistance (e.g., R-values and U-factors) and insulation type for envelope measures, such as walls, ceilings, and frame floors. Data were also

[58] Because doors are such a small portion of the building shell, information on doors was collected and included in the REM/Rate models for diagnostic visits, but not included in reporting.

collected on the level of insulation for foundation walls and slab floors in conditioned spaces, and the area, framing, and glazing material of windows.

This section focuses on key components of the thermal envelope. The above grade walls section details walls between conditioned and ambient space, the ceiling section details flat and vaulted ceilings, and the frame floor section details floors over unconditioned basements. The foundation wall, slab floor, and window sections focus on measures found in conditioned space. For additional EDC-specific analysis, see Appendix D.

For each data point, information is reported to the extent it could be determined onsite. For example, when assessing insulation type and thickness, auditors were constrained by what they could see and feel in homes with sealed cavities. *Primary insulation type* is defined as the insulation type (or combination of types, denoted with a "+" in the tables below) found in the majority of the home for each measure. Average R-value is calculated as an area-weighted average, following RESNET protocols, that accounts for scenarios where a home has walls insulated to varying degrees.[59] For example, one home was primarily insulated with fiberglass batts, but it included a small addition that was insulated with closed-cell spray foam. For this home, the batts represented the sole observation of a primary insulation type, but the foam insulation in the addition was factored into the area-weighted R-value calculation for all exterior walls in the home. Additionally, if the majority of wall area in a home was uninsulated, the home was considered to have primarily uninsulated walls, but the R-values of any present insulation was included in the average R-value calculations.

Each section below also includes a table detailing insulation grade for a given measure. Insulation grade is a rating of how well the insulation was installed in the building cavity – Grade I is the highest (best) rating and Grade III is the lowest. Poor insulation grade lowers the thermal performance of the shell assembly. For more detail on insulation grade, including examples, see Appendix E. Tables showing insulation grade only include observations of a measure found in the diagnostic sample of homes, as these were the only homes where insulation grade was assessed. Grade is a necessary REM/Rate input for modeling wall assemblies when generating HERS Index scores, which was only done for the diagnostic sample.

6.2 Conditioned to Ambient Walls

This section details the primary insulation type and average R-value for conditioned to ambient (exterior) walls in sampled homes.

6.2.1 Primary Insulation Type

Statewide, 60% of exterior walls were primarily insulated with fiberglass batts or a combination including fiberglass batts, while over a third (34%) were primarily uninsulated (Table 36). The proportion of walls confirmed to be uninsulated is higher than the confirmed proportion in the previous baseline study (19%) and shows that upgrading wall insulation remains a major

[59] RESNET is a recognized national standards-making body for building energy-efficiency rating and certification systems in the United States, including the HERS Index. http://www.resnet.us/

opportunity for energy savings.[60] This is especially true in attached single-family homes, which were almost as likely to be uninsulated (45%) as insulated.[61] The observed increase in primarily uninsulated homes is the result of the SWE team considering the relative areas of assemblies that have varying levels of insulation in each home. The previous study characterized whichever insulation was present regardless of if said insulation only comprised a small portion of the home.

Fiberglass was the most common wall insulation across all home types. Rigid foam, present in 9% of walls either alone or in combination with fiberglass, was the next most common insulation type. All mobile or manufactured homes were insulated, either with fiberglass or a combination including fiberglass. Due to federal construction requirements, this result was expected.[62]

Table 37 shows ambient wall primary insulation organized by home vintage. Not surprisingly, many uninsulated walls in the sample are clustered among homes built before 1960, and almost 60% of ambient walls in homes built before 1940 were uninsulated.

[60] The previous study also specified that they were unable to confirm the presence or lack of insulation in exterior walls in 29% of homes. In the current study, just two homes had walls with unknown insulation. The 19% value in the previous study may understate the share of uninsulated walls considering that at least some of the other 29% of *unknowns* were likely uninsulated.

[61] In attached single-family homes, walls assessed for insulation were only exterior walls to ambient (outdoor) conditions. Walls between adjacent units (adiabatic) were assessed for HERS modeling in diagnostic visits but were not assessed for primary insulation or R-value calculations here.

[62] Manufactured homes are subject to the federal Manufactured Home Construction and Safety Standards (i.e., HUD Code) administered by the Department of Housing and Urban Development (HUD). Manufactured homes built to this standard have a certification label as evidence of compliance. For more information, see the applicable Code of Federal Regulation, CFR 24 3280.

Table 36: Ambient Wall Primary Insulation

Insulation Type	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*145*	*47*	*26*	*69*	*287*
Fiberglass Batts (FGB)	59%	40%	92%	48%	52%
No Insulation	23%	45%	--	39%	34%
FGB + Rigid Foam[1]	7%	6%	8%	4%	7%
Dense-pack Cellulose	4%	4%	--	3%	3%
Rigid Foam[1]	2%	--	--	3%	2%
Closed-Cell Spray Foam	1%	--	--	--	1%
Rock Wool Batts	1%	--	--	3%	1%
Open-cell Spray Foam	1%	2%	--	--	<1%
Blown-in FG	1%	2%	--	--	<1%
Closed-cell Spray Foam + FGB	1%	--	--	--	<1%
UFFI Foam[2]	1%	--	--	--	<1%

[1] Rigid foam includes expanded polystyrene (EPS), extruded polystyrene (XPS), and polyisocyanurate.
[2] Urea-formaldehyde.

Table 37: Ambient Primary Wall Insulation by Home Vintage

Insulation Type	Before 1940	1940-1959	1960-1979	1980-1999	2000-2009	2010 or later	Statewide[3]
n	*78*	*46*	*63*	*64*	*20*	*15*	*286*
Fiberglass Batts (FGB)	24%	44%	71%	81%	85%	47%	52%
No Insulation	58%	46%	18%	5%	--	13%	34%
FGB + Rigid Foam[1]	1%	4%	5%	13%	15%	7%	7%
Dense-pack Cellulose	8%	2%	--	2%	--	13%	3%
Rigid Foam[1]	6%	--	--	--	--	--	2%
Closed-Cell Spray Foam	1%	--	2%	--	--	--	1%
Rock Wool Batts	--	2%	3%	--	--	--	1%
Open-cell Spray Foam	--	--	--	--	--	13%	<1%
Blown-in FG	1%	--	--	--	--	7%	<1%
Closed-cell Spray Foam + FGB	--	--	2%	--	--	--	<1%
UFFI Foam[2]	--	2%	--	--	--	--	<1%

[1] Rigid foam includes expanded polystyrene (EPS), extruded polystyrene (XPS), and polyisocyanurate.
[2] Urea-formaldehyde.
[3] Excludes one home that did not have verified insulation type data and two homes that did not have verified vintage data.

6.2.2 Ambient Wall Insulation Grade

Homes in the diagnostic sample most commonly had Grade II (46%) or III (33%) insulation in walls (Table 38). This is not surprising since Grade I installations are rare even in new construction and generally require high quality spray or dense pack insulation and an assessment by an auditor before the wall cavity is enclosed. As Table 36 showed, most homes had walls with fiberglass batt insulation, which is unlikely to earn a Grade I rating even in ideal conditions. Auditors following

RESNET rating guidelines are especially unlikely to give fiberglass insulation a Grade I in a closed cavity they cannot fully inspect.

Table 38: Exterior Wall Insulation Grades

Grade	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Statewide
n	*53*	*10*	*9*	*72*
I	9%	--	--	6%
II	40%	70%	3 (33%)	46%
III	38%	10%	6 (67%)	33%
No Cavity Insulation	13%	20%	--	16%

6.2.3 Average R-value

The average per-home R-value for conditioned to ambient walls statewide was R-8.6 (Table 39). Among home types, manufactured and mobile homes had the highest average wall R-value at 12.1, in part because no homes in that sample had uninsulated walls. The detached, attached, and multifamily samples all included sites where exterior walls were completely uninsulated. In total, 61 of the 287 sites where insulation data could be attained had uninsulated exterior walls. Excluding uninsulated sites increases the average R-value for the remaining 226 homes to R-11.2.

Of the 61 uninsulated sites in the sample, over half were in PECO or Duquesne territory. PECO homes had the lowest average ambient wall R-value among the EDCs at R-6.1, significantly lower than all other EDCs aside from Duquesne (R-7.3). For more R-value information split by EDC, see Table 185 in Appendix D.

Table 39: Average Conditioned to Ambient Wall R-value

R-values	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide[1]
n	*145*	*47*	*26*	*69*	*287*
Minimum	0.0	0.0	6.0	0.0	0.0
Maximum	26.0	21.0	19.0	21.5	26.0
Mean	**10.2**	**8.1**	**12.1**	**7.5**	**8.6**
Median	11.0	6.2	11.0	11.0	11.0
Std. Dev.	7.0	7.8	3.3	6.5	6.9

[1] Excludes two homes that did not have verified R-value data.

Table 40 further breaks down wall R-values by home vintage. Predictably, average R-values rise through each period until they hit a high point of R-15.7 in homes built between 2000 and 2009. These values highlight the opportunity for efficiency gains through targeting older, under or uninsulated homes with insulation upgrades.

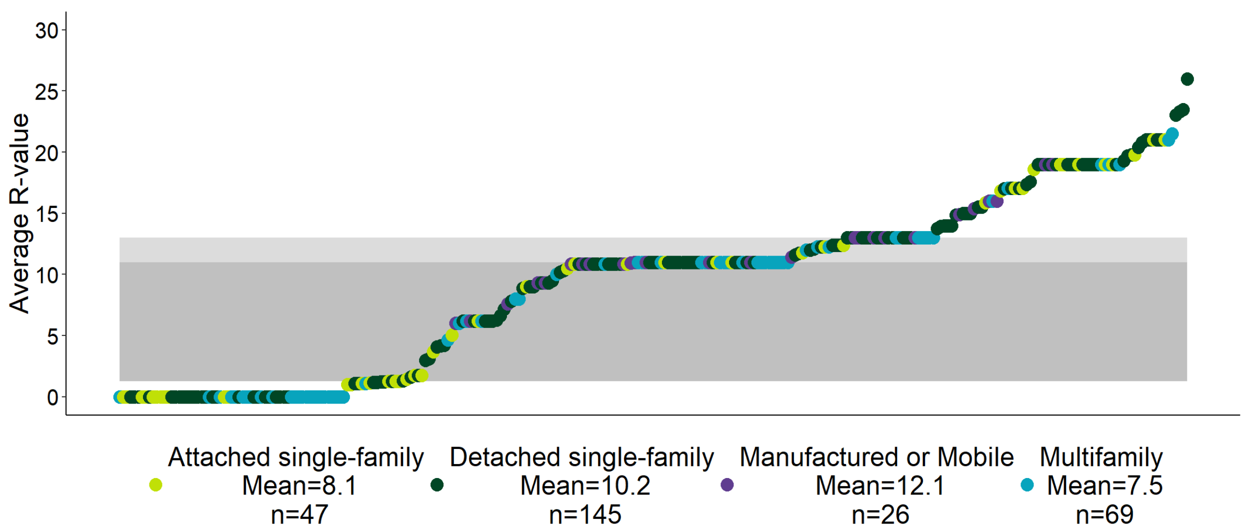
Table 40: Above Grade Wall R-value by Vintage

R-values	Before 1940	1940-1959	1960-1979	1980-1999	2000-2009	2010 or later	Statewide[1]
n	*78*	*46*	*63*	*64*	*20*	*14*	*285*
Minimum	0.0	0.0	0.0	0.0	10.8	0.0	0.0
Maximum	23.3	20.4	26.0	23.5	21.0	21.5	26.0
Mean	**4.8**	**6.3**	**9.6**	**13.6**	**15.7**	**16.1**	**8.6**
Median	1.3	6.2	11.0	13.0	15.7	18.0	11.0
Std. Dev.	6.1	6.3	5.4	5.1	3.4	6.0	6.9

[1] Excludes two homes that did not have verified R-value data and two homes that did not have verified vintage data.

Figure 16 displays per-home R-values for all sites in the sample. Aside from the large grouping of uninsulated homes at the left, a large cluster of homes at the statewide median of R-11 and secondary groupings at R-13 and R-19 stand out. This reflects the nominal R-values of standard fiberglass batts – by far the most common insulation type found in the sample – in typical 2x4 or 2x6 framing. R-11 and R-13 fiberglass batts are designed for 2x4 walls, the most common framing dimension in the sample. R-19 batts fill 2x6 cavities, the next most common framing type.

Figure 16: Per-home Ambient Wall R-values



6.3 Ceilings

The following section describes onsite data collected on two main types of ceilings:

- Flat ceilings, where there is attic space above the ceiling and can also be thought of as unconditioned attic floors.
- Vaulted ceilings, which refer to a ceiling assembly that has no attic space above it and is insulated at the roof deck/rafters.

Auditors also collected data on attic hatches. However, they are excluded here because attic hatches comprised such a small percent of ceiling area.

6.3.1 Flat Ceiling Primary Insulation Type

In flat ceiling assemblies, fiberglass batts were the most common insulation type statewide, present in half of homes either alone (45%) or in combination with another type of insulation (5%) (Table 41). Fiberglass batts were also the most common primary insulation type regardless of home type, though attached single-family homes were equally likely to have uninsulated ceiling assemblies (28% each). There were 15 row homes in the attached single-family sample (mostly in the Philadelphia and Pittsburgh areas), which typically had fully uninsulated building shells. This subgroup consistently increases the proportions of uninsulated homes in the attached category. This is more of an issue for ceilings when compared to walls because a majority of walls in row homes are adiabatic.[63] Seventeen percent of flat ceilings statewide were primarily uninsulated, meaning that the majority of the ceiling area had no insulation. Blown-in insulation was also common (fiberglass,15% or cellulose, 14%). While flat ceilings were more consistently insulated than walls, they also represent an opportunity for energy savings via R-value upgrades.

Table 42 shows the prevalence of primary insulation types by home vintage. Most uninsulated flat ceilings are found in homes dating from before 1940, and no homes built after 1980 had uninsulated ceilings.

[63] "Adiabatic" refers to walls between two conditioned spaces such as a wall separating two attached homes.

Table 41: Flat Ceiling Primary Insulation

Insulation Type	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*138*	*39*	*19*	*52*	*248*
Fiberglass Batts (FGB)	54%	28%	79%	48%	45%
No Insulation	9%	28%	--	14%	17%
Blown-in Fiberglass	13%	20%	5%	21%	15%
Blown-in Cellulose	15%	10%	5%	12%	14%
Blown-in Cellulose + FGB	2%	3%	5%	2%	2%
Blown-in Fiberglass + FGB	3%	3%	--	--	2%
Blown-in Rock Wool	1%	3%	--	--	2%
Vermiculite	1%	--	--	--	1%
Rock Wool Batt	1%	--	--	--	1%
FGB + Rigid Foam	--	3%	5%	--	1%
Rigid Foam	--	--	--	4%	1%
Open-cell Spray Foam	--	3%	--	--	<1%

Table 42: Primary Flat Ceiling Insulation by Home Vintage

Insulation Type	Before 1940	1940-1959	1960-1979	1980-1999	2000-2009	2010 or later	Statewide[1]
n	*70*	*43*	*53*	*50*	*19*	*11*	*246*
Fiberglass Batts (FGB)	36%	49%	66%	60%	58%	18%	45%
No Insulation	31%	9%	8%	--	--	--	17%
Blown-in Fiberglass	9%	12%	8%	26%	21%	46%	15%
Blown-in Cellulose	16%	19%	9%	4%	16%	27%	14%
Blown-in Cellulose + FGB	--	--	6%	6%	--	--	2%
Blown-in Fiberglass + FGB	3%	2%	2%	2%	--	--	2%
Blown-in Rock Wool	3%	2%	--	--	--	--	2%
Vermiculite	1%	2%	--	--	--	--	1%
Rock Wool Batt	--	5%	--	--	--	--	1%
FGB + Rigid Foam	1%	--	--	--	5%	--	1%
Rigid Foam	--	--	2%	2%	--	--	1%
Open-cell Spray Foam	--	--	--	--	--	9%	<1%

[1] Excludes two homes that did not have verified vintage data.

6.3.2 Flat Ceiling Insulation Grade

About half of the diagnostic sample had Grade II insulation, while 18% had Grade I insulation (Table 43). Just 5% of the 69 diagnostic homes with flat attic space were uninsulated.

Table 43: Flat Ceiling Insulation Grade

Grade	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Statewide
n	*51*	*10*	*8*	*69*
I	18%	50%	--	18%
II	50%	20%	1 (13%)	49%
III	32%	10%	7 (88%)	28%
No Cavity Insulation	--	20%	--	5%

6.3.3 Flat Ceiling R-value

The average statewide flat ceiling R-value was R-19.6 (Table 44), with little variation in the average by home type. Attached single-family homes had the lowest average R-value (R-17.8), while detached single-family homes had the highest average (R-22.1). Twenty-seven sites had flat ceilings that were completely uninsulated. As with above grade walls, we found that all mobile or manufactured homes had insulated ceilings. Narrowing the sample to the 219 homes with some type of insulation present in flat ceilings, the average statewide R-value rises to R-22.9. For comparison, the 2015 IECC R-value requirement for flat ceilings is R-49.0, a value that should be attainable in most homes with flat ceilings. Using a site in the diagnostic sample as an example, increasing the insulation of a 2,000 sq.ft. home with R-19.6 flat ceiling insulation to R-49.0 reduces the HERS Index score by 4 points, leaving all else the same.

Table 44: Average Flat Ceiling R-value

R-value	Detached single-family	Attached single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*137*	*39*	*19*	*51*	*246*
Minimum	0.0	0.0	6.2	0.0	0.0
Maximum	53.6	44.4	38.0	42.5	53.6
Mean	**22.1**	**17.8**	**20.0**	**20.0**	**19.6**
Median	20.9	19.0	17.1	19.0	19.0
Std. Dev.	12.1	14.0	9.8	13.1	12.5

Table 45 displays average flat ceiling R-value by home vintage. Average R-value increases over each period, peaking among the newest sub-sample of homes (built in or after 2010). Flat ceilings with attic space typically allow for easier application of new insulation, and the table highlights the potential for efficiency gains through adding insulation to older homes that pull the statewide average R-value down.

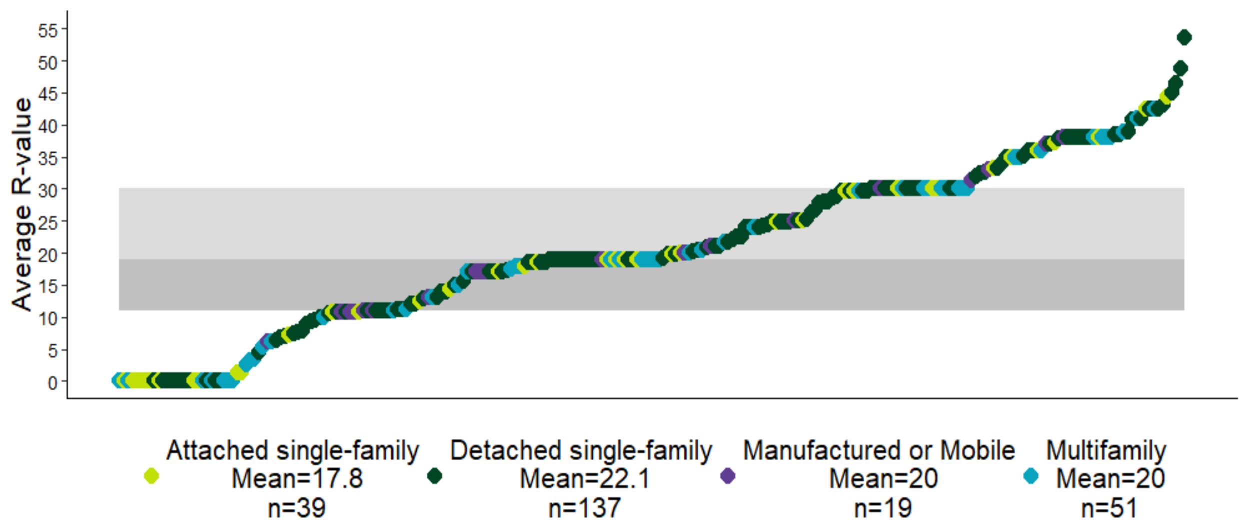
Table 45: Flat Ceiling R-value by Home Vintage

R-values	Before 1940	1940-1959	1960-1979	1980-1999	2000-2009	2010 or later	Statewide[1]
n	*69*	*42*	*53*	*50*	*19*	*11*	*244*
Minimum	0.0	0.0	0.0	6.2	10.8	19.8	0.0
Maximum	43.0	46.5	53.6	38.9	38.0	44.4	53.6
Mean	**14.7**	**19.1**	**20.4**	**25.3**	**28.6**	**33.2**	**19.5**
Median	12.0	19.0	19.0	25.8	30.0	33.3	19.0
Std. Dev.	13.2	12.6	11.8	8.7	9.0	7.3	12.5

[1] Excludes two homes that did not have verified vintage data.

Figure 17 displays the distribution of per-home average R-values for flat ceilings in the sample. Groupings are visible around the statewide median of R-19 and again at R-30. These clusters fit with the data shown in Table 41, as they are two common R-value options for fiberglass batts, the most prevalent insulation type in the sample.

Figure 17: Per-home Flat Ceiling R-values



6.3.4 Vaulted Ceiling Primary Insulation Type

Vaulted ceilings were less common in the sample than ceilings with attic space and can be more difficult to access to verify the presence and type of insulation. Where data could be collected on vaulted ceilings, the cavities were primarily insulated with fiberglass batts (73%) or uninsulated (17%), similar to other shell measures in the sample (Table 46). Multifamily (39%) and attached single-family (33%) sites had the highest proportions of uninsulated vaulted ceilings.

Table 47 shows primary insulation types organized by the age of the home. Most uninsulated vaulted ceilings are found in homes built before 1960, and none are found in homes built after 1980.

Table 46: Primary Vaulted Ceiling Insulation

Insulation Type	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*62*	*12*	*9*	*13*	*96*
Fiberglass Batts (FGB)	79%	67%	8 (89%)	31%	73%
No Insulation	11%	33%	--	39%	17%
Cellulose	7%	--	1 (11%)	8%	7%
FGB + Vermiculite	2%	--	--	--	2%
Rigid Foam	--	--	--	23%	1%
Blown-in Fiberglass	2%	--	--	--	1%

Table 47: Primary Vaulted Ceiling Insulation by Home Vintage

Insulation Type	Before 1940	1940-1959	1960-1979	1980-1999	2000-2009	2010 or later	Statewide
n	*29*	*10*	*21*	*24*	*11*	*1*	*96*
Fiberglass Batts (FGB)	55%	40%	81%	88%	100%	--	73%
No Insulation	35%	40%	10%	--	--	--	17%
Cellulose	7%	10%	5%	4%	--	1 (100%)	7%
FGB + Vermiculite	--	10%	--	--	--	--	2%
Rigid Foam	--	--	5%	8%	--	--	1%
Blown-in Fiberglass	3%	--	--	--	--	--	1%

6.3.5 Vaulted Ceiling Insulation Grade

About half of homes in the diagnostic sample with vaulted ceilings had Grade II insulation, while another third had Grade III (Table 48).

Table 48: Vaulted Ceiling Insulation Grade

Grade	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Statewide
n	*24*	*3*	*3*	*30*
1	4%	--	--	2%
2	50%	1 (33%)	1 (33%)	53%
3	38%	1 (33%)	2 (67%)	33%
No Cavity Insulation	8%	1 (33%)	--	11%

6.3.6 Vaulted Ceiling R-value

The average vaulted ceiling R-value statewide was R-17.6 (Table 49). Attached single-family and multifamily sites were more likely to have uninsulated vaulted ceilings, which is reflected in the lower average R-values for those groups (R-14.2 and R-13.8, respectively). Sixteen homes in the sample had uninsulated vaulted ceilings (Figure 18). The average R-value for the vaulted ceilings among the 80 sampled homes with insulation present was R-21. When looking at average vaulted ceiling R-values by home vintage, the average climbs as expected with each time period save for a small dip among homes built in the 1940s and 1950s (Table 50).

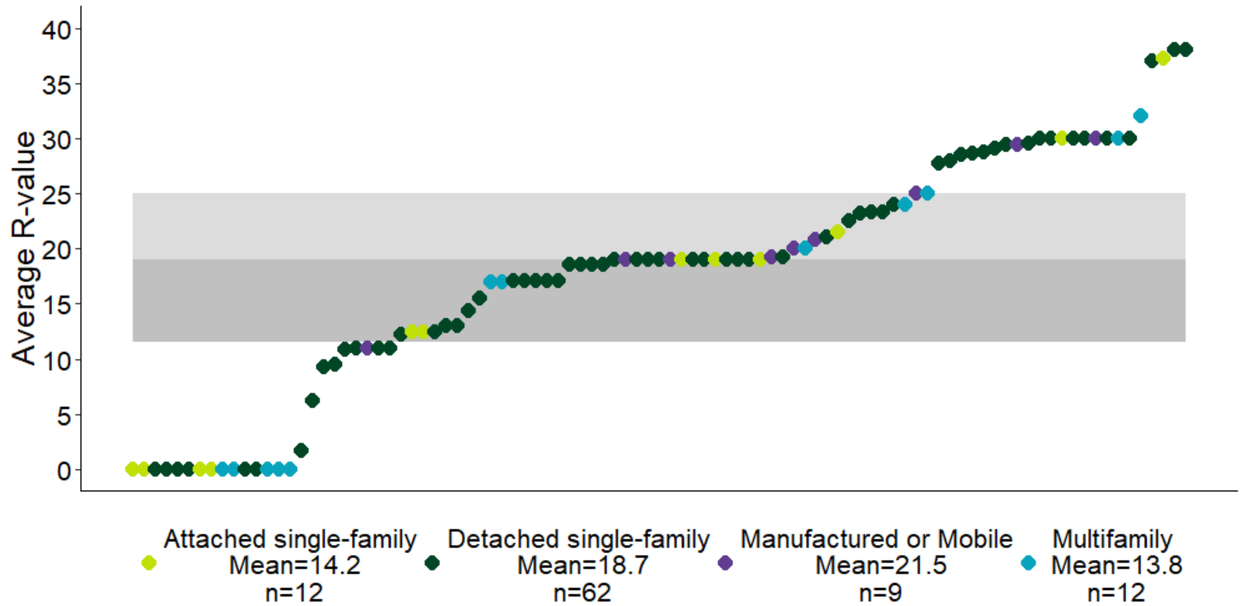
Table 49: Average Vaulted Ceiling R-value

R-value	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*62*	*12*	*9*	*12*	*95*
Minimum	0.0	0.0	11.0	0.0	0.0
Maximum	38.0	37.2	30.0	32.0	38.0
Mean	**18.7**	**14.2**	**21.5**	**13.8**	**17.6**
Median	19.0	15.7	20.0	17.0	19.0
Std. Dev.	9.8	12.5	5.9	12.9	10.4

Table 50: Vaulted Ceiling R-value by Home Vintage

R-values	Before 1940	1940-1959	1960-1979	1980-1999	2000-2009	2010 or later	Statewide
n	*29*	*10*	*21*	*24*	*11*	*0*	*95*
Minimum	0.0	0.0	0.0	11.0	12.4	-	0.0
Maximum	30.0	30.0	29.6	38.0	38.0	-	38.0
Mean	**12.9**	**10.4**	**18.0**	**23.1**	**25.4**	**-**	**17.6**
Median	12.4	10.2	19.0	20.4	25.0	-	19.0
Std. Dev.	11.0	10.3	8.5	6.5	9.6	-	10.4

Figure 18: Per-home Vaulted Ceiling R-values



6.4 Frame Floors

In homes with unconditioned basements,[64] the frame floor separating the basement from conditioned space above it serves as the lower boundary of the building envelope. Typically, the cavities between the floor joists are open, allowing auditors to easily verify the presence, type, and R-value of insulation.

6.4.1 Primary Frame Floor Insulation Type

A full three-quarters of sampled homes with unconditioned basements had uninsulated frame floors between basements and conditioned space (Table 51). This represents a major opportunity for insulation upgrades, especially since these cavities are usually open and allow for easy application of insulation materials. Manufactured or mobile homes did not follow this general trend due to regulations on their construction – 84% had insulated framed floors and all contained fiberglass batts.

Examining frame floor insulation by home vintage shows that while uninsulated floors are more common among the larger samples of older homes built before 1960, newer homes also have uninsulated floors over unconditioned basements (Table 52). All three homes built after 2010 with floors bordering unconditioned basements lacked floor insulation, though the majority of homes with floors over unconditioned basements built between 1980 and 2009 did have insulation present.

[64] Unconditioned basements here are defined as spaces that lack a heating source adequate to fully heat the room year-round and are not finished spaces (i.e., do not have walls and ceiling cavities closed and drywall or other finishing materials installed). This classification method follows RESNET protocols. Enclosed crawl spaces are grouped with unconditioned basements in this analysis.

Table 51: Primary Frame Floor Insulation

Insulation Type	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*93*	*26*	*19*	*25*	*163*
No Insulation	72%	85%	16%	88%	75%
Fiberglass Batts (FGB)	25%	15%	79%	12%	22%
Rigid Foam	2%	--	--	--	2%
Rock Wool Batts	1%	--	--	--	1%
FGB + Mobile Home Wrap	--	--	5%	--	<1%

Table 52: Primary Frame Floor Insulation by Home Vintage

Insulation Type	Before 1940	1940-1959	1960-1979	1980-1999	2000-2009	2010 or later	Statewide
n	*69*	*32*	*30*	*22*	*7*	*3*	*163*
No Insulation	87%	91%	57%	18%	14%	100%	75%
Fiberglass Batts (FGB)	10%	6%	43%	82%	71%	--	22%
Rigid Foam	3%	--	--	--	--	--	2%
Rock Wool Batts	--	3%	--	--	--	--	1%
FGB + Mobile Home Wrap	--	--	--	--	14%	--	<1%

6.4.2 Frame Floor Insulation Grade

Over a third of homes in the diagnostic sample had uninsulated frame floors, while another 44% had low-quality Grade III insulation installs (Table 53). Floors insulated with fiberglass (the most common insulation type) or rock wool batts are more difficult to insulate to better than Grade II or III given the difficulty in maintaining insulation contact with the floorboards without compression.

Table 53: Frame Floor Insulation Grade

Grade	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Statewide
n	*22*	*4*	*8*	*34*
I	5%	--	--	5%
II	14%	--	1 (13%)	15%
III	46%	2 (50%)	5 (63%)	44%
No Cavity Insulation	36%	2 (50%)	2 (25%)	36%

6.4.3 Frame Floor R-value

Due to the prevalence of uninsulated frame floors over unconditioned basements, the average R-value was only R-4.0 (Table 54). Manufactured or mobile homes stood out from the other home types with an average of R-14.0. When only looking at the 59 sites with insulation present, the average R-value rose to R-11.7.[65]

Table 54: Average per-home Frame Floor R-value

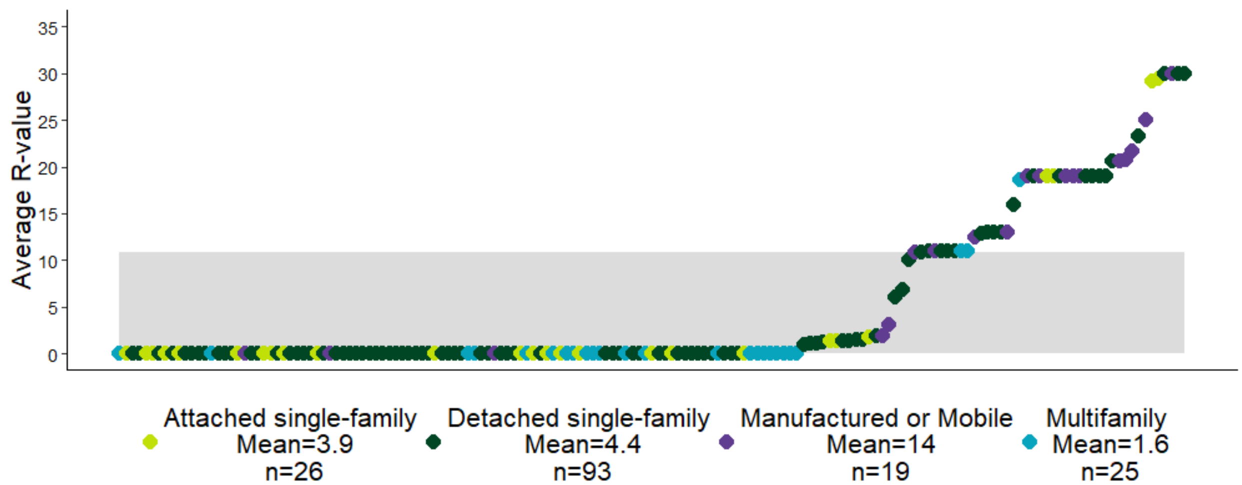
R-value	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*93*	*26*	*19*	*25*	*163*
Minimum	0.0	0.0	0.0	0.0	0.0
Maximum	30.0	29.4	30.0	18.6	30.0
Mean	**4.4**	**3.9**	**14.0**	**1.6**	**4.0**
Median	0.0	0.0	19.0	0.0	0.0
Std. Dev..	7.9	9.1	9.2	4.7	8.5

[65] Even in homes with insulated frame floors, it is common to see the stair treads to conditioned space left uninsulated. Auditors recorded these uninsulated areas – following RESNET protocols – and factored them into the area-weighted R-value calculation, which can degrade overall R-value substantially.

Table 55: Frame Floor R-value by Home Vintage

R-values	Before 1940	1940-1959	1960-1979	1980-1999	2000-2009	2010 or later	Statewide
n	*69*	*32*	*30*	*22*	*7*	*3*	*163*
Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Maximum	23.2	19.0	30.0	30.0	30.0	0.0	30.0
Mean	**1.6**	**1.7**	**6.4**	**14.9**	**18.3**	**0.0**	**4.0**
Median	0.0	0.0	0.0	19.0	19.0	0.0	0.0
Std. Dev.	4.8	5.1	8.6	9.4	11.1	-	8.5

Figure 19: Per-home Frame Floor R-values



6.5 Foundation Walls

Conditioned basements were present in 40% of homes. In conditioned basements, auditors checked for insulation along the interior and exterior of the foundation walls. Interior insulation was found in 62 homes, but the presence of exterior insulation was only confirmed in four homes. Exterior insulation can be difficult to verify without building plans or construction photos as it is often covered by a protective layer and cut off below grade. So, while exterior continuous insulation is uncommon on foundation walls in older homes, it is possible its prevalence is underrepresented in the sample.

6.5.1 Primary Foundation Wall Insulation Type

Nearly half of homes in the sample with conditioned basement space had foundation walls that were primarily uninsulated (Table 56, Table 57). Beyond that, fiberglass batts were the most common insulation type (32% of homes), followed by rigid foam (14%).

Table 56: Primary Foundation Wall Insulation

Insulation Type	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*79*	*13*	*4*	*19*	*115*
No Insulation	42%	46%	1 (25%)	74%	49%
Fiberglass Batts (FGB)	36%	31%	3 (75%)	26%	32%
Rigid Foam	18%	8%	--	--	14%
FGB + Rigid Foam	4%	--	--	--	3%
Open-cell Spray Foam	1%	8%	--	--	2%
Closed-cell Spray Foam	--	8%	--	--	<1%

Table 57: Primary Foundation Wall Insulation by Home Vintage

Insulation Type	Before 1940	1940-1959	1960-1979	1980-1999	2000-2009	2010 or later	Statewide[1]
n	*18*	*21*	*32*	*26*	*9*	*7*	*113*
None	72%	52%	53%	27%	2 (22%)	2 (29%)	48%
Fiberglass batts (FGB)	22%	33%	22%	58%	6 (67%)	--	33%
Rigid foam	--	10%	19%	8%	1 (11%)	4 (43%)	13%
FGB + Rigid foam	--	--	3%	8%	--	--	3%
Open-cell Spray Foam	--	--	3%	--	--	1 (14%)	2%
Closed-cell Spray Foam	6%	--	--	--	--	--	2%

[1] Excludes two homes that did not have verified vintage data.

