MEMO

Date: March 16, 2022
To: Board of Directors
From: Dan Rubado, Sr. Project Manager, Planning and Evaluation
Subject: **Recurve Analysis of Residential Insulation Impacts, 2013-2018**

EXECUTIVE SUMMARY

Energy Trust used an impact analysis tool built by Recurve Analytics to evaluate energy savings from residential insulation projects completed in single-family and manufactured homes from 2013 to 2018. Energy savings were analyzed for ceiling, wall, and floor insulation projects in gas- and electric-heated homes. Projects that combined multiple insulation measures were also analyzed separately. Weather-normalized annual energy usage prior to the installation was compared with the year immediately following installation. The change in annual energy usage was evaluated against changes in energy usage during the same time period in a matched comparison group.

Residential insulation projects had energy savings that varied substantially and were not in line with savings claimed by Energy Trust's Residential program at the time. For electric-heated homes, electricity savings were about 40 percent lower than expected. We were unable to assess wall insulation savings in electric-heated homes due to a small available sample size. Overall electricity savings per home were estimated at 810 kWh per year for ceiling insulation and 490 kWh per year for floor insulation. Savings for combined ceiling and floor insulation projects were roughly additive. In gas-heated homes, gas savings were roughly double what was expected across measures. Overall gas savings per home were estimated at 93 therms per year for ceiling insulation, 75 therms per year for floor insulation, and 53 therms per year for wall insulation. Savings for combined insulation measures were roughly additive.

It is relatively common for real-world energy savings to differ from the engineering estimates used to claim savings for many energy efficiency measures. These types of discrepancies are identified through Energy Trust's evaluation process. Measure and program savings are then adjusted accordingly going forward. The differences in observed versus expected savings have a small impact on Residential program energy savings overall. Insulation measures in electric-heated homes made up less than 1 percent of the total electricity savings claims in the residential sector, from 2013 to 2018. In gas-heated homes, insulation measures made up only 4 percent of the total gas savings claims in the residential sector.

There were no clear trends in electricity or gas savings over time for different insulation measures. There were, however, many differences in gas and electricity savings for other factors, such as home size, home vintage, use of cooling, and annual energy usage. Many of these differences did not have a clear pattern across insulation measures and heating fuels. The strongest trend, by far, was the association between baseline annual energy usage and energy savings—savings increased sharply from low- to high-usage homes in both gas- and electric-heated homes.

To better compare the results of this study to Energy Trust's measures, we have transformed the savings estimates per home to savings per square foot of insulation. These values are listed in Table ES1.

Table ES1: Estimated savings per square foot of insulation, by heating fuel and measure

Heating Fuel	Fuel Analyzed	Measure	Savings Estimate Per Sq. Ft. of Insulation
Electric	kWh	Ceiling	0.87
		Floor	0.57
		Wall	0.76
Gas	Therms	Ceiling	0.114
		Floor	0.092
		Wall	0.083

We also observed electricity savings in gas-heated homes, although only trivial electricity savings were claimed by the program. These electricity savings estimates were relatively small and uncertain but appeared consistently across analyses. We transformed the savings estimates per home to savings per square foot of insulation to match Energy Trust's insulation measures. These values are listed in Table ES2, below.

Table ES2: Estimated electricity savings per square foot of insulation in gas heated homes, by measure

Heating Fuel	Fuel Analyzed	Measure	Savings Estimate Per Sq. Ft. of Insulation
Gas	kWh	Ceiling	0.14
		Floor	0.19
		Wall	0.13

We recommend comparing Energy Trust's current insulation measures to the savings values estimated in this analysis. If there is a substantial discrepancy, then the deemed savings for the insulation measures may need to be adjusted to better align with the billing analysis results. In addition, we recommend that the Regional Technical Forum (RTF) review the results of this study and incorporate the findings into their insulation measures. We also recommend that Energy Trust claim electricity savings for ceiling, floor, and wall insulation measures installed in gas-heated homes, in line with these findings.

We recommend conducting a thorough review of program rules and installation requirements for insulation measures in electric-heated homes to determine the drivers of lower-than-expected savings. More thorough screening for supplemental fuels, like wood and gas, may be necessary to improve insulation measure electricity savings. However, screening out homes with supplemental fuel use may be counter to Energy Trust's DEI efforts, as many rural residents use wood stoves to supplement their electric heating systems. Alternatively, offsets in wood use could be quantified and valued as non-energy benefits.

INTRODUCTION AND OVERVIEW OF METHODS

Energy Trust used an impact analysis tool built by Recurve Analytics (Recurve)[1] to evaluate the gas and electricity savings from insulation installed in existing single-family and manufactured homes between 2013 and 2018. Energy Trust's Residential program has provided incentives for insulation retrofits since 2003, to increase existing insulation levels or insulate previously uninsulated spaces in existing homes. Insulation projects are primarily driven and installed by trade ally contractors that promote home weatherization and use Energy Trust incentives to help make sales. Trade allies must meet certain requirements, agree to meet Energy Trust standards, and remain in good standing. Energy Trust provides trade allies with training, prescribes installation requirements, and conducts quality assurance inspections to ensure that the expected energy savings are achieved. In addition, a small portion of insulation projects are "self-installed" by homeowners, which are subject to the same installation requirements.

From 2013 to 2018, the Residential program offered incentives primarily for three broad categories of insulation measures—ceiling, wall, and floor. Ceiling insulation projects were required to bring the final R-value up to R38 or greater. Wall insulation projects were required to bring the final R-value up to R11 or greater or fill the wall cavity. Floor insulation projects were required to bring the final R-value up to R30 or greater or fill the floor cavity. Throughout this period, there were separate measures for gas- and electric-heated homes, with deemed savings claimed in therms and kWh, respectively. Only homes with low levels of existing insulation qualified for incentives.

From 2013 to 2018, there were several versions of each insulation measure in effect and deemed savings have varied somewhat over time as measures were updated (see Table 2). The largest change occurred in mid-2014, when separate insulation measures were created for heating zones 1 and 2 (defined by the Regional Technical Forum or RTF),[2,3] to differentiate deemed savings by climate. This change in the measure configuration was only applied to gas-heated homes. Higher energy savings were expected from insulation measures in heating zone 2, due to the colder climate. However, the volume of projects in heating zone 2 has been consistently low over time, due to the relatively small population.

For ceiling insulation, the requirement for existing insulation levels was changed in 2013 to R12 or less, to qualify. Previously, the program offered a separate measure allowing existing insulation levels between R13 and R18, which was discontinued in 2013. In mid-2015, an additional ceiling insulation measure, with much lower savings, was created to once again allow incentives in homes with existing insulation levels from R13 to R18. The volume of projects using this measure has been relatively low. For wall and floor insulation measures during the analysis period, existing insulation had to be either minimal or completely absent to qualify. These requirements were put in place to increase energy savings and improve the cost-

[1] Recurve is a software developer that uses open source software to quantify energy impacts. Recurve uses standard weather normalization methods developed by CalTRACK. More information can be found on the Recurve and CalTRACK website at https://www.recurve.com/ and https://www.caltrack.org/.

[2] Heating zones are geographic areas defined by the Regional Technical Forum, based on the number of heating degree-days during a typical year. Heating zone 1 represents areas of the state with relatively mild winters, such as Western Oregon. Heating zones 2 and 3 (combined hereafter into zone 2) represent areas of the state with cold winters, like the mountains and Central and Eastern Oregon. More information can be found on the RTF website at https://rtf.nwcouncil.org/work-products/supporting-documents/climate-zones.

[3] The Regional Technical Forum (RTF), is an advisory committee to the Northwest Power and Conservation Council that provides the region with "consistent and reliable quantification of energy savings estimates for specific efficient technologies or actions." More information can be found on the RTF website at https://rtf.nwcouncil.org/

effectiveness of insulation measures by targeting homes that could benefit the most from insulation. However, many of the insulation measures in effect during our analysis period were offered under a cost-effectiveness exception from the Oregon Public Utility Commission.

Insulation project savings were claimed based on the quantity of insulation installed, so the savings claimed per home varied substantially depending on the size of home and amount of insulation installed. The overall average deemed savings values, insulation quantity, and savings claimed per home for insulation projects installed from 2013 to 2018 that were in Energy Trust's project tracking database are summarized for each major measure type in Table 1. A more detailed breakdown of insulation measures in effect during this time period is presented in Table 2.

Table 1: Summary of average deemed savings values and savings claimed per home for insulation measures by heating fuel and insulation type, from 2013-2018

Heating Fuel	Insulation Type	Average Deemed kWh Savings Per Sq. Ft. of Insulation	Average Deemed Therm Savings Per Sq. Ft. of Insulation	Average Insulation Quantity (Sq. Ft.)	Average kWh Savings Claimed Per Home	Average Therm Savings Claimed Per Home	Project Count
Electric	Ceiling	1.36	0	1,191	1,620	0	2,381
	Floor	0.97	0	1,131	1,102	0	1,559
	Wall	1.20	0	956	1,148	0	627
Gas	Ceiling	0.001	0.059	1,074	1.8	64	5,733
	Floor	0	0.040	996	0	40	2,890
	Wall	0	0.050	1,024	0	51	2,022

Source: Energy Trust Project Tracking database.

Table 2: Detailed deemed savings values and average savings claimed per home for insulation measures by heating fuel, insulation type, and heating zone, from 2013-2018

Heating Fuel	Insulation Type	Heating Zone	Years in Effect	Deemed kWh Savings Per Sq. Ft. of Insulation	Deemed Therm Savings Per Sq. Ft. of Insulation	Average Insulation Quantity (Sq. Ft.)	Average kWh Savings Claimed Per Home	Average Therm Savings Claimed Per Home	Project Count
Electric	Ceiling (R0-12)	Both	2013-2018	1.38	0	1,189	1,641	0	2,281
	Ceiling (R13-18)		2015-2018	0.91	0	1,228	1,117	0	100
	Floor		2013-2018	0.97	0	1,131	1,102	0	1,559
	Wall		2013-2018	1.20	0	956	1,148	0	627
Gas	Ceiling (R0-12)	Both	2013-2014	0.005	0.060	1,032	6.4	62	1,495
		1	2014-2018	0	0.060	1,083	0	65	3,868
		2	2014-2018	0	0.070	1,179	0	83	132
	Ceiling (R13-18)	1	2015-2018	0	0.040	1,137	0	45	234
		2	2015-2018	0	0.040	1,273	0	51	17
	Floor	Both	2013-2014	0	0.040	993	0	40	1,053
		1	2014-2018	0	0.040	992	0	40	1,757
		2	2014-2018	0	0.050	1,130	0	56	80
	Wall	Both	2013-2014	0	0.050	1,063	0	53	700
		1	2014-2018	0	0.050	1,004	0	50	1,287
		2	2014-2018	0	0.060	977	0	59	35

Source: Energy Trust Project Tracking database and Residential Insulation Measure Approval Documents.

The Recurve impact analysis tool used monthly utility billing data to conduct pre/post billing analyses of whole home energy usage. Energy usage data were weather normalized using typical meteorological year data.[4] Normalized annual energy usage in the year immediately preceding the installation was compared with that of the year immediately following installation. The change in normalized annual energy usage was then evaluated against changes in energy usage during the same time period for a comparison group.

For this analysis, matched comparison groups were created for different cohorts of treatment sites, based on measure type and installation year and month. Stratified sampling was used to select comparison sites from a pool of non-participating residential customers based on key usage characteristics (e.g., baseline heating load, cooling load, total annual usage, etc.), matched to each treatment site cohort. The strata were defined based on the distribution of usage characteristics in each cohort of treatment sites. For each treatment group, all possible combinations of usage characteristics were used to define strata and select a variety of comparison group candidates. The comparison group candidate with the best match to a given treatment group cohort was selected for use in the analysis. The difference between the treatment and matched comparison groups in the average change in normalized annual energy was analyzed overall, by insulation measure, and for factors of interest.