6.5.2 Foundation Wall Insulation Grade

All diagnostic sites with foundation wall insulation present were detached single-family homes (Table 58). Just over half (52%) of homes in the diagnostic sample had uninsulated foundation walls in conditioned space.

Table 58: Foundation Wall Insulation Grade

Grade	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Statewide
n	*39*	*2*	*0*	*41*
I	13%	--	--	12%
II	31%	--	--	30%
III	8%	--	--	7%
No Cavity Insulation	49%	2 (100%)	--	52%

6.5.3 Foundation Wall R-value

The statewide average R-value for foundation walls in conditioned space was R-5 (Table 59). This was reduced substantially by the 49% of homes in the sample with conditioned basement space enclosed by primarily uninsulated foundation walls. Removing the uninsulated walls from the sample, the R-value of insulated walls nearly doubles to R-9.5. Figure 20 shows per-home foundation wall R-values. The maximum R-value observed in the sample was R-33.0, found in an attached single-family home that used high density closed-cell spray foam. The other home that stands out in the figure was a detached single-family home that used a combination of exterior rigid foam and interior fiberglass batts to achieve R-24.8.

Table 59: Average Foundation Wall R-value

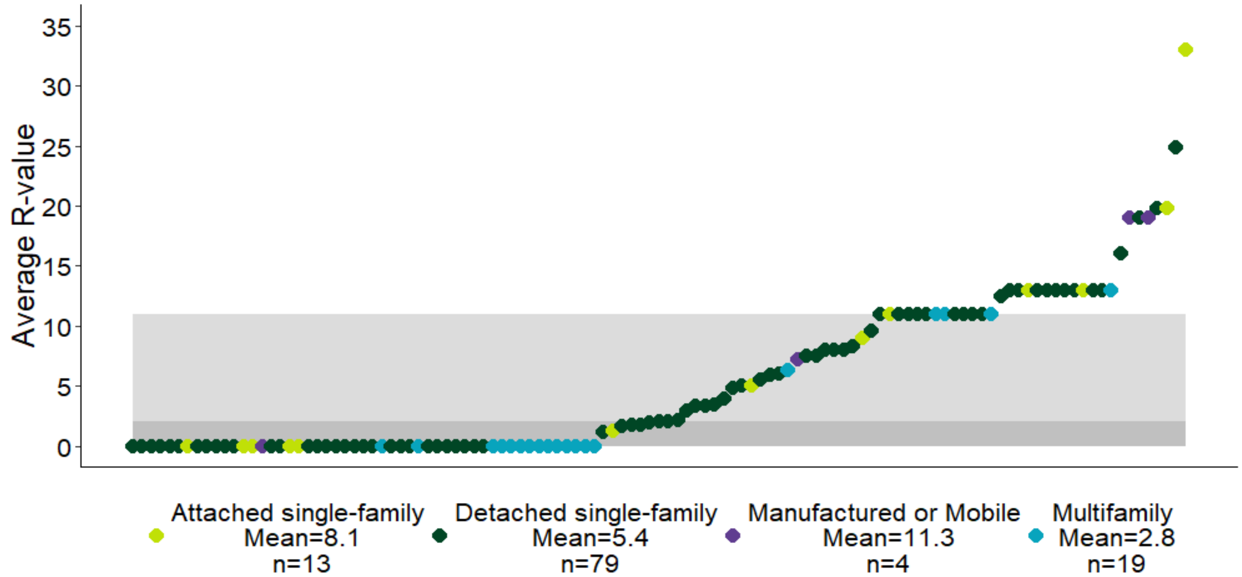
R-value	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*79*	*13*	*4*	*19*	*115*
Minimum	0.0	0.0	0.0	0.0	0.0
Maximum	24.8	33.0	19.0	13.0	33.0
Mean	**5.4**	**8.1**	**11.3**	**2.8**	**5.0**
Median	3.0	5.0	13.1	0.0	2.0
Std. Dev.	6.0	10.0	9.4	4.9	6.7

Table 60: Average Foundation Wall R-value by Home Vintage

R-values	Before 1940	1940-1959	1960-1979	1980-1999	2000-2009	2010 or later	Statewide[1]
n	*18*	*21*	*32*	*26*	*9*	*7*	*113*
Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Maximum	11.0	19.0	19.8	24.8	13.0	33.0	33.0
Mean	**2.6**	**4.9**	**4.2**	**7.5**	**7.6**	**11.2**	**5.1**
Median	0.0	0.0	1.4	7.6	8.0	8.0	2.1
Std. Dev.	4.5	6.3	5.7	7.0	5.5	11.9	6.7

[1] Excludes two homes that did not have verified vintage data.

Figure 20: Per-home Foundation Wall R-values



6.6 Slab Floors

Slab floors form the lower boundary of the thermal envelope in homes with conditioned basement space or with on-grade floors that have no basement underneath. It is best practice to insulate slabs that serve as part of the thermal boundary, though the presence of insulation is usually not possible to verify post-construction without building plans or other documentation. Auditors were able to verify the presence of slab insulation at just two sites out of the 174 that had slab floor bordering conditioned space – both were multifamily sites with building plans available. In both cases, there was rigid foam insulation along the slab perimeter and underneath the slab, with R-values of R-10.0 and R-6.0.

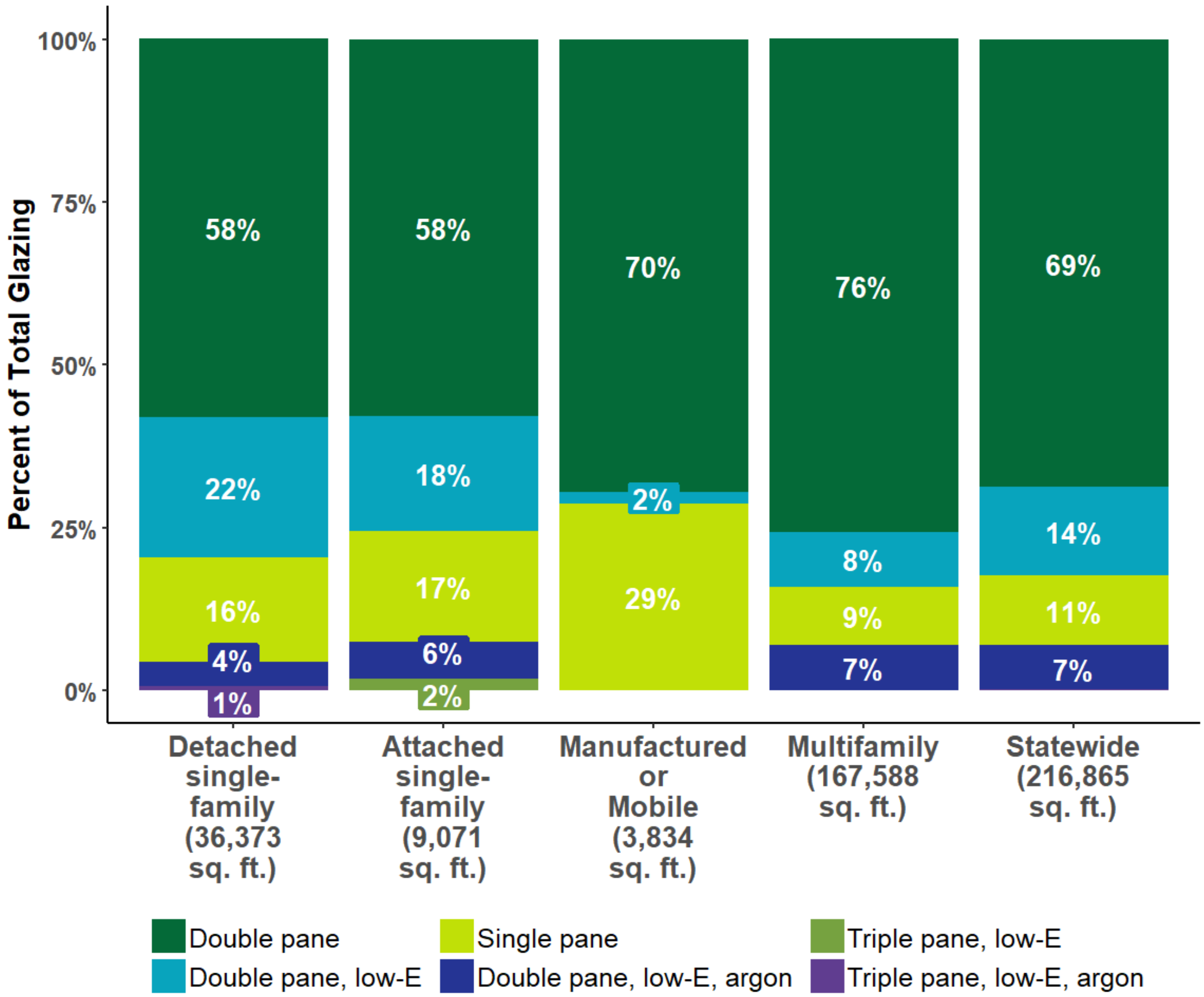
6.7 Windows

During onsite visits, auditors recorded the framing and material of glazing (i.e., windows), as well as the size of each window in the home. This section looks at the prevalence of glazing types *as a percent of total window area*, rather than using counts of windows. Average glazing area per site is calculated as the percent of exterior wall area composed of glazing for each home. All window data is limited to windows located in conditioned space.

6.7.1 Glazing Types

Double pane windows were the predominant glazing type statewide, making up about 70% of glazing by total area and about 90% when including double pane windows with added efficiency features like a low-emissivity coating (14%) and/or argon gas (7%) (Figure 21). Windows with a low-emissivity coating made up about 21% of window area in the sample, while argon gas was present in just 7% of glazing. The verification of the presence of argon gas is difficult to assess without documentation and thus is likely underestimated. Similar recent existing homes baseline studies saw higher proportions of low-emissivity coatings on windows, including a study in Maine which found 56% of window area to have low-emissivity coatings. Triple pane glazing made up less than 1% of window area in the sample and was only found in detached single-family homes. This is not surprising given that this type of glazing is rare even in new construction.

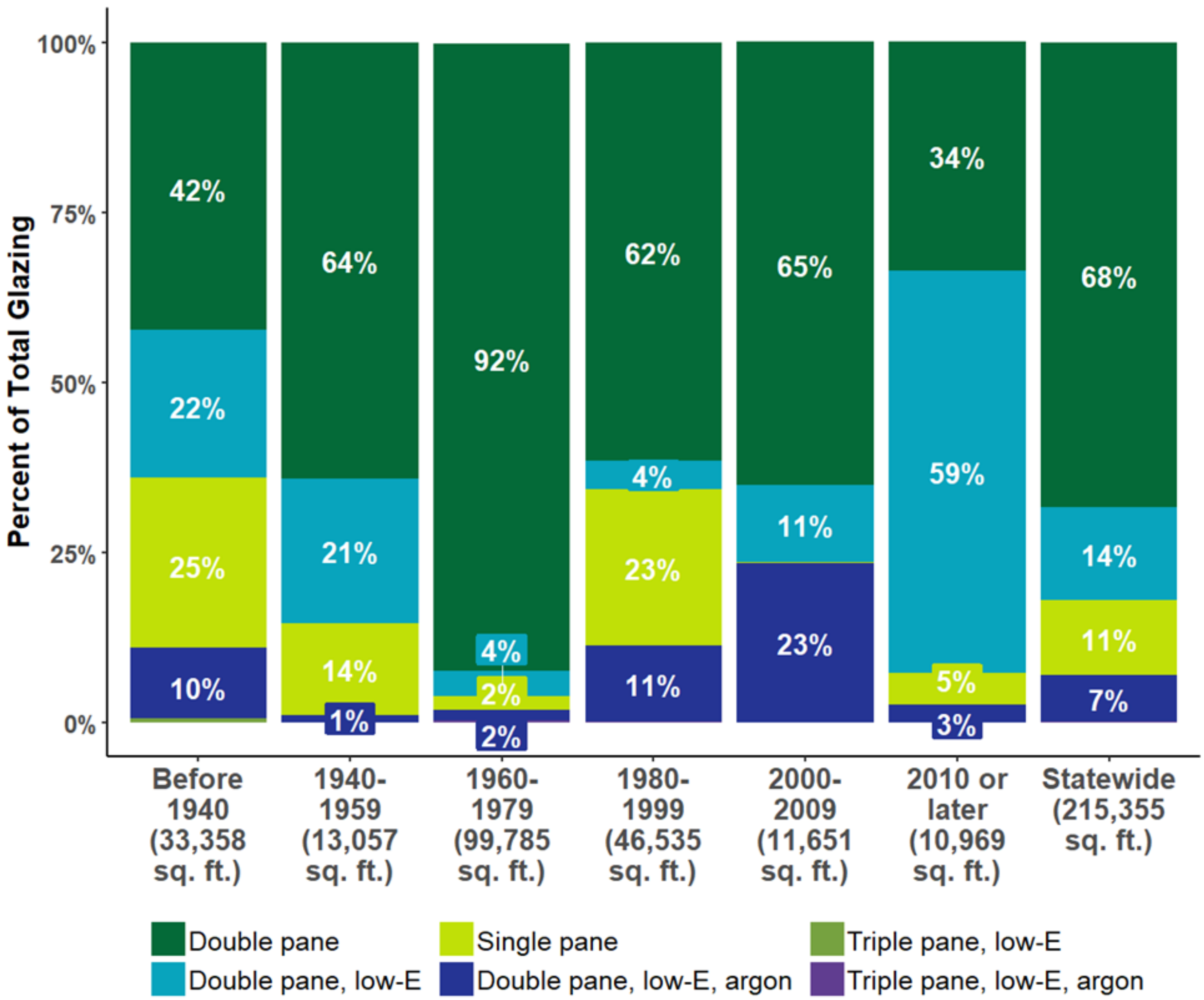
Figure 21: Glazing Types by Window Square Footage (Home Types)



Double pane glazing – either plain or with added efficiency features – was the most common type across all home types and EDCs, making up at least 70% of glazing in all subgroups aside from FE: Met-Ed homes, where 47% of glazing was single pane (Figure 33). On average, Met-Ed homes are newer than all sampled homes except those in Penn Power territory, so home vintage does not explain the discrepancy.

Figure 2 further breaks down the distribution of glazing types by the vintage of the home or building. Homes built before 1940 have the highest percentage of single-pane glazing—which is to be expected—but also have the second-largest proportion of double-pane glazing with a low-emissivity coating. This likely reflects older homes that have gone through the process of having old, less efficient windows replaced with updated materials. Plain double pane glazing represents the largest proportion of window area for each age group save for homes built after 2010, where almost 60% of glazing is double pane with a low-emissivity coating.

Figure 22: Glazing Percentages by Home Vintage[1]



[1] Excludes two homes that did not have verified vintage data. Triple pane glazing makes up less than one half of one percent of glazing in any one of these categories, and as such does not appear in the figure.

6.7.2 Exterior Glazing Percentages

Statewide, glazing comprises about 16% of a home's exterior wall area on average (Table 61). These values were derived from comparing the measured square footage of ambient (exterior) walls to the square footage of glazing located in those same walls at each site. Whether splitting the data by home type or EDC, there was little variation from the statewide average (Table 194).

Table 61: Glazing as a Percent of Exterior Wall Area (Home Types)

Glazing	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*145*	*48*	*26*	*70*	*289*
Minimum	7%	7%	7%	5%	5%
Maximum	33%	32%	37%	35%	37%
Mean	**14.2%**	**18.2%**	**12.4%**	**16.1%**	**15.5%**
Median	14%	18%	11%	15%	15%
Std. Dev.	4.5%	5.6%	5.7%	5.9%	5.4%

Section 7 Ducts

This section focuses on the location and insulation of supply and return ducts. Unlike the 2013 baseline, this report does not rely on qualitative duct leakage assessments since they are unreliable given the amount of ductwork that is not visible in existing homes. Instead, for quantified analysis on duct leakage, see Section 5 Diagnostic Sub-Sample Results. The 2009 IECC has more stringent insulation requirements for supply ducts than for return ducts.[66,67]

7.1 Duct Location

Approximately 60% of the full sample had duct systems. Table 62 and Table 63 show that, 22% of homes had the majority of ductwork located in unconditioned spaces (attics, basements, crawlspaces, and/or garages). Twenty-one percent of homes had more than 90% of supply ductwork located in conditioned space, while 22% of homes had more than 90% of return ductwork located in conditioned spaces.

About 8% of homes had all ducts in unconditioned spaces, while 19% of homes had all ducts in conditioned spaces. Manufactured or mobile homes were more likely to have ducts in unconditioned spaces, whereas the multifamily homes were more likely to have ducts in conditioned spaces.

Table 62: Supply Duct Location

(Base: Homes)

	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*145*	*48*	*26*	*70*	*289*
No Ducts	26%	42%	19%	47%	40%
<50% Conditioned	30%	15%	58%	7%	22%
50%-90% Conditioned	26%	25%	4%	16%	16%
>90% Conditioned	18%	19%	19%	30%	21%

66 Pennsylvania adopted the 2009 IECC in 2009, which requires minimum insulation of R-8 for supply ducts in attics and R-6 for all other ducts. In 2018, Pennsylvania adopted the 2015 IECC which treats return and supply ducts the same. No homes in the full sample were subject to the 2015 IECC.

67 Unlike the previous study, results are presented separately for supply and return ducts to account for differences in code requirements.

Table 63: Return Duct Location
(Base: Homes)

	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*145*	*48*	*26*	*70*	*289*
No Ducts	26%	42%	19%	47%	40%
<50% Conditioned	30%	10%	54%	10%	22%
50%-90% Conditioned	26%	27%	--	13%	15%
>90% Conditioned	19%	21%	27%	30%	22%

Table 64 and Table 65 show ductwork location based on the year the home was built. Almost half of the homes built before 1940 had no ductwork, while 7% of homes built in 2000 or later had no ductwork. Homes built before 1940 had 5% of supply ducts and 6% of return ducts located in conditioned space. Over half of the homes built in 2000 or later had more than 90% of the ductwork in conditioned space.

Table 64: Supply Duct Location by Home Vintage

(Base: Homes)

	Before 1940	1940-1959	1960-1979	1980-1999	2000-2009	2010 or later	Statewide[1]
n	*78*	*46*	*64*	*64*	*20*	*15*	*287*
No Ducts	49%	33%	36%	27%	--	20%	41%
<50% Conditioned	24%	28%	22%	30%	10%	20%	23%
50%-90% Conditioned	22%	22%	23%	16%	25%	27%	16%
>90% Conditioned	5%	17%	19%	28%	65%	33%	21%

[1] Excludes two homes that did not have verified vintage data.

Table 65: Return Duct Location by Home Vintage

(Base: Homes)

	Before 1940	1940-1959	1960-1979	1980-1999	2000-2009	2010 or later	Statewide[1]
n	*78*	*46*	*64*	*64*	*20*	*15*	*287*
No Ducts	49%	33%	36%	27%	--	20%	41%
<50% Conditioned	24%	28%	22%	27%	15%	13%	22%
50%-90% Conditioned	21%	22%	23%	16%	20%	27%	15%
>90% Conditioned	6%	17%	19%	31%	65%	40%	22%

[1] Excludes two homes that did not have verified vintage data.

As noted earlier, of all the homes that had ducts, 72% had ducts in unconditioned areas. Table 66 and Table 67 show the percent of duct area in each location in an average home by home type and statewide. More than half of these ducts were located in unconditioned basements (53% supply and 55% return) and more than a quarter of these ducts were in attics (27% supply and 27% return). Manufactured/mobile homes were more likely to have ducts in crawl spaces compared to other home types. Note that the percentages of ducts in unconditioned spaces are based on total duct area across the whole sample and that since the table shows penetration, values do not sum to 100%.

Table 66: Unconditioned Supply Duct Location Penetration

(Base: Homes with ducts in unconditioned spaces)

	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*85*	*20*	*16*	*18*	*139*
Unconditioned Basement	58%	51%	13%	66%	53%
Attic, Exposed	23%	32%	--	14%	25%
Crawl Space	7%	1%	87%	--	14%
Garage	9%	17%	--	11%	6%
Attic, Under Insulation	4%	--	--	10%	2%

Table 67: Unconditioned Return Duct Location

(Base: Homes with ducts in unconditioned spaces)

	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*85*	*20*	*16*	*18*	*139*
Unconditioned Basement	59%	61%	16%	62%	55%
Attic, Exposed	23%	22%	--	19%	25%
Crawl Space	6%	--	84%	--	12%
Garage	8%	17%	--	13%	6%
Attic, Under Insulation	4%	--	--	6%	2%

7.2 Duct Insulation

Where ductwork was located outside of conditioned spaces, auditors recorded the level of duct insulation present in the home. Table 68 and Table 69 show that the average R-value of ducts per home by home type and statewide. The average was R-2.7 for supply ducts and R-2.4 for return ducts. More than half of the observed ducts (53% supply and 57% return) had no insulation. Note that these observations are limited to homes with ductwork in unconditioned spaces and where the surveyor was able to confirm the level of insulation.

Table 68: Unconditioned Supply Duct R-values

(Base: Homes with ducts in unconditioned spaces)

	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*85*	*20*	*16*	*18*	*139*
Min	0	0	0	0	0
Max	19	8	8	6	19
Mean	**2.9**	**2.6**	**2.0**	**1.1**	**2.7**
Median	0	0	0	0	0
Std. Dev.	3.51	3.32	2.92	2.14	3.36

Table 69: Unconditioned Space Return Duct R-values

(Base: Homes with ducts in unconditioned spaces)

	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*85*	*20*	*16*	*18*	*139*
Min	0	0	0	0	0
Max	19	8	8	6	19
Mean	**2.7**	**2.0**	**1.3**	**0.8**	**2.4**
Median	0	0	0	0	0
Std. Dev.	3.5	3.0	2.8	1.9	3.4

Section 8 Mechanical Equipment

This section describes the heating, cooling, and water heating equipment that was observed during onsite audits. Analysis covered types, fuels, capacities, efficiency, and ENERGY STAR status.

Figure 23: Mechanical Equipment Results Highlights

Key Findings: Heating

- Natural gas was the primary heating fuel in 54% of housing units, followed by electricity (23%) and fuel oil (15%).
- Furnaces were the most common primary heating system type (45%), followed by boilers (28%) and air-source heat pumps (11%).
- The average Annual Fuel Utilization Efficiency (AFUE) for residential furnaces was 87.9 AFUE, average efficiency for residential boilers was 83.0 AFUE, and average efficiency of heat pumps was 8.7 HSPF.[68]
- Only 32% of all heating systems were ENERGY STAR qualified (excludes heating equipment not covered by the ENERGY STAR program).

Key Findings: Cooling

- Central air-conditioners were present at 34% of homes, air-source heat pumps at 12%, and ductless min-splits at 12%.
- The average SEER[69] of cooling systems was 13.1.
- Forty percent of homes had at least one room air conditioner.

Key Findings: Domestic Hot Water

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[68] Heating Season Performance Factor (HSPF) is a standard measure of heating efficiency for air source heat pumps. It is the ratio of the heat output during the heating season to the electricity input.

[69] Seasonal Energy Efficiency Ratio (SEER) is a standard measure of cooling efficiency. It is the ratio of the cooling output during the cooling season to the electricity input.

- The vast majority of water heaters were conventional standalone, storage tanks (87%); fueled by natural gas (48%), electricity (34%), and propane (5%).
- Heat pump water heaters (HPWH), highly efficient water heating systems, had an average efficiency of 2.80 UEF, but only comprised 2% of water heater systems.
- Electric water heaters represented 41% of water heaters and had an average efficiency of 1.03 UEF.
- Fossil fuel standalone water heaters were the most common equipment type statewide (53%) and had an average UEF of 0.61.
- Only 15% of water heaters were ENERGY STAR qualified (excludes systems that do not fit in ENERGY STAR criteria).

8.1 HEATING EQUIPMENT

This section focuses on residential equipment serving only a single unit in homes or multifamily buildings. Heating equipment was designated as primary or supplemental. Primary heating equipment is that with the largest capacity or that which serves the largest portion of the home's conditioned floor area. For example, a home with two natural gas furnaces will have one primary system type (*furnace*) and one primary fuel type (*natural gas*). Supplemental heating refers to any equipment type that did not supply the majority of a home's heating load.

Multifamily sites had heating equipment that served only one residential unit or heating equipment that served multiple-units. In some cases, supplemental heating systems served common areas. Shared heating equipment was found in 20 of the 70 (30%) multifamily buildings audited. Heating systems that served only common areas were observed in eight multifamily buildings. In these cases, the tenant space was heated by equipment that served individual units. Shared heating equipment is excluded from analysis unless otherwise noted.

Similar to the occurrence of shared heating equipment in multifamily buildings, some buildings had commercial-sized heating equipment.[70] Statewide, 15 commercial heating systems were identified during the multifamily onsite audits. Of the 15 commercial systems, nine were commercial boilers, which were typically observed in multifamily buildings with 50+ units (67% of commercial boilers). The boilers all served multiple units and the average thermal efficiency was 86.3%.[71] One commercial sized electric furnace provided heating for common areas. Statewide, the average capacity for commercial grade heating equipment was 969,984 Btuh (British thermal units per hour). The remaining five commercial heating systems were packaged heating and cooling systems located on rooftops of two multifamily buildings. However, lack of rooftop access and faded nameplates made identifying output capacities and efficiencies impossible. Commercial heating equipment is excluded from analysis unless otherwise noted.

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[70] Commercial heating equipment consisted of boilers, furnaces, and packaged rooftop-units. Boilers with capacities over 300,000 Btuh. and furnaces with capacities over 275,000 Btuh. are considered commercial sized equipment.
[71] Commercial heating equipment efficiencies are reported as a thermal efficiency and expressed as a percentage.

8.1.1 Primary Heating Systems

Table 70 displays the primary heating fuel distribution. Primary heating systems were fueled with natural gas most frequently (54%), followed by electricity (23%) and fuel oil (15%). Manufactured/mobile home heating equipment was fueled by propane more than other fuels (35%). Fuel oil systems were somewhat common in detached single-family homes (16%) and manufactured/mobile homes (19%) but were rarely found in other home types. One home in the sample was primarily heated with coal.

Table 70: Primary Heating Fuel by Home Type

(Base = Homes)

Fuel	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*145*	*48*	*26*	*70*	*289*
Natural Gas	59%	73%	19%	57%	54%
Electric	17%	21%	19%	39%	23%
Oil	16%	4%	19%	4%	15%
Propane	6%	2%	35%	--	5%
Wood	1%	--	4%	--	1%
Pellet	1%	--	--	--	1%
Coal	--	--	4%	--	<1%

Statewide, furnaces were the most common primary heating system (43%, Table 71). Boilers were the second most common for both detached and attached single-family homes, and statewide. Air-source heat pumps (ASHPs) and ductless mini splits accounted for approximately 11% of primary heating systems statewide.[72] The previous study found ASHPs at 9% of homes.

[72] Packaged Terminal Air Conditioners are referred to as PTACs and Packaged Terminal Air Conditioner Heat Pumps are referred to as PTHPs. PTACs and PTHPs are all-in-one heating and cooling systems that are installed through a wall. PTACs provide heat through electric resistance coils, while the PTHP supplies both cooling and heating needs more efficiently using the heat pump. Wall Furnaces and space heaters include in-the-wall furnaces, space heaters, and portable space heaters. Combined appliance refers to a boiler designed to provide both space and water heating.

Table 71: Primary Heating Equipment by Home Type

(Base = Homes)

Type	Detached single-family	Attached single-family	Manufactured or Mobile	Multifamily	Statewide
n	*145*	*48*	*26*	*70*	*289*
Furnace Total	58%	44%	73%	39%	43%
Natural Gas	77%	95%	21%	85%	74%
Oil	13%	--	26%	4%	14%
Propane	8%	5%	37%	--	10%
Electric	1%	--	16%	11%	2%
Boiler Total	23%	35%	8%	23%	32%
Natural Gas	64%	88%	50%	88%	69%
Oil	33%	12%	--	13%	29%
Propane	3%	--	50%	--	2%
ASHP (Electric)	9%	15%	4%	4%	10%
Electric Baseboard	5%	6%	4%	14%	9%
Stove[73]	3%	--	8%	--	2%
Wood	2 (50%)	--	1 (50%)	--	58%
Pellet	2 (50%)	--	--	--	31%
Coal	--	--	1 (50%)	--	11%
PTHP (electric)	--	--	--	10%	1%
Ductless Mini Split (Electric)	1%	--	--	1%	1%
Wall Furnace/Space Heater	1%	--	4%	--	1%
Oil	1 (50%)	--	--	--	56%
Electric	1 (50%)	--	--	--	32%
Propane	--	--	1 (100%)	--	12%
Combined Appliance (Nat. Gas)[74]	--	--	--	1%	1%
PTAC (Electric)	--	--	--	3%	1%
GSHP-Closed Loop (Electric)	--	--	--	1%	<1%
Packaged Rooftop Unit (Heating + Cooling)	--	--	--	3%	<1%

Forty-five percent of primary heating systems were in conditioned space (Table 72).[75] The majority of primary heating equipment for manufactured/mobile homes (89%) and multifamily

[73] The stove equipment type in this report refers to stoves fueled by wood, pellets, or coal. There were no observations of kitchen stoves being used as a primary heating source.
[74] Refers to systems that provide both space and water heating in a single appliance.
[75] Note that the counts for primary system location are not the count of homes, rather the count of heating systems that match the primary equipment type and fuel. For example, a home with two identical systems would have one primary equipment type and fuel, but two locations – a common layout would be one system in an unconditioned basement and one system in the attic.

homes (64%) were in conditioned space. Conversely, detached and attached single-family homes had more systems located in unconditioned space (57% and 60%, respectively).

Table 72: Primary System Location by Home Type

(Base = Systems)

Location	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*149*	*48*	*26*	*71*	*294*
Unconditioned Basement/Enclosed Crawl	51%	56%	12%	27%	49%
Conditioned Area/Conditioned Crawl Space	43%	40%	89%	64%	45%
Attic	4%	2%	--	1%	3%
Garage or Open Crawl Space	2%	2%	--	1%	3%
Ambient	--	--	--	6%	1%

8.1.2 Age of Heating Equipment

Table 73 presents the vintage distribution of heating equipment, with available data, found during onsite audits.[76] Equipment age information was obtained from nameplates, serial numbers, and contacting manufacturers.[77] The average age across all system types was 35 years. This analysis does not include heating equipment where age was unobtainable, which could bias the results towards newer systems. Heating equipment manufactured between 2011 to 2015 was the most common (24%). Statewide, 45% of boiler systems and 34% of furnaces were manufactured prior to 2001.

Note that the vintage bins used throughout the report for mechanical systems and appliances differ from those used for homes since mechanical systems and appliances have shorter life-spans than homes, are replaced more frequently, and have more rapid technological improvements.

[76] Electric resistance heating equipment with 100% efficiency were excluded.

[77] The date of manufacture was not available using the methods described above for 143 heating systems. The heating equipment with unidentified ages consisted mostly of electric baseboards, wall furnaces, space heaters, and stoves (84% of equipment with unknown ages).

Table 73: Heating Equipment Vintages by Equipment Type

(Base = Systems)

Vintage	Furnace	Boiler[1]	ASHP	Ductless Mini Split	Other[2]	Statewide
n	*142*	*71*	*36*	*14*	*36*	*299*
2016 to 2018	11%	7%	17%	29%	3%	11%
2011 to 2015	20%	20%	36%	36%	33%	24%
2006 to 2010	18%	10%	19%	36%	19%	18%
2001 to 2005	17%	18%	8%	--	14%	14%
1991 to 2000	23%	20%	14%	--	14%	17%
1981 to 1990	7%	13%	6%	--	14%	9%
1980 or earlier	4%	13%	--	--	3%	6%

[1] The boiler category includes two combined appliances.
[2] The other category includes wall furnaces/space heaters, GSHPs, PTHPs, and stoves.

8.1.3 Heating Equipment ENERGY STAR Status

Heating equipment was verified to be ENERGY STAR qualified through physical observation of the ENERGY STAR logo on the equipment, supplemental research on the ENERGY STAR website, manufacturer websites, and prior ENERGY STAR version equipment lists.[78] Table 74 presents the ENERGY STAR status of all heating equipment observed onsite, excluding equipment that does not fall into current ENERGY STAR heating system classifications (e.g., stoves, fireplaces). Thirty-two percent of heating equipment was ENERGY STAR qualified. Most EDCs heating equipment ranged from 24-35% ENERGY STAR qualified; however, 51% of heating equipment was ENERGY STAR qualified in FE: West Penn territory.[79]

Table 74: Heating Equipment ENERGY STAR Status by Home Type

(Base = Systems)

ENERGY STAR	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*157*	*48*	*26*	*64*	*295*
Yes	35%	36%	19%	27%	32%
No	65%	64%	81%	73%	68%

8.1.4 Heating System Efficiencies

This section only includes residential heating equipment. Commercial heating equipment is summarized above. The statewide average efficiency for all fossil-fuel fired furnace and boiler equipment with known efficiency values was 86.3 AFUE (Table 75).

[78] Equipment that was designated ENERGY STAR at the time of its manufacture was deemed ENERGY STAR qualified even if standards had increased past the equipment's individual efficiency.
[79] See Table 190.

It is often difficult to determine efficiency values for older equipment. Excluding older equipment could potentially bias efficiency results towards newer systems. To examine this, the SWE applied age-based default efficiency values to equipment with no obtainable efficiency information but a known date of manufacture.[80] The statewide average efficiency including age-based default values for all heating systems was 85.5 AFUE. This represents only a 1% reduction from the value resulting from using only confirmed efficiencies (86.3) Given this small bias, the tables in this report are based only on confirmed efficiencies.

Table 75: Residential Grade Heating System Efficiency by Home Type

(Base = Systems)

AFUE	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*105*	*25*	*18*	*31*	*179*
Min	65.0	71.5	66.0	75.0	65.0
Max	98.1	97.0	95.1	96.0	98.1
Mean	**87.7**	**86.2**	**82.5**	**84.8**	**86.3**
Median	87.5	82.3	80.0	82.0	85.0
Std. Dev.	6.9	7.3	6.7	6.7	7.1

The statewide average efficiency for all residential fossil-fuel fired furnaces with known efficiency values was 88.0 AFUE (Table 76).[81] The average furnace efficiency in detached and attached single-family homes was significantly higher than multifamily and manufactured/mobile homes. There were no significant differences in average furnace efficiency among the EDCs. If age-based defaults are included, the average AFUE drops to 86.5.

Table 76: Residential Grade Furnaces (Fossil Fueled) by Home Type

(Base = Systems)

AFUE	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*76*	*15*	*16*	*21*	*128*
Min	76.0	80.0	80.0	75.0	75.0
Max	98.1	97.0	95.1	95.0	98.1
Mean	**89.3**	**90.1**	**83.5**[a,b]	**83.4**[a,b]	**88.0**
Median	92.1	92.2	80.0	80.0	92.0
Std. Dev.	6.6	6.6	5.6	6.4	7.0

[a] Significantly different from the detached single-family sample at the 95% confidence level.
[b] Significantly different from the attached single-family sample at the 95% confidence level.

Figure 24 presents each efficiency value (in AFUE) for all fossil fuel furnaces. The current federal minimum standard for gas furnace efficiency is 80 AFUE, which went into effect in 2007. The

[80] REM/Rate energy modeling software provides default efficiency values based on vintage, equipment type, and fuel.
[81] Fossil fuel fired furnaces include natural gas, propane, and fuel oil. Electric furnaces were excluded from the analysis as they are 100% efficient.

furnaces that fall below the federal minimum were manufactured prior to 2007 (see Table 73 for heating equipment age distributions). The jump in furnace efficiency shown in the figure may be attributed the equipment age – increased average efficiency trended from the oldest to the newest equipment. However, common efficiency ratings for furnaces fell into two general groups with values from 80-85 AFUE and 92+ AFUE.

Figure 24: Residential Grade Furnace AFUE by Home Type

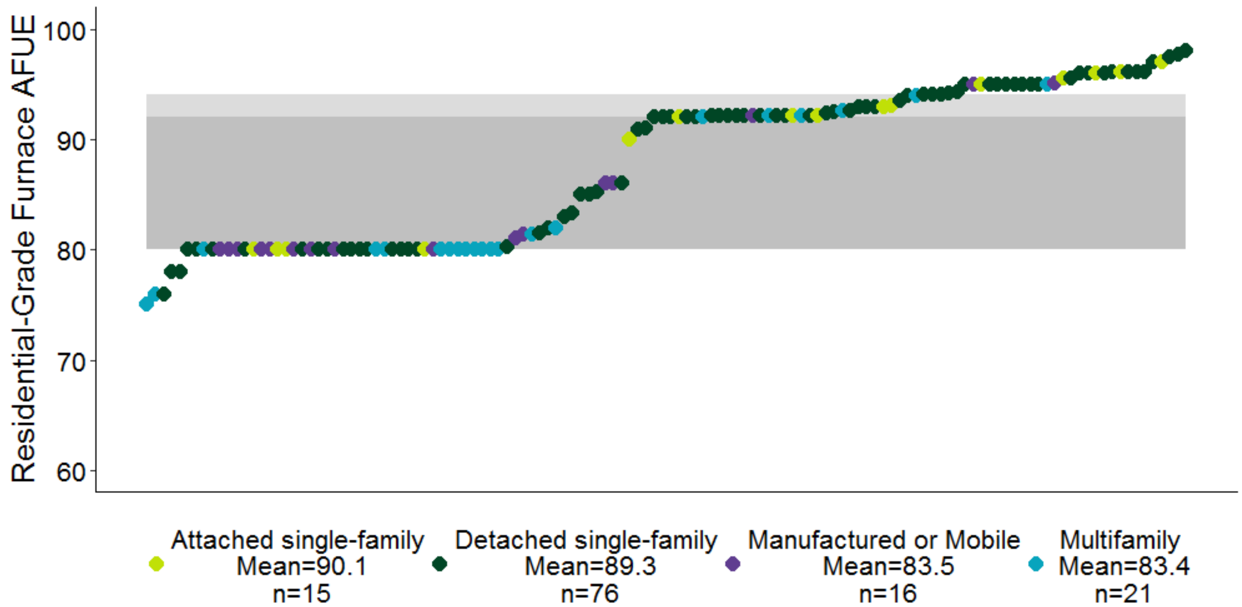


Table 77 and Table 78 show furnace efficiency by fuel type. Propane furnaces were more efficient (91.2 AFUE) than natural gas furnaces (88.4 AFUE). All propane furnaces met the minimum federal requirement; however, some natural gas furnace efficiencies fell below the federal minimum efficiency requirement.

Table 77: Residential Grade Natural Gas Furnace AFUE by Home Type

(Base = Systems)

AFUE	Detached Single-family	Attached Single-family	Manufacture/ Mobile	Multifamily	Statewide
n	*58*	*14*	*4*	*20*	*96*
Min	76.0	80.0	80.0	75.0	75.0
Max	98.1	97.0	95.1	95.0	98.1
Mean	**90.0**	**90.0**	**84.1**	**83.5**	**88.4**
Median	92.3	92.5	80.7	80.0	92.1
Std. Dev.	6.8	6.8	7.3	6.5	7.2

Table 78: Residential Grade Propane Furnace AFUE by Home Type

(Base = Systems)

AFUE	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*8*	*1*	*7*	--	*16*
Min	80.0	92.2	80.0	--	80.0
Max	96.0	92.2	95.0	--	96.0
Mean	**91.7**	**92.2**	**84.0**	**--**	**91.2**
Median	92.2	92.2	80.0	--	92.0
Std. Dev.	5.0	NA	6.6	--	6.7

The statewide average efficiency for all residential boilers with known efficiency values was 83.5 AFUE (Table 79). Multifamily boilers were significantly more efficient than attached single-family homes.[82] When age-based defaults are included, the AFUE drops to 80.3.

Table 79: Residential Grade Boilers (All Fuel Types) by Home Type

(Base = Systems)

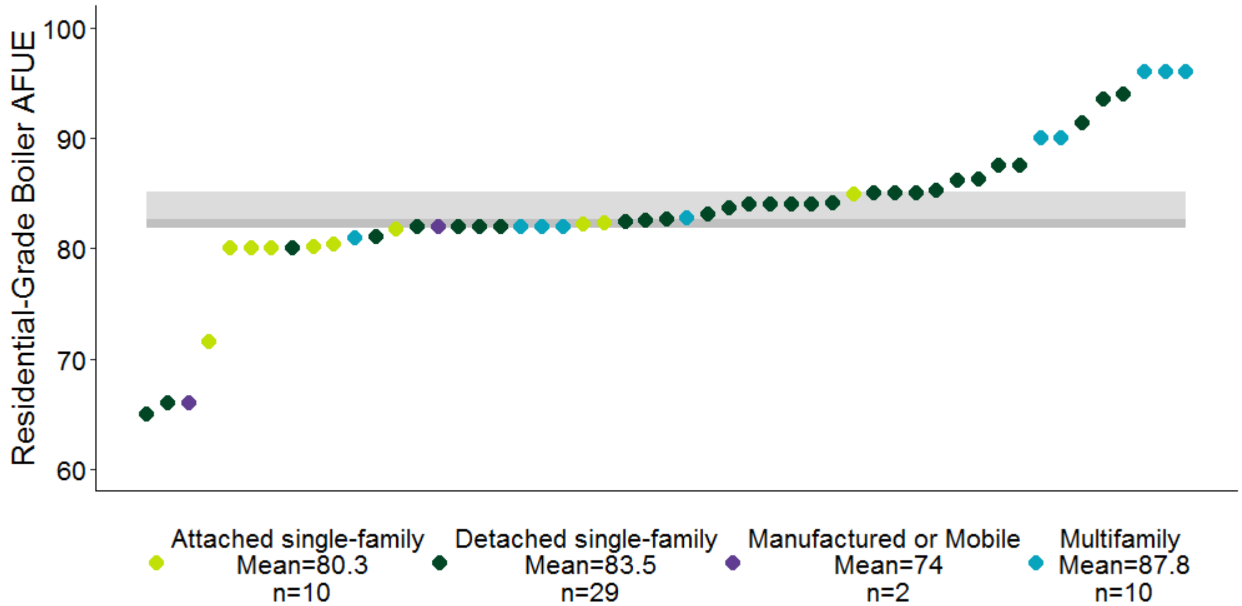
AFUE	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*29*	*10*	*2*	*10*	*51*
Min	65.0	71.5	66.0	80.9	65.0
Max	94.0	84.9	82.0	96.0	96.0
Mean	**83.5**	**80.3**[a]	**74.0**	**87.8**[a]	**83.5**
Median	84.0	80.2	74.0	86.4	82.6
Std. Dev.	6.0	3.5	11.3	6.5	6.5

[a] Significantly different from Detached Single-family at the 95% confidence level.

[82] The average efficiency for propane and fuel oil boilers are not displayed due to small sample sizes.

Figure 25 displays the efficiency for each boiler found during onsite audits. Boilers with efficiency values below 80 AFUE were older systems.

Figure 25: Residential Grade Boiler AFUE by Home Type



The average efficiencies for natural gas boilers appear in Table 80. Statewide, the average efficiency was 82.4 AFUE. Multifamily homes had more efficient natural gas boilers than the other home types.

Table 80: Residential Grade Natural Gas Boiler AFUE by Home Type

(Base = Systems)

AFUE	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*17*	*9*	*1*	*9*	*36*
Min	65.0	71.5	66.0	80.9	65.0
Max	94.0	82.3	66.0	96.0	96.0
Mean	**81.8**	**79.8**	**66.0**	**88.3**	**82.4**
Median	82.4	80.1	66.0	90.0	82.0
Std. Dev.	7.1	3.3	--	6.7	7.4

Table 81 displays the average efficiency for all ASHP and ductless mini split systems found during the onsite audits. The average heating seasonal performance factor (HSPF) was 8.7 statewide.[83] Figure 26 displays the HSPF for each ASHP and ductless mini split observed during the onsite

[83] HSPF ratings are the ratio of total heat supplied over the watt-hours consumed for the duration of a season.

audits. The average coefficient of performance (COP)[84] for Ground-source heat pumps (GSHP) was 3.7.[85]

Table 81: ASHP and Ductless Mini Split HSPF by Home Type

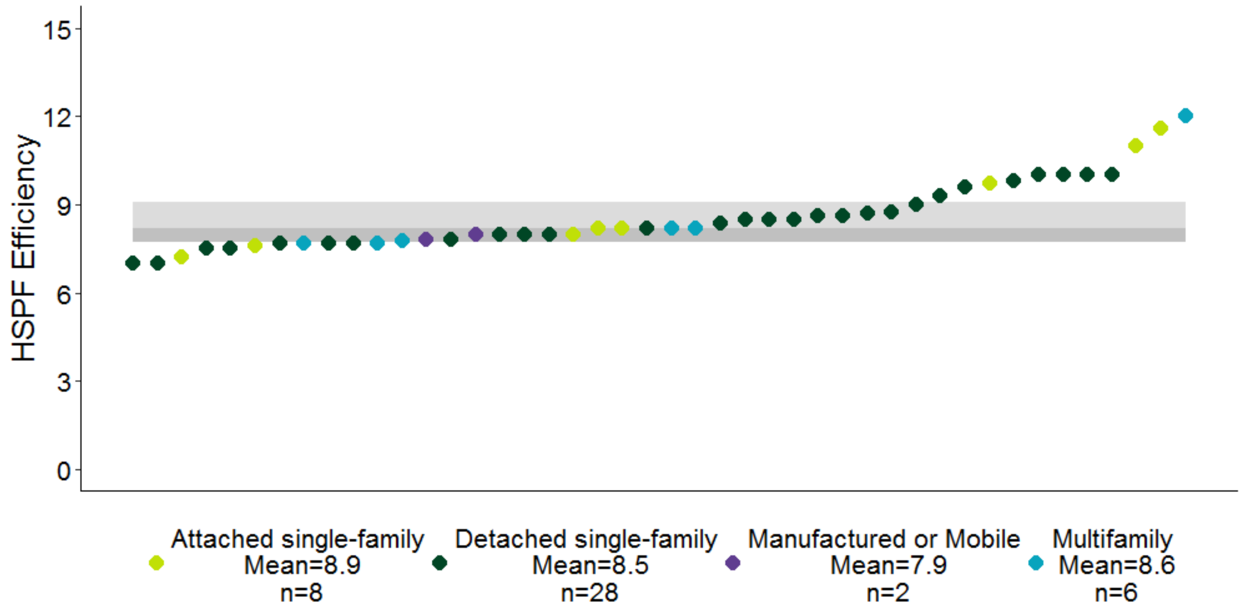
(Base = Systems)

HSPF	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*28*	*8*	*2*	*6*	*44*
Min	7.0	7.2	7.8	7.7	7.0
Max	10.0	11.6	8.0	12.0	12.0
Mean	**8.5**	**8.9**	**7.9**	**8.6**	**8.7**
Median	8.5	8.2	7.9	8.0	8.2
Std. Dev.	0.9	1.6	0.1	1.7	1.2

[84] The coefficient of performance is an efficiency rating for heat pumps that shows the ratio of heating or cooling output over the mechanical work required. Higher values indicate greater efficiency.

[85] One multifamily building, located in PPL service territory, had individual GSHPs for each unit and separate GSHPs for common space.

Figure 26: ASHP and Ductless Mini Split HSPF by Home Type



8.1.5 Furnace ECMs

An electronically communicated motor (ECM) is a brushless DC motor that offers efficiency gains relative to the industry standard permanent split capacitor (PSC) Motor.[86] Statewide, 16% of furnaces were equipped with ECMs (Table 82).

Table 82: ECM Motors in All Furnaces by Home Type

(Base = Systems)

ECM	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*93*	*22*	*20*	*28*	*163*
Yes	20%	31%	12%	8%	16%
No	80%	69%	88%	92%	84%

8.1.6 Heating Capacity

Table 83 presents the heating capacity per square foot of conditioned floor area for homes with residential heating equipment. The total capacity (in Btuh.) of all heating equipment in each home is summed and then divided by the square feet of conditioned floor area in the home. Multifamily residential units have the smallest average heating capacity per square foot. Manufactured/mobile

[86] ECMs offer two major advantages over PSC motors. First, ECMs use significantly less electricity than PSC motors while producing comparable air flow. Second, ECMs are variable speed motors with the flexibility to adjust air flow depending on the demand being called for by the furnace or central air conditioning system – PSC motors operate like on/off switches. Not all ENERGY STAR-qualified furnaces have ECM motors – some have multi-speed fans but not fully variable ECMs.

homes have the highest average heating capacity, which is due to some homes having two or more large capacity heating systems serving a relatively small conditioned floor area.

Table 83: Heating System Capacity (Btuh/sq.ft.)

Btuh/sq.ft.	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*133*	*38*	*24*	*48*	*243*
Min	8.6	13.7	19.7	4.0	4.0
Max	158.3	127.5	297.4	153.1	297.4
Mean	**49.5**	**46.7**	**78.1**	**32.8**	**48.7**
Median	45.3	42.6	68.0	26.6	42.3
Std. Dev.	27.7	27.3	58.3	25.9	33.5

8.1.7 Supplemental Heating Equipment

Supplemental heating equipment was present at 38% of homes. Table 84 presents the fuel distribution of all supplemental heating systems. The most common fuel types for supplemental heating equipment were electricity (70%), natural gas (14%), and wood (7%).

Table 84: Supplemental Heating Fuel by Home Type

(Base = Systems)

Fuel	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*87*	*18*	*20*	*5*	*130*
Electric	63%	83%	65%	5 (100%)	70%
Natural Gas	17%	11%	5%	--	14%
Wood	9%	--	5%	--	7%
Propane	7%	6%	15%	--	6%
Pellet	2%	--	--	--	1%
Kerosene	1%	--	--	--	1%
Oil	--	--	5%	--	1%
Coal	--	--	5%	--	<1%

The majority of supplementary heating systems were wall furnaces and space heaters (49%, Table 85).[87] Electric baseboards comprised 22% of supplemental heating systems. ASHPs and ductless mini splits represented 11% of supplemental heating equipment.

[87] Wall Furnaces and space heaters include in-the-wall furnaces, space heaters, and portable space heaters.

Table 85: Supplemental Heating Equipment by Home Type
(Base = Systems)

Type	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*87*	*18*	*20*	*5*	*130*
Wall Furnace/Space Heater	45%	50%	50%	5 (100%)	49%
Electric Baseboard	22%	33%	15%	--	22%
Stove	16%	--	15%	--	11%
Ductless Mini Split	6%	11%	5%	--	6%
ASHP	6%	--	10%	--	5%
Furnace	2%	6%	5%	--	4%
Fireplace	2%	--	--	--	2%
Boiler	1%	--	--	--	1%

8.2 Cooling Equipment

The following section describes residential space cooling equipment found by the SWE team. Residential systems are defined by their cooling output capacities and must be lower than 60,000 Btuh. Any cooling system with an output capacity greater than 60,000 Btuh is classified as commercial. Multifamily units surveyed were cooled by either a system serving a single unit or multiple units. Commercial equipment, shared equipment, and equipment serving only common spaces (e.g., hallways in large multifamily buildings) is excluded from analysis unless otherwise noted.

Supplemental cooling systems serving communal areas were found in four multifamily homes. Six multifamily homes had systems serving multiple units.

Table 86 displays a penetration table of cooling systems, permanent and removable, found by home type. It includes commercial systems and systems serving multiple units. Statewide, 92% of homes had a cooling system. A small minority (4%) possessed a room air conditioner in addition to their permanent space cooling system.

Table 86: Space Cooling Penetration by Home Type

System Type	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide[1]
n	*145*	*48*	*26*	*70*	*289*
Room Air Conditioner	32%	48%	42%	37%	41%
Central Air Conditioner	48%	31%	38%	29%	35%
ASHP	12%	15%	12%	6%	12%
Ductless HP	5%	4%	4%	1%	4%
PTAC	--	--	--	6%	1%
PTHP	--	--	--	10%	1%
Chiller	--	--	--	3%	1%
GSHP	--	--	--	1%	<1%
None	10%	4%	8%	10%	8%

[1] Values do not sum to 100% since 4% of homes had room air conditioners in addition to a permanent system.

8.2.1 Residential Permanent Space Cooling

This section describes residential-scale permanent space cooling systems surveyed by the SWE team. These systems include central air conditioners, air source heat pumps (ASHP), ductless heat pumps (Ductless HP), ground source heat pumps (GSHP), packaged terminal air conditioners, and packaged terminal heat pumps.

Table 87 describes residential permanent cooling system penetration by home type. Statewide, around 52%[88] of homes surveyed contained a form of permanent cooling system. Detached single-family homes were more likely to contain a permanent cooling system than other home types. The most common type (34%) of permanent cooling system was central air conditioners, followed by ASHP (14%). All types of permanent cooling systems were much more common in detached and attached single-family and manufactured or mobile homes than multifamily, but this difference was partially offset by the prevalence of PTAC or PTHP systems.[89] Three homes had multiple types of permanent cooling. One had a chiller and a CAC, another had an ASHP and a ductless HP, and a third had a CAC and a ductless HP.

As noted above, the rest of this section excludes commercial grade systems. There were six commercial cooling systems: three chillers, two central air conditioners, and one ASHP. The capacity of the six commercial-grade cooling systems averaged 436,440 Btuh. The chillers had an average EER of 9.8. One CAC had a SEER of 13.0 while the other CAC's SEER was undeterminable. The ASHP had a SEER of 9.7. Four of the six commercial-grade systems were in multifamily buildings, while the other two were in large, single-family homes averaging over 3,500 square feet of CFA.

[88] This value is lower than the 2013 baseline report because the proportion of multifamily homes compared to the total home types surveyed was significantly higher in this year's report and multifamily homes are less likely to have permanent air conditioning systems.
[89] PTACs and PTHPs were only found in multifamily buildings.

Table 87: Permanent Cooling Penetration by Home Type

System Type	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*145*	*48*	*26*	*70*	*289*
CAC	48%	31%	38%	29%	35%
ASHP	12%	15%	12%	4%	12%
Ductless HP	5%	4%	4%	1%	4%
PTAC	--	--	--	6%	1%
PTHP	--	--	--	10%	1%
Chiller	--	--	--	3%	1%
GSHP	--	--	--	1%	<1%
None	38%	50%	46%	54%	46%

Table 88 summarizes the vintages of permanent cooling systems. The average age for permanent cooling systems was 12 years, and nearly two thirds (64%) were manufactured between 2001 and 2015.

Table 88: Permanent Cooling Vintages by Home Type

(Base: Systems)

Vintage	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*101*	*24*	*12*	*32*	*169*
2016 to 2018	13%	8%	17%	13%	12%
2011 to 2015	24%	29%	17%	31%	26%
2006 to 2010	19%	29%	8%	31%	22%
2001 to 2005	16%	17%	33%	13%	16%
1991 to 2000	23%	17%	17%	9%	18%
1981 to 1990	4%	--	8%	3%	4%
1980 or earlier	2%	--	--	--	2%

The ENERGY STAR status of permanent space cooling systems is displayed in Table 89. Statewide, around one quarter (24%) of systems were ENERGY STAR qualified. Interestingly, none of the manufactured or mobile homes surveyed had an ENERGY STAR qualified system present. Single-family homes were far more likely to contain a qualified system than multifamily homes surveyed.

Table 89: Permanent Cooling ENERGY STAR Status by Home Type

(Base: Systems)

ENERGY STAR	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*102*	*24*	*14*	*31*	*171*
Yes	24%	29%	--	13%	24%
No	76%	71%	100%	87%	76%

Table 90 presents statistics on seasonal energy-efficiency ratings, or SEER, found statewide. A SEER rating is a ratio of the cooling output for a typical cooling season and the total electric energy input during the same period.[90] A higher rating is indicative of a more efficient system.

Statewide, the average SEER rating was 13.1, but the surveyed systems varied widely from a low of 6.1 to a high of 26. Across most home types, the mean SEER rating was consistent; however, manufactured or mobile homes were found to have a lower rating than the statewide average.

Table 90: Permanent Cooling System SEER Rating by Home Type

SEER	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*101*	*24*	*11*	*31*	*167*
Min	6.1	10.0	10.0	8.2	6.1
Max	26.0	20.6	14.0	25.0	26.0
Mean	**13.1**	**13.2**	**11.5**	**12.7**	**13.1**
Median	13.0	13.0	10.0	13.0	13.0
Std. Dev.	2.9	2.6	1.8	3.4	2.9

Table 91 summarizes the SEER ratings of central air-conditioners. The average SEER of 12.0 is below the current federal standard of 13.0. However, that standard only applies to systems manufactured after January 1, 2015. The central air-conditioners with SEER values less than 10.0 were all at least 28 years old.

[90] In some cases, systems surveyed had an efficiency rating in EER rather than SEER. In these cases, the SWE team would convert the EER ratings to SEER using the following formula: SEER = (1.12-√(1.2544-0.08*EER)) / 0.04.

Table 91: Central Air Conditioner SEER Rating

SEER	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*71*	*15*	*7*	*15*	*108*
Min	6.1	10.0	10.0	9.4	6.1
Max	16.0	16.0	13.0	14.5	16.0
Mean	**12.2**	**12.6**	**10.9**	**11.9**	**12.0**
Median	13.0	13.0	10.0	13.0	13.0
Std. Dev.	2.2	1.7	1.5	1.8	2.1

Table 92 summarizes the SEER ratings of air-source heat pumps and ductless mini splits. The average SEER of 14.9 is higher than that of conventional central air conditioners since heat pumps can reach higher levels of efficiency.

Table 92: ASHP/Ductless Mini Split SEER Rating

SEER	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*30*	*9*	*4*	*7*	*50*
Min	10.5	11.0	10.0	9.7	9.7
Max	26.0	20.6	14.0	25.0	26.0
Mean	**15.0**	**14.3**	**12.8**	**14.4**	**14.9**
Median	14.5	13.8	13.5	13.0	14.0
Std. Dev.	3.3	3.4	1.9	4.9	3.4

Table 93 shows the total cooling capacity per home normalized by conditioned floor area.[91] Statewide, the mean capacity per square foot was 15.9 Btuh/sq.ft. and was consistent across home types, with the exception of manufactured or mobile homes. Manufactured or mobiles consistently possessed a higher area-weighted cooling capacity, with roughly double that of other home types surveyed. The calculated values ranged widely, from a low of 3 Btuh/sq.ft. to a high of 49.3 Btuh/sq.ft..

[91] Systems that served multiple units were excluded from these calculations because it was impossible to determine exactly how many units, and thus the square footage, they served.

Table 93: Permanent Cooling System Capacity (Btuh/sq.ft.)

	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*89*	*24*	*11*	*30*	*154*
Min	3.0	6.9	7.9	9.3	3.0
Max	42.2	31.5	49.3	39.7	49.3
Mean	**15.0**	**15.7**	**30.9**	**17.2**	**15.9**
Median	13.6	15.2	31.2	14.9	14.9
Std. Dev.	6.4	5.5	11.1	7.0	7.9

8.2.2 Room Air Conditioners

This section summarizes room air conditioners found during audits. Since some audits took place during heating seasons when room air conditioners were likely to be stored away, auditors asked occupants if they had any room air conditioners stored away. Table 94 displays room air conditioner saturation by home type. Statewide, around 40% of homes contained at least one room air conditioner. They were more prevalent in attached single-family and manufactured or mobile homes than other home types surveyed. No homes surveyed had more than three room air conditioners in total.

Table 94: Room Air Conditioner Saturation by Home Type

Count	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*145*	*48*	*26*	*70*	*289*
0	67%	54%	58%	64%	60%
1	15%	23%	23%	23%	21%
2	12%	15%	19%	6%	12%
3	6%	8%	--	7%	7%

Table 95 describes room air conditioner vintage by home type. The mean age of surveyed room air conditioners was ten years, and nearly two thirds (62.8%) were manufactured between 2006 and 2015. Over one quarter (27.3%) of multifamily room air conditioners were manufactured within the last two years, a much larger proportion than any other home type.

Table 95: Room Air Conditioner Vintage by Home Type

Age	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*64*	*30*	*16*	*33*	*143*
2016 to 2018	3%	7%	--	27%	8%
2011 to 2015	39%	40%	50%	18%	35%
2006 to 2010	25%	30%	32%	24%	28%
2001 to 2005	17%	13%	13%	24%	19%
1991 to 2000	11%	7%	--	6%	7%
1981 to 1990	2%	--	--	--	<1%
1980 or earlier	3%	3%	6%	--	3%

The ENERGY STAR status for room air conditioners is displayed in Table 96. One third (32.8%) of room air conditioners were found to be ENERGY STAR qualified. The results were consistent across home types, but systems in multifamily homes were less likely than other home types to be ENERGY STAR qualified (only 22.9%).

Table 96: Room Air Conditioner ENERGY STAR Status by Home Type

ENERGY STAR	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*76*	*32*	*15*	*35*	*158*
Yes	34%	28%	33%	23%	33%
No	66%	72%	67%	77%	67%

Room air conditioner efficiencies are measured in the energy efficiency ratio (EER), the ratio of cooling capacity to the electrical power input. The statewide average EER was 10.2 (Table 97). The mean efficiency was consistent across home types.

Table 97: Room Air Conditioner EER Rating by Home Type

	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*66*	*28*	*13*	*34*	*141*
Min	8.0	9.0	8.9	8.0	8.0
Max	12.1	12.0	10.8	12.2	12.2
Mean	**10.2**	**10.2**	**10.0**	**10.3**	**10.2**
Median	10.7	9.8	9.7	10.7	10.5
Std. Dev.	0.9	0.7	0.6	1.0	0.9

Table 98 describes room air conditioner capacities by home type. The mean capacity was 7,643.4 Btuh, but the values varied from 5,000 to 18,500 Btuh. Detached single-family homes had a much higher capacity on average. This is likely due to the larger conditioned area associated with these home types, and as a result, larger room areas needing to be cooled. Average CFA is included in the table below for reference.

Table 98: Room Air Conditioner Capacity by Home Type

	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
Average CFA	**2,295**	**1,778**	**1,166**	**1,031**	**1,881**
n	*66*	*32*	*14*	*35*	*147*
Min	5,000	5,000	5,000	5,000	5,000
Max	18,500	12,000	12,000	12,000	18,500
Mean	**8,588**	**6,667**	**7,050**	**7,050**	**7,643**
Median	8,000	6,000	6,500	6,000	6,500
Std. Dev.	3,259	2,067	1,832	2,517	2,852

8.3 Water Heating Equipment

This section presents the water heating equipment types, fuels, capacities and efficiencies found during onsite audits. Two single-family detached homes had two water heating systems and one manufactured/mobile home had two systems. One manufactured/mobile home did not have a water heating system.[92]

Like in the heating and cooling sections, commercial and shared equipment are excluded from analysis unless otherwise noted. Shared water heating systems were present at 32 multifamily buildings, providing hot water for multiple units or the common areas (i.e., laundry facilities and bathrooms). Shared water heating equipment was typically located in mechanical rooms or basements. Statewide, the average efficiency of shared water heaters was 0.80 Uniform Energy Factor (UEF) for 21 systems with data available. The average thermal efficiency (TE) was 84% in eight systems with data available.[93]

Statewide, 16 commercial water heaters were identified during onsite audits – nine standalone storage tanks, five indirect storage tanks, and two instantaneous systems.[94] Commercial water heaters were primarily found in multifamily buildings and served multiple units or common areas; half of the commercial water heaters were in buildings with 50+ units. One commercial-sized

[92] In addition to the home without a water heater, auditors were unable to access water heaters in three detached homes, three attached homes, one manufactured/mobile home, and eight multifamily sites. The home without a water heater used oil for space heating and electricity for the kitchen stove.

[93] Thermal efficiency is the amount of energy delivered as heated water compared to the energy consumption of the water heater and is a typical efficiency metric for commercial-grade water heaters. Residential water heater efficiency was previously rated as an Energy Factor (EF), which has since been superseded by the UEF. See Section 8.3.5 for a discussion of efficiency measures for residential water heaters.

[94] Commercial water heaters consisted of standalone, indirect, and instantaneous equipment. Electric standalones with capacity greater than 120 gallons and natural gas standalones with capacity greater than 100 gallons were considered commercial sized equipment.

electric instantaneous system was found in a detached single-family home. Natural gas was the predominant commercial water heater fuel (85%) and the remaining systems were electric. The average thermal efficiency of commercial water heaters was 86% (n=9).

8.3.1 Water Heater Fuel

Table 99 presents the water heater fuel type for each home in the sample. Two sites with multiple water heaters had different fuel types – one detached home used electricity and propane while one multifamily site used natural gas and electricity.[95] The majority of homes used natural gas for water heating (55%), followed by electricity (35%). Unlike other home types, manufactured/mobile homes were more likely to use electric water heaters (76%) than any other fuel.

Table 99: Water Heating Fuel by Home Type

(Base = Homes)

Fuel	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*143*	*45*	*25*	*62*	*275*[1]
Natural Gas	53%	69%	16%	58%	55%
Electric	35%	29%	76%	40%	35%
Propane	5%	2%	4%	--	5%
Oil	6%	--	4%	--	5%
No DHW system	<1%	--	--	--	<1%
Propane and Electric	<1%	--	--	--	<1%
Natural Gas and Electric	--	--	--	2%	<1%

[1] Excludes 14 homes for which water heater details were inaccessible.

8.3.2 Water Heater Type and Fuel

Table 100 shows the breakdown of residential water heater systems and fuel types. The vast majority (87%) of water heaters observed during onsite audits were standalone systems. Standalone water heaters were primarily fueled by natural gas (48%) and electricity (34%). Detached and attached single-family homes were more likely to have natural gas standalone systems than electric systems. Conversely, multifamily units and manufactured/mobile homes were more likely to have electric standalone systems than natural gas systems.

[95] The water heater for common space applications at this multifamily site uses electric fuel, while the system that provides hot water for the tenants uses natural gas.

Table 100: DHW Type and Fuel by Home Type
(Base = Systems)

Type and Fuel	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n (water heaters)	*143*	*45*	*26*	*64*	*278*
Storage, standalone	88%	98%	92%	86%	87%
Natural Gas	51%	67%	15%	39%	48%
Electric	32%	29%	69%	47%	34%
Propane	5%	2%	4%	--	5%
Oil	--	--	4%	--	<1%
Indirect w/ Storage Tank	4%	--	--	6%	4%
Oil	1%	--	--	5%	2%
Natural Gas	2%	--	--	--	2%
Electric	--	--	--	2%	<1%
Instantaneous	2%	2%	4%	6%	4%
Natural Gas	1%	2%	--	5%	3%
Electric	1%	--	--	--	1%
Propane	--	--	4%	2%	1%
Tankless Coil	4%	--	--	2%	3%
Oil	4%	--	--	--	3%
Natural gas	--	--	--	2%	<1%
Heat Pump Water Heater (Electric)	3%	--	4%	--	2%

8.3.3 Water Heater Age

Table 101 displays the age distribution of water heater equipment observed during the onsite audits.[96] The average water heater age is nine years. Most water heaters were manufactured between 2011 and 2015 (38%), followed by 2006-2010 (21%) and 2001-2005 (16%).

[96] Some water heater ages were unidentifiable due to tank wrap covering nameplates, inaccessible nameplates, or manufacturing companies becoming obsolete or unresponsive.

Table 101: Water Heater Vintages by Home Type

(Base = Systems)

Vintage	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*136*	*44*	*22*	*70*	*272*
2016 to 2018	13%	11%	27%	14%	15%
2011 to 2015	35%	48%	27%	49%	38%
2006 to 2010	27%	16%	14%	4%	21%
2001 to 2005	18%	18%	14%	14%	16%
1991 to 2000	7%	5%	9%	11%	7%
1981 to 1990	2%	--	9%	6%	3%
1980 or earlier	--	2%	--	1%	<1%

8.3.4 Water Heater ENERGY STAR Status

Statewide, 15% of water heaters were verified to be ENERGY STAR qualified (Table 102). The analysis excludes water heaters that did not fall into current ENERGY STAR classifications (i.e., indirect water heaters with storage tanks and tankless coils). Attached single-family homes were more likely to have ENERGY STAR qualified water heaters than any other home type. In most EDCs, 5-13% of water heaters were ENERGY STAR qualified; PECO and PPL had significantly higher shares (21% and 23%, respectively).[97]

Table 102: Water Heater ENERGY STAR Status by Home Type

(Base = Systems)

ENERGY STAR	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*134*	*45*	*26*	*70*	*275*
Yes	9%	23%	9%	11%	15%
No	91%	77%	91%	89%	85%

8.3.5 Water Heater Efficiency

Table 103 shows the average UEF for water heaters by home type and statewide. The UEF is an energy performance metric for water heaters that went into effect December 19, 2016.[98] Prior to the implementation of the UEF metric, energy efficiency was rated using the Energy Factor (EF) metric. The SWE team used RESNET protocols to convert EF ratings to UEF ratings.[99] Table 103 includes all systems with UEF or EF ratings except six tankless coil systems and five indirect

[97] See Table 219

[98] https://www.regulations.gov/document?D=EERE-2015-BT-TP-0007-0042

[99] Water heaters with Energy Factor (EF) ratings were converted to the Uniform Energy Factor using the RESNET conversion worksheet. It should be noted that indirect water heaters with storage tanks and tankless coils do not have conversion factors from the EF to the UEF; efficiency values reported utilize the EF rating, noted in the table.

systems for which there are no RESNET protocols to convert EF ratings to UEF ratings. Statewide, the average UEF is 0.78.

Table 103: Water Heater UEF by Home Type

(Base = Systems)

	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	130	43	20	49	242
Min	0.53	0.55	0.56	0.56	0.53
Max	3.25	0.93	3.69	0.99	3.69
Mean	**0.78**	**0.70**	**0.99**	**0.79**	**0.78**
Median	0.66	0.62	0.92	0.88	0.68
Std. Dev.	0.36	0.15	0.65	0.15	0.34

Table 104 presents the statewide average UEF or EF for each residential water heater system type observed onsite. The SWE team calculated Energy Factors for indirect water heaters as 92% of boiler efficiency. For tankless coil systems, energy factors were based on home occupancy.[100] The statewide average efficiency of fossil fuel-fired storage tank water heaters is 0.61 UEF. The average efficiency for electric standalone systems was 0.90 UEF, while the combined average efficiency for all electric equipment types was 1.03 UEF. Heat pump water heaters (HPWH) had a much higher UEF (2.80) than any other system type.

Table 104: Average Residential Water Heater Efficiency

(Base = Systems)

Uniform Energy Factor	*n*	Statewide
Storage, Standalone (Fossil Fuels, UEF)	*131*	0.61
Storage, Standalone (Electric, UEF)	*99*	0.90
Instantaneous (UEF)	*7*	0.94
Indirect w/ Storage Tank (EF)	*5*	0.81
Tankless Coil (EF)	*6*	0.50
Heat Pump Water Heater (UEF)	*5*	2.80

Insulating (hot water) pipe wrap and storage tank wrap increases efficiency by mitigating thermal losses. Four percent of water heaters had fully insulated pipes, 12% had mostly insulated pipes, and 76% had no pipe insulation. Statewide, 4% of standalone water heaters were wrapped with insulation, with an average R-value of 6.3.

[100] Based on Northeast Home Energy Rating System Alliance protocols, the EF was assumed as 0.45 for three occupants, 0.50 for four occupants, 0.55 for five occupants, 0.60 for six occupants, and 0.65 for seven occupants.