[4] Wilcox S, Marion W. 2008. Technical Report: Users Manual for TMY3 Data Sets. National Renewable Energy Laboratory. Accessed online on 2/24/2022 from: https://www.nrel.gov/docs/fy08osti/43156.pdf.
The TMY3 data are based on historical weather data from 1976-2005 or 1991-2005, depending on the station.

This analysis provides estimates of the average annual energy savings resulting from insulation measures, given typical weather conditions. Homes that completed additional measures, other than insulation, were removed from the analysis to isolate the impact of the insulation measures and simplify the analysis. This step caused significant attrition and had a large impact on the number of homes available for analysis. When multiple insulation measures were installed together, they were analyzed together as an independent measure package. A potential limitation of this analysis is that the results may not represent the population of insulation projects in the broader program because we were only able to analyze measures that were installed by themselves, or in concert with other insulation measures. Lastly, several standard data screens are applied to remove outliers, atypical homes, and homes unsuitable for pre/post billing analysis from the analysis sample.

The summary of results presented in the following section show the overall savings for insulation measures in electric-heated and gas-heated homes. We analyzed insulation projects along several dimensions, including heating zone, home size, home age, baseline heating energy usage, use of cooling equipment, and program year. We assessed the reliability of each energy savings estimate, based on the relative precision and sample size available, and assigned a reliability rating to each estimate from very high to very low. Savings were not assessed for groups with less than 40 sites available in the analysis sample. The reliability rating criteria are summarized in Table 3, below.

Table 3: Criteria used to develop reliability ratings for energy savings estimates

Reliability Rating	Relative Precision Criteria (@ 90% Conf.)	Sample Size Criteria
Very High	<10%	≥200
High	<20%	≥120
Moderate	<50%	≥80
Low	<100%	≥50
Very Low	≥100%	≥40
Not Reported	Any	<40

INSULATION SAVINGS RESULTS

Overall Savings by Insulation Measure

Electric-heated homes

Ceiling insulation projects in electric-heated homes saved an average of 810 kWh per home per year (+/- 310). These projects installed an average of roughly 940 square feet of insulation and had savings claims of 1,280 kWh savings per home, so the realization rate for ceiling insulation was 64 percent. Floor insulation projects saved somewhat less, with an average of 490 kWh per home per year (+/- 490). These projects installed an average of 860 square feet of insulation and had savings claims of 830 kWh per home, so the realization rate for floor insulation projects was 59 percent. Homes that installed both ceiling and floor insulation saved an average of 1,240 kWh per home per year (+/- 830). These projects installed an average of 1,780 square feet of insulation and had savings claims of 2,070 kWh per home, so the realization rate for combined ceiling and floor insulation projects was 60 percent. There were an insufficient number of wall insulation projects available for analysis to assess the electricity savings.

Figure 1 shows the differences in annual electricity savings estimates per home for the different types of insulation measures installed in electric-heated homes.

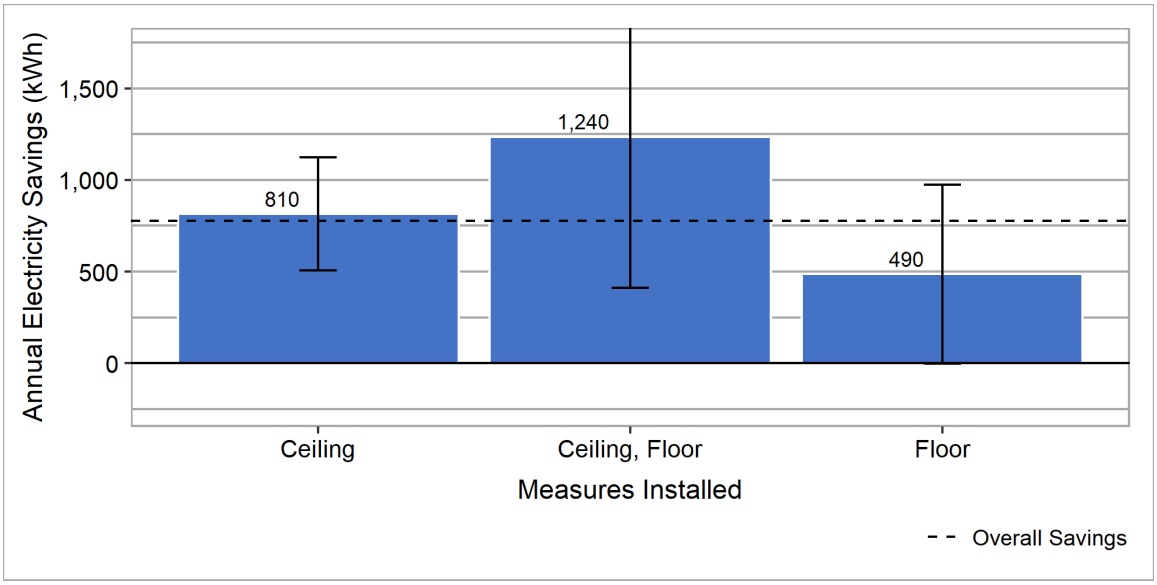


Figure 1: Electricity savings per home for electric-heated homes, by insulation measure

Table 4 summarizes the annual electricity savings estimates per home, in kWh, for the different insulation measures installed in electric-heated homes. Contextual information, like precision, sample size, and annual baseline energy usage, is also provided.

Table 4: Electricity savings per home for electric-heated homes, by insulation measure

Measure	N[1]	Est. Annual Savings[2]	Absolute Precision[3]	% Savings[4]	Baseline Annual Usage[5]	Est. Heating Usage[5]	Est. Cooling Usage[5]	Avg. Savings Claimed	RR[6]	Reliability Rating[7]
Ceiling	354	810	310	5.2%	15,600	5,690	760	1,280	64%	Moderate
Ceiling, Floor	82	1,240	830	8.1%	15,180	6,070	670	2,070	60%	Low
Floor	216	490	490	3.0%	16,240	5,750	510	830	59%	Very Low
Wall*	--	--	--	--	--	--	--	--	--	--
All	**731**	**780**	**230**	**5.0%**	**15,650**	**5,790**	**650**	**1,230**	**63%**	**Moderate**

* This category is not reported due to an insufficient sample size (n <40).

[1] N is the final treatment group sample size available for each analysis. Only measure categories with n ≥40 are reported, so the sample sizes for individual measure categories do not sum to equal the "All" measures category. The "All" measures category includes less prevalent insulation measure not reported separately.

[2] The estimated weather normalized annual electricity savings in kWh, using TMY3 weather data, after removal of effects observed in the matched comparison group.

[3] Absolute precision of the savings estimate at the 90 percent confidence level.

[4] Electricity savings as a percentage of the weather normalized baseline annual usage.

[5] The estimated weather normalized total annual electricity usage, heating usage, and cooling usage in kWh during the baseline.

[6] Realization rate. The savings estimate as a percentage of the average expected (claimed) savings.

[7] Reliability rating of the savings estimate, based on relative precision and sample size.

These results indicate that insulation savings were roughly 40 percent lower than expected in electric-heated homes, across measure types. Ceiling insulation produced higher savings than floor insulation, while ceiling and floor insulation together produced roughly additive savings. Although the precision and reliability of the electricity savings estimates were moderate to very low, the fact that the relative magnitude of savings for the different insulation measures makes logical sense gives us some confidence in the findings.

Gas-heated homes

Ceiling insulation projects in gas-heated homes saved an average of 93 therms per home per year (+/- 7) and 110 kWh (+/- 140). These projects installed an average of about 810 square feet of insulation and had savings claims of 48 therms and 10 kWh per home, so the realization rates were 193 percent for gas and 1,280 percent for electricity. Floor insulation projects saved an average of 75 therms per home per year (+/- 14) and 150 kWh (+/- 370). These projects installed an average of 800 square feet of insulation and had savings claims of 32 therms per home, so the gas realization rate was 230 percent. Wall insulation projects saved an average of 53 therms per home per year (+/- 15) and 80 kWh (+/- 430). These projects installed an average of 640 square feet of insulation and had savings claims of 32 therms per home, so the gas realization rate was 165 percent.

Homes that installed both ceiling and floor insulation saved an average of 156 therms per home per year (+/- 17) and 250 kWh (+/- 330). These projects installed an average of 1,600 total square feet of insulation and had savings claims of 79 therms, so the gas realization rate was 197 percent. Homes that installed both ceiling and wall insulation saved an average of 136 therms per home per year (+/- 26) and 530 kWh (+/- 480). These projects installed an average of 1,230 total square feet of insulation and had savings claims of 67 therms, so the gas realization rate was 203 percent.

Figures 2 and 3 show the difference in annual gas and electricity savings estimates per home, respectively, along with their precision, for the different types of insulation measures installed in gas-heated homes.

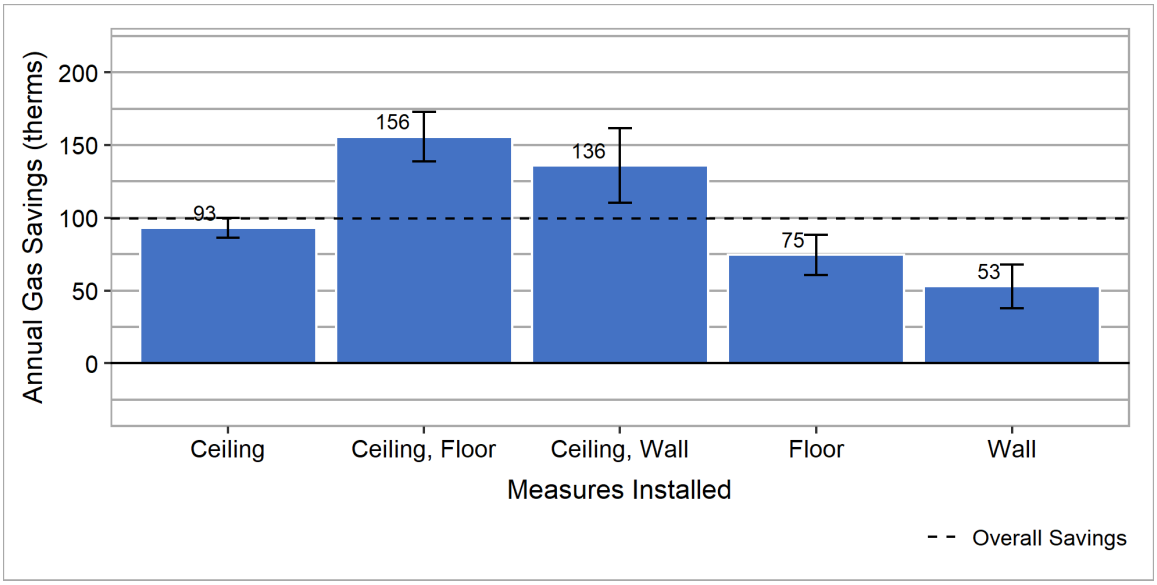


Figure 2: Gas savings per home for gas-heated homes, by insulation measure

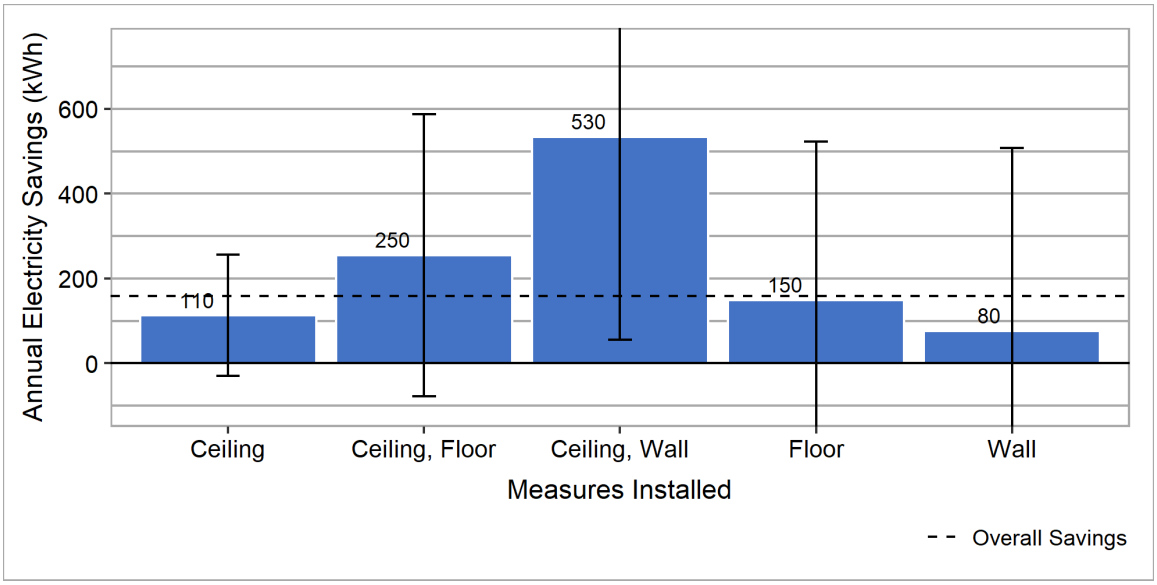


Figure 3: Electricity savings per home for gas-heated homes, by insulation measure

Table 5 summarizes the annual gas and electricity savings estimates per home (in therms and kWh, respectively) for the different insulation measures installed in gas heated homes. Contextual information, like precision, sample size, and annual baseline energy usage, is also provided.

Table 5: Energy savings per home for gas-heated homes, by fuel and insulation measure

Fuel	Measure	N[1]	Est. Annual Savings[2]	Absolute Precision[3]	% Savings[4]	Baseline Annual Usage[5]	Est. Heating Usage[5]	Est. Cooling Usage[5]	Avg. Savings Claimed	RR[6]	Reliability Rating[7]
Therms	Ceiling	1,070	93	7	13.5%	692	567	N/A	48	193%	Very High
	Ceiling, Floor	236	156	17	21.9%	713	591	N/A	79	197%	High
	Ceiling, Wall	125	136	26	22.1%	616	500	N/A	67	203%	High
	Floor	244	75	14	10.7%	700	563	N/A	32	230%	High
	Wall	125	53	15	9.5%	558	449	N/A	32	165%	Moderate
	All	**1,848**	**100**	**5**	**14.7%**	**678**	**555**	**N/A**	**51**	**195%**	**Very High**
kWh	Ceiling	835	110	140	1.2%	9,120	1,670	830	10	1,282%	Very Low
	Ceiling, Floor	181	250	330	3.1%	8,330	1,660	750	0	N/A	Very Low
	Ceiling, Wall	109	530	480	6.3%	8,440	1,590	550	0	N/A	Low
	Floor	215	150	370	1.5%	9,770	1,770	760	0	N/A	Very Low
	Wall	108	80	430	0.8%	9,460	1,820	450	0	N/A	Very Low
	All	**1,491**	**160**	**120**	**1.8%**	**9,070**	**1,690**	**750**	**0**	**N/A**	**Low**

[1] N is the final treatment group sample size available for each analysis. Only measure categories with n ≥40 are reported, so the sample sizes for individual measure categories do not sum to equal the "All" measures category. The "All" measures category includes less prevalent insulation measure not reported separately.

[2] The estimated weather normalized annual energy savings, using TMY3 weather data, after removal of effects observed in the matched comparison group.

[3] Absolute precision of the savings estimate at the 90 percent confidence level.

[4] Energy savings as a percentage of the weather normalized baseline annual usage.

[5] The estimated weather normalized total annual energy usage, heating usage, and cooling usage during the baseline.

[6] Realization rate. The savings estimate as a percentage of the average expected (claimed) savings.

[7] Reliability rating of the savings estimate, based on relative precision and sample size.

The results show that gas savings for insulation projects were roughly double what was expected in gas-heated homes, across all types of insulation projects. Ceiling insulation yielded the highest savings, followed by floor, then wall insulation. Ceiling and floor insulation installed together, and ceiling and wall insulation installed together, produced roughly additive savings. The reliability ratings of the gas savings estimates were moderate to very high, giving us confidence in the findings.

The results for electricity savings in gas-heated homes were not as clear. Given the relatively low savings detected and high variability of electricity usage, much higher sample sizes would be required to develop precise savings estimates. Although the electricity savings had low to very low reliability ratings and were not statistically different from zero in most cases, the results were consistent with the gas savings results and formed a coherent pattern, even if the individual estimates were uncertain. This provides evidence of modest electricity savings resulting from insulation installed in gas-heated homes. This was somewhat unexpected since most of the insulation measures in effect during the analysis period did not include electricity savings and only nominal electricity savings were claimed by the program for some ceiling insulation measures.

In the sections below, we examine the impact of the following factors on insulation savings per home. Appendix A contains more detailed results, including information like sample sizes, baseline energy usage, and percent savings.

- Heating zone
- Home size
- Home age
- Use of cooling
- Annual energy usage
- Program year

Savings by Heating Zone

This analysis categorizes homes by the heating zone they are located in. As noted in the introduction section, heating zones are geographic areas defined by the RTF, based on the number of heating degree-days during a typical winter. The intent of this analysis was to compare insulation energy savings between homes located in heating zones 1 and 2. Unfortunately, most homes available for analysis were in heating zone 1, and there were not enough insulation projects in heating zone 2 to estimate their electricity savings. Instead, we present heating zone 1 savings compared to the overall results.

Electric-heated homes

Electricity savings for insulation projects in electric-heated homes in heating zone 1 were very similar to the overall savings results, because most projects were in heating zone 1. Savings were about 40 percent lower than expected, across insulation types. Although the reliability ratings of the electricity savings estimates were moderate to very low, the relative magnitude of savings for the different insulation measures followed the expected pattern, adding credibility to the results.

Figure 4 shows the differences in electricity savings estimates per home, along with their precision, for the different types of insulation measures installed in electric-heated homes in heating zone 1.

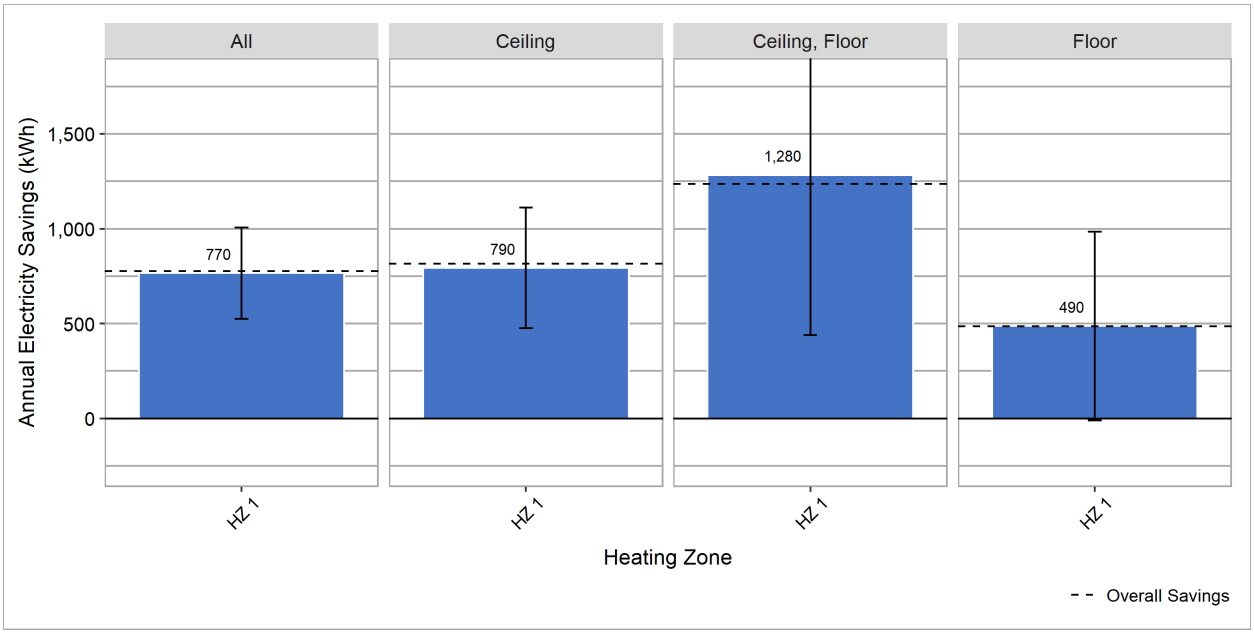


Figure 4: Electricity savings per home for electric-heated homes in heating zone 1, by insulation measure

Gas-heated homes

Gas savings for insulation projects in gas-heated homes in heating zone 1 were very similar to the overall savings results as well. The reliability ratings for the gas savings estimates were moderate to very high, giving us confidence in these results. Savings across all insulation measures were roughly twice the expected amount.

The relative magnitude of electricity savings in gas heated homes in heating zone 1 were somewhat consistent with the gas savings results and were very similar to the overall savings results. Although, the savings estimates for individual insulation measures in heating zone 1 were much less certain than the gas savings estimates, they formed a coherent pattern. These results provide evidence of modest but significant electricity savings occurring in gas heated homes heating zone 1.

Figures 5 and 6 show the differences in gas and electricity savings estimates per home, respectively, along with their precision, for the different types of insulation measures installed in gas-heated homes in heating zone 1.

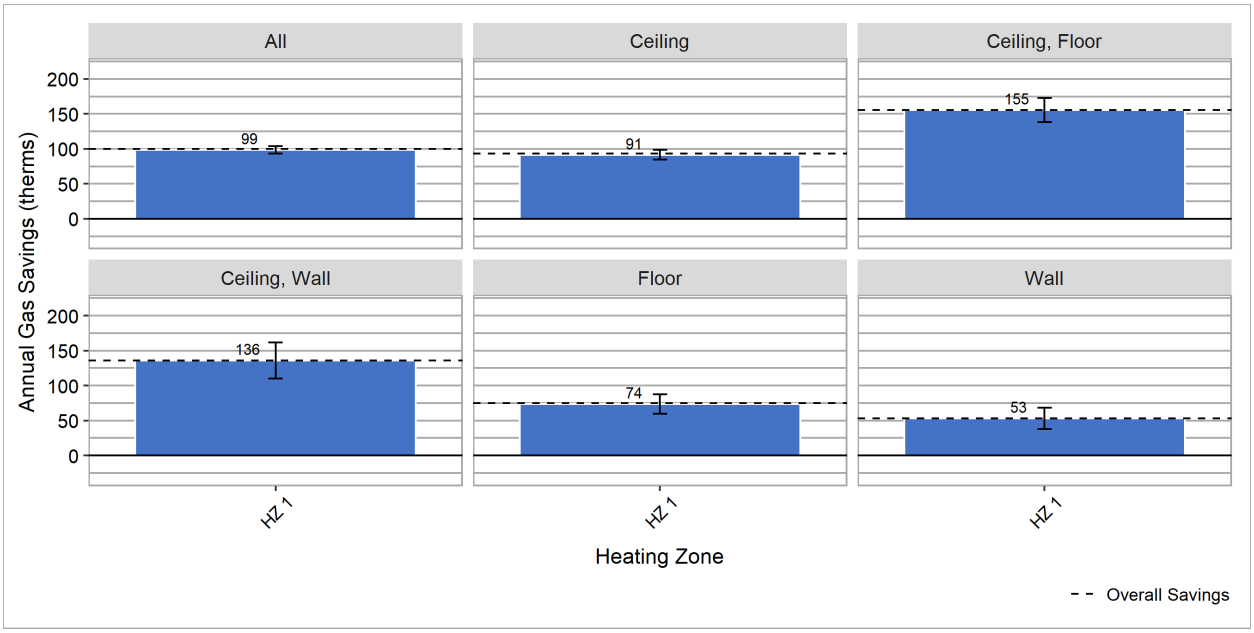


Figure 5: Gas savings per home for gas-heated homes in heating zone 1, by insulation measure