8.3.6 Standalone Water Heater Volume

Table 105 displays the storage volume of all residential-sized standalone water heaters. Statewide, the majority (79%) of storage tank water heaters ranged in size from 40-55 gallons. This was the most prevalent size for all home types. Larger tank sizes (above 75 gallons) were more common in multifamily buildings and detached single-family homes (16% and 8%, respectively). Water heaters in multifamily sites with greater than 75 gallons of storage volume served multiple units and common areas.

Table 105: Standalone Water Heater Capacity (Gallons) by Home Type

(Base = Systems)

Gallons	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*134*	*43*	*24*	*57*	*258*
< 40	1%	16%	33%	23%	13%
40 to 55	91%	79%	67%	60%	79%
55 to 75	1%	2%	--	2%	2%
>75	8%	2%	--	16%	7%

8.3.7 Manufactured or Mobile Home Heat Tape

Manufactured homes commonly have plumbing located in crawl spaces with ambient conditions. To prevent such pipes from freezing in the winter, some manufactured or mobile homes employ an electric heat tape wrapped around the pipes. Electric heat tape can consume a significant amount of electricity. Auditors found heat tape at eight (33%) manufactured or mobile homes. Five of the heat tape systems had circuit breaker or switch controls, one had thermostatic controls, and one used a simple plug.

8.3.8 Faucets and Shower Heads

Auditors looked for aerators on all faucets and shower heads and recorded nominal flow rates when visible.[101] Overall, homes had an average of 3.4 sinks, including one kitchen sink, two bathroom sinks, and 0.4 utility sinks (Table 106). Aerators were present on 81% of faucets and low-flow aerators (i.e., having a flow rate less than or equal to 1.5 gallons/minute) were on 57% of faucets (Table 107). This is an increase from the previous study, which found low-flow aerators on 35% of faucets. The average overall flow rate for all sink types was 1.8 gallons/minute (Table 108).

[101] Nominal flow rates were recorded for 65% of faucets and 53% of shower heads. Flow rates are nominal (i.e. as labeled on the aerator) and not a measurement of actual water flow at the faucet or showerhead.

Table 106: Average Number of Faucets

Type	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*145*	*48*	*26*	*70*	*289*
Kitchen	1.1	1.0	1.0	1.0	1.0
Bathroom	2.4	2.1	1.6	1.2	2.0
Utility	0.6	0.5	0.1	0.0	0.4
Overall	4.0	3.4	2.7	2.2	3.4

Table 107: Share of Faucets with Low-Flow Aerators

Type	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*584*	*165*	*70*	*156*	*975*
Yes	58%	59%	71%	56%	57%
No	42%	41%	29%	44%	43%

Table 108: Average Faucet Flow Rate

Type	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
Kitchen *(n=191)*	2.0	1.9	1.9	1.9	2.0
Bathroom *(n=417)*	1.8	1.8	1.9	1.7	1.8
Utility *(n=23)*	2.0	2.4	2.4	--	2.2
Overall *(n=631)*	1.8	1.9	2.0	1.8	1.8

The average home had 1.5 shower heads. Only 4% of shower heads were low flow (i.e., had a flow rate less than 2.0 gallons/minute) and the average flow rate was 2.3 gallons/minute (Table 109). The previous study found that 45% of showers were low flow.[102]

[102] The SWE team recognizes the large discrepancy between the two reports. The SWE team views the 4% value to be more consistent with recent residential construction studies in Massachusetts, Rhode Island, and Connecticut. The average flow rates in those studies for shower heads range from 2.3 to 2.4. Given the federal maximum allowable flow rate for shower heads is 2.5, it seems only a small percentage of shower heads could have flow rates less than 2.0. The previous study was conducted by a different firm and thus the methods are not entirely verifiable.

Table 109: Shower Head Count, Aerators, and Flow Rate

Type	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
Count of Faucets	*242*	*71*	*41*	*76*	*430*
Avg # Per Home	1.7	1.5	1.6	1.1	1.5
Low Flow %	6%	11%	6%	7%	4%
Average Flow Rate	2.3	2.3	2.4	2.2	2.3

8.4 Ventilation

Data were collected on mechanical ventilation systems found onsite, including heat recovery ventilation (HRV) and energy recovery ventilation (ERV) systems.[103] This study did not assess bath fans as ventilation strategies and only considered full house ventilation technologies. Only one ERV system was found during the onsite audits. ERV systems are a "balanced ventilation system" that supply fresh air to the home while expelling stale air. The ERV system was in a single-family detached home in FE: Met-Ed territory. The ERV was controlled with a dehumidistat and had a sensible recovery rate of 71%, total recovery rate of 48%, and power consumption of 102 watts.

8.5 Renewables

Just three homes (1%, weighted) had a total of four solar photovoltaic (PV) systems for onsite power generation. Key details for the PV systems are provided in Table 110. All three homes were detached single-family homes. None of the sampled sites had solar thermal hot water systems or wind power generation systems.

Table 110: Solar Photovoltaic Systems

Array Area (sq. ft.)	Power Production (kW)	Inverter Efficiency	Orientation	EDC
162	2.4	0.99	Northeast	Duquesne
216	3.2	0.99	Southwest	Duquesne
339	5.7	NA	Southeast	PPL
403	6.1	0.97	Southeast	FE: Met-Ed

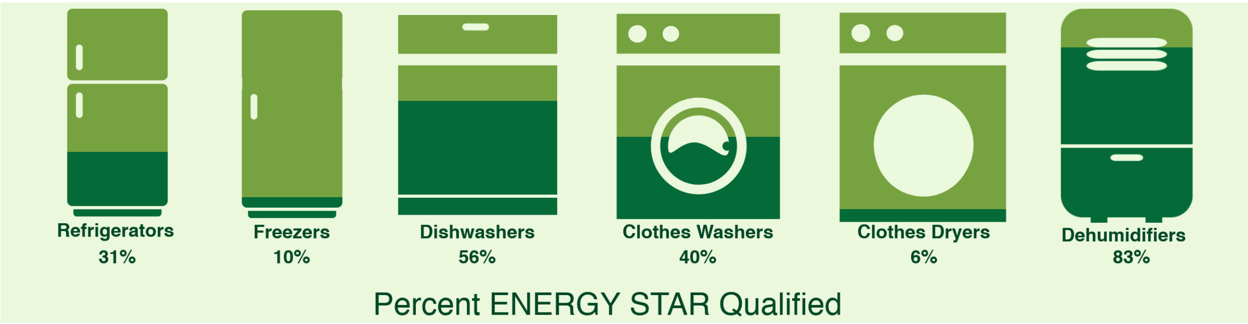
[103] The difference between an Energy Recovery Ventilator (ERV) and a Heat Recovery Ventilator (HRV) is that in an ERV, the heat exchanger transmits some amount of water vapor along with the heat energy, whereas only heat is transferred in a HRV.

Section 9 Appliances

This chapter presents the SWE team's statewide findings for appliances. The SWE team collected data on refrigerators, standalone freezers, ovens and ranges, dishwashers, clothes washers, clothes dryers, and dehumidifiers.

Data was collected onsite and nameplate information was collected for all appliances whenever possible. The SWE team utilized the nameplate information collected (primarily manufacturer's model and serial numbers) to look up information uncollected or unable to be confirmed onsite. This includes appliance energy consumption, vintage, efficiency, ENERGY STAR status, and other appliance-specific details. Some appliances, primarily older-vintage models, did not have specifications available online or onsite. In these instances, the SWE team requested information from manufacturers.

Figure 27: Appliance Results Highlights



9.1 Refrigerators

This section describes the SWE team's key findings for refrigerators. As expected, Table 111 shows there was at least one refrigerator present at each site surveyed. Further shown in Table 111, 63 (23%) of the sites surveyed had a secondary refrigerator and 11 (4%) sites had three or more refrigerators.[104] Larger home types are more likely to have multiple refrigerators as shown by detached single-family homes being the most likely (40%), followed by attached single-family (23%). Manufactured or mobile homes and multifamily units were unlikely to contain a secondary refrigerator unit.

[104] Mini Fridges were recorded separately from normal-sized models by the SWE team but were included in these counts.

Table 111: Number of Refrigerators Per Household

Number of Refrigerators	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*145*	*48*	*26*	*70*	*289*
1	61%	77%	89%	96%	73%
2	34%	19%	12%	3%	23%
3+	6%	4%	--	1%	4%[1]

[1]One site contained four refrigerators.

Table 112 describes surveyed refrigerator vintages, when available, divided into seven distinct vintage buckets.[105] The average age of refrigerators was 12 years. Primary refrigerators were newer on average (11 years) than secondary refrigerators (16 years; Table 113). Manufactured or mobile homes were more likely to have older refrigerators than the other home types.

Table 112: Refrigerator Vintages by Home Type

(Base: Refrigerators)

Vintage	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*200*	*59*	*27*	*73*	*359*
2016 to 2018	12%	12%	11%	14%	15%
2011 to 2015	26%	36%	22%	33%	28%
2006 to 2010	20%	24%	11%	21%	19%
2001 to 2005	18%	10%	26%	10%	14%
1991 to 2000	17%	15%	22%	18%	17%
1981 to 1990	6%	3%	7%	56%	5%
1980 or earlier	2%	--	--	--	1%

Table 113: Refrigerator Vintage by Primary and Secondary Status

(Base: Refrigerators)

Vintage	Primary	Secondary	Statewide
N	*285*	*74*	*359*
2016 to 2018	14%	4%	15%
2011 to 2015	30%	24%	28%
2006 to 2010	21%	15%	19%
2001 to 2005	15%	18%	14%
1991 to 2000	15%	26%	17%
1981 to 1990	4%	10%	5%
1980 or earlier	<1%	4%	1%

[105] While the report uses generalized vintage bins for all appliances and mechanical equipment for consistency, note that the current federal standards for refrigerators went into effect in 2014 and the previous standard was applicable from 2001 to 2014.

Table 114 describes refrigerator configuration. Statewide, most refrigerators had a top freezer door configuration. Multifamily units surveyed were almost entirely (91%) comprised of top freezer models.

Table 114: Refrigerator Door Configuration by Home Type

(Base: Refrigerators)

Door Configuration	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*211*	*61*	*29*	*74*	*375*
Top Freezer	41%	48%	59%	91%	52%
Bottom Freezer	24%	18%	10%	3%	20%
Side by Side	23%	23%	24%	5%	19%
Mini Fridge	10%	12%	7%	1%	9%
Single Door	1%	--	--	--	1%

Table 115 describes refrigerators by their internal storage volume. Statewide, the average refrigerator volume was 18.8 ft^3 and was relatively consistent across home types. However, refrigerators in multifamily units were smaller than refrigerators in other home types.

Table 115: Refrigerator Volume by Home Type

(Base: Refrigerators)

Volume	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*198*	*58*	*26*	*72*	*354*
Min	1.7	1.7	14.0	2.0	1.7
Max	29.8	28.0	27.2	27.0	29.8
Mean	**19.6**	**18.8**	**19.7**	**16.7**	**18.8**
Median	20.5	18.3	18.4	16.5	18.5
Std. Dev.	6.3	6.5	3.1	3.5	5.8

Table 116 and Table 117 display the average energy consumption and the ENERGY STAR status of surveyed refrigerators, respectively. Statewide, the average energy consumption was 570 kWh per year. Note this does not account for capacity and is thus not a reflection of efficiency.

Table 117 describes the ENERGY STAR status of refrigerators. Around one-third (31%) of refrigerators statewide were ENERGY STAR qualified. Manufactured or mobile homes were less likely to have ENERGY STAR qualified refrigerators than all other home types. Additionally, the SWE team found primary refrigerators were far more likely to be ENERGY STAR qualified than secondary models.

Table 116: Refrigerator kWh Consumption per Year
(Base: Refrigerators)

	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*190*	*56*	*25*	*65*	*336*
Min	230.0	230.0	363.0	300.0	230.0
Max	1,565.0	1,147.0	1,787.0	1,190.0	1,787.0
Mean	**602.3**	**513.3**	**647.9**	**493.8**	**569.9**
Median	563.0	481.5	630.0	454.0	524.0
Std. Dev.	237.3	157.6	271.6	160.4	220.8

Table 117: Refrigerator ENERGY STAR Status by Home Type
(Base: Refrigerators)

ENERGY STAR	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*200*	*59*	*28*	*65*	*352*
Yes	33%	36%	18%	32%	31%
No	67%	64%	82%	68%	69%

9.2 Freezers

Table 118 describes standalone freezer counts by home type. This section covers key findings related to standalone freezers. Statewide, auditors found 100 standalone freezers in 96 homes. Most freezers were found in detached or attached single-family homes, with manufactured or mobile homes and multifamily units being less likely (27% and 19%, respectively) to contain a standalone freezer appliance.

Table 118: Standalone Freezer Counts by Home Type

Counts	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*145*	*48*	*26*	*70*	*289*
0	55%	65%	73%	90%	65%
1	43%	33%	27%	10%	33%
2	2%	2%	--	--	1%

As show in Table 119, freezer door configuration was split almost evenly. There were variations across home type, but sample sizes are too low to make reliable comparisons.

Table 119: Freezer Door Configuration by Home Type

(Base: Freezers)

Door Configuration	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*68*	*18*	*7*	*7*	*100*
Chest	44%	61%	5 (71%)	5 (71%)	51%
Upright	56%	39%	2 (29%)	2 (29%)	50%

Table 120 displays freezer vintages. Statewide, the average freezer age was 14 years. The largest proportion of freezers were manufactured between 1991 to 2000.[106]

Table 120: Freezer Vintages by Home Type

(Base: Freezers)

Vintage	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*58*	*14*	*5*	*7*	*84*
2016 to 2018	9%	21	--	--	11%
2011 to 2015	19%	43%	2 (40%)	3 (42%)	23%
2006 to 2010	21%	7%	--	2 (29%)	16%
2001 to 2005	16%	14%	1 (20%)	1 (14%)	13%
1991 to 2000	26%	14%	2 (40%)	1 (14%)	29%
1981 to 1990	7%	--	--	--	5%
1980 or earlier	3%	--	--	--	2%

Table 121 describes freezer capacities, which were 12.2 ft^3 on average statewide. Their capacities ranged broadly, from a minimum 3.0 ft^3 to a maximum 24.6 ft^3.

Table 121: Freezer Capacity by Home Type

(Base: Freezers)

	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*59*	*13*	*5*	*7*	*84*
Min	3.0	3.5	5.0	3.5	3.0
Max	24.6	16.7	21.0	14.1	24.6
Mean	**13.6**	**8.8**	**11.2**	**7.6**	**12.2**
Median	14.8	7.2	10.0	5.4	13.8
Std. Dev.	5.5	4.7	6.8	4.2	5.8

106 While the report uses generalized vintage bins for all appliances and mechanical equipment for consistency, note that the current federal standards for freezers went into effect in 2014 and the previous standard was applicable from 2001 to 2014.

Table 122 describes the average annual energy consumption, in kWh/year, by home type. Freezer annual energy consumption averaged around 435 kWh per year statewide, but the range of values varied widely. This is expected given the broad range of freezer capacities shown in Table 121.

Table 122: Freezer Energy Consumption by Home Type (kWh/year)

(Base: Freezers)

kWh/yr	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*58*	*13*	*5*	*7*	*83*
Min	198.0	172.0	172.0	193.0	172.0
Max	1,026.0	615.0	471.0	442.0	1,026.0
Mean	**478.5**	**330.1**	**304.4**	**290.7**	**435.4**
Median	450.5	277.0	282.0	242.0	435.0
Std. Dev.	222.8	147.3	114.8	92.8	214.3

Table 123 describes the ENERGY STAR status of freezers surveyed statewide by home type. The SWE team was able to determine the ENERGY STAR status for all but one of the surveyed models, and the proportion of qualified freezers was only around 10%.[107]

Table 123: Freezer ENERGY STAR Status by Home Type

(Base: Freezers)

ENERGY STAR	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*64*	*16*	*6*	*6*	*92*
Yes	12%	6%	1 (17%)	--	10%
No	88%	94%	5 (83%)	6 (100%)	90%

9.3 Ovens and Ranges

This section presents the key features and characteristics of in-unit cooking appliances. "Oven and range" refers to the standard kitchen appliance found throughout most sites surveyed, containing both an oven and range system within one singular appliance. Conversely, "Oven only" and "Range only" refers to standalone oven and range systems, respectively.

Table 124 describes the counts of oven and range combinations, standalone ovens, and standalone ranges found by the auditors. Statewide, roughly 85% of appliances surveyed were combination oven and ranges, while the rest contained a combination of the two standalone units. Although uncommon, five homes surveyed contained a standalone oven or range in addition to their primary combination oven and range.

[107] The freezer with unknown ENERGY STAR status was excluded from Table 109.

Table 124: Oven and Range Type by Home Type

(Base: Ovens and ranges)

Type	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*172*	*52*	*26*	*73*	*323*
Oven and Range	78%	90%	100%	99%	85%
Oven Only	12%	6%	--	--	9%
Range Only	8%	4%	--	1%	7%

Table 125 displays the fuel types for the oven and ranges. Over half (53%) of homes had electric oven and ranges, followed by natural gas (42%) and propane (5%). Although uncommon in single-family and multifamily homes, propane was prevalent throughout manufactured or mobile homes.

Table 125: Oven and Range Fuel Type by Home Type

Fuel Type	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*145*	*48*	*26*	*70*	*289*
Electric	57%	42%	39%	60%	53%
Natural Gas	38%	56.%	23%	39%	42%
Propane	5%	2%	39%	1%	5%

Table 126 displays the saturation of convection ovens. Statewide, roughly 24% of surveyed ovens were convection ovens. Only one of the 156 electric ranges was an induction range.

Table 126: Convection Oven Saturation

(Base: Appliances)

Convection Oven	Frequency	Percent
Yes	72	24%
No	234	76%

9.4 DISHWASHERS

This section describes the key characteristics of dishwashers found throughout the study. Table 127 displays dishwasher penetration by home type. Of the 289 homes surveyed by the SWE team, 175 (59%) had a dishwasher present.[108]

Table 127: Dishwasher Penetration by Home Type

Type	Detached Single-family	Attached Single-family	Multifamily	Manufactured/ Mobile	Overall
n	*145*	*48*	*70*	*26*	*289*
No Dishwasher	23%	42%	69%	50%	41%
Full Size	76%	56%	31%	50%	59%
Mini	1%	2%	--	--	<1%

Table 128 displays dishwasher vintages by home type. The average age for surveyed dishwashers was ten years, and over two thirds (68%) of dishwashers have been manufactured since 2006.

Table 128: Dishwasher Vintages by Home Type

(Base: Dishwashers)

Vintage	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*109*	*27*	*12*	*21*	*169*
2016 to 2018	8%	15%	8%	19%	10%
2011 to 2015	35%	33%	8%	10%	31%
2006 to 2010	26%	41%	17%	24%	27%
2001 to 2005	17%	7%	42%	29%	18%
1991 to 2000	12%	4%	17%	14%	12%
1981 to 1990	3%	--	--	5%	2%
1980 or earlier	--	--	8%	--	<1%

Table 129 and Table 130 show the annual electricity consumption and ENERGY STAR status of in-unit dishwashers, respectively. The average energy consumption statewide was roughly 322 kWh per year, with systems ranging from 220 to 692 kwh per year. Statewide, 56% of surveyed dishwashers were ENERGY STAR qualified, with detached and attached single-family homes being much more likely to contain an ENERGY STAR qualified dishwasher than other home types.

[108] The previous study found dishwashers at 67% of homes. The larger share of manufactured or mobile homes in this study compared to the previous study accounts for the apparent reduction in dishwasher penetration because manufactured or mobile homes are significantly less likely to have dishwashers than all other home types.

Table 129: Dishwasher Consumption (kWh/year)

(Base: Dishwashers)

kWh/yr	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*94*	*27*	*9*	*17*	*147*
Min	245.0	220.0	270.0	260.0	220.0
Max	636.0	564.0	692.0	543.0	692.0
Mean	**321.2**	**315.1**	**366.6**	**318.2**	**322.2**
Median	306.0	304.0	347.0	306.0	306.0
Std. Dev.	74.3	75.8	128.9	65.5	77.8

Table 130: Dishwasher ENERGY STAR Status

(Base: Dishwashers)

ENERGY STAR	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*111*	*27*	*13*	*21*	*172*
Yes	61%	70%	46%	43%	56%
No	39%	30%	54%	57%	44%

9.5 In-unit Clothes Washers

Table 131 describes the statewide clothes washer penetration. Of the 289 units surveyed, 232 (80%) unique sites contained an in-unit clothes washer and one single-family home had two clothes washers present. The vast majority (over 94%) of single family and manufactured or mobile homes had a clothes washer. Conversely only 31% of multifamily units contained an in-unit system. This is due to the presence of communal washers occasionally found within many multifamily buildings.

Table 131: Clothes Washer Penetration by Home Type

Type	Detached Single-family	Attached Single-family	Manufactured / Mobile	Multifamily	Statewide
n	*145*	*48*	*26*	*70*	*289*
0	3%	6%	4%	69%	20%
1+	97%	94%	96%	31%	80%

Statewide, the average clothes washer age was nine years. As shown in Table 132, the majority (76%) of clothes washers sampled were manufactured between 2006 and 2018, with over half (53%) having been manufactured since 2011. Attached and detached single-family homes are around twice as likely to have had a clothes washer manufactured since 2011 than other home types surveyed.

Table 132: Clothes Washer Vintages by Home Type

(Base: In-unit clothes washers)

Vintage	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*139*	*45*	*25*	*21*	*230*
2016 to 2018	18%	9%	12%	10%	18%
2011 to 2015	35%	44%	20%	19%	36%
2006 to 2010	22%	27%	28%	38%	22%
2001 to 2005	10%	7%	24%	19%	10%
1991 to 2000	12%	13%	8%	10%	12%
1981 to 1990	4%	--	8%	5%	3%
1980 or earlier	1%	--	--	--	<1%

Table 133 displays the average configuration for surveyed clothes washers. The majority (77%) of clothes washers statewide were top load clothes washers. Detached and attached single-family homes were more likely to have front load washers than manufactured or mobile and multifamily homes.

Table 133: Clothes Washer Configuration

(Base: In-unit clothes washers)

Type	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*141*	*45*	*25*	*22*	*233*
Top Load	74%	82%	92%	91%	77%
Front Load	26%	18%	8%	9%	24%

Table 134 displays the average clothes washer capacity. The statewide average was roughly 3.7 ft^3. Like the other appliances, capacities ranged broadly from a low of 2.1 ft^3 to a high of 5.3 ft^3. Average capacities were consistent across home types, but clothes washers in multifamily units were more likely to have smaller capacities. Again, this is likely due to space constraints inherent to these home types.

Table 134: Clothes Washer Capacity (ft^3)

(Base: In-unit clothes washers)

Ft^3	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*130*	*39*	*23*	*20*	*212*
Min	2.5	2.8	2.8	2.1	2.1
Max	5.3	5.2	5.0	4.3	5.3
Mean	**3.7**	**3.7**	**3.6**	**3.2**	**3.7**
Median	3.5	3.4	3.5	3.2	3.5
Std. Dev.	0.6	0.6	0.6	0.6	0.6

Table 135 displays the efficiencies of clothes washers as measured by the Integrated Modified Energy Factor (IMEF).[109] A higher IMEF indicates a more efficient appliance. Clothes washers in detached and attached single-family units were, on average, more efficient than those surveyed in manufactured or mobile homes and multifamily units. This is due to the newer vintage associated with clothes washers in single-family homes.

Table 135: Clothes Washer Efficiency (IMEF)

(Base: In-unit clothes washers)

IMEF	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*126*	*40*	*23*	*19*	*208*
Min	0.6	0.7	0.6	0.6	0.6
Max	2.9	2.9	2.9	2.6	2.9
Mean	**1.6**	**1.5**	**1.4**	**1.1**	**1.6**
Median	1.4	1.3	1.1	0.8	1.3
Std. Dev.	0.7	0.7	0.7	0.5	0.7

Table 136 describes the ENERGY STAR status of surveyed in-unit clothes washers. On average, roughly 40% of surveyed in-unit clothes washers were verified as ENERGY STAR qualified. Multifamily units surveyed were significantly less likely to have a qualified clothes washer in-unit, while detached and attached single-family units were the most likely.

[109] Some clothes washers surveyed reported their efficiencies in the Modified Energy Factor (MEF). In these cases, the SWE team converted their efficiencies to IMEF units using the formula prescribed by RESNET: MEF = 0.503 +0.95*MEF.

Table 136: Clothes Washer ENERGY STAR Status

(Base: In-unit clothes washers)

ENERGY STAR	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*141*	*45*	*25*	*22*	*233*
Yes	43%	36%	28%	18%	40%
No	57%	64%	72%	82%	60%

9.6 Shared Clothes Washers

Forty of the sampled multifamily buildings have shared clothes washers located in common space. There were eight sites that did not have laundry facilities present. Two sites had laundry facilities within the complex that were not located in the audited building and twenty sites had in-unit laundry – two of which also had common laundry facilities in the building.

A total of 140 shared clothes washers were observed: 76 top-load (54%) and 64 front-load (46%) models. Most shared clothes washers were manufactured in 2006 or later (93%), and 77% were manufactured between 2011 and 2018.

Table 137: Shared Clothes Washer Vintages by Building Size

(Base: Shared clothes washers)

Vintage	2-4 units	5-19 units	20-49 units	50+ units	Statewide
n	*2*	*32*	*37*	*69*	*140*
2016 to 2018	--	13%	30%	33%	28%
2011 to 2015	--	47%	35%	54%	49%
2006 to 2010	2 (100%)	13%	24%	7%	16%
2001 to 2005	--	13%	11%	6%	6%
1991 to 2000	--	9%	--	--	1%
Unknown	--	6%	--	--	1%

The IMEF is an energy performance metric for residential clothes washers used by ENERGY STAR as of March 7, 2015.[110] The higher the IMEF, the more energy efficient the clothes washer is. Prior to the IMEF transition, the Modified Energy Factor (MEF) performance metric was used for clothes washers. Note that clothes washers found in common areas included both residential and commercial models. The ENERGY STAR requirements for commercial models use the MEF performance metric as of February 5, 2018.[111] The statewide average IMEF for shared washing machines was 1.60 (Table 138).

[110] Current ENERGY STAR minimum requirements for clothes washer IMEF are as follows: residential top-load (2.06), residential front-load (2.76), and commercial front-load (2.20 MEF).

[111] A conversion factor was applied to clothes washers rated in MEF to determine an equivalent IMEF. IMEF = (MEF-.503)/.95.

Table 138: Shared Clothes Washer Efficiency (IMEF) by Building Size

(Base: Shared clothes washers)

IMEF	2-4 units	5-19 units	20-49 units	50+ units	Statewide
n	*2*	*30*	*35*	*69*	*136*
Min	0.90	0.63	1.05	0.92	0.63
Max	1.05	2.10	2.61	2.61	2.61
Mean	**0.98**	**1.06**	**1.79**	**1.66**	**1.60**
Median	0.98	0.90	1.79	1.26	1.26
Std. Dev.	0.11	0.30	0.38	0.57	0.54

The statewide average annual rated energy consumption of shared clothes washers was 226 kWh/year.[112] Buildings with 2-4 units and 5-19 units had more energy intensive clothes washers than larger buildings (Table 139). Clothes washers in buildings with 20-49 units were more efficient than washers in buildings with 50+ units. The larger occupant population found in 20-49 and 50+ unit buildings may drive more building owners towards more efficient clothes washers to reduce operational costs.

Table 139: Shared Clothes Washer Rated Energy Consumption by Building Size (kWh/Year)

(Base: Shared clothes washers)

kWh/Year	2-4 units	5-19 units	20-49 units	50+ units	Statewide
n	*2*	*18*	*31*	*45*	*96*
Min	278	124	44	90	44
Max	533	533	417	416	533
Mean	**406**	**380**	**162**	**232**	**226**
Median	406	416	142	278	148
Std. Dev.	180	127	112	126	144

Table 140 displays the ENERGY STAR status for shared clothes washers. Forty-eight percent of clothes washers in common areas were ENERGY STAR qualified. Shared clothes washers in PPL, PECO, and FE: West Penn service territories had greater than 50% ENERGY STAR saturation.

[112] Information regarding the rated energy consumption (in kWh/year) was not available for 44 clothes washers.

Table 140: Shared Clothes Washer ENERGY STAR Status by Building Size
(Base: Shared clothes washers)

ENERGY STAR	2-4 units	5-19 units	20-49 units	50+ units	Statewide
n	*2*	*32*	*37*	*69*	*140*
Yes	--	22%	62%	44%	48%
No	2 (100%)	78%	38%	57%	52%

9.7 In-unit Clothes Dryers

This section describes the SWE team's key findings for in-unit clothes dryers. Table 141 describes the statewide clothes dryer penetration by home type. Of the 289 units surveyed by the SWE team, 231 (79%) contained in-unit clothes dryers and one site had two present. Only a small proportion (6%) of in-unit clothes dryers surveyed were ENERGY STAR qualified. However, this is likely due to the late adoption of ENERGY STAR ratings for clothes dryers, which did not begin until 2015.

Table 141: Clothes Dryer Penetration

Count	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*145*	*48*	*26*	*70*	*289*
0	3%	8%	4%	69%	21%
1+	97%	92%	96%	31%	79%

Table 142 describes clothes dryer vintages by home type. The average clothes dryer age was 12 years and over half (58%) of those clothes dryers were newer than 2006. Their vintages did not vary across home types.

Table 142: Clothes Dryer Vintages by Home Type

(Base: In-unit clothes dryers)

Vintage	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*137*	*43*	*23*	*21*	*224*
2016 to 2018	12%	9%	--	5%	12%
2011 to 2015	28%	30%	17%	14%	25%
2006 to 2010	21%	21%	17%	33%	22%
2001 to 2005	19%	23%	30%	24%	21%
1991 to 2000	10%	12%	30%	24%	13%
1981 to 1990	5%	5%	--	--	4%
1980 or earlier	5%	--	4%	--	4%

Table 143 displays clothes dryers by fuel type. Almost three quarters (74%) were electric, while the other quarter (25%) were natural gas. Very few surveyed clothes dryers (1%) utilized propane as their fuel source, with most of those examples represented in manufactured or mobile homes.

Table 143: Clothes Dryer Fuel Types

(Base: In-unit clothes dryers)

Clothes Dryer Fuel	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*140*	*44*	*25*	*22*	*231*
Electric	71%	68%	84%	77%	74%
Natural Gas	28%	30%	8%	23%	25%
Propane	1%	2%	8%	--	1%

Some clothes dryers possess moisture sensing technology, which enables them to prematurely end the drying cycle if it senses its load has reached the desired level of dryness, reducing the system's overall run-time and energy consumption. Table 144 describes the moisture sensing capabilities of surveyed clothes dryers. Overall, roughly 60% of all clothes dryers statewide utilize moisture sensing technology. Manufactured and mobile homes were significantly less likely to contain clothes dryers with moisture sensing capabilities.

Table 144: Clothes Dryer Moisture Sensing Feature

(Base: In-unit clothes dryers)

Moisture Sensing	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*138*	*43*	*23*	*20*	*224*
Yes	57%	63%	39%	65%	59%
No	43%	37%	61%	35%	41%

9.8 Shared Clothes Dryers

Forty of the sampled multifamily buildings had shared clothes dryers located in common space. There were eight sites that did not have laundry facilities present. Two sites had laundry facilities within the complex that were not located in the audited building, and twenty sites had in-unit laundry – two of which also had common laundry facilities in the building.

A total of 138 shared clothes dryers were observed: 71 electric (52%) and 66 natural gas (48%) models. Most shared clothes dryers were manufactured since 2006 (85%); 69% were manufactured between 2011 and 2018. No shared clothes dryers with available data met ENERGY STAR qualifications.

Moisture sensors were installed in 65% of shared clothes dryers (Table 145). Moisture sensors help reduce energy consumption of clothes dryers by ceasing operation when clothes are dry, rather than using a timer to cease operation. PPL and FE: West Penn were the only EDCs with less than 50% saturation of moisture sensors in shared clothes dryers (44% and 36%).

Table 145: Moisture Sensors in Shared Clothes Dryers by Building Size

(Base: Shared dryers)

Sensor	2-4 units	5-19 units	20-49 units	50+ units	Statewide
n	*2*	*34*	*38*	*64*	*138*
Yes	1 (50%)	62%	71%	59%	65%
No	1 (50%)	38%	18%	41%	33%
Unknown	--	--	11%	--	2%

9.9 Dehumidifiers

This section describes in-unit dehumidifiers found during audits. Table 146 shows dehumidifier penetration by home types. Overall, the SWE team recorded 90 in-unit dehumidifiers; however, eight sites had two dehumidifiers, and one site had three. In total, 80 unique sites (28%) out of the 289 had an in-unit dehumidifier. The majority (83%) of surveyed dehumidifiers were found in detached single-family homes. The prevalence of dehumidifiers is most likely correlated with the increased presence of basements in single-family homes, which tend to be cool and damp.

Table 146: Dehumidifier Penetration by Home Type

Make	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*145*	*48*	*26*	*70*	*289*
0	53%	83%	92%	97%	72%
1+	47%	17%	8%	3%	28%

Table 147 displays dehumidifier vintages by home type. Statewide, the average dehumidifier age was eight years and almost two thirds (66%) of dehumidifiers have been manufactured since 2011.

Table 147: Dehumidifier Vintages by Home Type

(Base: Dehumidifiers)

Vintage	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*75*	*8*	*3*	*4*	*90*
2016 to 2018	20%	2 (25%)	1 (33%)	2 (50%)	21%
2011 to 2015	44%	4 (50%)	2 (67%)	1 (25%)	45%
2006 to 2010	17%	2 (25%)	--	--	16%
2001 to 2005	12%	--	--	1 (25%)	11%
1991 to 2000	4%	--	--	--	4%
1981 to 1990	3%	--	--	--	3%

Table 148 displays dehumidifier capacity in pints per day. Statewide, the average dehumidifier capacity was 50 pints/day. Small sample sizes prohibit comparisons between home types.

Table 148: Dehumidifier Capacity by Home Type (pints/day)

(Base: Dehumidifiers)

Pints/day	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*75*	*8*	*3*	*4*	*90*
Min	25.0	25.0	50.0	30.0	25.0
Max	72.0	70.0	72.0	50.0	72.0
Mean	**50.7**	**48.4**	**64.0**	**35.0**	**50.1**
Median	50.0	50.0	70.0	30.0	50.0
Std. Dev.	14.4	17.8	12.2	10.0	14.9

Table 149 describes dehumidifier ENERGY STAR qualification status by home type. Statewide, nearly 83% of all models surveyed were ENERGY STAR qualified. Again, the small sample size makes it difficult to make direct comparisons between home types.

Table 149: Dehumidifier ENERGY STAR Status by Home Type

(Base: Dehumidifiers)

ENERGY STAR	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*75*	*8*	*3*	*4*	*90*
Yes	83%	6 (75%)	3 (100%)	1 (25%)	83%
No	17%	2 (25%)	--	3 (75%)	17%

Section 10 Lighting

This section details findings from data collected on lighting technology at homes in the sample. The SWE team analyzed lighting data to determine levels of penetration (the percentage of homes with at least one observation of a specific lighting technology) and saturation (the percentage of total sockets filled by each technology type).

Key findings:

- LED bulbs were found in 75% of homes in the statewide sample. Incandescent bulbs were found in 91% of homes, slightly more than CFLs (89%).
- LED saturation is now equal to CFL saturation – both types filled 20% of sockets. LEDs seem to be replacing inefficient bulb types such as incandescent bulbs.
- Combined, efficient bulb types filled just over half of sockets in the sample (51%), while incandescent (44%) and halogen (4%) bulbs filled most of the remainder.
- PPL, which converted to an exclusively-LED lighting program earlier than other EDCs, had LED bulbs in 27% of sockets, a significantly higher proportion than other EDCs. CFL saturation in PPL homes is on par with other EDCs, and incandescent saturation is lower in PPL homes than all other EDCs.
- Mobile or manufactured sites have significantly higher LED saturation than other home types.
- Detached single-family homes have significantly lower LED saturation and a significantly higher level of incandescent saturation than other home types.