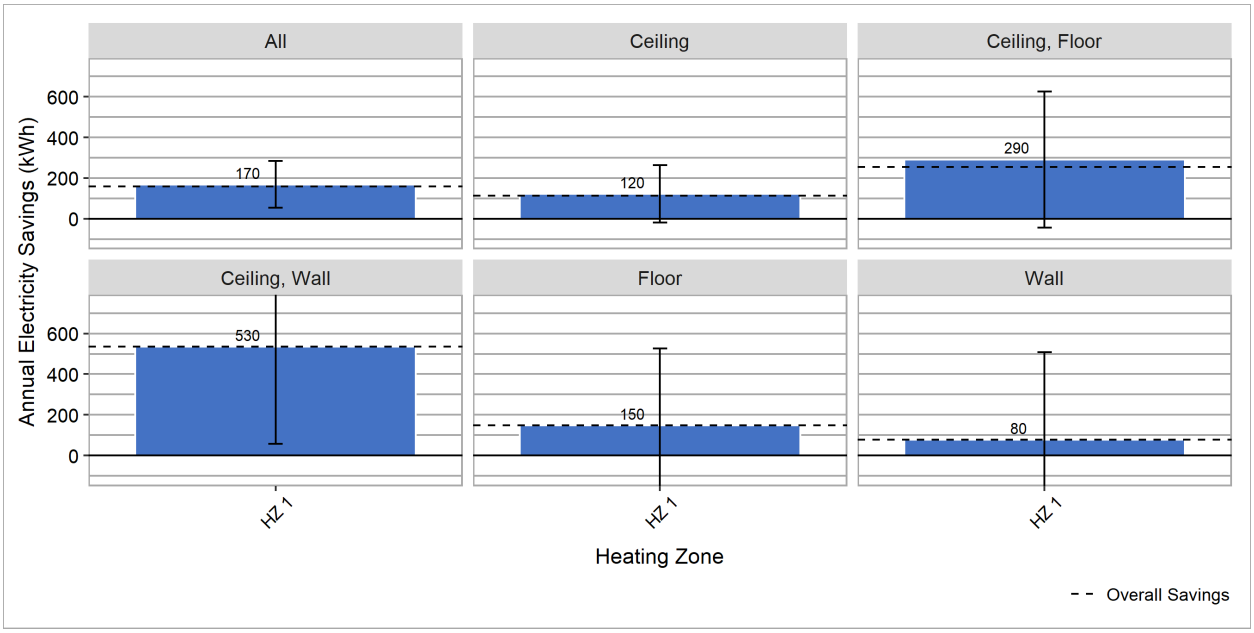


Figure 6: Electricity savings per home for gas-heated homes in heating zone 1, by insulation measure

Savings by Home Size

For this analysis, homes were divided into three categories with roughly equal sample sizes, based on home size. Homes were categorized as follows: less than 1,400 square feet, 1,400 to 2,199 square feet, and 2,200 square feet or more.

Electric-heated homes

There were no clear differences or consistent patterns in electricity savings for insulation measures in electric-heated homes by home size. The savings estimates were relatively uncertain for each home size category, with moderate to low reliability ratings overall, and were not significantly different from one another. Some categories had very small sample sizes.

Figure 7 shows the differences in electricity savings estimates per home, along with their precision, for the different types of insulation measures installed in electric-heated homes by home size category.

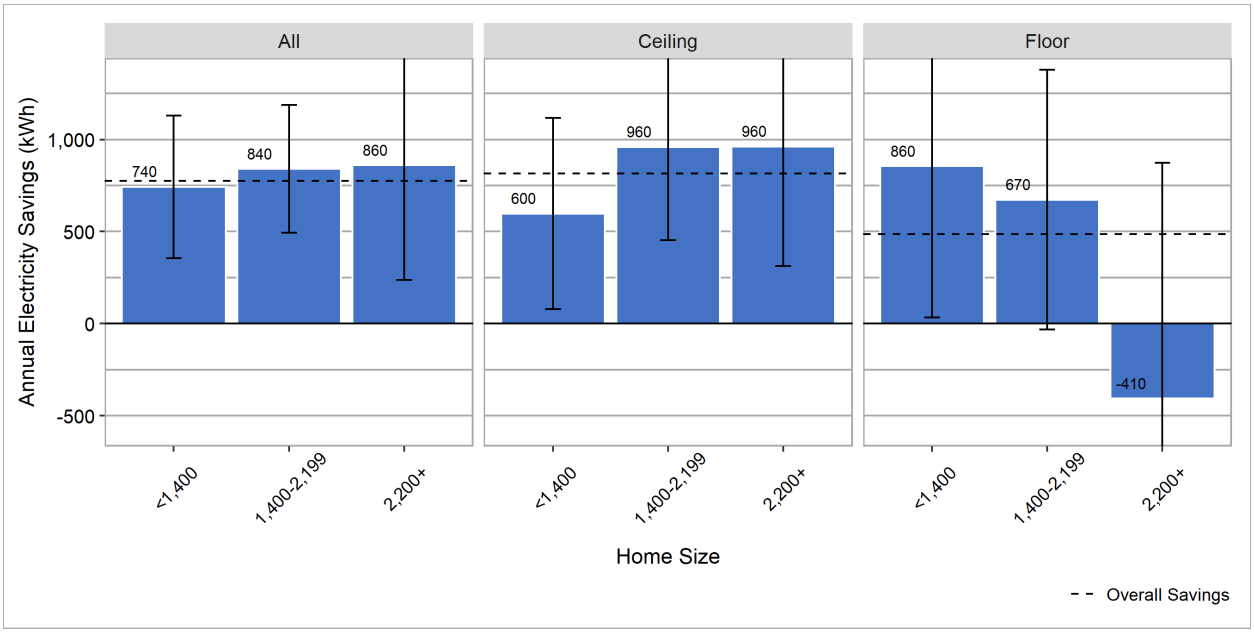


Figure 7: Electricity savings per home for electric-heated homes, by insulation measure and home size

Gas-heated homes

Gas savings for insulation projects in gas-heated homes varied somewhat by home size, depending on the measure, but had good precision, with high to very high reliability ratings overall. Across all insulation measures, mid-size homes had higher gas savings than large homes and large homes had higher savings than small homes. For ceiling and floor insulation, similar patterns were seen, although the savings estimates were somewhat less reliable for individual measures. Projects with both ceiling and floor insulation had similar gas savings across home sizes. For wall insulation and combined ceiling and wall insulation projects, no clear differences in gas savings could be discerned between home size categories.

Electricity savings for gas heated homes showed inconsistent differences between home sizes for different measures and the estimates were less certain than for gas savings, with low to very low reliability ratings overall. Across all insulation measures, electricity savings appeared to decrease as home size increased. Ceiling insulation had a similar pattern, with savings appearing to decrease as home size increased. Floor insulation savings appeared to be highest for large homes and near zero for small and mid-size homes, although the differences were not statistically significant. For wall insulation, ceiling and wall insulation combined, and ceiling and floor insulation combined, no differences in electricity savings could be discerned between home size categories.

Figures 8 and 9 show the differences in gas and electricity savings estimates per home, respectively, along with their precision, for the different types of insulation measures installed in gas-heated homes by home size.

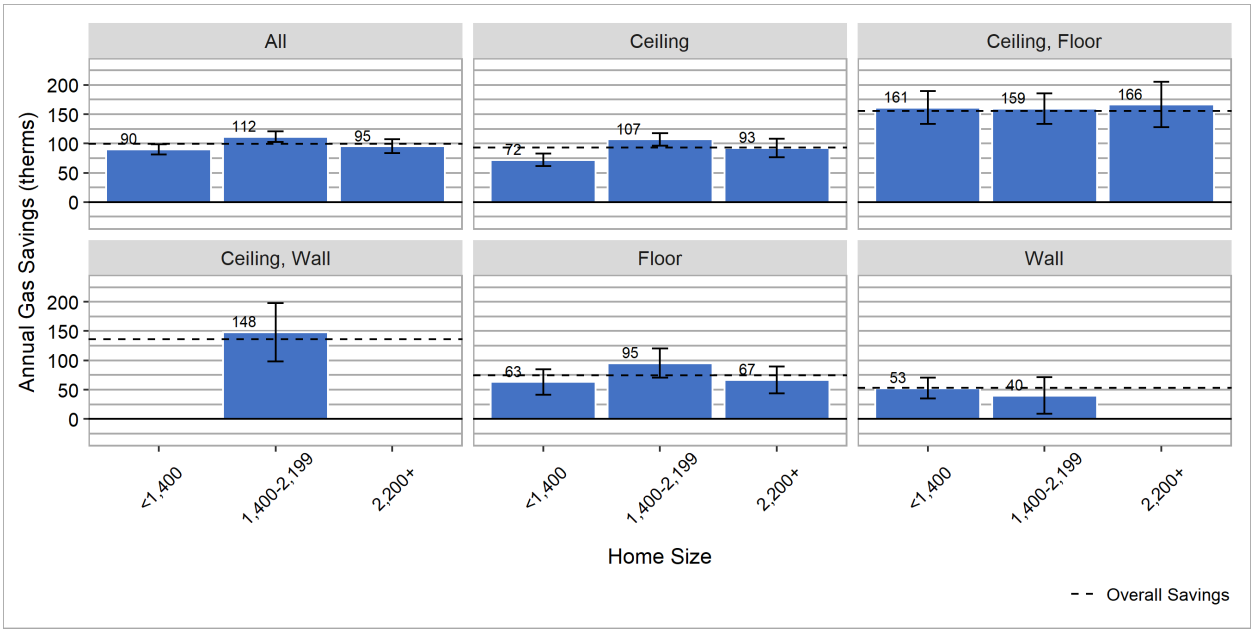


Figure 8: Gas savings per home for gas-heated homes, by insulation measure and home size

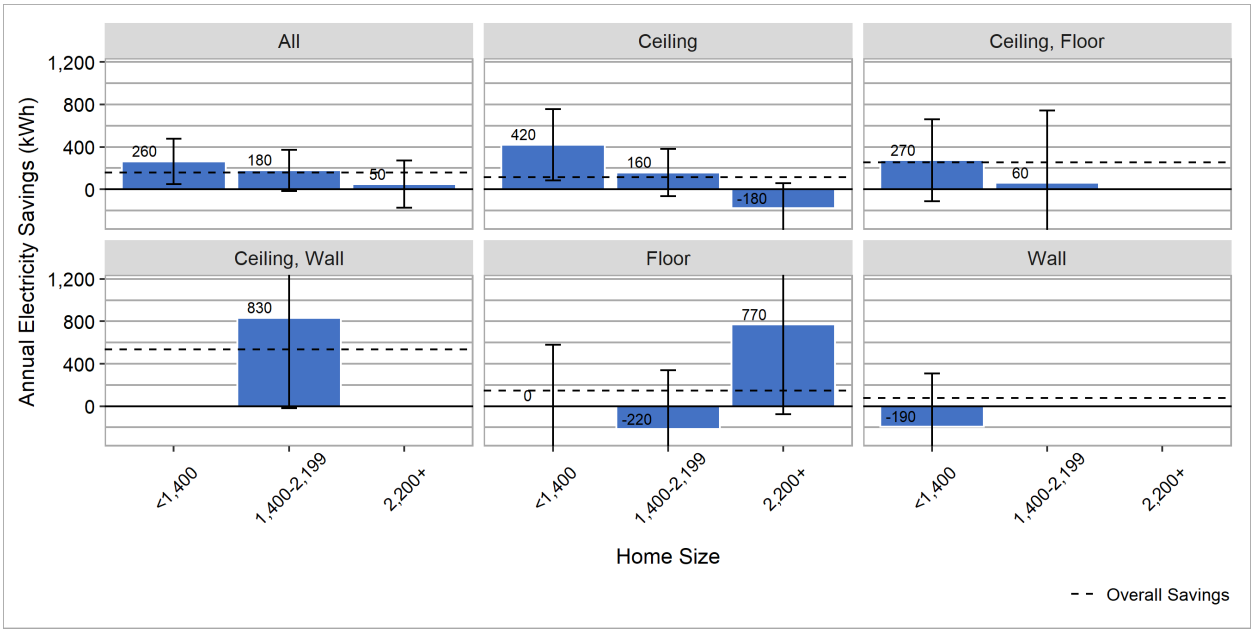


Figure 9: Electricity savings per home for gas-heated homes, by insulation measure and home size

Savings by Home Vintage

Homes were divided up into three age categories for this analysis. These categories roughly aligned with changes in home building techniques and building codes in the US and divided the sample into three similarly sized groups. The age categories were: before 1950, 1950 to 1969, and 1970 and after.