10.1 Lighting Data Collection

Auditors collected data on all light fixtures, including the location, fixture type (hard-wired or plug-in), number of sockets, and lamp types. CFLs, LEDs (including integrated LED fixtures), and fluorescent tubes are considered energy-efficient lamp types. Inefficient types include incandescent, halogen, and other uncommon types, such as xenon. The tables below include bulbs from all sockets observed in each home (or housing unit in the case of multifamily sites), including interior, exterior, hard-wired, and plug load. Common area lighting in multifamily sites is excluded from the main tables in this section, data for those bulbs can be found in section 10.3.3.

10.2 Lighting Penetration

Statewide, three quarters of homes had at least one LED (Table 150). Incandescent bulbs had the highest penetration rate at 91%. CFLs followed closely behind at 89%. Halogen bulbs were present in less than half (46%) of homes. Met-Ed homes had the highest level of LED penetration at 90%, followed by PPL at 82%. LED penetration was lowest in PECO homes at just 65%, a statistically significant difference from both Met-Ed and PPL. Penetration numbers for incandescent bulbs remained high across EDCs, above 90% for all except PECO at 85%.

Table 150: Bulb Type Penetration by EDC

Bulb Type	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*46*	*44*	*51*	*39*	*38*	*32*	*39*	*289*
LED	**65%**	**82%**[a]	73%	**90%**[a]	71%	81%	74%	75%
CFL	89%	80%	84%	95%	95%	84%	95%	89%
Fluorescent	65%	64%	67%	74%	76%	63%	82%	74%
Incandescent	85%	91%	92%	95%	92%	97%	95%	91%
Halogen	44%	43%	47%	44%	40%	53%	51%	46%

[a] Significantly different from PECO at the 95% confidence level.

Detached single-family homes had the highest level of LED bulb penetration in the sample at 83%, while multifamily sites had the lowest at 64% (Table 151). Multifamily units had the lowest level of CFL penetration (80%) and the lowest level of incandescent bulb penetration at 74%. All other home types had incandescent penetration rates above 96%.

Table 151: Bulb Type Penetration by Home Type

Bulb Type	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*145*	*48*	*26*	*70*	*289*
LED	83%	73%	73%	64%	75%
CFL	91%	98%	81%	80%	89%
Fluorescent	83%	73%	35%	53%	74%
Incandescent	98%	96%	100%	74%	91%
Halogen	61%	44%	23%	24%	46%

10.3 Lighting Saturation

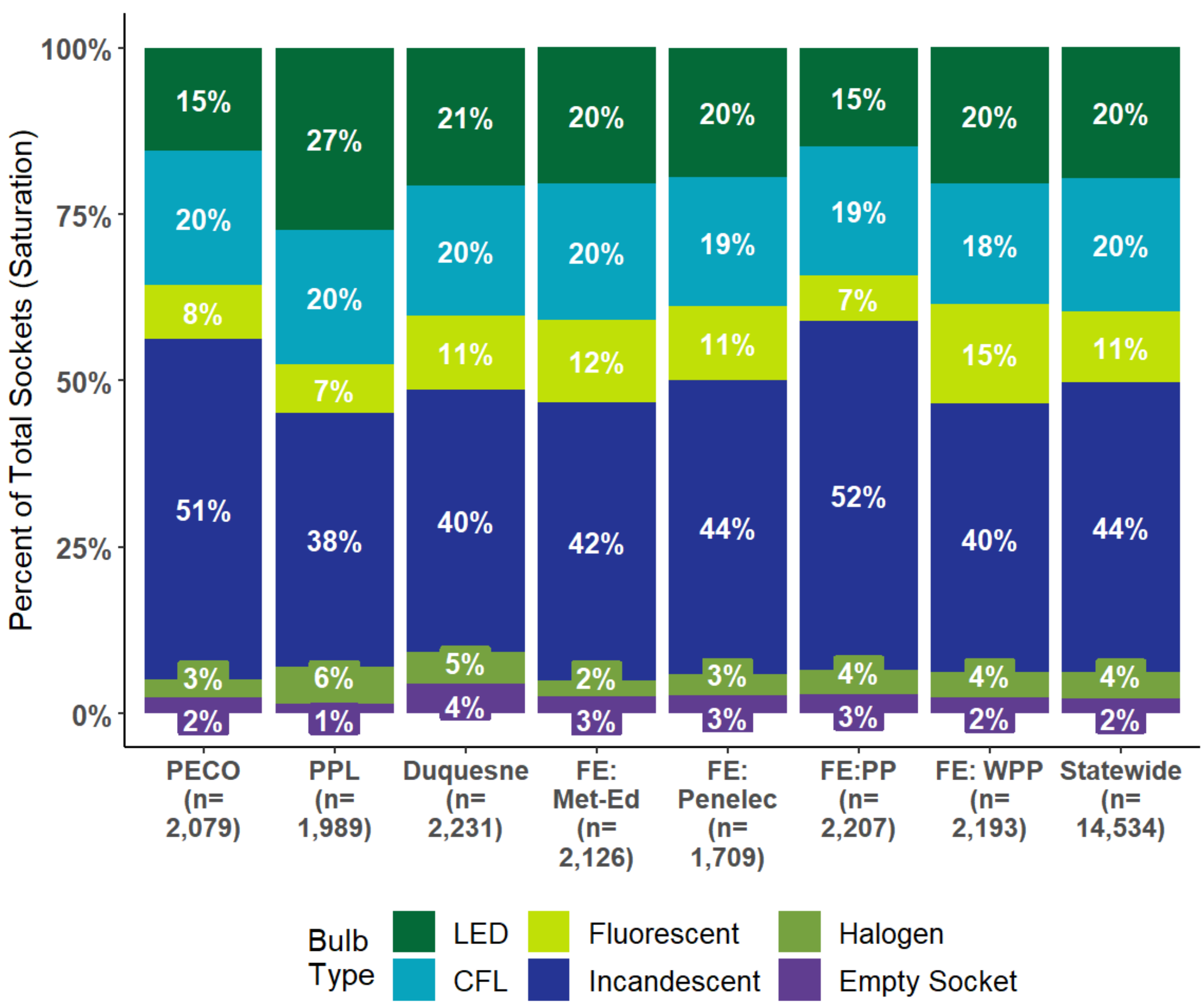
Bulb type saturation provides a better picture of the relative prevalence of efficient lighting than penetration, as it considers every socket in the sample. LED bulbs filled 20% of all sockets observed in the statewide sample (Figure 28). LED bulbs have caught up to CFLs in terms of socket saturation; CFLs were also found in 20% of sockets in the statewide sample despite their higher level of penetration. In the previous baseline, CFL bulbs filled 22% of interior sockets compared to just 2% for LED bulbs. Efficient bulbs combined (LED, CFL, and fluorescent) fill up just over half of all sockets statewide, while incandescent bulbs occupy 44% of sockets. Halogen bulbs fill just 4% of all sockets, and no more than 5% for any specific EDC.

The saturation of LEDs (20%) was less than that of other states with similar programs such as Rhode Island and Massachusetts, but greater than that of New York which stopped incentivizing

LEDs in 2014. Recent studies have found 2018 LED saturations of 33% in Rhode Island, 27% in Massachusetts, and 14% in New York.[113]

PPL stands out from other EDCs with a 27% LED saturation rate, 6% above the next-highest value (Duquesne). The 27% LED saturation rate among PPL homes is significantly higher than all other EDCs. The higher LED saturation rate in PPL homes also seems to come at the expense of incandescent bulbs – CFL saturation in the PPL sample is on par with other EDCs and incandescent saturation is the lowest of all groups. PPL switched to incentivizing LEDs in their lighting programs earlier than the other EDCs in the state. These results suggest that PPL's early engagement has led to increased lighting efficiency in PPL's service territory over that of the other EDCs.

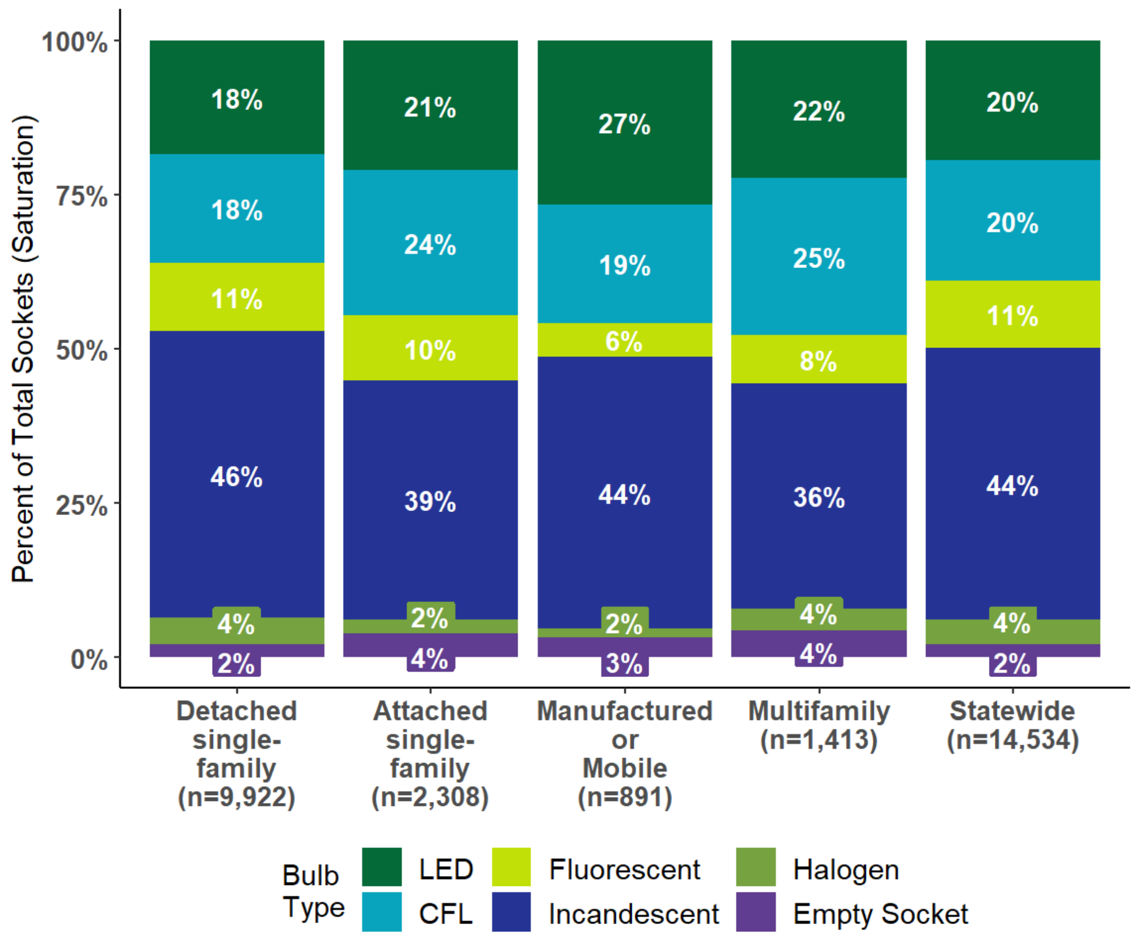
Figure 28: Bulb Type Saturation by EDC



[113] RI2311 National Grid Rhode Island Lighting Market Assessment. July 27, 2018. Submitted to National Grid Rhode Island by NMR Group, Inc. http://www.ripuc.org/eventsactions/docket/5.%20RI2311%20RASS%20Lighting%20Report%20Final%2027July2018.pdf

Mobile or manufactured homes have LEDs installed in 27% of sockets, which is significantly higher than other home types. Detached single-family homes have LEDs installed in just 18% of total sockets, which is significantly lower than other home types. Detached single-family homes also use CFLs less frequently (18%) and have a significantly higher saturation of incandescent bulbs (46%) than other home types (Figure 29).

Figure 29: Bulb Type Saturation by Home Type



10.3.1 Efficient Lighting Saturation by Bulb Shape

Combined LED and CFL saturation among standard bulbs, which include A-line bulbs of all types and spiral CFLs, was 57% (Table 152). LED bulbs made up 23% of this proportion, compared to 34% for CFLs. LED bulbs largely hold their share of sockets when looking at reflector bulbs with a 22% saturation rate. However, CFLs only make up 4% of reflector bulbs in the sample. Specialty bulbs have the lowest rates of LED and CFL saturation: just 16% of specialty bulbs are LEDs (14%) or CFLs (2%). The significant advantage in LED saturation observed in PPL homes remains apparent among standard and specialty bulbs; however, they lag behind most other EDCs in reflector LED saturation.

Table 152: LED and CFL Saturation by Bulb Shape (EDCs)

Bulb Shape	Bulb Type	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n (Total bulbs)		*1,125*	*1,121*	*1,261*	*1,223*	*1,063*	*1,209*	*1,228*	*8,230*
Standard	LED	16%	34%	26%	22%	20%	16%	23%	23%
	CFL	37%	30%	33%	34%	30%	31%	31%	34%
n (Total bulbs)		*312*	*295*	*182*	*230*	*139*	*358*	*248*	*1764*
Reflector	LED	28%	15%	12%	50%	32%	15%	23%	22%
	CFL	2%	5%	7%	2%	1%	13%	3%	4%
n (Total bulbs)		*593*	*545*	*686*	*615*	*459*	*575*	*662*	*4135*
Specialty	LED	10%	21%	17%	8%	17%	14%	17%	14%
	CFL	1%	9%	1%	2%	1%	1%	1%	2%

Detached single-family homes have comparable, if slightly lower, CFL and LED saturation rates among standard bulbs when compared to other home types (Table 153). Reflector and specialty bulbs in detached single-family homes lag further behind other types in both LED and CFL saturation. Mobile or manufactured homes, which had significantly higher overall LED saturation than other homes types, have the highest LED saturation among both standard and specialty bulbs.

Table 153: LED and CFL Saturation by Bulb Shape (Home Types)

Bulb Shape	Bulb Type	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n (Total bulbs)		*5,388*	*1,358*	*551*	*933*	*8,230*
Standard	LED	22%	20%	30%	24%	23%
	CFL	31%	36%	29%	38%	34%
n (Total bulbs)		*1366*	*293*	*44*	*61*	*1764*
Reflector	LED	20%	38%	36%	31%	22%
	CFL	4%	14%	2%	3%	4%
n (Total bulbs)		*2958*	*568*	*268*	*341*	*4135*
Specialty	LED	13%	19%	24%	17%	14%
	CFL	1%	2%	3%	9%	2%

10.3.2 Efficient Lighting Saturation by Room Type

Efficient lighting types (LED, CFL, and fluorescent bulbs) are most commonly found in laundry or utility rooms, garages, and basements or crawl spaces in the statewide sample (Table 154). Attics, dining rooms, hallways or entry ways, and home exteriors have the lowest level of efficient socket saturation, all under 40%. Since efficient bulbs provide the most savings in rooms with higher hours of use (HOU), the relatively low efficient saturations in living rooms, dining rooms, and home exteriors stand out as opportunities for further progress.[114]

Table 154: Efficient Lighting Saturation by Room Type

Room	Detached Single-family		Attached Single-family		Manufactured/ Mobile		Multifamily		Statewide	
	n		*n*		*n*		*n*		*n*	
Laundry/ Utility	*161*	70%	*22*	50%	*27*	41%	*31*	81%	*241*	72%
Garage	*371*	67%	*82*	74%	*2*	50%	*11*	100%	*466*	71%
Basement	*1401*	65%	*219*	69%	*48*	69%	*52*	69%	*1720*	67%
Kitchen	*988*	59%	*283*	68%	*112*	57%	*201*	65%	*1584*	61%
Other	*66*	50%	*14*	71%	*2*	100%	*17*	24%	*99*	52%
Bedroom	*1588*	45%	*415*	55%	*187*	54%	*272*	50%	*2462*	49%
Living Room	*1248*	46%	*285*	52%	*145*	62%	*239*	57%	*1917*	48%
Bathroom	*1238*	41%	*323*	47%	*161*	37%	*268*	53%	*1990*	45%
Closet	*217*	41%	*58*	74%	*13*	31%	*42*	60%	*330*	45%
Office	*243*	41%	*77*	58%	*30*	67%	*7*	29%	*357*	44%
Exterior	*857*	38%	*152*	48%	*75*	47%	*46*	61%	*1130*	38%
Foyer/ Hallway	*738*	31%	*202*	47%	*52*	46%	*117*	61%	*1109*	38%
Dining Room	*642*	29%	*158*	42%	*37*	51%	*108*	43%	*945*	36%
Attic	*85*	31%	*11*	18%	--	--	*2*	--	*98*	35%

10.3.3 Average Bulb Type Saturation Per Home

Table 155 shows the average saturation of each bulb type on a per home basis (i.e., the percent of sockets that have a given bulb type in an average home). Overall, 55% of sockets in the average home had efficient bulbs (i.e., LED, CFL, or fluorescent). On average, 22% of sockets in a home had LED bulbs and 23% had CFL bulbs. Incandescent bulbs were installed in 38% of sockets per home.

[114] The Pennsylvania TRM lists living rooms, dining rooms, and exteriors as rooms with high HOU relative to other locations in the home. http://www.puc.pa.gov/filing_resources/issues_laws_regulations/act_129_information/technical_reference_manual.aspx

Table 155: Average Bulb Type Saturation Per Home

Bulb Type	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*145*	*48*	*26*	*70*	*289*
LED	20%	23%	23%	21%	22%
CFL	19%	25%	21%	28%	23%
Fluorescent	11%	11%	5%	8%	10%
Incandescent	44%	35%	45%	33%	38%
Halogen	4%	2%	1%	4%	3%
Empty Sockets	3%	5%	4%	6%	3%

10.4 Common Area Lighting Penetration

Statewide, LED bulbs were found in 41% of multifamily common areas.[115] CFLs were the most common lighting technology observed in common areas statewide (63%). PPL had the highest LED penetration rate at 67%, followed by FE: Met-Ed at 57%. The highest penetration rates for CFLs were found in PECO and FE: Penn Power sites (86% and 80%, respectively). Incandescent bulb penetration rates for EDCs were much lower in common areas compared to single-family and multifamily in-unit residences (Table 156). Counts are presented for groups with sample sizes less than ten.

[115] Note that halfway through the study, the SWE team switched to recruiting occupants rather than property managers and thus did not have access to all common areas.

Table 156: Shared Space Lighting Penetration by EDC

EDC	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*7*	*9*	*10*	*7*	*2*	*5*	*3*	*43*
LED	3 (43%)	6 (67%)	10%	4 (57%)	--	1 (20%)	--	41%
CFL	6 (86%)	5 (56%)	30%	4 (57%)	--	4 (80%)	2 (67%)	63%
Fluorescent	2 (29%)	6 (67%)	60%	3 (43%)	--	3 (60%)	2 (67%)	46%
Incandescent	5 (71%)	3 (33%)	30%	4 (57%)	1 (50%)	2 (40%)	--	48%
Halogen	2 (29%)	2 (22%)	10%	--	1 (50%)	4 (80%)	2 (67%)	27%
High Pressure Sodium	--	1 (11%)	--	1 (14%)	--	--	--	5%
Metal Halide	2 (29%)	--	--	--	--	--	--	10%

Multifamily buildings with 50+ units had the highest level of LED and fluorescent bulb penetration in common area lighting (40% and 90%). Buildings with 2-4 units and 5-19 units had high incandescent bulb penetration (71% and 50%, respectively). Counts are presented for groups with sample sizes less than ten.

Table 157: Common Area Lighting Penetration by Building Size

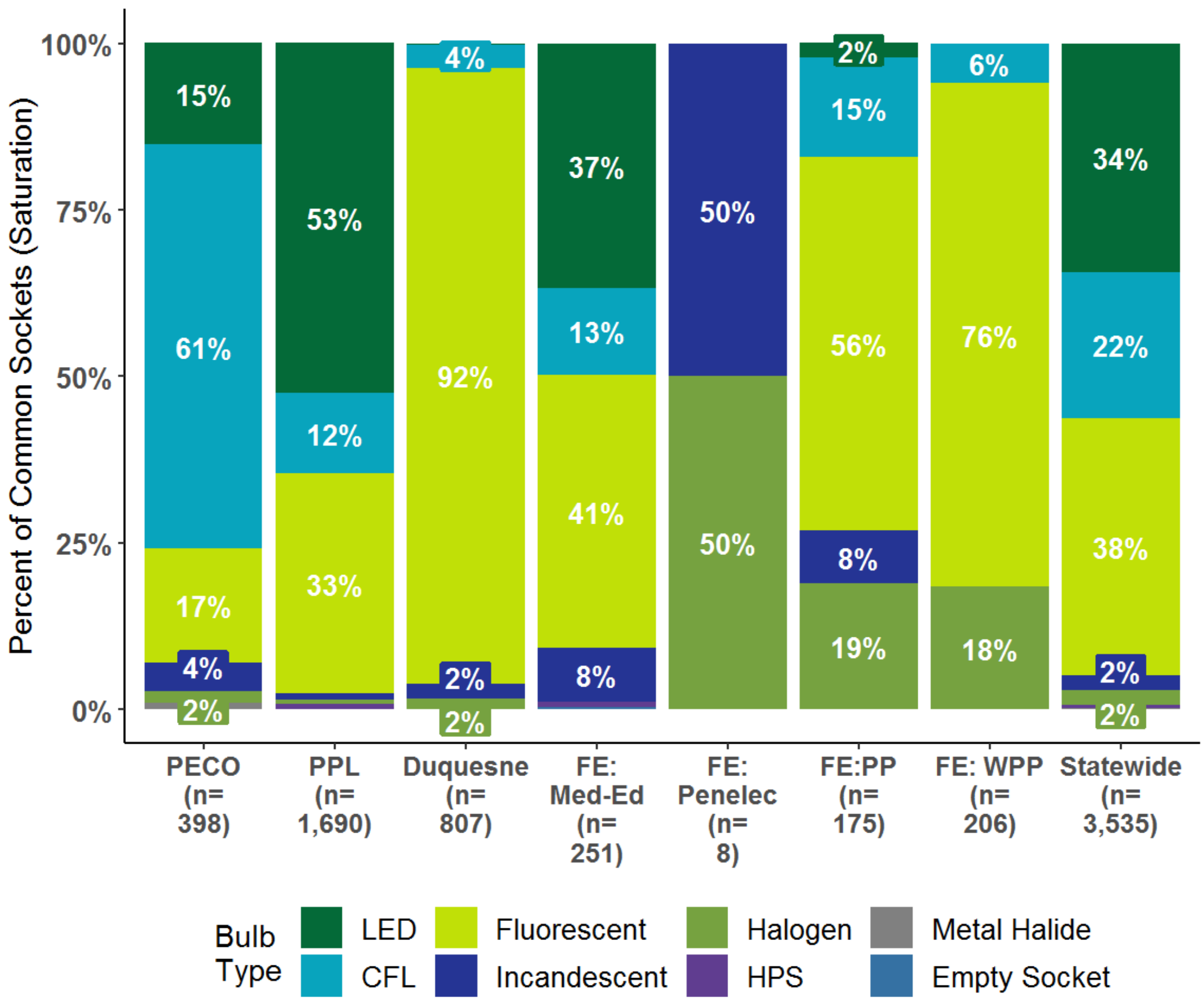
Bulb Type	2-4 units	5-19 units	20-49 units	50+ units	Statewide
n	*7*	*20*	*6*	*10*	*43*
LED	3 (43%)	35%	1 (17%)	40%	41%
CFL	5 (71%)	55%	4 (67%)	40%	63%
Fluorescent	1 (14%)	40%	4 (67%)	90%	46%
Incandescent	5 (71%)	50%	1 (17%)	20%	48%
Halogen	1 (14%)	35%	2 (33%)	20%	27%
HPS	--	5%	--	10%	5%
Metal Halide	--	5%	--	10%	10%

10.5 Common Area Lighting Saturation

Fluorescent bulbs filled the most common area lighting sockets statewide (38%; see Figure 30). LED bulbs were the second most common lighting technology, filling 34% of sockets. LED, CFL, and fluorescent bulbs were installed at much higher rates than incandescent and halogen bulbs. Common area LED bulb saturation was higher than the LED saturation rate in single-family and in-unit sockets (34% vs. 20%, See Figure 29). One likely reason for higher LED saturation rates in common space relative to single-family homes and multifamily housing units is that property managers or building owners are responsible for paying electricity bills for common areas.

PPL has the highest saturation of LED bulbs installed in common space at 53%, significantly higher than all other EDCs. The higher LED saturation levels found in PPL common areas may be due to adopting LED incentives into programs earlier than other EDCs in the state. Duquesne had 92% of common area sockets filled with fluorescent bulbs. No LED bulbs were installed in the common areas of Duquesne, FE: West Penn, and FE: Penelec sites.[116]

Figure 30: Common Space Light Bulb Saturation by EDC

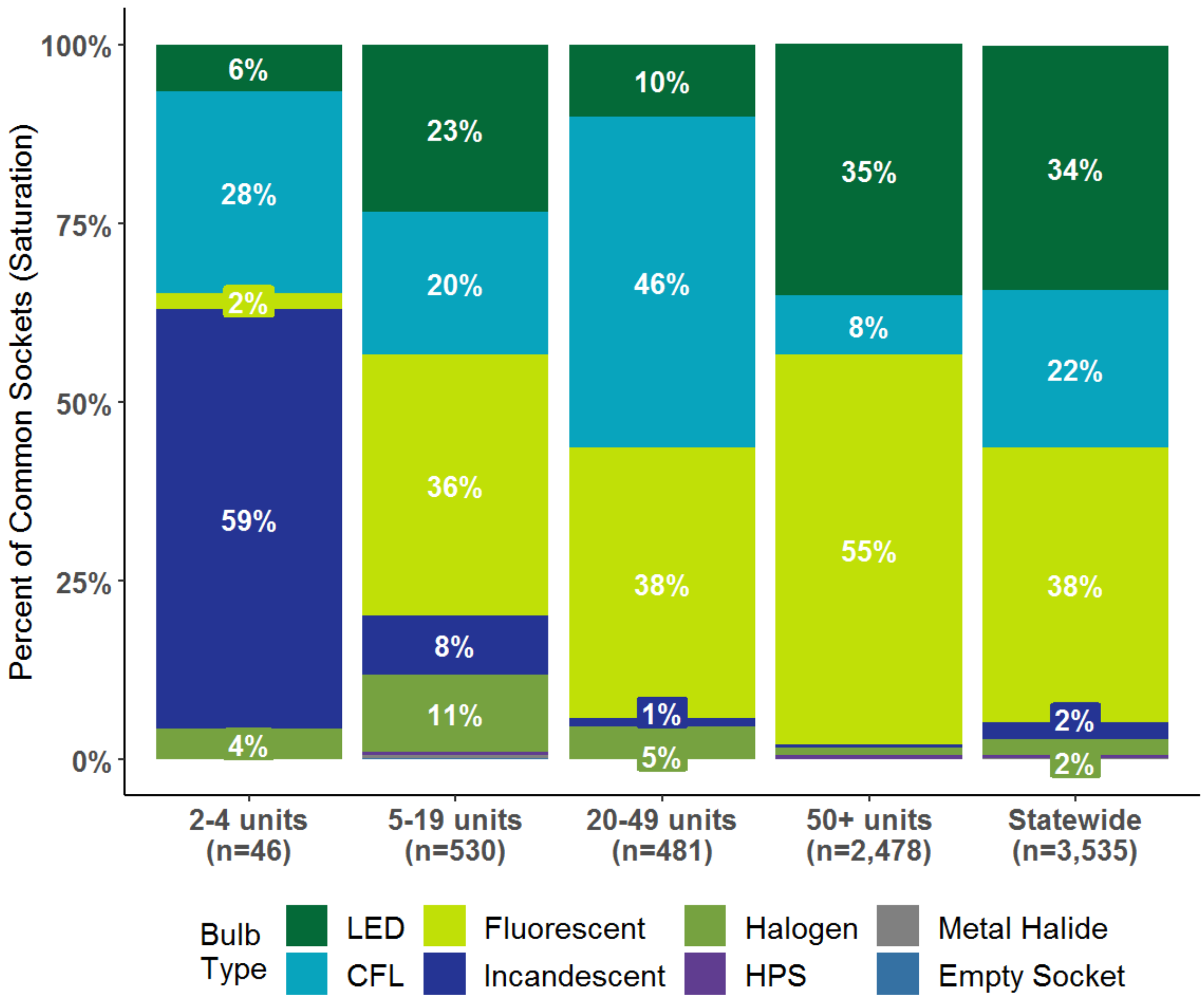


[116] Shared space lighting was not applicable for a majority of the FE: Penelec multifamily sample. There were two cases where the auditor only had access to the in-unit lighting.

Large multifamily buildings drive saturation results in common areas due to larger socket counts. Buildings with 50+ units are only 24% of the sample but account for 70% of the sockets in this analysis. Fluorescent bulbs hold the largest share of sockets in multifamily buildings with over 50 units (55%). Large multifamily buildings (50+ units) had significantly higher LED saturation rates (35%) than all other building sizes. Multifamily buildings with 20-49 units have a significantly higher CFL socket saturation than other building sizes. Smaller multifamily buildings had more incandescent and halogen bulbs filling common area sockets; however, statewide incandescent and halogen bulbs accounted for only 4% of common area sockets (Figure 31).

Figure 31: Bulb Type Saturation by Building Size

(Base: Sockets)



Section 11 Electronics

This section presents findings on electronics recorded during onsite visits. To ensure electronics were identified consistently, auditors asked occupants about laptops and other portable electronics that might not have been present or visible during audits. Primary electronics types were televisions, computers, and advanced power strips. Peripheral equipment included set-top boxes, video players, and printers. Auditors recorded information on the type of television and computer, as well as ENERGY STAR status for all eligible equipment. Note that auditors were shown vacant units on multiple occasions when performing multifamily audits, in which case electronics were not present, reducing the sample sizes in the tables that follow.

Key Findings:

- On average, homes have 2.6 televisions
- Thirty-one percent of televisions are ENERGY STAR qualified
- Fifteen percent of computers are ENERGY STAR qualified

Table 158 shows the number of TVs per home in the sample. It was common for homes to have either two (30%) or three (29%) TVs in the home, and the statewide average was 2.6 per home.

Table 158: Number of Televisions per Home

Number of TVs	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*144*	*48*	*26*	*63*	*281*
0	1%	4%	4%	3%	2%
1	16%	13%	23%	35%	18%
2	27%	23%	46%	41%	30%
3	26%	35%	12%	16%	29%
4	17%	17%	15%	5%	13%
5+	13%	8%	--	--	9%
Average	**2.9**	**2.8**	**2.1**	**1.8**	**2.6**

Almost 60% of televisions observed statewide are between 30 and 50 inches (Table 159). Fifty-three percent of TV screens statewide measure less than 40 inches. When looking at just flat screen (LED, LCD, and plasma) televisions, screens shift slightly toward larger sizes, with 52% of that sample having screens 40 inches or larger (Table 160).

Table 159: Television Screen Size

(Base: Televisions)

Screen Size	Detached Single-family	Attached Single-family	Manufactured / Mobile	Multifamily	Statewide
n	*415*	*134*	*55*	*116*	*720*
< 20“	8%	5%	9%	5%	7%
20“-29”	19%	19%	31%	16%	18%
30“-39”	26%	32%	31%	22%	28%
40“-49”	30%	25%	16%	38%	30%
50“-59”	12%	13%	9%	18%	13%
60" & Up	6%	5%	4%	2%	5%

Table 160: Flat Screen TV Screen Size

(Base: Televisions[1])

Screen Size	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*359*	*117*	*40*	*103*	*619*
< 20“	5%	3%	3%	3%	4%
20“-29”	15%	16%	18%	12%	15%
30“-39”	27%	33%	43%	21%	29%
40“-49”	34%	27%	22%	42%	33%
50“-59”	13%	15%	10%	20%	14%
60" & Up	6%	6%	5%	2%	5%

[1]Includes LED, LCD, and plasma TVs.

Half of computers observed statewide were laptops, and 36% were desktops. Tablet computers such as iPads or Kindles made up the remaining 14% of computers recorded (Table 161).

Table 161: Computer Types

(Base: Computers)

Type	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*244*	*69*	*26*	*57*	*396*
Laptop	48%	51%	65%	39%	51%
Desktop	40%	38%	23%	33%	36%
Tablet	12%	12%	12%	28%	14%

Statewide, almost every home (98%) had a television, and almost 70% had a computer (Table 162). The most common television peripheral in homes were set-top boxes (in 76% of homes), followed by DVD or Blu-Ray players (in 57% of homes). Printers were found in about half of homes statewide. Auditors also recorded smart power strips during onsite visits – the statewide penetration rate for smart power strips was 5%.

Table 162: Penetration Rates for Electronics

Equipment Type	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*144*	*48*	*26*	*63*	*281*
Television	99%	96%	96%	97%	98%
Set Top Box	87%	65%	69%	57%	76%
Computer	80%	75%	50%	46%	68%
DVD Player[1]	67%	56%	42%	52%	57%
Smart Power Strip	5%	0%	4%	3%	5%
Printer	63%	67%	38%	22%	49%
Game Console	37%	50%	15%	33%	37%
Sound System	19%	19%	8%	13%	19%

[1]Includes DVD and Blu-Ray players.

ENERGY STAR status can be difficult to confirm while onsite. Typically, auditors rely on visual confirmation of the ENERGY STAR symbol on the equipment, as it can be difficult to access equipment nameplates while in the home or verify status after the fact. The table below displays confirmed ENERGY STAR saturation among the major equipment types recoded during onsite audits. The reliance on visual confirmation of ENERGY STAR status means that these values realistically represent a lower bound for ENERGY STAR saturation among electronics in the sample.

Table 163: Confirmed ENERGY STAR Saturation for Electronics

Type	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n	*416*	*134*	*55*	*116*	*721*
Television	32%	28%	26%	35%	31%
n	*244*	*69*	*26*	*57*	*396*
Computer	14%	15%	8%	4%	15%
n	*107*	*40*	*12*	*14*	*173*
Printer	70%	73%	75%	79%	73%
n	*277*	*64*	*28*	*53*	*422*
Set-Top Box	13%	2%	18%	3.8%	11%
n	*55*	*10*	*2*	*10*	*77*
Monitor	27%	40%	–	20%	27%
n	*140*	*40*	*15*	*39*	*234*
DVD player	21%	20%	7%	41%	24%

Section 12 Willingness to Pay Survey

As part of the residential baseline study, the SWE team conducted a willingness-to-pay survey with a member of the participating household during the site audits. The willingness-to-pay survey provided insight on factors that are important to customers when deciding between standard and higher efficiency options, their likelihood to purchase higher efficiency options based under several different payback period scenarios, and the importance of service and program assistance that utilities can provide. While the findings from this exercise are presented in this report, these findings will be used as inputs in the follow-up market potential study of residential customers.

Key findings:

- Respondents prioritize the following:
  - Performance;
  - Electricity bill savings;
  - Cost and savings information, especially for air sealing and insulation; and
  - Improved reliability and reduced maintenance costs for all other measures, particularly for heat pumps and water heaters.
- On average, respondents reported high likelihoods to purchase energy-efficient measures if the utility covers the additional purchase cost of the higher efficiency option.
- Central air conditioning, air sealing, insulation, and heat pumps had the highest purchase likelihoods for all three payback periods. Room air conditioners had the lowest likelihood.
- The three most important services utilities can offer, according to respondents, are as follows:
  - Cash rebates;
  - Ensuring contractors and retail stores offer high-efficiency options and competitive pricing; and
  - Free or low-cost energy audits.