Electric-heated homes

The electricity savings for insulation measures in electric-heated homes showed some weak trends, but the estimates were relatively uncertain for each home vintage category, with moderate to low reliability ratings overall. Some categories had very small sample sizes. Across all insulation measures, electricity

savings appeared to increase as homes became newer, although the differences were not statistically significant. A similar pattern was seen with ceiling insulation savings, but with less reliable savings estimates. For floor insulation and combined ceiling and floor insulation projects, no clear differences in electricity savings could be discerned by home age.

Figure 10 shows the differences in electricity savings estimates per home, along with their precision, for the different types of insulation measures installed in electric-heated homes by home vintage.

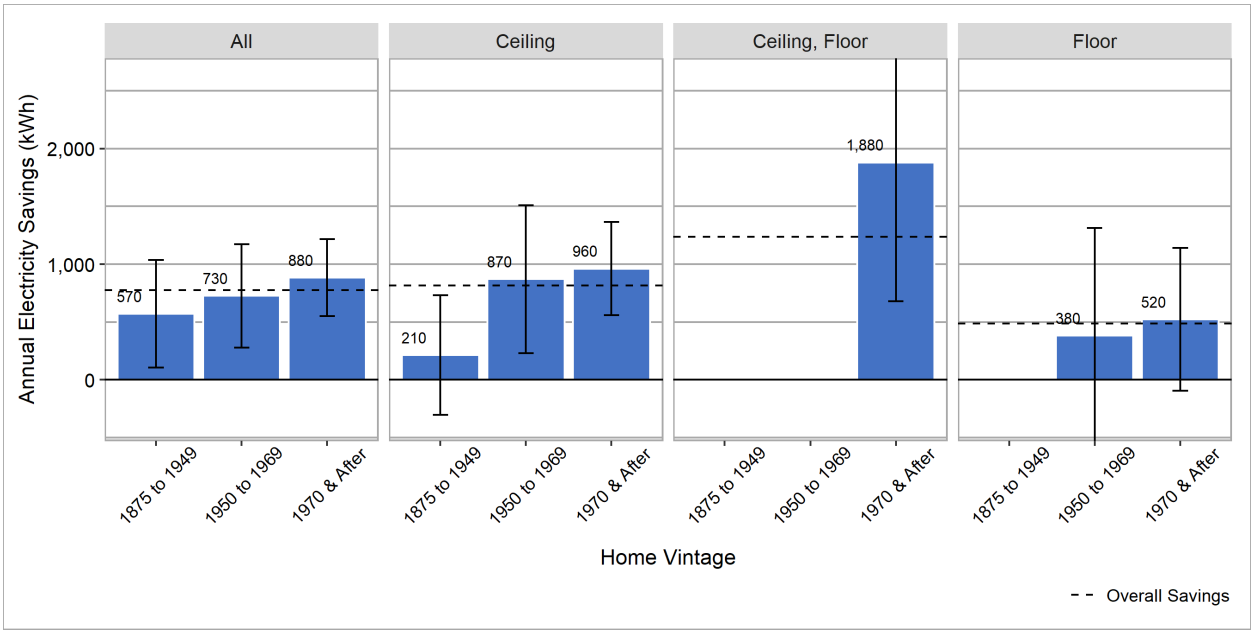


Figure 10: Electricity savings per home for electric-heated homes, by insulation measure and home vintage

Gas-heated homes

Gas savings for insulation projects in gas-heated homes showed few significant variations by home age, but there were some minor differences depending on the measure. These savings estimates had good precision, with high to very high reliability ratings overall. Across all insulation measures, older homes had lower gas savings compared to mid-century and newer homes, which were similar to one another. Ceiling insulation savings showed a similar pattern. Floor insulation savings were similar across home vintages, although the certainty of these savings estimates was somewhat lower. For the remaining insulation measures, differences in savings by home age could not be fully assessed due to small sample sizes.

Electricity savings for gas heated homes by home age showed somewhat consistent differences across different insulation measures. These estimates were less certain than the gas savings estimates, with reliability ratings of low to very low overall. Across all insulation measures, newer homes saved more electricity than older and mid-century homes. Similar patterns in savings were seen in both ceiling and floor insulation, although the certainty of the savings estimates was very low. For the remaining insulation measures, differences in savings by home age could not be fully assessed due to small sample sizes.

Figures 11 and 12 show the differences in gas and electricity savings estimates per home, respectively, along with their precision, for the different types of insulation measures installed in gas-heated homes by home vintage.

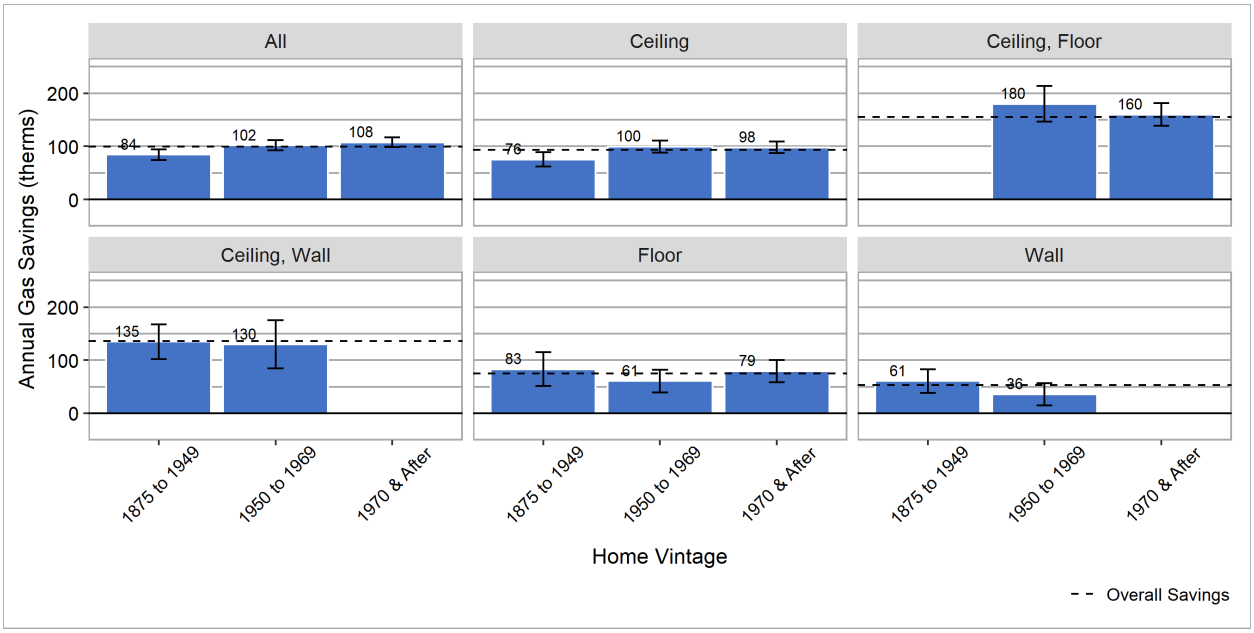


Figure 11: Gas savings per home for gas-heated homes, by insulation measure and home vintage

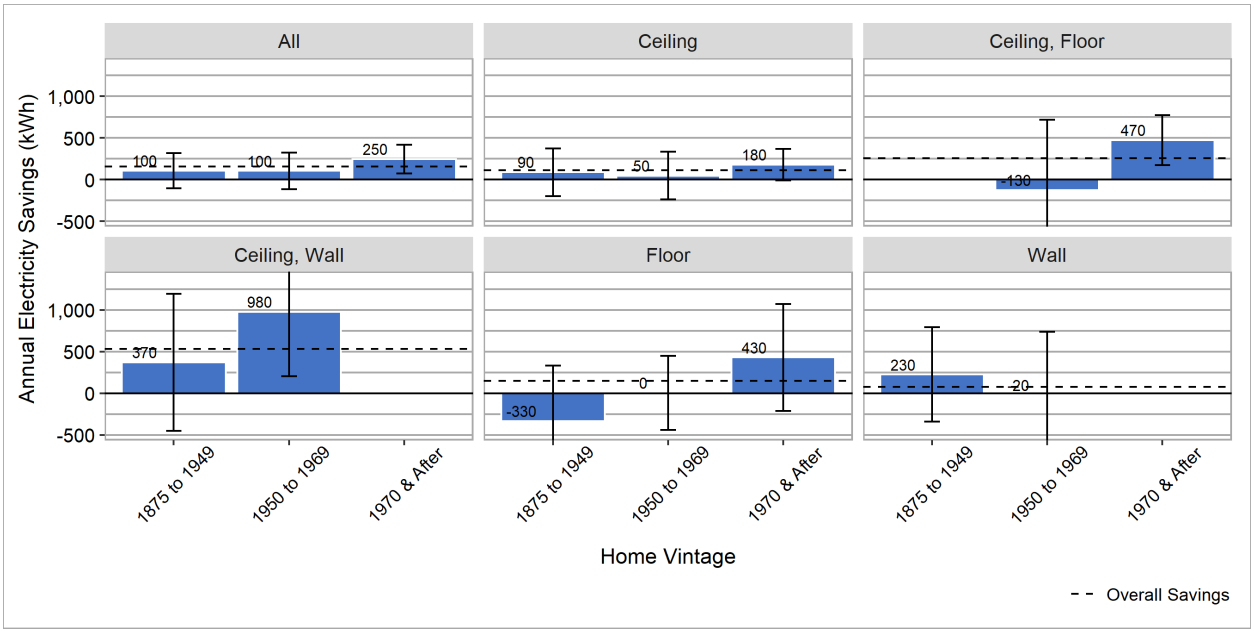


Figure 12: Electricity savings per home for gas-heated homes, by insulation measure and home vintage