12.1 Survey Details

Field technicians administered the willingness-to-pay survey with each participant during the site visit. First, the technician would verify the presence of central air conditioning, a heat pump, or electric resistance heat in the home. The presence of these determined the eligible efficient measures for the respondent. The survey tool would then randomly choose a measure from the eligible measures and update the survey language appropriately. Measures were divided into two categories, as indicated in Table 164. Category 1 measures received higher priority due to their higher potential for savings. The survey tool would select a Category 2 measure only if the respondent was ineligible for any of the Category 1 measures. Table 165 indicates the number of responses by measure.[117]

Table 164: Efficient Measures in Survey

Measure Category	Measure	Measure eligible if home has:
1	Central air conditioner	CAC
	Heat pump	Heat pump
	Insulation	Electric heat, CAC, or heat pump
	Air sealing	Electric heat, CAC, or heat pump
2	Refrigerator	
	Clothes washer	
	Room air conditioner	Neither CAC or heat pump
	Water heater	

Table 165: Responses by Measure

	Air Sealing	CAC	Clothes Washer	Heat Pump	Insulation	RAC	Refrigerator	Water Heater	Total*
Number of Responses	44	34	47	33	41	30	34	34	297

* Total of 297 measure responses from 262 respondents. Some respondents answered survey questions for multiple measures.

The survey included a battery of three questions. The first question asked respondents to rate the importance, on a scale of 0 to 10, of a list of factors that might influence their decision to purchase the higher efficiency option. The second question asked respondents to rate their likelihood to purchase the higher efficiency measure given a payback period of four years, two years, one year, or if the utility covered the entire cost difference. The final question asked respondents to rate the importance of a list of possible utility services or programs designed to assist them in purchasing higher efficiency equipment. The survey instrument is included in Appendix L.

12.2 Factors Influencing Higher Efficiency Decisions

Evaluators asked respondents to rate the importance of factors when deciding between standard and higher efficiency options on a scale of 0 (not at all important) to 10 (extremely important). Table 166 shows average respondent ratings by measure and factor for air sealing and insulation. Confidence in the performance of the new measure (average of 8.4 out of 10) and its electricity savings (average of 8.3 out of 10) are the two highest ranked factors for respondents' decision to

[117] The number of responses exceeds the number of site visits because in the initial implementation of the survey respondents were asked to complete the survey for up to three different measures. This proved to be burdensome for respondents so the SWE team decided to reduce the survey to a single measure in the interest of improving response rates and response quality. All respondents after 2/27/2018 were asked about a single measure.

install the higher efficiency option. Less important are immediate availability of the measure (6.1 out of 10) and time to conduct research (5 out of 10).

Table 166: Higher Efficiency Deciding Factors – Air Sealing and Insulation[1]

Deciding Factors	Air Sealing (n=39)	Insulation (n=35)
Confidence that the new measure will perform as well as old measure	8.2	8.7
Confidence that the measure will yield expected electricity bill savings.	7.9	8.8
Having adequate information on the costs and savings of the measure	8.2	8.3
The purchase price of the measure	7.9	7.3
Enhanced experience resulting from the measure	7.4	7.6
Time required to research and review options and obtain price quotes	6.4	5.9
Immediate availability of the measure	5.2	4.7

[1] The shaded boxes in the table correspond to the average ratings, ranging from dark green for most important to light yellow for least important.

For all other measures, Table 167 shows the average customer rating by measure and factor for non-air sealing and insulation measures. Improved reliability and lower maintenance costs (average of 8.4 out of 10), confidence in the electricity bill savings (average of 8.1 out of 10), and the performance of the new measure (average of 8.1 out of 10) are the three highest ranked factors for respondents' decision to install the higher efficiency option. Time to conduct research (average of 6.3 out of 10) and immediate measure availability (average of 6.4 out of 10) were least important.

Table 167: Higher Efficiency Deciding Factors – Non-air Sealing and Insulation Measures[1]

Deciding Factors	CAC (n=33)	Clothes Washer (n=43)	Heat Pump (n=33)	RAC (n=22)	Refrig-erator (n=29)	Water Heater (n=31)
Improved reliability and lower maintenance costs of the high-efficiency option	8.3	8.3	8.7	8.1	8.0	8.7
Confidence that the higher efficiency option will yield the expected electricity bill savings	8.0	8.2	7.9	8.0	8.0	8.6
Confidence that the higher efficiency option will perform as well as the standard option	7.9	8.0	8.3	8.2	8.0	8.3
Having adequate information on the costs and savings of the higher efficiency option	7.9	8.3	7.8	6.5	7.6	8.1
The difference in purchase price between the high-efficiency and standard option	6.8	6.7	6.7	7.1	7.9	7.3
Enhanced performance and features of the higher efficiency option	7.9	6.8	7.1	7.3	5.9	6.4
Immediate availability of the measure	6.0	6.7	6.1	5.6	6.3	7.5
Time required to research and review options and obtain price quotes	5.8	6.7	6.2	5.4	6.3	6.7

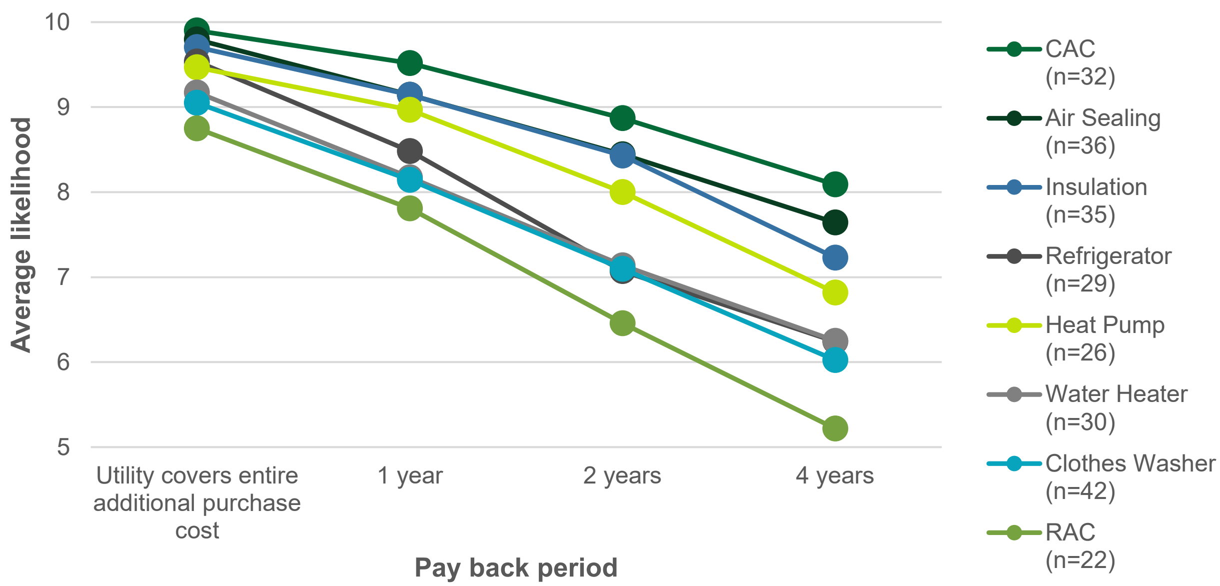
[1] The shaded boxes in the table correspond to the average ratings ranging from dark green for most important to light yellow for least important.

12.3 Likelihood to Purchase by Payback Period

Evaluators asked respondents to indicate how likely they are to purchase higher efficiency measures under various payback conditions on a scale of 0 (not at all likely) to 10 (extremely likely). Figure 32 shows that a higher efficiency CAC was most likely to be purchased, while a higher efficiency RAC was least likely if the respondents' electric utility covered the entire additional purchase cost of the higher efficiency option.

When asked about their likelihood to purchase high-efficiency measures with one, two, and four-year payback periods, respondents indicated the higher efficiency CAC, air sealing, and insulation had the highest purchase likelihood. Higher efficiency RACs were least likely to be purchased with one, two, and four-year payback periods followed by clothes washers.

Figure 32: Likelihood to Purchase Higher Efficiency Measures by Payback Period



12.4 Utility Service and Program Assistance

When asked to rate the importance of services or programs provided by utilities to assist with purchasing higher efficiency equipment, respondents answered on a scale of 0 (not at all important) to 10 (extremely important). Respondents indicated the three most important services and programs that utilities can offer are cash rebates, ensuring contractors and retail stores offer high-efficiency options at competitive pricing, and free or low-cost energy audits (Table 168). CAC and refrigerator respondents provided the highest ratings (9.3 and 9.1 out of 10, respectively) to cash rebates, indicating the service is of great importance. Respondents provided the lowest importance ratings for educational campaigns, low cost financing, and case studies.

Overall, insulation and water heating respondents provided the highest importance ratings (7.7 out of 10) for all services and programs offered by utilities, whereas services and programs were less important to heat pump respondents (7.1 out of 10).

Table 168: Utility Services and Programs Assistance by Importance[1]

Types of Services and Programs Assistance	Air Sealing (n=34)	CAC (n=33)	Clothes Washer (n=40)	Heat Pump (n=33)	Insul-ation (n=35)	RAC (n=21)	Refrig-erator (n=28)	Water Heater (n=31)
Cash rebate to reduce the larger purchase cost of the high-efficiency option.	8.8	9.3	8.3	8.0	8.7	8.5	9.1	8.6
Ensure that contractors and retail stores offer high-efficiency options at competitive pricing.	7.9	8.1	7.9	7.8	8.5	8.0	8.2	8.5
Free or low-cost energy audit of your home to identify efficiency opportunities and provide customized estimates of their costs and savings.	8.1	7.8	8.3	8.1	8.1	8.4	7.8	8.4
Information to help you understand your choices, costs, and savings from installing higher efficiency options.	7.8	7.7	7.5	7.3	7.7	7.7	7.6	7.5
Case studies of other residents that installed the high-efficiency option, and the benefits and savings they achieved from participating in the programs.	6.7	7.2	6.7	6.8	7.5	6.5	6.0	7.2
Low cost financing to assist with the larger purchase cost of the high-efficiency option.	6.8	6.3	6.8	5.8	6.8	6.7	7.4	7.0
Educational campaign to inform you about high-efficiency products available in the market.	5.9	6.3	6.2	5.7	7.1	6.4	6.9	7.0

[1] The shaded boxes in the table correspond to the average ratings ranging from dark green for most important to light yellow for least important.

Appendix A Detailed Electricity Consumption Data

Table 169: Annual Electricity Consumption by EDC, Home Type, and Heating Fuel

EDC	Home Type	Heating Fuel	Consumption (MWh)	Customers	Per Customer (kWh)
PECO	Det. Single-family	Bottled, tank, or LP gas	368,281	31,276	11,775
PECO	Det. Single-family	Coal or coke	12,465	1,454	8,574
PECO	Det. Single-family	Electricity	1,150,817	78,856	14,594
PECO	Det. Single-family	Fuel oil, kerosene, etc.	1,528,563	156,393	9,774
PECO	Det. Single-family	No fuel used	13,131	935	14,039
PECO	Det. Single-family	Other fuel	35,433	2,883	12,290
PECO	Det. Single-family	Solar energy	6,183	342	18,077
PECO	Det. Single-family	Utility gas	3,134,054	273,863	11,444
PECO	Det. Single-family	Wood	74,871	7,715	9,705
PECO	Att. Single-family	Bottled, tank, or LP gas	36,475	4,793	7,610
PECO	Att. Single-family	Coal or coke	1,844	357	5,160
PECO	Att. Single-family	Electricity	782,043	75,245	10,393
PECO	Att. Single-family	Fuel oil, kerosene, etc.	313,376	40,620	7,715
PECO	Att. Single-family	No fuel used	11,938	1,559	7,656
PECO	Att. Single-family	Other fuel	6,195	612	10,121
PECO	Att. Single-family	Solar energy	545	118	4,619
PECO	Att. Single-family	Utility gas	3,259,528	402,586	8,096
PECO	Att. Single-family	Wood	3,615	435	8,307
PECO	Multifamily	Bottled, tank, or LP gas	23,402	5,052	4,633
PECO	Multifamily	Electricity	1,528	212	7,221
PECO	Multifamily	Fuel oil, kerosene, etc.	1,040,287	158,570	6,560
PECO	Multifamily	No fuel used	78,699	15,247	5,162
PECO	Multifamily	Other fuel	16,002	3,211	4,984
PECO	Multifamily	Utility gas	10,553	2,576	4,097
PECO	Multifamily	Wood	295	40	7,455
PECO	Multifamily	Bottled, tank, or LP gas	927,480	185,088	5,011
PECO	Multifamily	Coal or coke	627	119	5,247
PECO	Manuf./Mobile	Electricity	26,285	3,400	7,731
PECO	Manuf./Mobile	Fuel oil, kerosene, etc.	25,138	2,436	10,319
PECO	Manuf./Mobile	No fuel used	34,205	4,092	8,358
PECO	Manuf./Mobile	Other fuel	980	114	8,592
PECO	Manuf./Mobile	Solar energy	1,698	273	6,213
PECO	Manuf./Mobile	Utility gas	17,622	2,326	7,575
PECO	Manuf./Mobile	Wood	1,651	219	7,529
PPL	Det. Single-family	Bottled, tank, or LP gas	535,884	45,697	11,727
PPL	Det. Single-family	Coal or coke	303,826	29,338	10,356
PPL	Det. Single-family	Electricity	3,368,093	196,034	17,181

EDC	Home Type	Heating Fuel	Consumption (MWh)	Customers	Per Customer (kWh)
PPL	Det. Single-family	Fuel oil, kerosene, etc.	2,338,440	226,537	10,323
PPL	Det. Single-family	No fuel used	27,955	2,169	12,886
PPL	Det. Single-family	Other fuel	95,464	7,305	13,067
PPL	Det. Single-family	Solar energy	7,577	641	11,823
PPL	Det. Single-family	Utility gas	2,041,727	208,177	9,808
PPL	Det. Single-family	Wood	461,104	39,683	11,620
PPL	Att. Single-family	Bottled, tank, or LP gas	32,375	3,315	9,767
PPL	Att. Single-family	Coal or coke	37,405	4,128	9,061
PPL	Att. Single-family	Electricity	749,461	57,574	13,017
PPL	Att. Single-family	Fuel oil, kerosene, etc.	432,550	44,361	9,751
PPL	Att. Single-family	No fuel used	8,542	497	17,196
PPL	Att. Single-family	Other fuel	7,428	645	11,525
PPL	Att. Single-family	Utility gas	877,034	100,502	8,727
PPL	Att. Single-family	Wood	16,381	1,318	12,425
PPL	Multifamily	Bottled, tank, or LP gas	25,769	4,116	6,260
PPL	Multifamily	Coal or coke	8,794	1,525	5,766
PPL	Multifamily	Electricity	1,161,126	122,363	9,489
PPL	Multifamily	Fuel oil, kerosene, etc.	133,625	20,487	6,522
PPL	Multifamily	No fuel used	7,356	1,066	6,899
PPL	Multifamily	Other fuel	9,337	1,207	7,739
PPL	Multifamily	Utility gas	606	59	10,267
PPL	Multifamily	Wood	500,434	81,573	6,135
PPL	Multifamily	Bottled, tank, or LP gas	5,070	385	13,175
PPL	Manuf./Mobile	Coal or coke	116,874	12,008	9,733
PPL	Manuf./Mobile	Electricity	5,311	490	10,831
PPL	Manuf./Mobile	Fuel oil, kerosene, etc.	79,427	5,962	13,323
PPL	Manuf./Mobile	No fuel used	194,413	20,853	9,323
PPL	Manuf./Mobile	Other fuel	507	48	10,594
PPL	Manuf./Mobile	Solar energy	6,871	626	10,973
PPL	Manuf./Mobile	Utility gas	35,740	4,033	8,862
PPL	Manuf./Mobile	Wood	18,107	1,914	9,462
Duquesne	Det. Single-family	Bottled, tank, or LP gas	23,465	2,683	8,746
Duquesne	Det. Single-family	Coal or coke	1,168	149	7,845
Duquesne	Det. Single-family	Electricity	200,881	16,094	12,481
Duquesne	Det. Single-family	Fuel oil, kerosene, etc.	80,003	8,322	9,613
Duquesne	Det. Single-family	No fuel used	1,772	319	5,548
Duquesne	Det. Single-family	Other fuel	7,129	759	9,386
Duquesne	Det. Single-family	Solar energy	--	--	--
Duquesne	Det. Single-family	Utility gas	2,383,280	300,434	7,933
Duquesne	Det. Single-family	Wood	20,109	2,171	9,264
Duquesne	Att. Single-family	Bottled, tank, or LP gas	3,260	587	5,557
Duquesne	Att. Single-family	Electricity	53,902	6,032	8,936
Duquesne	Att. Single-family	Fuel oil, kerosene, etc.	4,840	585	8,278

EDC	Home Type	Heating Fuel	Consumption (MWh)	Customers	Per Customer (kWh)
Duquesne	Att. Single-family	No fuel used	261	75	3,459
Duquesne	Att. Single-family	Utility gas	276,457	45,079	6,133
Duquesne	Att. Single-family	Wood	73	16	4,460
Duquesne	Multifamily	Bottled, tank, or LP gas	8,009	2,155	3,717
Duquesne	Multifamily	Coal or coke	183	96	1,911
Duquesne	Multifamily	Electricity	293,140	48,551	6,038
Duquesne	Multifamily	Fuel oil, kerosene, etc.	2,827	621	4,554
Duquesne	Multifamily	No fuel used	5,910	1,254	4,711
Duquesne	Multifamily	Other fuel	7,341	1,516	4,843
Duquesne	Multifamily	Utility gas	460,179	90,559	5,082
Duquesne	Multifamily	Wood	--	5	--
Duquesne	Manuf./Mobile	Bottled, tank, or LP gas	3,982	546	7,288
Duquesne	Manuf./Mobile	Coal or coke	45	5	9,557
Duquesne	Manuf./Mobile	Electricity	11,651	943	12,352
Duquesne	Manuf./Mobile	Fuel oil, kerosene, etc.	11,390	1,366	8,338
Duquesne	Manuf./Mobile	No fuel used	--	--	--
Duquesne	Manuf./Mobile	Other fuel	680	82	8,312
Duquesne	Manuf./Mobile	Utility gas	12,227	1,767	6,919
Duquesne	Manuf./Mobile	Wood	--	149	--
FE: Met-Ed	Det. Single-family	Bottled, tank, or LP gas	277,175	22,909	12,099
FE: Met-Ed	Det. Single-family	Coal or coke	57,488	5,461	10,526
FE: Met-Ed	Det. Single-family	Electricity	1,096,749	65,509	16,742
FE: Met-Ed	Det. Single-family	Fuel oil, kerosene, etc.	1,000,700	95,304	10,500
FE: Met-Ed	Det. Single-family	No fuel used	12,687	903	14,052
FE: Met-Ed	Det. Single-family	Other fuel	40,917	3,081	13,281
FE: Met-Ed	Det. Single-family	Solar energy	1,687	275	6,141
FE: Met-Ed	Det. Single-family	Utility gas	1,070,325	107,333	9,972
FE: Met-Ed	Det. Single-family	Wood	182,037	15,986	11,387
FE: Met-Ed	Att. Single-family	Bottled, tank, or LP gas	12,510	1,245	10,045
FE: Met-Ed	Att. Single-family	Coal or coke	1,986	288	6,903
FE: Met-Ed	Att. Single-family	Electricity	261,472	19,908	13,134
FE: Met-Ed	Att. Single-family	Fuel oil, kerosene, etc.	161,840	15,620	10,361
FE: Met-Ed	Att. Single-family	No fuel used	1,940	158	12,240
FE: Met-Ed	Att. Single-family	Other fuel	820	100	8,190
FE: Met-Ed	Att. Single-family	Utility gas	415,215	49,625	8,367
FE: Met-Ed	Att. Single-family	Wood	3,576	347	10,318
FE: Met-Ed	Multifamily	Bottled, tank, or LP gas	7,985	1,348	5,924
FE: Met-Ed	Multifamily	Coal or coke	1,266	173	7,330
FE: Met-Ed	Multifamily	Electricity	317,166	36,070	8,793
FE: Met-Ed	Multifamily	Fuel oil, kerosene, etc.	50,704	7,417	6,837
FE: Met-Ed	Multifamily	No fuel used	3,593	441	8,156
FE: Met-Ed	Multifamily	Other fuel	2,994	685	4,371
FE: Met-Ed	Multifamily	Utility gas	436	30	14,292

EDC	Home Type	Heating Fuel	Consumption (MWh)	Customers	Per Customer (kWh)
FE: Met-Ed	Multifamily	Wood	161,493	27,743	5,821
FE: Met-Ed	Multifamily	Bottled, tank, or LP gas	3,233	137	23,520
FE: Met-Ed	Manuf./Mobile	Coal or coke	50,126	5,676	8,832
FE: Met-Ed	Manuf./Mobile	Electricity	459	38	12,039
FE: Met-Ed	Manuf./Mobile	Fuel oil, kerosene, etc.	39,708	2,946	13,481
FE: Met-Ed	Manuf./Mobile	No fuel used	73,466	8,035	9,143
FE: Met-Ed	Manuf./Mobile	Other fuel	126	13	9,874
FE: Met-Ed	Manuf./Mobile	Solar energy	3,401	334	10,180
FE: Met-Ed	Manuf./Mobile	Utility gas	30,091	3,492	8,617
FE: Met-Ed	Manuf./Mobile	Wood	5,149	561	9,172
FE: Penelec	Det. Single-family	Bottled, tank, or LP gas	179,552	19,751	9,091
FE: Penelec	Det. Single-family	Coal or coke	108,923	12,469	8,736
FE: Penelec	Det. Single-family	Electricity	585,736	43,097	13,591
FE: Penelec	Det. Single-family	Fuel oil, kerosene, etc.	666,952	76,151	8,758
FE: Penelec	Det. Single-family	No fuel used	9,127	746	12,238
FE: Penelec	Det. Single-family	Other fuel	44,269	4,660	9,500
FE: Penelec	Det. Single-family	Solar energy	1,279	121	10,575
FE: Penelec	Det. Single-family	Utility gas	1,319,505	175,630	7,513
FE: Penelec	Det. Single-family	Wood	299,198	32,788	9,125
FE: Penelec	Att. Single-family	Bottled, tank, or LP gas	2,744	393	6,984
FE: Penelec	Att. Single-family	Coal or coke	1,094	100	10,988
FE: Penelec	Att. Single-family	Electricity	41,576	4,091	10,164
FE: Penelec	Att. Single-family	Fuel oil, kerosene, etc.	23,496	2,807	8,372
FE: Penelec	Att. Single-family	No fuel used	383	48	8,047
FE: Penelec	Att. Single-family	Other fuel	630	66	9,612
FE: Penelec	Att. Single-family	Utility gas	67,108	10,318	6,504
FE: Penelec	Att. Single-family	Wood	3,205	293	10,928
FE: Penelec	Multifamily	Bottled, tank, or LP gas	8,190	1,530	5,353
FE: Penelec	Multifamily	Coal or coke	2,823	536	5,269
FE: Penelec	Multifamily	Electricity	217,737	27,625	7,882
FE: Penelec	Multifamily	Fuel oil, kerosene, etc.	22,697	3,523	6,442
FE: Penelec	Multifamily	No fuel used	2,283	603	3,784
FE: Penelec	Multifamily	Other fuel	3,334	610	5,464
FE: Penelec	Multifamily	Utility gas	40	3	13,428
FE: Penelec	Multifamily	Wood	193,528	40,080	4,829
FE: Penelec	Multifamily	Bottled, tank, or LP gas	4,050	304	13,309
FE: Penelec	Manuf./Mobile	Coal or coke	50,247	6,179	8,132
FE: Penelec	Manuf./Mobile	Electricity	4,480	493	9,096
FE: Penelec	Manuf./Mobile	Fuel oil, kerosene, etc.	41,145	3,602	11,424
FE: Penelec	Manuf./Mobile	No fuel used	106,378	13,719	7,754
FE: Penelec	Manuf./Mobile	Other fuel	1,189	108	10,973
FE: Penelec	Manuf./Mobile	Solar energy	5,271	539	9,786
FE: Penelec	Manuf./Mobile	Utility gas	83,163	12,672	6,563

EDC	Home Type	Heating Fuel	Consumption (MWh)	Customers	Per Customer (kWh)
FE: Penelec	Manuf./Mobile	Wood	21,961	2,634	8,336
FE: Penn Power	Det. Single-family	Bottled, tank, or LP gas	22,741	1,965	11,571
FE: Penn Power	Det. Single-family	Coal or coke	2,573	277	9,300
FE: Penn Power	Det. Single-family	Electricity	276,148	15,406	17,925
FE: Penn Power	Det. Single-family	Fuel oil, kerosene, etc.	119,351	10,327	11,557
FE: Penn Power	Det. Single-family	No fuel used	--	82	--
FE: Penn Power	Det. Single-family	Other fuel	7,939	688	11,539
FE: Penn Power	Det. Single-family	Solar energy	248	23	10,627
FE: Penn Power	Det. Single-family	Utility gas	811,277	76,642	10,585
FE: Penn Power	Det. Single-family	Wood	50,471	4,033	12,514
FE: Penn Power	Att. Single-family	Bottled, tank, or LP gas	381	41	9,187
FE: Penn Power	Att. Single-family	Coal or coke	86	12	7,333
FE: Penn Power	Att. Single-family	Electricity	14,258	1,162	12,268
FE: Penn Power	Att. Single-family	Fuel oil, kerosene, etc.	1,404	127	11,039
FE: Penn Power	Att. Single-family	No fuel used	--	3	--
FE: Penn Power	Att. Single-family	Other fuel	226	28	8,147
FE: Penn Power	Att. Single-family	Utility gas	40,108	4,985	8,045
FE: Penn Power	Att. Single-family	Wood	1,046	99	10,571
FE: Penn Power	Multifamily	Bottled, tank, or LP gas	1,099	197	5,579
FE: Penn Power	Multifamily	Coal or coke	60	5	12,221
FE: Penn Power	Multifamily	Electricity	84,423	8,021	10,526
FE: Penn Power	Multifamily	Fuel oil, kerosene, etc.	2,161	345	6,269
FE: Penn Power	Multifamily	No fuel used	893	180	4,950
FE: Penn Power	Multifamily	Other fuel	1,341	342	3,921
FE: Penn Power	Multifamily	Utility gas	62,321	11,068	5,631
FE: Penn Power	Multifamily	Wood	7	2	3,259
FE: Penn Power	Manuf./Mobile	Bottled, tank, or LP gas	16,041	1,551	10,341
FE: Penn Power	Manuf./Mobile	Coal or coke	428	35	12,406
FE: Penn Power	Manuf./Mobile	Electricity	28,213	1,770	15,939
FE: Penn Power	Manuf./Mobile	Fuel oil, kerosene, etc.	19,931	2,094	9,519
FE: Penn Power	Manuf./Mobile	No fuel used	474	18	26,603
FE: Penn Power	Manuf./Mobile	Other fuel	3,050	226	13,525
FE: Penn Power	Manuf./Mobile	Utility gas	16,499	2,135	7,728
FE: Penn Power	Manuf./Mobile	Wood	4,547	397	11,446
FE: West Penn	Det. Single-family	Bottled, tank, or LP gas	136,870	11,442	11,962
FE: West Penn	Det. Single-family	Coal or coke	71,920	6,056	11,876
FE: West Penn	Det. Single-family	Electricity	1,019,549	59,727	17,070
FE: West Penn	Det. Single-family	Fuel oil, kerosene, etc.	803,416	68,888	11,663
FE: West Penn	Det. Single-family	No fuel used	9,335	661	14,120
FE: West Penn	Det. Single-family	Other fuel	40,811	3,214	12,698
FE: West Penn	Det. Single-family	Solar energy	1,023	93	10,988
FE: West Penn	Det. Single-family	Utility gas	2,991,950	290,603	10,296
FE: West Penn	Det. Single-family	Wood	251,942	20,360	12,374

EDC	Home Type	Heating Fuel	Consumption (MWh)	Customers	Per Customer (kWh)
FE: West Penn	Att. Single-family	Bottled, tank, or LP gas	4,238	455	9,322
FE: West Penn	Att. Single-family	Coal or coke	1,087	73	14,871
FE: West Penn	Att. Single-family	Electricity	106,682	8,554	12,471
FE: West Penn	Att. Single-family	Fuel oil, kerosene, etc.	25,495	2,566	9,934
FE: West Penn	Att. Single-family	No fuel used	693	101	6,866
FE: West Penn	Att. Single-family	Other fuel	132	7	17,683
FE: West Penn	Att. Single-family	Utility gas	202,873	25,279	8,025
FE: West Penn	Att. Single-family	Wood	2,680	124	21,679
FE: West Penn	Multifamily	Bottled, tank, or LP gas	9,301	1,452	6,404
FE: West Penn	Multifamily	Coal or coke	1,327	144	9,239
FE: West Penn	Multifamily	Electricity	391,715	40,308	9,718
FE: West Penn	Multifamily	Fuel oil, kerosene, etc.	18,584	2,361	7,872
FE: West Penn	Multifamily	No fuel used	3,938	752	5,236
FE: West Penn	Multifamily	Other fuel	6,928	837	8,282
FE: West Penn	Multifamily	Utility gas	43	2	18,372
FE: West Penn	Multifamily	Wood	278,026	42,017	6,617
FE: West Penn	Multifamily	Bottled, tank, or LP gas	2,505	205	12,217
FE: West Penn	Manuf./Mobile	Coal or coke	50,681	5,001	10,135
FE: West Penn	Manuf./Mobile	Electricity	4,192	295	14,187
FE: West Penn	Manuf./Mobile	Fuel oil, kerosene, etc.	144,758	8,742	16,559
FE: West Penn	Manuf./Mobile	No fuel used	135,314	13,711	9,869
FE: West Penn	Manuf./Mobile	Other fuel	799	66	12,057
FE: West Penn	Manuf./Mobile	Solar energy	3,000	333	9,007
FE: West Penn	Manuf./Mobile	Utility gas	74,820	8,774	8,527
FE: West Penn	Manuf./Mobile	Wood	19,975	1,710	11,681

B

Appendix B Data Inputs

Table 171 through Table 175 detail the data inputs collected at each type of audit. Single-family diagnostic audits received full energy modeling and required the most comprehensive data collection including air leakage testing, duct leakage testing, and data on all envelope walls. Single-family basic audits were simplified and included only data on key measures such as exterior walls, appliances, lights, and mechanical equipment. Multifamily audits involved a similar level of data collection as the basic audits, with the addition of some shell measures and details on the ownership of the complex.

Table 171: Detailed Data Inputs: General Information

Measure	Single-family Diagnostic	Single-family Basic	Multifamily
House Type	✓	✓	✓
Vintage	✓	✓	✓
Stories	✓	✓	✓
Bedrooms	✓	✓	✓
Occupants	✓	✓	✓
Income Status	✓	✓	✓
Primary Heating Fuel	✓	✓	✓
Conditioned Floor Area	✓	✓	✓
Conditioned Volume	✓	✓	✓
Willingness to Pay Survey	✓	✓	✓

Table 172: Detailed Data Inputs: Insulation/Shell Measures

Measure	Single-family Diagnostic	Single-family Basic	Multifamily
Exterior Walls	✓	✓	✓
All Envelope Walls	✓		
Ceilings	✓	✓	✓
Frame Floors	✓	✓	✓
Rim/Band Joists	✓		✓
Windows	✓	✓	✓
Skylights	✓	✓	✓
Slab Floors	✓	✓	✓
Foundation Walls	✓	✓	✓

Table 173: Detailed Data Inputs: Mechanical Equipment

Measure	Single-family Diagnostic	Single-family Basic	Multifamily
Heating Equipment	✓	✓	✓
Water Heating Equipment	✓	✓	✓
Cooling Equipment	✓	✓	✓
Duct Insulation	✓	✓	✓
Renewables	✓	✓	✓
Faucets and Showerheads	✓	✓	✓

Table 174: Detailed Data Inputs: General Fixtures and Appliances

Measure	Single-family Diagnostic	Single-family Basic	Multifamily
Thermostats	✓	✓	✓
Faucets	✓	✓	✓
Lighting Type and Controls	✓	✓	✓
Electronics	✓	✓	✓
Refrigerators	✓	✓	✓
Dishwashers	✓	✓	✓
Ovens and Ranges	✓	✓	✓
Clothes Washers/Dryers	✓	✓	✓
Pools	✓	✓	✓

Table 175: Detailed Data Inputs: Diagnostic Testing

Measure	Single-family Diagnostic	Single-family Basic	Multifamily
Blower Door Tests	✓		
Duct Blaster Tests	✓		

C

Appendix C Detailed Diagnostic Results

This appendix splits diagnostic results (e.g., HERS Index score, ACH50, and duct leakage to outside) by additional factors such as heating fuel, income status, and EDC not shown in Section 5 Diagnostic Sub-Sample Results.

Table 176: HERS Index Score by Primary Heating Fuel

	Electricity	Natural Gas	Propane	Oil	Kerosene	Statewide
n	*30*	*29*	*6*	*5*	*2*	*72*
Min	76.0	68.0	75.0	103.0	125.0	68.0
Max	249.0	355.0	168.0	200.0	220.0	355.0
Mean	**127.0**	**139.2**	**109.5**	**151.6**	**172.5**	**132.3**
Median	110.5	121.0	108.5	138.0	172.5	119.5
Std. Dev.	43.8	57.9	34.0	42.9	67.2	50.0

Table 177: HERS Index Score by Low-income Status

	No	Yes	Refused	Total
n	*60*	*11*	*1*	*72*
Min	68.00	89.00	160	68.0
Max	355.00	220.00	160	355.0
Mean	**131.67**	**140.45**	**160**	**132.3**
Median	118.50	125.00	160	119.5
Std. Dev.	51.6	43.67	160	50.0

Table 178: HERS Index Score by EDC

	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*11*	*11*	*10*	*10*	*10*	*10*	*10*	*72*
Min	75.0	79.0	106.0	76.0	92.0	68.0	80.0	68.0
Max	222.0	200.0	355.0	182.0	220.0	186.0	149.0	355.0
Mean	**140.0**	**121.0**	**178.4**,	**119.9**[a]	**142.7**	**126.4**	**106.0**[a]	**132.3**
Median	128.0	109.0	167.0	115.5	131.5	119.0	99.5	119.5
Std. Dev.	48.4	40.7	75.5	35.2	49.8	41.31	21.4	50.0

[a] Significantly different from the Duquesne sample at the 95% confidence level.

Table 179: ACH50 by Primary Heating Fuel

	Electricity	Natural Gas	Propane	Oil	Kerosene	Total
n	*30*	*29*	*6*	*5*	*2*	*72*
Min	2.7	2.1	2.5	9.2	11.5	2.1
Max	25.9	25.1	46.5	31.9	18.4	46.5
Mean	**9.9**	**10.2**	**14.0**	**17.1**	**15.0**	**11.4**
Median	7.9	9.3	7.5	16.0	15.0	9.4
Std. Dev.	5.6	5.2	16.8	8.9	4.8	7.3

Table 180: ACH50 by EDC

	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*11*	*11*	*10*	*10*	*10*	*10*	*10*	*72*
Min	3.2	2.5	5.1	2.7	2.1	5.3	4.1	2.1
Max	25.1	25.9	46.5	17.0	32.0	18.6	11.9	46.5
Mean	**13.1**	**10.4**	**14.5**	**7.7**[a]	**13.6**	**9.4**	**8.0**[a]	**11.4**
Median	11.1	7.0	12.6	7.5	11.6	9.0	7.4	9.4
Std. Dev.	6.3	7.8	11.7	3.9	8.6	4.1	2.8	7.3

[a] Significantly different from the PECO sample at the 95% confidence level.

Table 181: Duct Leakage to Outside by Heating Fuel (CFM25/100 sq.ft.)