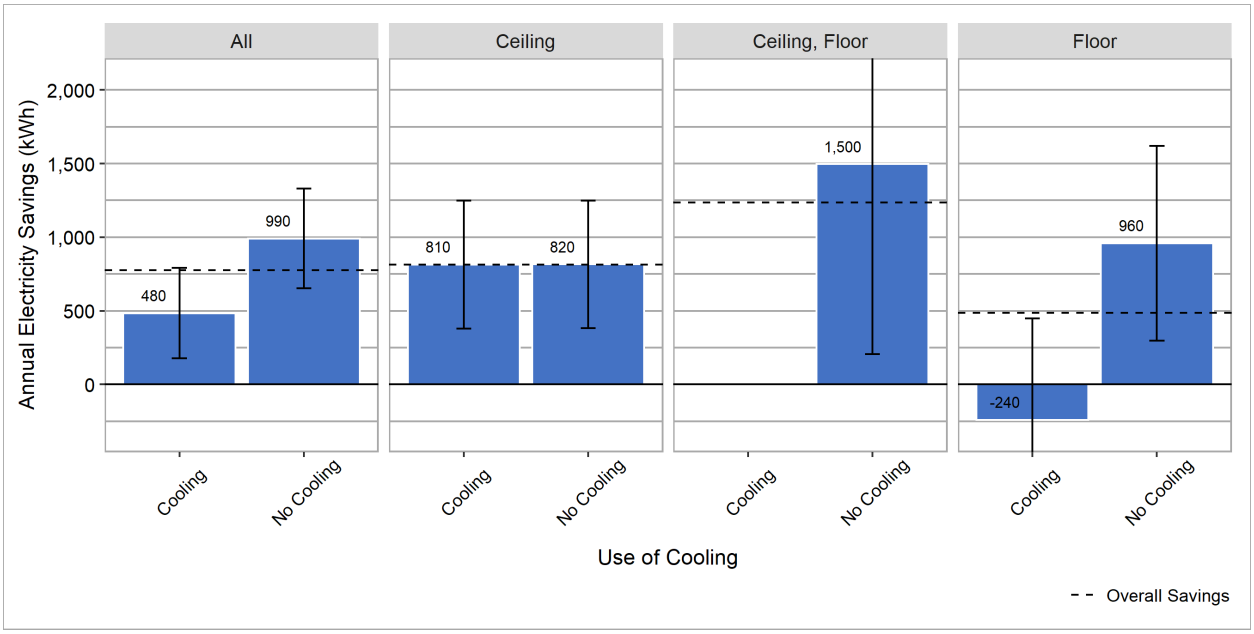
Savings by Use of Cooling Equipment

For the purpose of this analysis, we categorized homes into two categories by estimated cooling energy. The estimated weather normalized annual cooling usage, based on the cooling component of the weather regression model for monthly electricity usage, was used to determine if a home used cooling equipment. Homes were considered to use cooling equipment if a cooling coefficient was included in the best-fit weather model and the estimated cooling usage was 350 kWh per year or more. Homes that did not meet these criteria were considered to have no significant cooling usage.

Electric-heated homes

Electricity savings in electric-heated homes by use of cooling equipment were inconsistent across different insulation measures. The savings estimates were relatively uncertain, with moderate to low reliability ratings overall. Across all insulation measures, homes that used cooling equipment appeared to save less electricity than homes with no cooling. For ceiling insulation, there was no apparent difference in savings between homes with cooling and those with no cooling, and both were similar to the overall average. Floor insulation savings were near zero for homes with cooling and above the overall average for homes with no cooling. For ceiling and floor insulation combined, differences in savings between homes with and without cooling usage could not be assessed due to small sample sizes.

Figure 13 shows the differences in electricity savings estimates per home, along with their precision, for the different types of insulation measures installed in electric-heated homes by use of cooling equipment.



Gas-heated homes

Electricity savings for gas heated homes showed somewhat consistent differences by use of cooling across insulation measures, although the estimates had low certainty, with reliability ratings of low to very low overall. Across all insulation measures, homes that used cooling equipment appeared to save less electricity than homes with no cooling. Similar patterns in savings were seen for ceiling insulation, floor insulation, wall insulation, and ceiling and floor insulation combined. For projects with both ceiling and wall insulation, no clear differences in electricity savings could be discerned by use of cooling, although the certainty of the savings estimates was very low.

We did not analyze gas savings by use of cooling, since we would not expect to see any differences in gas usage by use of cooling equipment.

Figure 14 shows the differences in electricity savings estimates per home, along with their precision, for the different types of insulation measures installed in gas-heated homes by use of cooling equipment.

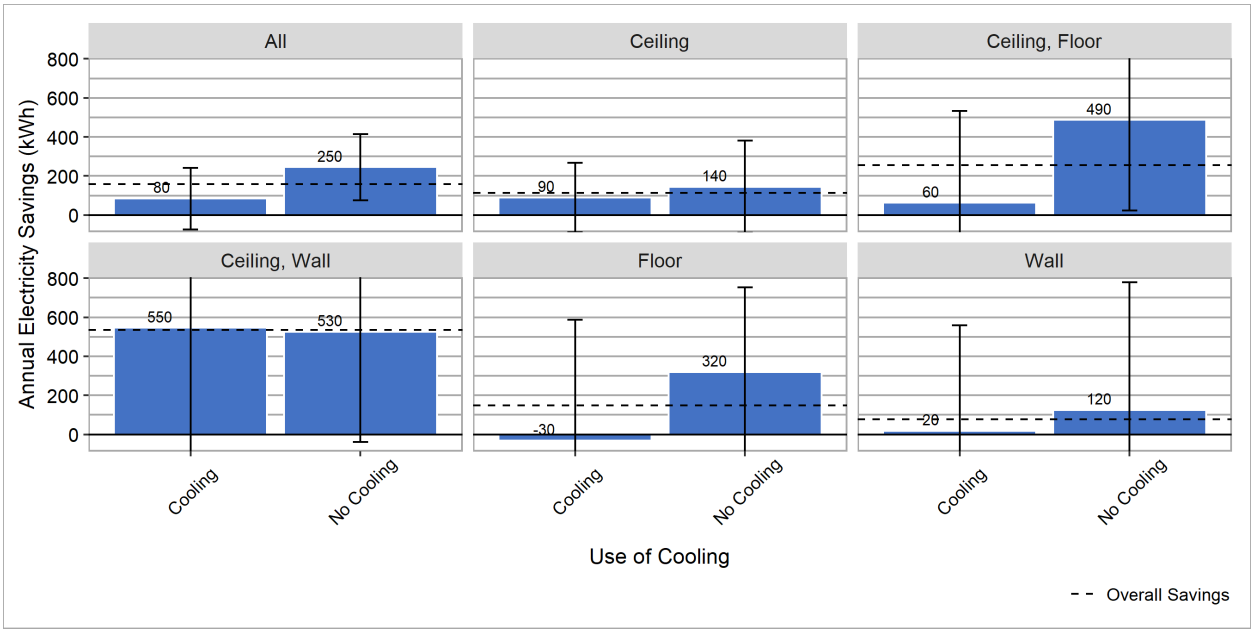


Figure 14: Electricity savings per home for gas-heated homes, by insulation measure and use of cooling

Savings by Annual Energy Usage

Homes were divided into three groups based on their baseline annual energy usage for this analysis. The groups were created so that each had a similar sample size. The annual usage groups were defined separately for each heating fuel. For electric-heated homes the categories were defined as follows: low usage was less than 11,500 kWh per year, moderate usage was between 11,500 and 17,999 kWh per year, and high usage was 18,000 kWh per year or more. For gas usage in gas-heated homes, the categories were defined as follows: low usage was less than 530 therms per year, moderate usage was between 530 and 759 therms per year, and high usage was 760 therms per year or more. For electricity usage in gas heated-homes, the categories were defined as follows: low usage was less than 6,200 kWh per year, moderate usage was between 6,200 and 9,999 kWh per year, and high usage was 10,000 kWh per year or higher.

Electric-heated homes

Electricity savings estimates in electric-heated homes had very consistent patterns by annual usage category across different insulation measures, with moderate to very high reliability ratings overall. Across all insulation measures, the low usage category increased electricity usage on average, the moderate usage category realized modest savings similar to the overall average, and the high usage category had very high electricity savings. Similar patterns in savings were seen for ceiling insulation and floor insulation. Differences in electricity savings by annual usage category could not be fully assessed for other insulation measures due to small sample sizes.

Figure 15 shows the differences in electricity savings estimates per home, along with their precision, for the different types of insulation measures installed in electric-heated homes by baseline annual electricity usage category.

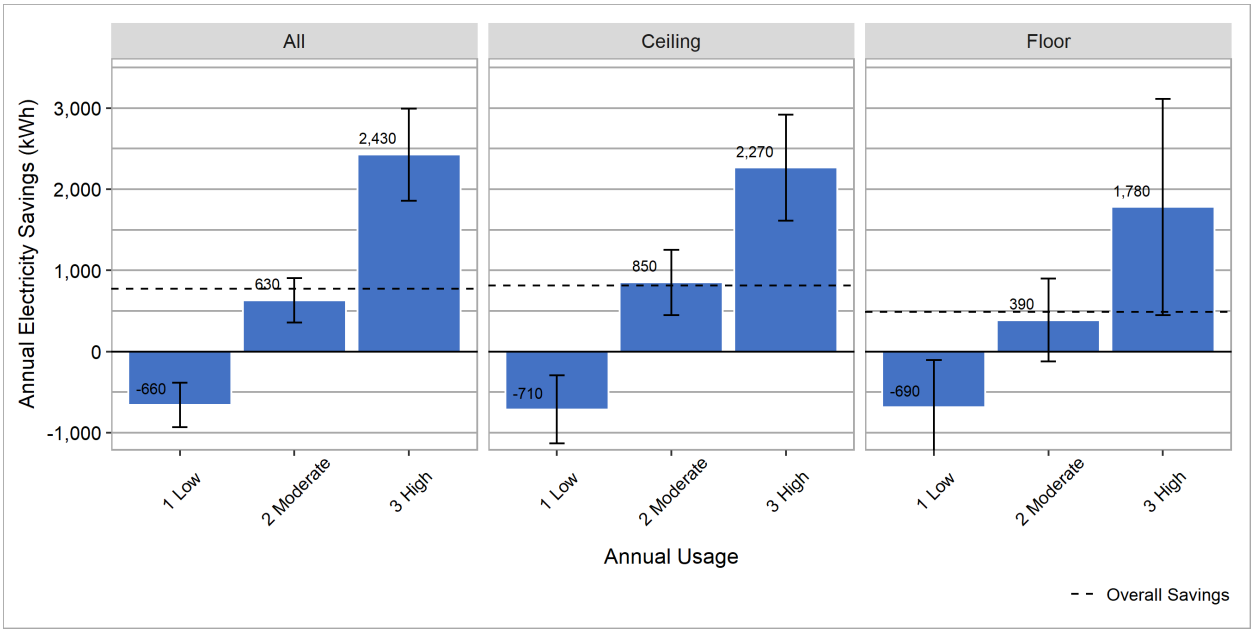


Figure 15: Electricity savings per home for electric-heated homes, by insulation measure and baseline annual electricity usage

Gas-heated homes

Gas savings estimates in gas-heated homes had very consistent patterns by annual usage category across different insulation measures, with high to very high reliability ratings overall. Across all insulation measures, the low usage category saw the lowest gas savings, the moderate usage category realized substantially higher savings, similar to the overall average, and the high usage category saw, by far, the highest gas savings. Similar trends in savings were seen for ceiling insulation, floor insulation, and ceiling and floor insulation combined. For wall insulation and ceiling and wall insulation combined, differences in gas savings by annual usage category could not be fully assessed because of small sample sizes, but the trend appeared to hold.

Electricity savings in gas-heated homes also showed very consistent patterns by annual usage category across different insulation measures, although the estimates were somewhat less certain than the gas savings estimates, but still had moderate to very high reliability ratings overall. Across all insulation measures, homes with low annual usage significantly increased their electricity usage, moderate usage homes had little change in usage, and high usage homes realized high electricity savings. Similar trends in savings were seen for ceiling insulation, floor insulation, and ceiling and floor insulation combined. For wall insulation and ceiling and wall insulation combined, differences in electricity savings by annual usage category could not be fully assessed.

Figures 16 and 17 show the differences in gas and electricity savings estimates per home, respectively, along with their precision, for the different types of insulation measures installed in gas-heated homes by baseline annual energy usage category.

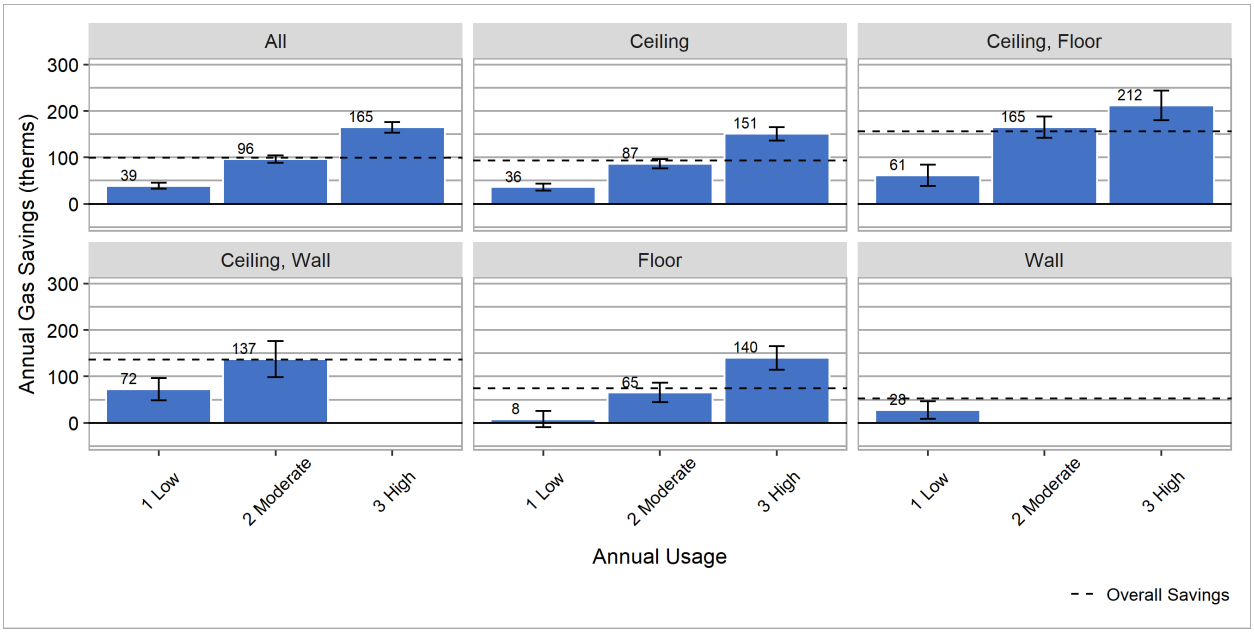


Figure 16: Gas savings per home for gas-heated homes, by insulation measure and baseline annual gas usage

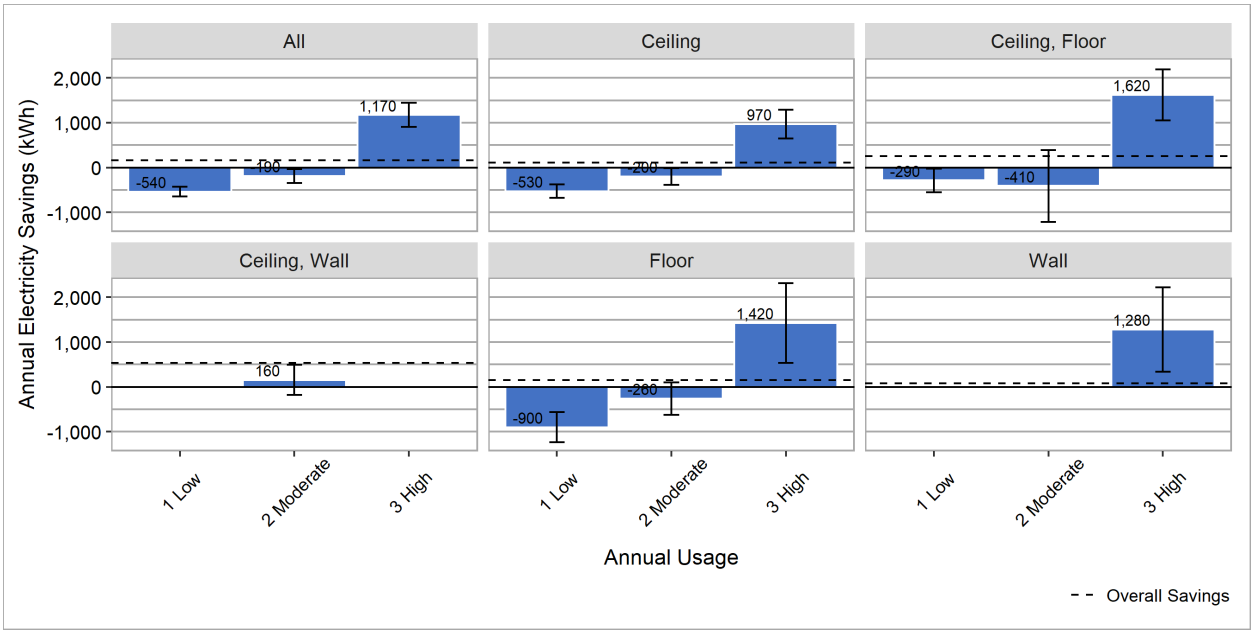


Figure 17: Electricity savings per home for gas-heated homes, by insulation measure and baseline annual electricity usage

Trends over Time

We analyzed insulation savings by installation year, from 2013 to 2018, to see if changes were occurring over time. To ensure large enough sample sizes to achieve meaningful results, we combined individual program years into two-year periods.

Electric-heated homes

There was no consistent trend in electricity savings in electric-heated homes over time for different insulation measures. Electricity savings by program year had moderate to low reliability ratings overall, so differences by program year could not be assessed with any certainty. Across all insulation measures, there was a slight, but insignificant decline in electricity savings over time. Looking at savings for all insulation measures simply reveals a change in the prevalence of insulation measures with different levels of savings over time, not a real decline in measure savings. The downward time trend in savings was not reflected in the ceiling or floor insulation results, which did not show any obvious patterns.

The trend over time in estimated electricity savings per home for the different types of insulation measures installed in electric-heated homes is shown in Chart 18, below.

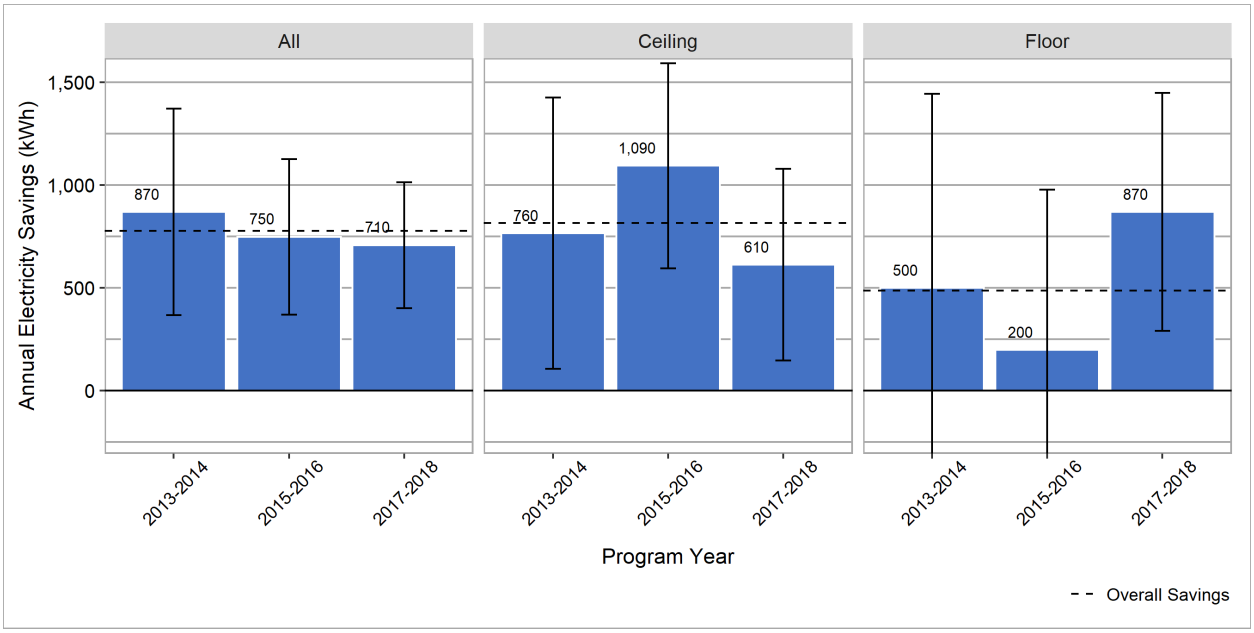


Figure 18: Electricity savings per home for electric-heated homes, by insulation measure and program year

Gas-heated homes

There were no meaningful changes in gas savings in gas-heated homes over time for different insulation measures. The savings results by program year were quite certain, with very high reliability ratings overall. Across all insulation measures, there was a slight, but insignificant increase in gas savings over time. However, looking at savings for all insulation measures simply reveals a change in the prevalence of insulation measures with different levels of savings, not a real increase in measure savings. There were no obvious trends over time for ceiling insulation, floor insulation, or ceiling and floor insulation combined. For the remaining insulation measures, differences in gas savings by program year could not be fully assessed due to small sample sizes.

There were no significant changes in electricity savings in gas-heated homes over time for different insulation measures. These savings estimates had low to very low reliability ratings overall, so differences by program year could not be assessed with any certainty. Across all insulation measures, there was a slight, but insignificant increase in electricity savings over time. However, looking at savings for all insulation measures simply reveals a change in the prevalence of insulation measures with different levels

of savings, not a real increase in measure savings. There were no obvious trends over time for ceiling insulation, floor insulation, or ceiling and floor insulation combined. For the remaining insulation measures, differences in electricity savings by program year could not be fully assessed due to small sample sizes.

Figures 19 and 20 show the differences in gas and electricity savings estimates per home, respectively, along with their precision, for the different types of insulation measures installed in gas-heated homes over time.