(Base = Systems)

	Electricity	Natural Gas	Propane	Oil	Kerosene	Total
n	*21*	*32*	*7*	*5*	*2*	*67*
Min	0.0	0.0	7.0	4.9	9.2	0.0
Max	30.6	43.4	24.0	23.5	13.0	43.4
Mean	**14.3**	**15.9**	**14.1**	**13.7**	**11.1**	**14.6**
Median	17.6	18.5	11.1	12.7	11.1	16.0
Std. Dev.	9.7	11.0	6.1	8.0	2.6	9.7

Table 182: Duct Leakage to Outside by Low-income Status (CFM25/100 sq.ft.)

(Base = Systems)

	Yes	No	Refused	Total
n	*5*	*61*	*1*	*67*
Min	1.8	0.0	32.6	0.00
Max	30.6	43.4	32.6	43.4
Mean	**13.9**	**14.7**	**32.6**	**14.6**
Median	13.0	16.8	32.6	16.0
Sd.	10.6	9.5	NA	9.7

Table 183: Duct Leakage to Outside by EDC (CFM25/100 sq.ft.)

(Base = Systems)

	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*12*	*8*	*11*	*9*	*9*	*11*	*7*	*67*
Min	0.00	1.83	0.00	4.25	0.60	0.00	0.00	0.0
Max	32.60	30.58	23.99	43.42	32.25	26.48	37.09	43.4
Mean	**15.9**	**11.4**	**15.7**	**16.3**	**15.3**	**13.0**	**16.7**	**14.6**
Median	18.77	9.71	20.21	14.96	12.95	17.12	20.14	16.0
Std. Dev.	9.01	8.79	8.54	11.60	9.64	9.89	13.11	9.7

Appendix D Building Envelope Results by EDC

D.1 Above Grade Walls

D.1.1 Primary Wall Insulation

Table 184: Primary Ambient Wall Insulation by EDC

Insulation Type	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*46*	*44*	*51*	*38*	*38*	*32*	*39*	*288*
Fiberglass Batts (FGB)	41%	59%	43%	55%	55%	72%	74%	52%
None	50%	23%	39%	26%	26%	9%	18%	34%
FGB + Rigid Foam	9%	14%	2%	5%	5%	3%	5%	7%
Dense-pack Cellulose	--	--	8%	3%	11%	3%	--	3%
Rigid Foam	--	4.5%	2.0%	--	--	3%	3%	2%
Closed-cell Spray Foam	--	--	2%	3%	--	--	--	1%
Rock Wool Batts	--	--	2%	3%	--	3%	--	1%
Open-cell Spray Foam	--	--	--	--	3%	3%	--	<1%
Blown-in Fiberglass	--	--	--	3%	--	3%	--	<1%
Closed-cell Spray Foam + FGB	--	--	--	3%	--	--	--	<1%
Urea-formaldehyde Foam (UFFI)	--	--	2%	--	--	--	--	<1%

D.1.2 Average R-value

Table 185: Average Ambient Wall R-values by EDC

R-value	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*46*	*44*	*50*	*38*	*38*	*32*	*39*	*287*
Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Maximum	19.0	26.0	21.0	20.8	19.8	23.5	23.1	26.0
Mean	**6.1**	**11.1**	**7.3**	**9.7**	**9.0**	**12.2**	**11.6**	**8.6**
Median	2.7	11.2	9.3	11.0	10.2	12.3	11.0	11.0
Std. Dev.	6.5	7.5	6.5	6.6	6.4	6.1	6.6	6.9

D.2 Ceilings

D.2.1 Flat Ceilings

D.2.1.1 Primary Flat Ceiling Insulation

Table 186: Primary Flat Ceiling Insulation by EDC

Insulation	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*41*	*39*	*37*	*32*	*32*	*30*	*37*	*248*
Fiberglass batts (FGB)	44%	41%	60%	47%	41%	70%	54%	45%
None	24%	10%	16%	3%	25%	--	3%	17%
Blown-in Fiberglass	12%	23%	8%	31%	3%	13%	16%	15%
Cellulose	7%	18%	5%	13%	25%	10%	14%	14%
Cellulose + FGB	--	3%	3%	3%	3%	3%	3%	2%
Blown-in Fiberglass + FGB	--	3%	5%	3%	--	--	3%	2%
Blown-in Rock Wool	5%	--	--	--	--	--	3%	2%
Vermiculite	2%	--	--	--	--	--	3%	1%
Rock Wool Batts	--	3%	--	--	3%	--	--	1%
FGB + Rigid Foam	5%	--	--	--	--	--	--	1%
Rigid Foam	--	--	3%	--	--	--	3%	1%
Open-cell Spray Foam	--	--	--	--	--	3%	--	<1%

D.2.1.2 Flat Ceiling Average R-value

Table 187: Average Flat Ceiling R-value by EDC

R-value	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*40*	*38*	*37*	*32*	*32*	*30*	*37*	*246.0*
Minimum	0	0	0	0	0	8	0	0
Maximum	43	39	43	49	54	47	44	54
Mean	**15.2**	**23.9**	**17.6**	**21.9**	**15.9**	**27.2**	**24.9**	**19.6**
Median	12	25	18	20	14	30	25	19
Std. Dev.	12.6	12.2	11.5	12.2	13.5	10.4	10.4	12.5

D.2.2 Vaulted Ceilings

D.2.2.1 Primary Vaulted Ceiling Insulation

Table 188: Primary Vaulted Ceiling Insulation by EDC

Insulation	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*11*	*12*	*20*	*17*	*14*	*10*	*12*	*96*
FGB	91%	75%	60%	88%	43%	80%	75%	73%
None + None	--	8%	20%	6%	43%	20%	17%	17%
Cellulose	9%	17%	--	6%	14%	--	--	7%
FGB + Vermiculite, Loose Fill	--	--	--	--	--	--	8%	2%
Rigid Foam	--	--	15%	--	--	--	--	1%
Blown-in Fiberglass	--	--	5%	--	--	--	--	1%

D.2.2.2 Vaulted Ceiling Average R-value

Table 189: Average Vaulted Ceiling R-value by EDC

R-value	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*11*	*12*	*20*	*17*	*14*	*10*	*12*	*96*
Minimum	6	0	0	0	0	0	0	0
Maximum	30	38	32	28	30	38	37	38
Mean	**18.2**	**22.3**	**17.7**	**16.1**	**12.4**	**20.8**	**19.2**	**17.6**
Median	17	20	19	17	15	19	19	19
Std. Dev.	8.5	9.4	10.7	7.3	12.0	12.8	12.1	10.6

D.3 Frame Floors

D.3.1 Primary Insulation Type

Table 190: Primary Frame Floor Insulation Type by EDC

Insulation	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*30*	*25*	*26*	*24*	*26*	*9*	*23*	*163*
None	73%	60%	85%	50%	73%	8 (89%)	70%	75%
Fiberglass Batts (FGB)	20%	36%	15%	50%	23%	1 (11%)	30%	22%
Rigid Foam	--	4%	--	--	4%	--	--	2%
Rock Wool Batts	3%	--	--	--	--	--	--	1%
FGB + Mobile Home Wrap	3%	--	--	--	--	--	--	<1%

D.3.2 Average R-value

Table 191: Average Frame Floor R-value by EDC

	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*30*	*25*	*26*	*24*	*26*	*9*	*23*	*163*
Minimum	0	0	0	0	0	0	0	0
Maximum	25	30	19	30	23	11	30	30
Mean	**3.9**	**7.0**	**1.9**	**8.3**	**4.1**	**1.4**	**6.6**	**4.0**
Median	0	0	0	6	0	0	0	0
Std. Dev.	7.3	9.8	5.4	9.3	7.7	3.6	11.2	8.5

D.4 CONDITIONED FOUNDATION WALLS

D.4.1 Primary Foundation Wall Insulation

Table 192: Primary Foundation Wall Insulation by EDC

Insulation	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*18*	*14*	*18*	*21*	*12*	*19*	*13*	*115*
None	78%	43%	56%	43%	25%	47%	23%	49%
Fiberglass Batts (FGB)	17%	36%	17%	48%	50%	37%	46%	32%
Rigid Foam	6%	14%	28%	5%	25%	5%	15%	14%
FGB + Rigid Foam	--	--	--	5%	--	--	15%	3%
Open-cell Spray Foam	--	7%	--	--	--	5%	--	2%
Closed-cell Spray Foam	--	--	--	--	--	5%	--	<1%

D.4.2 Average Foundation Wall R-value

Table 193: Average Foundation Wall R-value

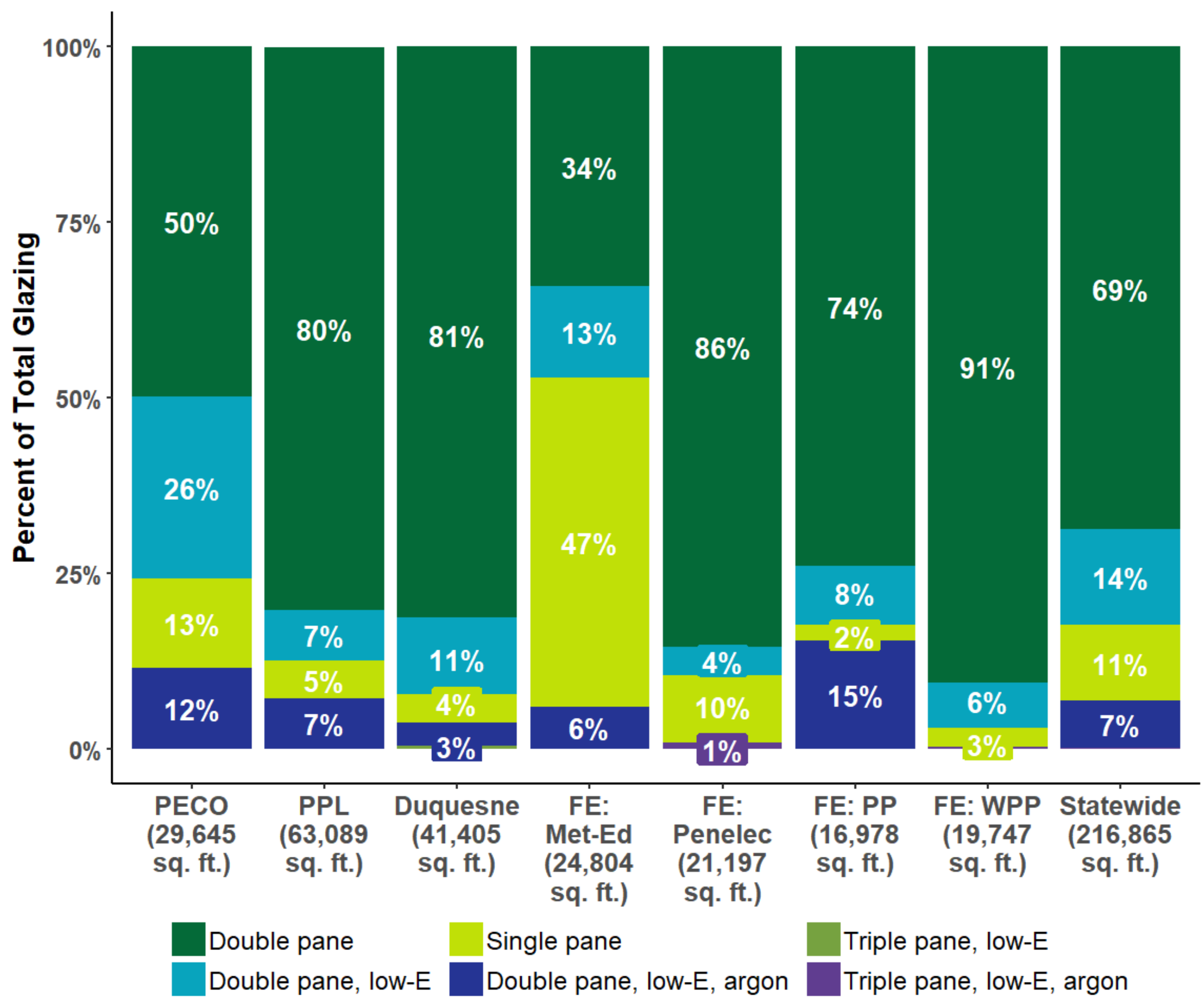
R-value	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*18*	*14*	*18*	*21*	*12*	*19*	*13*	*115*
Minimum	0	0	0	0	0	0	0	0
Maximum	13	20	13	19	19	33	25	33

Mean	**1.7**	**5.9**	**2.5**	**6.6**	**8.6**	**6.5**	**7.9**	**5.0**
Median	0	6	0	5	10	2	8	2
Std, Dev.	3.8	6.3	4.3	6.6	6.9	8.8	6.8	6.7

D.5 Windows

D.5.1 Glazing Types

Figure 33: Glazing Types by Window Square Footage (EDCs)



D.5.2 Exterior Glazing Percentages

Table 194: Glazing as a Percent of Exterior Wall Area (EDCs)

Glazing	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*46*	*44*	*51*	*39*	*38*	*32*	*39*	*289*
Minimum	7%	5%	6%	9%	7%	8%	7%	5%
Maximum	29%	25%	32%	35%	37%	30%	29%	37%
Mean	**16.7%**	**14.3%**	**14.2%**	**17.2%**	**13.0%**	**15.6%**	**15.4%**	**15.5%**
Median	16%	15%	13%	17%	13%	15%	15%	15%
Std. Dev.	4.8%	4.3%	5.5%	6.1%	5.2%	5.7%	5.2%	5.4%

Appendix E Insulation Grades

The Residential Energy Services Network (RESNET) provides guidelines and definitions for defining the quality of insulation installation. RESNET has specified three grades for designating the quality of insulation installation; the grades range from Grade I (the best) to Grade III (the worst). REM/Rate energy models take insulation grade into account when calculating shell measure efficiency – building assemblies that are recorded as having Grade I installations perform better in the energy simulation than those modeled as Grade II or Grade III, for example.

The RESNET definitions of Grade I, Grade II, and Grade III installation are provided below.[118]

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

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

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

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

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[118] Residential Energy Services Network. (2013). *Mortgage Industry National Home Energy Rating Systems Standards.* Oceanside, CA: Residential Energy Services Network.

Figure 34 shows a conditioned attic with closed-cell spray foam applied to the walls. This installation received a Grade I installation because the closed-cell spray foam has little to no gaps, has no compression, and the cavity is enclosed on all six sides.[119]

Figure 34: Grade I Closed-Cell Spray Foam – Exterior Walls

Figure 35 shows a Grade II install of unfaced fiberglass batts in a conditioned basement.[120] The insulation has gaps in the corners of certain bays and there is some compression – though relatively minor compression overall. The insulation is enclosed on all six sides including the air barrier, warranting a Grade II designation.

Figure 35: Grade II Fiberglass Batts – Basement Walls

[119] In the case of spray foam, a cavity may be open to the attic and still receive a Grade I installation because the spray foam itself is an air barrier.
[120] The basement in this case was considered conditioned volume, not conditioned floor area.

Figure 36 shows R-21 fiberglass batts in a 2x4 wall cavity. This installation automatically receives a Grade III designation due to the fact that the insulation is not enclosed on the vented attic side. According to the RESNET standards on Grade III installation, “This designation shall include wall insulation that is not in substantial contact with the sheathing on at least one side of the cavity, or wall insulation in a wall that is open (unsheathed) on one side and exposed to the exterior, ambient conditions or a vented attic or crawlspace.”

Figure 36: Grade III Fiberglass Batts – Attic Kneewalls

Figure 37 shows a Grade II installation of fiberglass batts in a frame floor cavity. While the insulation has a fair amount of compression, the gaps are minimal. The primary reason for the Grade II designation is that the fiberglass batts are in substantial contact with the subfloor. This example shows an installation that is right on the boundary of Grade II and Grade III installation. It should be noted that the bay with ductwork on the right side of the image would certainly represent a Grade III installation with substantial gaps and compression.

Figure 37: Grade II Fiberglass Batts – Frame Floor

Figure 38 shows frame floor insulation that received a Grade III designation. The insulation was installed incorrectly with the batting cut and installed perpendicular because the width was not the correct size. This install creates excessive gaps, compression, and sagging in the insulation. The sagging insulation creates an air space between the insulation and the subfloor, which ultimately diminishes the insulating characteristics of the fiberglass batts.

Figure 38: Grade III Fiberglass Batts – Frame Floor

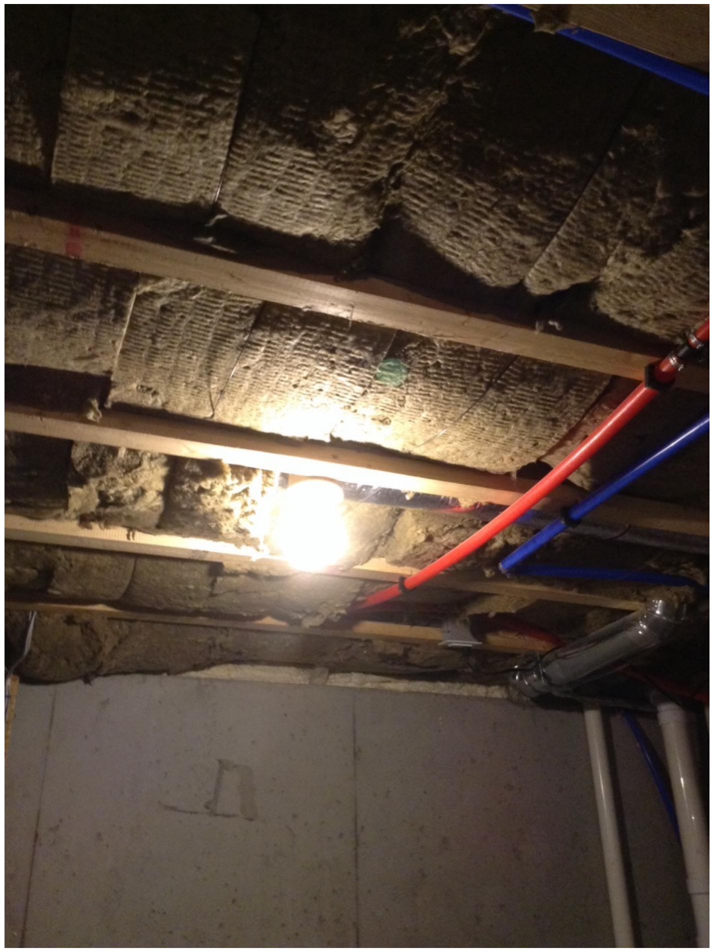


Figure 39 shows a Grade I installation of blown cellulose in an attic. This received a Grade I designation because the cellulose is blown in evenly, filling all the cavities with no gaps or voids and little to no compression. In addition, this attic has baffles at the eaves, which is required for attic insulation to achieve a Grade I installation.

Figure 39: Grade I Blown Cellulose – Attic

F

Appendix F Duct Results By EDC

Table 195: Supply Duct Location by EDC
(Base: Homes with ducts)

	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*27*	*20*	*36*	*26*	*24*	*31*	*29*	*193*
<50% Conditioned	26%	60%	25%	38%	50%	19%	48%	38%
50%-90% Conditioned	30%	5%	53%	31%	21%	45%	28%	28%
>90% Conditioned	44%	35%	22%	31%	29%	35%	24%	35%

Table 196: Return Duct Location by EDC
(Base: Homes with ducts)

	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*27*	*20*	*36*	*26*	*24*	*31*	*29*	*193*
<50% Conditioned	26%	60%	25%	42%	50%	23%	38%	37%
50%-90% Conditioned	19%	5%	53%	27%	21%	42%	31%	25%
>90% Conditioned	56%	35%	22%	31%	29%	35%	31%	37%

Table 197: Unconditioned Supply Duct Locations by EDC

(Base: Homes with ducts in Unconditioned Space)

	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*15*	*13*	*30*	*21*	*17*	*22*	*21*	*139*
Unconditioned Basement	32%	21%	67%	36%	75%	45%	60%	53%
Attic, exposed	29%	36%	4%	31%	8%	14%	16%	25%
Crawl Space	35%	43%	14%	15%	17%	3%	14%	14%
Garage	3%	--	15%	7%	--	23%	10%	6%
Attic, under insulation	--	--	--	11%	--	15%	--	2%

Table 198: Unconditioned Return Duct Locations by EDC

(Base: Homes with ducts in Unconditioned Space)

	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*15*	*13*	*30*	*21*	*17*	*22*	*21*	*139*
Unconditioned Basement	36%	22%	69%	38%	77%	43%	72%	55%
Attic, exposed	28%	36%	4%	34%	7%	22%	8%	25%
Crawl Space	33%	42%	14%	6%	16%	3%	8%	12%
Garage	3%	--	13%	10%	--	20%	12%	6%
Attic, under insulation	--	--	--	12%	--	12%	--	2%

Table 199: Unconditioned Supply Duct R-values by EDC

(Base: Homes with ducts in Unconditioned Space)

	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*15*	*13*	*30*	*21*	*17*	*22*	*21*	*139*
Min	0	0	0	0	0	0	0	0
Max	8	8	8	13	19	6	8	19
Mean	1.7	3.2	1.1	4.4	2.7	2.0	2.5	**2.7**
Median	0	4.25	0	4.30	0	0	0	0
Std. Dev.	2.92	2.98	2.40	3.44	4.34	2.84	3.28	3.36

Table 200: Unconditioned Return Duct R-values by EDC

(Base: Homes with ducts in Unconditioned Space)

	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*15*	*13*	*30*	*21*	*17*	*22*	*21*	*139*
Min	0	0	0	0	0	0	0	0
Max	8	8	8	13	19	6	8	19
Mean	0.8	3.1	1.0	4.4	2.4	1.7	2.0	**2.4**
Median	0	4.30	0	4.30	0	0	0	0
Std. Dev.	2.26	2.92	2.31	3.51	4.51	2.74	2.99	3.4

Appendix G Mechanical Equipment by EDC

G.1 Heating Equipment

Table 201: Primary Heating Fuel by EDC
(Base = Homes)

Fuel	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*46*	*44*	*51*	*39*	*38*	*32*	*39*	*289*
Natural Gas	61%	25%	78%	56%	61%	72%	49%	54%
Electric	20%	36%	18%	21%	13%	22%	31%	23%
Oil	13%	18%	--	10%	18%	6%	15%	15%
Propane	7%	18%	4%	8%	3%	--	3%	5%
Wood	--	2%	--	3%	--	--	3%	1%
Pellet	--	--	--	3%	3%	--	--	1%
Coal	--	--	--	--	3%	--	--	<1%

Table 202: Primary Heating Equipment by EDC
(Base = Homes)

Type	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*46*	*44*	*51*	*39*	*38*	*32*	*39*	*289*
Furnace	37%	23%	65%	46%	61%	88%	56%	43%
Boiler	41%	36%	18%	31%	21%	--	10%	32%
ASHP	13%	9%	2%	10%	--	9%	15%	10%
Electric Baseboard	7%	18%	2%	5%	8%	3%	8%	9%
Stove	--	2%	--	5%	5%	--	3%	2%
PTHP	--	5%	10%	--	--	--	--	1%
Ductless Mini Split	--	2%	--	--	3%	--	3%	1%
Wall Furnace/Space Heater	--	2%	--	3%	--	--	3%	1%
Combi Appliance	2%	--	--	--	--	--	--	1%
PTAC	--	--	--	--	3%	--	3%	1%
GSHP-closed Loop	--	2%	--	--	--	--	--	<1%
Packaged Rooftop Unit (Heating + Cooling)	--	--	4%	--	--	--	--	<1%

Table 203: Primary System Location by EDC

(Base = Systems)

Location	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*46*	*45*	*51*	*39*	*40*	*34*	*39*	*294*
Unconditioned Basement/Enclosed Crawl Space	48%	38%	46%	41%	53%	27%	44%	49%
Conditioned Area/Conditioned Crawl Space	44%	60%	52%	46%	45%	68%	49%	45%
Attic	2%	2%	--	3%	3%	6%	5%	3%
Garage or Open Crawl Space	7%	--	2%	--	--	--	3%	3%
Ambient	--	--	--	10%	--	--	--	1%

Table 204: Heating Equipment Vintages by EDC

(Base = Systems)

Vintage	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*50*	*50*	*44*	*46*	*41*	*33*	*35*	*299*
2016 to 2018	12%	10%	7%	11%	15%	9%	11%	11%
2011 to 2015	24%	32%	16%	20%	20%	33%	29%	24%
2006 to 2010	12%	22%	25%	17%	15%	12%	14%	18%
2001 to 2005	22%	10%	11%	24%	10%	15%	11%	14%
1991 to 2000	16%	16%	23%	17%	15%	27%	23%	17%
1981 to 1990	6%	4%	14%	4%	22%	3%	9%	9%
1980 or earlier	8%	6%	5%	7%	5%	--	3%	6%

Table 205: ENERGY STAR Status by EDC

(Base = Systems)

ENERGY STAR	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*51*	*46*	*47*	*41*	*38*	*35*	*37*	*295*
Yes	28%	35%	24%	25%	29%	34%	51%	32%
No	71%	65%	64%	75%	71%	54%	46%	66%
Unknown	2%	--	11%	--	--	11%	3%	2%

Table 206: Residential Heating System AFUE by Status by EDC

(Base = Systems)

AFUE	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*33*	*24*	*29*	*25*	*27*	*21*	*20*	*179*
Min	66.0	66.0	76.0	71.5	65.0	75.0	80.0	65.0
Max	96.1	94.3	97.7	96.1	98.1	97.0	97.0	98.1
Mean	**84.2**	**85.3**	**87.8**	**86.4**	**85.0**	**88.9**	**89.2**	**86.3**
Median	82.0	85.0	92.1	83.1	84.0	92.1	92.0	85.0
Std. Dev.	6.6	6.5	7.3	7.1	7.5	7.4	6.2	7.1

Table 207: Residential Grade Furnaces (Fossil Fueled) by EDC

(Base = Systems)

AFUE	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*17*	*12*	*25*	*14*	*20*	*21*	*19*	*128*
Min	80.0	80.0	76.0	80.0	76.0	75.0	80.0	75.0
Max	96.1	94.3	97.7	96.1	98.1	97.0	97.0	98.1
Mean	**85.5**	**86.7**	**88.7**	**87.0**	**86.2**	**88.9**	**89.7**	**88.0**
Median	80.3	89.0	92.1	86.8	83.5	92.1	92.1	92.0
Std. Dev.	7.1	6.2	7.4	6.9	7.1	7.4	6.0	7.0

Table 208: Residential Grade Natural Gas Furnace AFUE by EDC

(Base = Systems)

AFUE	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*12*	*4*	*23*	*11*	*13*	*19*	*14*	*96*
Min	80.0	80.0	76.0	80.0	76.0	75.0	80.0	75.0
Max	96.1	92.1	97.7	96.1	98.1	97.0	97.0	98.1
Mean	**86.0**	**83.0**	**88.3**	**88.8**	**87.4**	**89.4**	**91.6**	**88.4**
Median	80.0	80.0	92.1	92.1	92.0	92.2	92.8	92.1
Std. Dev.	7.5	6.0	7.6	6.8	7.8	7.6	5.3	7.2

Table 209: Residential Grade Propane Furnace AFUE by EDC

(Base = Systems)

AFUE	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: West Penn	Statewide
n	*3*	*7*	*2*	*2*	*1*	*1*	*16*
Min	80.0	80.0	92.1	80.0	95.0	92.2	80.0
Max	96.0	94.3	95.0	80.0	95.0	92.2	96.0
Mean	**85.7**	**89.0**	**93.5**	**80.0**	**95.0**	**92.2**	**91.2**
Median	81.0	92.0	93.5	80.0	95.0	92.2	92.0
Std. Dev.	9.0	6.2	2.1	0.0	NA	NA	6.7

Table 210: Residential Grade Boilers (Fossil Fueled) by EDC

(Base = Systems)

AFUE	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: West Penn	Statewide
n	*16*	*12*	*4*	*11*	*7*	*1*	*51*
Min	66.0	66.0	80.4	71.5	65.0	80.0	65.0
Max	94.0	93.5	84.0	96.0	90.0	80.0	96.0
Mean	**82.9**	**83.8**	**81.9**	**85.5**	**81.4**	**80.0**	**83.5**
Median	82.0	84.5	81.5	83.1	84.0	80.0	82.6

Std. Dev.	6.0	6.7	1.6	7.7	7.9	NA	6.5

Table 211: Residential Grade Natural Gas Boiler AFUE by EDC

(Base = Systems)

AFUE	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: West Penn	Statewide
n	*13*	*4*	*4*	*8*	*6*	*1*	*36*
Min	66.0	66.0	80.4	71.5	65.0	80.0	65.0
Max	94.0	91.4	84.0	96.0	90.0	80.0	96.0
Mean	**82.0**	**80.5**	**81.9**	**86.1**	**81.0**	**80.0**	**82.4**
Median	82.0	82.3	81.5	83.2	83.0	80.0	82.0
Std. Dev.	6.3	10.6	1.6	9.0	8.5	NA	7.4

Table 212: ASHP and Ductless Mini Split HSPF by EDC

(Base = Systems)

HSPF	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*10*	*7*	*3*	*6*	*5*	*4*	*9*	*44*
Min	7.5	7.7	7.7	7.8	7.7	7.0	7.0	7.0
Max	11.0	12.0	8.6	10.0	11.6	8.2	10.0	12.0
Mean	**8.6**	**8.6**	**8.0**	**8.8**	**9.6**	**7.7**	**8.4**	**8.7**
Median	8.5	8.0	7.8	8.6	9.6	7.8	8.2	8.2
Std. Dev.	1.1	1.5	0.5	0.9	1.4	0.5	1.1	1.2

Table 213: ECM Motors in All Furnaces by EDC

(Base = Systems)

ECM	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*18*	*13*	*34*	*19*	*25*	*30*	*24*	*163*
Yes	19%	--	22%	6%	16%	29%	22%	16%
No	81%	100%	78%	94%	84%	71%	78%	84%

Table 214: Heating Capacity per Square Foot of Conditioned Floor Area (Btuh/sq.ft.) by EDC

(Base = Homes)

Btuh/sq.ft.	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*41*	*39*	*38*	*30*	*37*	*25*	*33*	*243*
Min	11.3	4.0	8.7	14.1	8.2	12.0	10.3	4.0
Max	108.1	141.5	116.6	90.9	297.4	158.3	153.1	297.4
Mean	**43.2**	**48.4**	**51.3**	**38.5**	**66.0**	**43.4**	**45.8**	**48.7**
Median	42.3	36.0	47.1	33.4	50.4	34.6	41.7	42.3
Std. Dev.	21.9	37.0	27.5	20.2	50.7	30.6	30.1	33.5

Table 215: Supplemental Heating Fuel by EDC

(Base = Systems)

Fuel	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*17*	*29*	*17*	*23*	*16*	*7*	*21*	*130*
Electric	88%	72%	59%	61%	63%	5 (71%)	62%	70%
Natural Gas	12%	10%	24%	9%	13%	2 (29%)	14%	14%
Wood	--	7%	18%	9%	--	--	10%	7%
Propane	--	10%	--	13%	6%	--	14%	6%
Pellet	--	--	--	4%	6%	--	--	1%
Kerosene	--	--	--	--	6%	--	--	1%
Oil	--	--	--	--	6%	--	--	1%
Coal	--	--	--	4%	--	--	--	<1%

Table 216: Supplemental Heating Equipment by EDC

(Base = Systems)

Type	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*17*	*29*	*17*	*23*	*16*	*7*	*21*	*130*
Wall Furnace/Space Heater	53%	55%	53%	30%	63%	5 (71%)	33%	49%
Electric Baseboard	24%	24%	6%	30%	6%	1 (14%)	33%	22%
Stove	--	10%	24%	26%	6%	--	14%	11%
Ductless Mini Split	6%	7%	6%	9%	13%	--	--	6%
ASHP	12%	--	12%	--	6%	1 (14%)	5%	5%
Furnace	6%	--	--	4%	6%	--	5%	4%
Fireplace	--	--	--	--	--	--	10%	2%
Boiler	--	3%	--	--	--	--	--	1%

G.2 Cooling Equipment

Table 217: Cooling System Penetration by EDC

(Base: Systems)

Type	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*46*	*44*	*51*	*39*	*38*	*32*	*39*	*289*
Room Air Conditioner	43%	43%	33%	28%	55%	12%	38%	41%
Central Air Conditioner	37%	20%	43%	56%	26%	62%	36%	35%
ASHP	17%	11%	6%	10%	3%	12%	18%	12%
Ductless HP	2%	7%	2%	5%	8%	--	3%	4%
PTAC	--	2%	--	--	3%	--	5%	1%
PTHP	--	5%	10%	--	--	--	--	1%
Chiller	--	2%	2%	--	--	--	--	1%
GSHP	--	2%	--	--	--	--	--	<1%
None	7%	11%	10%	3%	11%	16%	5%	8%

Table 218: Residential Permanent Cooling System Penetration by EDC

(Base: Systems)

System Type	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Overall
n	*46*	*44*	*51*	*39*	*38*	*32*	*39*	*289*
Central Air Conditioner	37%	20%	43%	56%	26%	62%	36%	35%
ASHP	17%	9%	6%	10%	3%	12%	18%	12%
Ductless HP	2%	7%	2%	5%	8%	--	3%	4%
PTAC	--	2%	--	--	3%	--	5%	1%
PTHP	--	5%	10%	--	--	--	--	1%
Chiller	--	2%	2%	--	--	--	--	1%
GSHP	--	2%	--	--	--	--	--	<1%
None	43%	52%	41%	28%	61%	25%	38%	46%

Table 219: Permanent Cooling Vintages by EDC

(Base: Systems)

Vintage	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*27*	*23*	*27*	*28*	*14*	*27*	*23*	*169*
2016 to 2018	11%	9%	11%	14%	21%	7%	17%	12%
2011 to 2015	15%	39%	26%	14%	21%	26%	39%	26%
2006 to 2010	15%	26%	33%	25%	14%	22%	13%	22%
1991 to 2000	26%	9%	11%	25%	21%	30%	9%	18%
2001 to 2005	22%	17%	11%	21%	21%	15%	9%	16%
1981 to 1990	7%	--	4%	--	--	--	13%	4%
1980 or earlier	4%	--	4%	--	--	--	--	2%

Table 220: Permanent Cooling ENERGY STAR Status by Home Type

(Base: Systems)

ENERGY STAR	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	27	23	28	28	15	26	24	171
Yes	30%	17%	11%	18%	20%	12%	38%	24%
No	70%	83%	89%	82%	80%	89%	63%	76%

Table 221: Permanent Cooling System SEER Rating by EDC

(Base: Systems)

	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*26*	*23*	*27*	*28*	*14*	*26*	*23*	*167*
Min	7.0	10.0	6.1	10.0	8.2	10.0	7.4	6.1
Max	19.2	25.0	16.0	19.8	26.0	16.0	19.0	26.0
Mean	**12.3**	**13.5**	**12.6**	**12.9**	**14.0**	**12.7**	**13.1**	**13.1**
Median	12.0	13.0	13.0	13.0	13.0	13.0	13.5	13.0
Std. Dev.	2.6	3.6	2.1	2.7	5.1	1.8	2.6	2.9

Table 222: Central Air Conditioner SEER Rating by EDC

(Base: Systems)

	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*17*	*11*	*18*	*20*	*8*	*21*	*13*	*108*
Min	7.0	10.0	6.1	10.0	10.0	10.0	7.4	6.1
Max	16.0	16.0	15.5	16.0	14.0	16.0	16.0	16.0
Mean	**11.2**	**12.0**	**12.4**	**12.1**	**11.5**	**12.7**	**12.7**	**12.0**
Median	10.0	11.0	13.0	12.0	10.5	13.0	13.0	13.0
Std. Dev.	2.1	2.2	2.2	2.1	1.8	1.9	2.1	2.1

Table 223: ASHP/Ductless Mini Split SEER Rating by EDC

(Base: Systems)

	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*10*	*9*	*4*	*8*	*5*	*5*	*9*	*50*
Min	12.0	9.7	13.0	10.5	13.0	10.9	11.0	9.7
Max	19.2	25.0	16.0	19.8	26.0	14.0	19.0	26.0
Mean	**14.3**	**14.2**	**14.0**	**14.7**	**19.1**	**12.6**	**14.2**	**14.9**
Median	13.9	13.0	13.5	14.2	20.0	12.2	14.0	14.0
Std. Dev.	2.0	4.5	1.4	3.4	4.9	1.4	2.8	3.4

Table 224: Permanent Cooling System Capacity by EDC (Btuh/sq.ft.)

(Base: Central Air Conditioners)

	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*25*	*20*	*27*	*24*	*13*	*24*	*21*	*154*
Min	8.9	7.2	3.0	9.2	6.0	6.9	7.6	3.0
Max	39.0	39.7	43.5	31.2	49.3	30.9	23.8	49.3
Mean	**18.9**	**16.1**	**20.2**	**15.1**	**16.0**	**14.4**	**14.7**	**15.9**
Median	17.9	14.3	17.2	13.2	12.5	13.8	14.5	14.9
Std. Dev.	7.6	7.8	10.7	6.2	10.9	5.2	4.0	7.9

Table 225: Room Air Conditioner Saturation by EDC

(Base: Room Air Conditioners)

Count	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*46*	*44*	*51*	*39*	*38*	*32*	*39*	*289*
0	57%	57%	67%	72%	45%	88%	62%	59%
1	22%	25%	12%	13%	34%	6%	23%	22%
2	13%	14%	14%	8%	18%	3%	10%	12%
3	9%	5%	8%	8%	3%	3%	5%	7%

Table 226: Room Air Conditioner Saturation by EDC

(Base: Room Air Conditioners)

Vintage	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*25*	*23*	*22*	*19*	*27*	*6*	*21*	*143*
2016 to 2018	8%	13%	9%	16%	7%	--	5%	8%
2011 to 2015	16%	65%	18%	42%	30%	4 (67%)	38%	35%
2006 to 2010	44%	4%	32%	21%	33%	--	29%	28%
2001 to 2005	20%	17%	14%	16%	19%	2 (33%)	14%	19%
1991 to 2000	8%	--	14%	5%	7%	--	14%	7%
1981 to 1990	--	--	5%	--	--	--	--	<1%
1980 or earlier	4%	--	9%	--	4%	--	--	3%

Table 227: Room Air Conditioner ENERGY STAR Status by EDC

(Base: Room Air Conditioners)

ENERGY STAR	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*29*	*29*	*27*	*20*	*27*	*6*	*20*	*158*
Yes	28%	24%	26%	35%	41%	2 (50%)	25%	33%
No	72%	76%	74%	65%	59%	2 (50%)	75%	67%

Table 228: Room Air Conditioner EER Rating by Home Type

(Base: Room Air Conditioners)

	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*23*	*26*	*22*	*19*	*25*	*6*	*20*	*141*
Min	8.5	8.0	8.7	9.0	8.0	9.8	8.5	8.0
Max	12.1	11.2	12.2	11.4	11.8	11.4	12.0	12.2
Mean	**10.4**	**9.9**	**10.3**	**10.4**	**10.1**	**10.5**	**10.2**	**10.2**
Median	10.8	9.8	10.3	10.7	10.7	10.5	9.8	10.5
Std. Dev.	1.0	1.0	0.8	0.8	1.0	0.6	0.8	0.9

Table 229: Room Air Conditioner Capacity by EDC

	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*27*	*27*	*22*	*19*	*25*	*6*	*21*	*147*
Min	5,000	50,00	5,000	5,050	5,000	5,200	5,000	5,000
Max	12,000	12,000	12,000	15,100	18,500	12,400	12,000	18,500
Mean	**7,502**	**7,672**	**6,832**	**8,450**	**8,252**	**8,183**	**7,126**	**7,643**
Median	7,800	8,000	6,000	8,000	6,500	8,150	6,100	6,500
Std. Dev.	2,328	2,726	2,226	3,266	3,807	3,024	2,453	2,853

G.3 Water Heating Equipment

Table 230: DHW Fuel Mix by EDC

(Base = Homes)

Fuel	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*46*	*43*	*45*	*36*	*39*	*31*	*36*	*276*
Natural Gas	67%	30%	71%	47%	59%	58%	39%	55%
Electric	20%	56%	29%	44%	33%	42%	58%	35%
Propane	9%	7%	--	3%	3%	--	3%	5%
Oil	4%	7%	--	6%	5%	--	--	5%

Table 231: DHW Type and Fuel by EDC

(Base = Systems)

Type and Fuel	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n (water heaters)	*46*	*39*	*47*	*36*	*40*	*33*	*37*	*278*
Storage, Standalone	85%	77%	100%	89%	88%	94%	95%	87%
Natural Gas	57%	21%	68%	39%	58%	55%	30%	48%
Electric	20%	51%	32%	47%	25%	39%	62%	34%
Propane	9%	5%	--	3%	3%	--	3%	5%
Oil	--	--	--	--	3%	--	--	<1%
Indirect w/ Storage Tank	9%	--	--	6%	5%	--	3%	4%
Oil	4%	--	--	3%	--	--	--	2%
Natural Gas	4%	--	--	3%	3%	--	3%	2%
Electric	--	--	--	--	3%	--	--	<1%
Instantaneous	7%	8%	--	3%	--	3%	3%	4%
Natural Gas	7%	--	--	3%	--	3%	3%	3%
Propane	--	3%	--	--	--	--	--	1%
Electric	--	5%	--	--	--	--	--	1%
Tankless Coil	--	10%	--	2%	3%	3%	--	3%
Oil	--	8%	--	3%	3%	--	--	3%
Natural gas	--	--	--	--	3%	--	--	<1%
Heat Pump Water Heater (Electric)	--	5%	--	--	5%	--	--	2%

Table 232: Water Heater Vintages by EDC

(Base = Systems)

Vintage	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*50*	*40*	*43*	*33*	*38*	*31*	*37*	*272*
2016 to 2018	16%	28%	14%	6%	16%	3%	14%	15%
2011 to 2015	34%	33%	42%	36%	34%	48%	54%	38%
2006 to 2010	22%	18%	12%	24%	18%	13%	19%	21%
2001 to 2005	20%	15%	14%	27%	11%	26%	5%	16%
1991 to 2000	4%	8%	12%	6%	16%	7%	3%	7%
1981 to 1990	4%	--	5%	--	3%	3%	5%	3%
1980 or earlier	--	--	2%	--	3%	--	--	<1%

Table 233: Water Heater UEF by EDC

(Base = Systems)

	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*41*	*33*	*38*	*29*	*36*	*31*	*34*	*242*
Min	0.56	0.53	0.55	0.56	0.55	0.55	0.56	0.53
Max	0.99	3.25	0.95	0.95	3.69	2.40	0.93	3.69
Mean	**0.70**	**0.95**	**0.69**	**0.76**	**0.82**	**0.79**	**0.81**	**0.78**
Median	0.62	0.90	0.62	0.87	0.60	0.69	0.88	0.68
Std. Dev.	0.15	0.51	0.14	0.16	0.59	0.33	0.14	0.34

Table 234: Water Heater ENERGY STAR Status by EDC

(Base = Systems)

ENERGY STAR	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*43*	*38*	*42*	*32*	*37*	*32*	*34*	*258*
Yes	21%	24%	5%	6%	5%	13%	9%	15%
No	79%	76%	95%	94%	95%	88%	91%	85%

Table 235: Standalone Water Heater Capacity (Gallons) by EDC

(Base = Systems)

Storage Capacity	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*41*	*32*	*44*	*34*	*39*	*32*	*36*	*258*
< 40	20%	22%	11%	--	15%	--	8%	13%
40 to 55	68%	72%	82%	85%	82%	84%	86%	79%
55 to 75	5%	--	2%	--	--	--	--	2%
> 75	7%	6%	5%	15%	3%	16%	6%	7%

Appendix H Appliance ENERGY STAR Status by EDC

Table 236: Refrigerator ENERGY STAR Status by EDC

(Base = Refrigerators)

ENERGY STAR	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*55*	*53*	*53*	*50*	*46*	*43*	*52*	*352*
Yes	25%	32%	25%	34%	28%	51%	35%	31%
No	75%	68%	75%	66%	72%	49%	65%	69%

Table 237: Freezer ENERGY STAR Status by EDC

(Base = Freezers)

ENERGY STAR	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*11*	*13*	*19*	*13*	*13*	*9*	*14*	*92*
Yes	--	8%	11%	--	15%	11%	29%	10%
No	100%	92%	89%	100%	85%	89%	71%	90%

Table 238: Dishwasher ENERGY STAR Status by EDC

(Base = Dishwashers)

ENERGY STAR	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*27*	*22*	*28*	*29*	*21*	*23*	*22*	*172*
Yes	48%	55%	64%	52%	48%	74%	77%	56%
No	52%	45%	36%	48%	52%	26%	23%	44%

Table 239: Clothes Washer ENERGY STAR Status by EDC

(Base = Clothes Washers)

ENERGY STAR	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*36*	*31*	*41*	*34*	*32*	*27*	*32*	*233*
Yes	39%	35%	27%	50%	16%	44%	53%	40%
No	61%	65%	73%	50%	84%	56%	47%	60%

Table 240: Clothes Dryer ENERGY STAR Status by EDC

(Base = Clothes Dryers)

ENERGY STAR	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*35*	*30*	*41*	*34*	*32*	*27*	*32*	*231*
Yes	9%	7%	--	--	3%	--	9%	6%
No	91%	93%	100%	100%	97%	100%	91%	94%

Table 241: Dehumidifier ENERGY STAR Status by EDC

(Base = Dehumidifiers)

ENERGY STAR	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n	*9*	*11*	*15*	*11*	*15*	*16*	*13*	*90*
Yes	7 (78%)	91%	67%	82%	100%	69%	77%	83%
No	2 (22%)	9%	33%	18%	--	31%	23%	17%

Appendix I Supplementary Lighting Data

Table 242: Bulb Type Saturation by Shape (EDCs)[121]

Shape	Bulb Type	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	Statewide
n (Total bulbs)		*1,125*	*1,121*	*1,261*	*1,223*	*1,063*	*1,209*	*1,228*	*8,230*
Standard	LED	16%	34%	26%	22%	20%	16%	23%	23%
	CFL	37%	30%	33%	34%	30%	31%	31%	34%
	Fl.	--	--	--	--	--	--	--	0%
	Incan	47%	35%	39%	43%	49%	52%	45%	43%
	Halogen	--	--	2%	--	--	1%	1%	1%
n (Total bulbs)		*312*	*295*	*182*	*230*	*139*	*358*	*248*	*1,764*
Reflector	LED	28%	15%	12%	50%	32%	15%	23%	22%
	CFL	2%	5%	7%	2%	1%	13%	3%	4%
	Fl.	--	--	--	--	--	--	--	--
	Incan	56%	47%	44%	31%	44%	61%	55%	52%
	Halogen	14%	33%	37%	17%	24%	11%	18%	22%
n (Total bulbs)		*593*	*545*	*686*	*615*	*459*	*575*	*662*	*4,135*
Specialty	LED	10%	21%	17%	8%	17%	14%	17%	14%
	CFL	1%	9%	1%	2%	1%	1%	1%	2%
	Fl.	28%	27%	36%	43%	41%	26%	49%	37%
	Incan	60%	41%	44%	47%	37%	55%	30%	44%
	Halogen	2%	3%	2%	1%	4%	5%	4%	2%

[121] Fl. = fluorescent; Incan = Incandescent

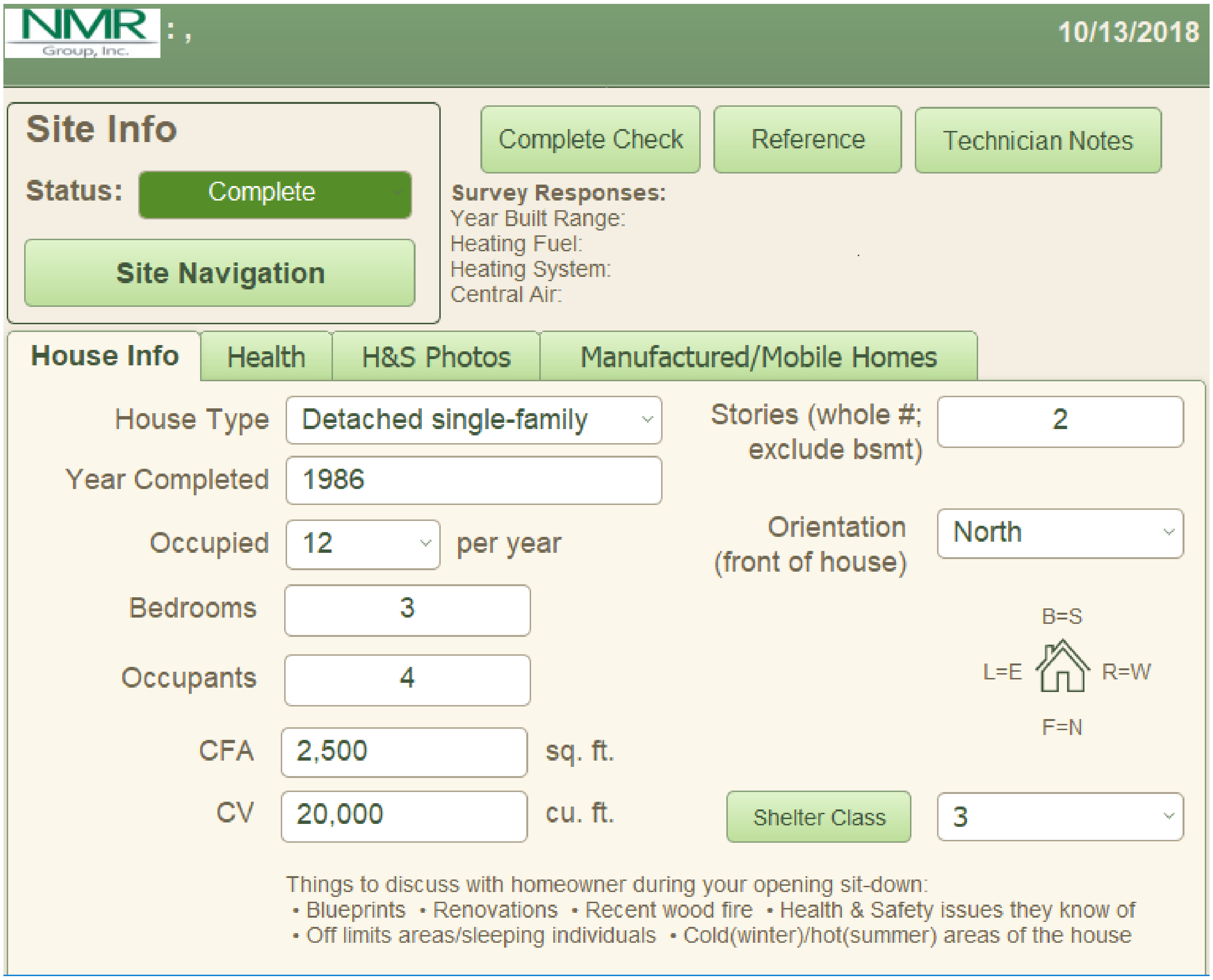
Table 243: Bulb Type Saturation by Shape (Home Types)

Shape	Bulb Type	Detached Single-family	Attached Single-family	Manufactured/ Mobile	Multifamily	Statewide
n (Total bulbs)		*5,388*	*1,358*	*551*	*933*	*8,230*
Standard	LED	22%	20%	30%	24%	23%
	CFL	31%	36%	29%	38%	34%
	Fl.	--	--	--	--	--
	Incan	46%	43%	41%	36%	43%
	Halogen	1%	--	--	1%	1%
n (Total bulbs)		*1,366*	*293*	*44*	*61*	*1,764*
Reflector	LED	20%	38%	36%	31%	22%
	CFL	4%	14%	2%	3%	4%
	Fl.	--	--	--	--	--
	Incan	54%	34%	43%	31%	52%
	Halogen	22%	14%	18%	34%	22%
n (Total bulbs)		*2,958*	*568*	*268*	*341*	*4,135*
Specialty	LED	13%	19%	24%	17%	14%
	CFL	1%	2%	3%	9%	2%
	Fl.	37%	42%	19%	30%	37%
	Incan	46%	36%	53%	39%	44%
	Halogen	3%	2%	2%	5%	2%

Appendix J Example Screen Shot of Electronic Data Collection Form

Figure 40 is an example of one of the data collection input pages used to collect data during onsite visits. The screen shown below is the page where the auditor will enter general site information from the visit, including home age, size, and orientation. For more complex homes, inputs such as CFA and CV will be calculated after the visit is concluded based on measurements taken onsite. The information shown in the data entry fields is not actual customer data, it is purely for demonstration purposes.

Figure 40: Data Collection Form Example – General Site Information



NMR Group, Inc. : , 10/13/2018

Site Info

Status: Complete

Site Navigation

Complete Check | Reference | Technician Notes

Survey Responses:
Year Built Range:
Heating Fuel:
Heating System:
Central Air:

House Info | Health | H&S Photos | Manufactured/Mobile Homes

House Type: Detached single-family
Year Completed: 1986
Occupied: 12 per year
Bedrooms: 3
Occupants: 4
CFA: 2,500 sq. ft.
CV: 20,000 cu. ft.

Stories (whole #; exclude bsmt): 2
Orientation (front of house): North

B=S
L=E R=W
F=N

Shelter Class: 3

Things to discuss with homeowner during your opening sit-down:
• Blueprints • Renovations • Recent wood fire • Health & Safety issues they know of
• Off limits areas/sleeping individuals • Cold(winter)/hot(summer) areas of the house

Appendix K Recruiting Screening Survey

Hello, this is ______ calling on behalf of [EDC NAME]. [EDC NAME] is participating in an important research project sponsored by the Pennsylvania Public Utility Commission (PUC). Recently, you should have received a letter from [EDC NAME] about a research study to assess the energy features of Pennsylvania homes. This survey should take less than 10 minutes, and the information you provide will help Pennsylvania improve its energy-efficiency programs and services for residents like you. Your responses will be kept strictly confidential.

[READ IF NEEDED: The Pennsylvania PUC is sponsoring this study. If you have questions, you can call (717) 425-7584 or email ra-act129@pa.gov and reference the "Pennsylvania Home Energy Efficiency Study"

You may also contact [EDC NAME] at [EDC Contact]

IS1. First, are you in a place right now where you can safely take the survey, or should we call you back?

1. Yes [CONTINUE]
2. No [SCHEDULE CALLBACK]
96. Don't know [SCHEDULE CALLBACK]

IS2. Are you the owner or person who is most knowledgeable about the home at [ADDRESS]'s characteristics and equipment?

1. Yes
2. No [ASK FOR THE BEST PERSON TO SPEAK WITH AND REPEAT INTRODUCTION]
96. Don't know [ASK FOR THE BEST PERSON TO SPEAK WITH AND REPEAT INTRODUCTION]
97. Refused [THANK AND TERMINATE]

SCREENERS

SC1. Which of the following best describes your home? [READ OPTIONS UNTIL RESPONSE GIVEN]

1. Manufactured home, mobile home or trailer
2. Detached single-family home
3. Townhouse or row home with shared adjacent walls (i.e., side-by-side units)
4. Apartment or condo in a two-unit building with units above and below one other

5. Apartment or condo in a three- or four-unit building with some units above and below one other
6. Apartment or condo in a building with five or more units
7. Or something else? [SPECIFY:]
96. Don't know [THANK AND TERMINATE]
97. Refused [THANK AND TERMINATE]

SC3. [IF SC1 = 4, 5, 6 or 7] Do you have access to all of the basement and attic spaces in the building?

1. Yes
2. No
96. (Don't know)

SC4. [IF SC3 = 2 or 96] Could we have the name and phone number of the building owner or manager? We are conducting a separate study of multifamily buildings and we will contact the building owner or manager about participating in the study. Thank you very much for your time and help with our study [TERMINATE]

HOME CHARACTERISTICS

I have a few questions about your home.

HC1. How many bedrooms are in your home? Count as bedrooms those rooms you would list if your home was for sale or rent. [Enter number, 96=DK, 97=Refused; Enter zero for a studio apartment with no bedrooms]

HC2. How many **total rooms** are in your home, not counting bathrooms, halls, garages, porches, and unheated or unfinished rooms? [Enter number, 96=DK, 97=Refused]

HC3. Approximately how large is the interior living space of your home in square feet? Please only include the heated areas of your home and exclude unfinished basements from your estimate. [READ LIST IF NECESSARY]

1. Less than 500 square feet
2. 500 to less than 1,000 square feet
3. 1,000 to less than 1,500 square feet
4. 1,500 to less than 2,000 square feet
5. 2,000 to less than 2,500 square feet
6. 2,500 to less than 3,000 square feet
7. 3,000 to less than 4,000 square feet
8. 4,000 to less than 5,000 square feet
9. 5,000 square feet or more
96. Don't know
97. Refused

HC4. When was your home built? [READ LIST IF NECESSARY]

1. 1930s or earlier
2. 1940s
3. 1950s
4. 1960s
5. 1970s
6. 1980s
7. 1990s
8. 2000s
9. 2010 or later
96. Don't know
97. Refused

HC5. Which type of fuel supplies most of the heating for your home? [READ LIST IF NECESSARY. SINGLE RESPONSE]

1. Natural gas
2. Oil (fuel oil, heating oil, or #2 oil)
3. Propane or other bottled or tank gas (LP, butane)
4. Electricity
5. Wood pellets
6. Wood (firewood or cord)
7. Kerosene
8. Coal
9. Solar
10. Or something else (Specify)
11. (NO heating fuel)
96. Don't know
97. Refused

HC6. [IF HC5≠11] What type of [HC5 FUEL] heating system supplies most of the heating for your home – a hot water or steam boiler, a warm air furnace, or something else? [READ LIST IF NECESSARY. SINGLE RESPONSE]

1. Hot water or steam boiler
2. Warm air furnace
3. Wood or pellet stove
4. Electric baseboard
5. Heat pump (includes air source or water source (geothermal) heat pumps and ductless heat pumps)
6. Or something else? (Specify)
7. (None)
96. Don't know
97. Refused

HC7 Do you have a central air conditioning system in your home? This includes a central air conditioner or a central heat pump that delivers cool air to your entire home, but **not** window air conditioners or ductless heat pumps that only cool specific rooms.

1. Yes
2. No
96. (Don't know)

HC8. Do you have ducts and registers in your home? They are typically used by a warm air furnace or a central air conditioning system to deliver warm or cool air to the entire home.

1. Yes
2. No
96. (Don't know)

DEMOGRAPHICS

Now I have a few questions about your household.

DEM1. Do you own or rent this home?

1. Own/buying
2. Rent/lease
3. Other [SPECIFY:]

DEM2. About how many months out of the year do you usually occupy this home? [PROBE FOR BEST ESTIMATE]

1. All year / year-round / 12 months
2. ENTER # MONTHS IF <12: ______
96. DON'T KNOW
97. REFUSED

DEM3. How long have you lived in your home? [READ CATEGORIES]

1. One year or less
2. Two to five years
3. Six to ten years
4. Eleven years to twenty years
5. Over twenty years
96. (Don't know)

DEM4. What is the highest level of education that you have completed? [READ CATEGORIES]

1. Less than high school
2. High school graduate
3. Technical or trade school graduate
4. Some college
5. College graduate
6. Some graduate school
7. Graduate degree
97. (Refused)

DEM5. What is your age? Are you . .

1. 18 to 24
2. 25 to 34
3. 35 to 44
4. 45 to 54
5. 55 to 64
6. 65 or over
97. (Refused)

DEM6. Counting yourself, how many people live in your home for most of the year?

1.	(1)	[GO TO DEM7_1]
2.	(2)	[GO TO DEM7_2]
3.	(3)	[GO TO DEM7_3]
4.	(4)	[GO TO DEM7_4]
5.	(5)	[GO TO DEM7_5]
6.	(6)	[GO TO DEM7_6]
7.	(7)	[GO TO DEM7_7]
8.	(8)	[GO TO DEM7_8]
9.	(9)	[GO TO DEM7_9]
10.	(10) or more	[GO TO DEM7_10]
11.	None – seasonally occupied	[GO TO DEM8]
96.	Don't know	[GO TO DEM8]
97.	Refused	[GO TO DEM8]

DEM7_1. [IF DEM6=1] Which of these categories best describes your total household income in 2017 before taxes – counting everyone living in your home?

1.	Less than $18,090, OR	[GO TO DEM8]
2.	$18,090 or more	[GO TO DEM8]
96.	Don't know	[GO TO DEM8]
97.	Refused	[GO TO DEM8]

DEM7_2. [IF DEM6=2] Which of these categories best describes your total household income in 2017 before taxes – counting everyone living in your home?

1.	Less than $24,360, OR	[GO TO DEM8]
2.	$24,360 or more	[GO TO DEM8]
96.	Don't know	[GO TO DEM8]
97.	Refused	[GO TO DEM8]

DEM7_3. [IF DEM6=3] Which of these categories best describes your total household income in 2017 before taxes – counting everyone living in your home?

1.	Less than $30,630, OR	[GO TO DEM8]
2.	$30,630 or more	[GO TO DEM8]
96.	Don't know	[GO TO DEM8]
97.	Refused	[GO TO DEM8]

DEM7_4. [IF DEM6=4] Which of these categories best describes your total household income in 2017 before taxes – counting everyone living in your house?

1.	Less than $36,900, OR	[GO TO DEM8]
2.	$36,900 or more	[GO TO DEM8]
96.	Don't know	[GO TO DEM8]
97.	Refused	[GO TO DEM8]

DEM7_5. [IF DEM6=5] Which of these categories best describes your total household income in 2017 before taxes – counting everyone living in your house?

1.	Less than $43,170 OR	[GO TO DEM8]
2.	$43,170 or more	[GO TO DEM8]
96.	Don't know	[GO TO DEM8]
97.	Refused	[GO TO DEM8]

DEM7_6. [IF DEM6=6] Which of these categories best describes your total household income in 2017 before taxes – counting everyone living in your house?

1.	Less than $49,440 OR	[GO TO DEM8]
2.	$49,440 or more	[GO TO DEM8]
96.	Don't know	[GO TO DEM8]
97.	Refused	[GO TO DEM8]

DEM7_7. [IF DEM6=7] Which of these categories best describes your total household income in 2017 before taxes – counting everyone living in your house?

1.	Less than $55,710, OR	[GO TO DEM8]
2.	$55,710 or more	[GO TO DEM8]
96.	Don't know	[GO TO DEM8]
97.	Refused	[GO TO DEM8]

DEM7_8. [IF DEM6=8] Which of these categories best describes your total household income in 2017 before taxes – counting everyone living in your house?

1.	Less than $61,980, OR	[GO TO DEM8]
2.	$61,980 or more	[GO TO DEM8]
96.	Don't know	[GO TO DEM8]
97.	Refused	[GO TO DEM8]

DEM7_9. [IF DEM6=9] Which of these categories best describes your total household income in 2017 before taxes – counting everyone living in your house?

1.	Less than $68,250, OR	[GO TO DEM8]
2.	$68,250 or more	[GO TO DEM8]
96.	Don't know	[GO TO DEM8]
97.	Refused	[GO TO DEM8]

DEM7_10. [IF DEM6=10] Which of these categories best describes your total household income in 2017 before taxes – counting everyone living in your house?

1.	Less than $74,520, OR	[GO TO DEM8]
2.	$74,520 or more	[GO TO DEM8]
96.	Don't know	[GO TO DEM8]
97.	Refused	[GO TO DEM8]

SAY "NOW I'M GOING TO ASK SOME QUESTIONS ABOUT BENEFITS YOU OR SOMEONE IN YOUR HOUSEHOLD MIGHT RECEIVE." [AS SOON AS ANYONE SAYS "YES" TO ANY DEM8 RESPONSE, SKIP TO DEM9.]

DEM8. Does anyone in your household receive assistance from any of the following sources? Please stop me if I mention assistance that your household receives. [ALWAYS READ #1 RESPONSE (LIHEAP) FIRST THEN RANDOMIZE AND READ REMAINING RESPONSES. SKIP TO DEM9 IF RESPONDENT SAYS YES TO ANY ITEM]

1. Assistance with energy costs through the Low-Income Home Energy Assistance Program or LIHEAP [pronounced "lie-heap"] [LIHEAP IS ADMINISTERED BY THE

PENNSYLVANIA DEPARTMENT OF HUMAN SERVICES. DO NOT INCLUDE HELP OR ASSISTANCE FROM FAMILY OR FRIENDS]

2. TANF [pronounced "Tan-if"] cash assistance program [Temporary Assistance for Needy Families]
3. Food assistance from the Women, Infants and Children program or WIC [pronounced "wick"]
4. Child Care assistance program
5. Medicaid
6. Food Stamps
7. Medicare Part D subsidy
8. Weatherization assistance from a Community Action Agency
9. Assistance with energy costs through a Low Income Assistance Plan from your electric or natural gas utility
10. Free or reduced-cost meals in a school breakfast or lunch program
11. [DO NOT READ] No one in our household receives assistance from any of these sources
96. Don't know
97. Refused

DEM9. [DO NOT READ] Gender

1. Female
2. Male

Onsite Recruitment

OS1. [VERY IMPORTANT!] Now I have one last question. The Pennsylvania Public Utility Commission (PUC) is interested in conducting home visits to assess the insulation, heating equipment, appliances, and lighting installed in homes. The Pennsylvania PUC would use this information to learn more about opportunities to save energy in Pennsylvania homes.

If you are selected for a home visit, ~~we~~ the study team will pay you $150 to allow a trained auditor to check the energy features of your home. The visit can be scheduled during weekdays, evenings, or weekends. You could be home during the visit, and the information gathered will remain confidential.

Could we include you on our list of volunteers? The visit will take place within the next few months.

[IF RESPONDENT ASKS HOW LONG THE ONSITE VISIT WILL TAKE SAY: "The basic visit lasts about 2 or 3 hours, depending on the size of your home. More detailed testing may take an additional hour."]

[IF RESPONDENT ASKS ABOUT THE 'MORE DETAILED MEASUREMENTS', SAY: "The additional testing may include a blower door test and a duct blaster test, where fans are used to measure the level of air leakage in your home and duct system."]

1. Yes
2. No [MAKE SURE THIS IS REALLY "NO" AND NOT "CAN'T DECIDE NOW"]
3. (Can't decide now – call back later)

OS2. [ASK IF OS1 = 1] Can I have your name please? [RECORD NAME]

OS3. [ASK IF OS1 = 1] Is there a better phone number to reach you at to schedule the visit? RECORD PHONE NUMBER

OS4. [ASK IF OS1=1] What is the best time during the week to reach you – morning, afternoon, or evening?

1. Morning
2. Afternoon
3. Evening
4. Anytime

98. Refused

OS5. [ASK IF OS1=2] Why are you not interested in the home visit? [DO NOT READ. PROBE. MULTIPLE RESPONSE]

1. Too busy / inconvenient
2. The visit will take too long
3. $150 is not enough money
4. I do not want anyone in my home
5. Other (specify)

96. Don't Know
97. Refused

[IF OS1=YES: READ “Someone from an organization called NMR Group that is assisting the Pennsylvania PUC with this study may call you in the next few weeks to schedule a visit.”]

Those are all the questions I have for you today. Thank you for your time.

Appendix L Willingness to Pay Survey

[IF MEASURE = AIR SEALING OR INSULATION GO TO QUESTION 3]
When considering the installation of a new [MEASURE] for your home, you can choose between standard and higher efficiency options. The higher efficiency options save energy and reduce electricity bills but cost more to purchase than the standard option. We are interested in learning the importance of a number of factors when making the choice between standard and higher efficiency options.

1. Please rate the importance of the following factors in your decision about whether to purchase the higher efficiency [MEASURE]. Use a scale of 0 to 10, where 0 = not at all important and 10 = extremely important: [RANDOMIZE ORDER]
    a. The difference in purchase price between the high-efficiency and standard option.
    b. Having adequate information on the costs and savings of the higher efficiency option.
    c. Confidence that the higher efficiency option will perform as well as the standard option.
    d. Confidence that the higher efficiency option will yield the expected electricity bill savings.
    e. The time required to research and review options and obtain price quotes.
    f. Immediate availability of the [MEASURE].
    g. Enhanced performance and features of the high-efficiency option; this could include improved design or aesthetics, better comfort, quieter operation, advanced controls or additional features.
    h. Improved reliability and lower maintenance costs of the high-efficiency option.

2. Please indicate how likely you are to purchase the higher efficiency [MEASURE] using a scale of 0 to 10, where 0 = not at all likely and 10 = extremely likely:
    a. If the additional purchase cost of the higher efficiency option pays for itself through electricity bill savings within 4 years.
    b. If the additional purchase cost of the higher efficiency option pays for itself through electricity bill savings within 2 years. [LIMIT ≥ 3a RESPONSE]
    c. If the additional purchase cost of the higher efficiency option pays for itself through electricity bill savings within 1 year. [LIMIT ≥ 3b RESPONSE]
    d. If your electric utility covered the entire additional purchase cost of the higher efficiency option. [LIMIT ≥ 3c RESPONSE]

[IF MEASURE IS NOT INSULATION OR AIR SEALING, SKIP TO Q5]
[INTRO FOR INSULATION OR AIR SEALING ONLY]
When considering upgrading the [MEASURE] for your home, the upgrade to your [MEASURE] saves energy and reduces electricity bills. We are interested in learning the importance of a number of factors when making the decision whether to upgrade your [MEASURE].

3. Please rate the importance of the following factors in your decision about whether to upgrade your [MEASURE]. Use a scale of 0 to 10, where 0 = not at all important and 10 = extremely important: [RANDOMIZE ORDER]

a. The purchase price of [MEASURE].
b. Having adequate information on the costs and savings of the [MEASURE].
c. Confidence that the [MEASURE] will perform as well as the current [MEASURE].
d. Confidence that the [MEASURE] will yield the expected electricity bill savings.
e. The time required to research and review options and obtain price quotes.
f. Immediate availability of the [MEASURE].
g. Enhanced experience resulting from the [MEASURE]; this could include better comfort and noise reduction.

4. Please indicate how likely you are to purchase the [MEASURE] using a scale of 0 to 10, where 0 = not at all likely and 10 = extremely likely:
   a. If the purchase cost pays for itself through electricity bill savings within 4 years.
   b. If the purchase cost pays for itself through electricity bill savings within 2 years. [LIMIT ≥ 3a RESPONSE]
   c. If the purchase cost pays for itself through electricity bill savings within 1 year. [LIMIT ≥ 3b RESPONSE]
   d. If your electric utility covered the entire purchase cost. [LIMIT ≥ 3c RESPONSE]

[ASK Q5 OF EVERYONE]

5. Below is a list of possible services and programs that your electric utility could offer to assist you in purchasing higher efficiency equipment or home improvements. Please rate the importance of each service or program using a scale of 0 to 10, where 0 = not at all important and 10 = extremely important: [RANDOMIZE ORDER][ONLY ASK ONCE PER RESPONDENT]
   a. Cash rebate to reduce the price differential between the high-efficiency and standard option.
   b. Advertising campaign to raise awareness about the high-efficiency products available in the market.
   c. Free or low-cost energy audit of your home to identify efficiency opportunities and provide customized estimates of their costs and savings.
   d. Ensure that contractors and retail stores offer high-efficiency options and competitive pricing.
   e. Information from a contractor or retail store employee to help you understand your choices, costs, and savings from installing higher efficiency options.
   f. Low cost financing to assist with the larger purchase cost of the high-efficiency option.
   g. Case studies of other residents that installed the high-efficiency option, and the benefits and savings they achieved from participating in the programs.