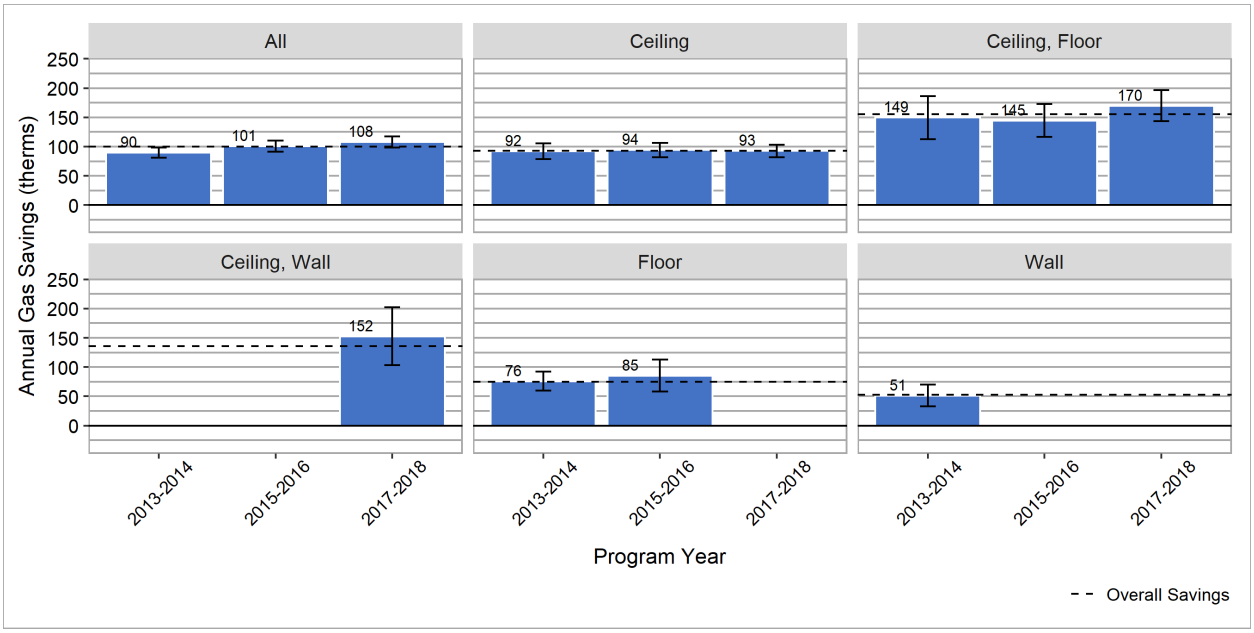


Figure 19: Gas savings per home for gas-heated homes, by insulation measure and program year

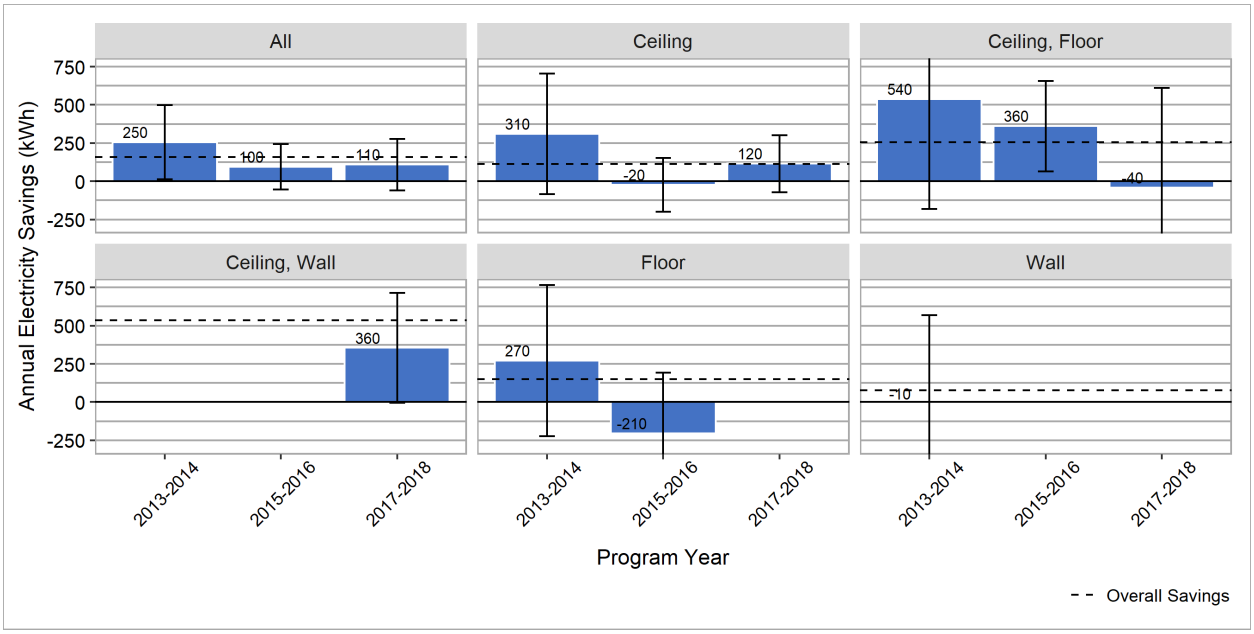


Figure 20: Electricity savings per home for gas-heated homes, by insulation measure and program year

CONCLUSIONS AND RECOMMENDATIONS

The Recurve analysis of residential insulation projects that received Energy Trust incentives found that energy savings were not in line with the insulation measures that Energy Trust had in place from 2013 to 2018 and deviated substantially from the savings claimed by the Residential program. Energy savings also varied substantially, depending on the insulation measure, heating fuel, and other factors.

For electric-heated homes, electricity savings were about 40 percent lower than expected for ceiling and floor insulation. We were unable to assess wall insulation savings due to a small available sample size resulting from high attrition. Overall savings per home for ceiling insulation were estimated at 810 kWh (+/- 310) per year, on average, 64 percent of expected. Overall savings per home for floor insulation were estimated at 490 kWh (+/- 490) per year, on average, 59 percent of expected. Savings for combined ceiling and floor insulation projects were roughly additive, at 1,240 kWh (+/- 830 kWh) per year per home, on average, 60 percent of expected.

In gas-heated homes, gas savings were roughly double what was expected across ceiling, floor, and wall insulation measures. There were also significant electricity savings attributable to insulation projects in gas-heated homes, even though only trivial kWh savings were claimed by the program. Overall savings per home for ceiling insulation were estimated at 93 therms (+/- 7) and 110 kWh (+/- 140) per year, on average, 193 percent of expected for gas. Overall savings per home for floor insulation were estimated at 75 therms (+/- 14) and 150 kWh (+/- 370) per year, on average, 230 percent of expected for gas. Overall savings per home for wall insulation were estimated at 53 therms (+/- 15) and 80 kWh (+/- 430) per year, on average, 165 percent of expected for gas. Savings for combined ceiling and floor insulation projects and ceiling and wall insulation projects were roughly additive.

It is relatively common for real-world energy savings to differ from the engineering estimates used to claim savings for many energy efficiency measures. These types of discrepancies are identified through Energy Trust's evaluation process. Measure and program savings are then adjusted accordingly going forward. While the differences in observed versus expected savings were relatively large for these residential insulation measures, the findings don't have a substantial impact on Residential program energy savings overall. Insulation measures in electric-heated homes made up only about 4 percent of the program's retrofit electricity savings claims from 2013-2018, and less than 1 percent of the total electricity savings for the residential sector. In gas-heated homes, insulation measures made up 9 percent of the program's retrofit gas savings claims and 4 percent of the total gas savings for the residential sector.

There were no clear trends in electricity or gas savings over time for different insulation measures. There were, however, many differences in gas and electricity savings for other factors, such as home size, home vintage, use of cooling, and annual energy usage. Unfortunately, we were unable to assess differences in insulation savings between heating zones 1 and 2, due to the small sample size of projects in heating zone 2. Many of the differences observed in savings between groups did not have any clear patterns across insulation measure types and heating fuel. The strongest trend, by far, to emerge was the association between insulation energy savings and baseline annual energy usage. Savings increased sharply from low- to high-usage homes in both gas- and electric-heated homes across a variety of insulation measures.

A potential limitation of this analysis is that the results may not represent the population of insulation projects in the broader program because we were only able to analyze measures that were installed by themselves, or in concert with other insulation measures. These projects may or may not differ from

insulation projects that installed other measures during the analysis period. We did observe that projects included in the analysis sample tended to install smaller quantities of insulation than in the overall program population. Another limitation is that we did not have data available on the square footage of insulation installed for individual projects, or the exact versions of the insulation measures used. However, we estimated the average deemed savings values per square foot used for each measure category, based on the overall program activity, and used the total savings claimed per project to estimate the average quantity of insulation installed per project. Using this information, we were able to compute the average savings per square foot of insulation. Using these values allows us to more directly compare the results of this analysis to the program's deemed savings values, although there is likely some degree of error involved, based on the assumptions described above.

It is not clear why gas-heated homes had such high savings and realization rates, other than the obvious explanation that the deemed savings values in effect during the analysis period dramatically underestimated the real-world gas savings from insulation. The much lower realization rates observed in electric-heated homes have several plausible explanations, foremost of which is that Energy Trust's insulation measures at the time were based on erroneous assumptions. For electric-heated homes, the savings were based on billing analysis results from gas-heated homes and simply converted to electricity savings, assuming an electric forced air furnace heating system and similar housing characteristics. However, we know from NEEA's Residential Building Stock Assessment[5] that electric-heated homes differ from those assumptions in several important ways.

Nearly half of electric-heated single-family homes in the Northwest have a heat pump (somewhat lower for manufactured homes). Since heat pumps are much more efficient than electric forced air furnaces, shell improvements in heat pump homes have a smaller savings opportunity. Many of the remaining electric-heated homes have zonal heating systems, like baseboards or wall heaters, which don't have directly comparable energy usage patterns to gas furnaces. In addition, heating costs can be very high for poorly insulated homes with zonal systems, so residents may sacrifice comfort to save money. Once a home is better insulated, residents may partially take back the electricity savings by increasing their heating setpoints to improve their comfort. Another important factor in electric-heated homes is the higher prevalence of secondary heating systems using supplemental fuels, like wood stoves. Again, this scenario results in a lower opportunity for savings since some of the heat is provided by a non-electric fuel. It may also result in residents reducing their supplemental fuel consumption rather than realizing the expected electricity savings. Electric-heated homes also tend to be smaller with lower heating loads and less opportunity for energy savings from insulation.

All of the home characteristics described above tend to lower electricity savings for insulation measures in electric-heated homes, compared to the assumptions used to develop the deemed savings values. The insulation measures analyzed in this report have since been discontinued and the deemed savings values have been updated based on the RTF's insulation measures, which use more accurate assumptions about HVAC equipment, home characteristics, and energy usage.

We recommend reviewing Energy Trust's current residential insulation measures and comparing the deemed savings values to the savings observed in this study. If there is a substantial discrepancy, then the

[5] Northwest Energy Efficiency Alliance. 2019. Residential Buildings Stock Assessment II: Single-Family Homes Report 2016-2017. Accessed online on 2/16/2022 from: https://neea.org/img/uploads/Residential-Building-Stock-Assessment-II-Single-Family-Homes-Report-2016-2017.pdf.

deemed savings for the updated insulation measures may need to be adjusted to better align with the billing analysis results. In addition, we recommend that the RTF review the results of this study and incorporate the findings into their insulation measures, which Energy Trust's current measures are based upon. To make this comparison, the observed savings must be put in terms of energy savings per square foot of insulation installed. This can be achieved by applying the insulation project realization rates to the deemed savings values per square foot of insulation (listed in Tables 1 and 2), to arrive at updated estimates of insulation savings per square foot. For wall insulation in electric-heated homes, we do not have a realization rate estimate, so we use the overall average realization rate across all insulation measures in electric-heated homes as an approximation. Our estimates of electric and gas savings per square foot of insulation installed, by insulation type, are listed in Table 6, below.

Table 6: Estimated savings per square foot of insulation installed, by heating fuel, fuel analyzed, and insulation measure

Heating Fuel	Fuel Analyzed	Measure	Average Deemed Savings Per Sq. Ft. of Insulation	Savings Realization Rate	Estimated Sq. Ft. of Insulation Installed	Estimated Savings Per Sq. Ft. of Insulation
Electric	kWh	Ceiling	1.36	64%	940	0.87
		Floor	0.97	59%	860	0.57
		Wall[*]	*1.20*	*63%*	--	*0.76*
Gas	Therms	Ceiling	0.059	193%	810	0.114
		Floor	0.040	230%	800	0.092
		Wall	0.050	165%	640	0.083

[*] The updated electricity savings estimate for wall insulation is an approximation based on the assumption that the electric realization rate for wall insulation projects is similar to that of all insulation projects in electric-heated homes.

For electricity savings in gas-heated homes, the savings estimates were relatively small but appeared consistently across analyses. These electricity savings are likely due to reduced furnace fan operation in the winter, and possibly reduced supplemental electric heat, such as wall heaters. We don't believe that reduced air conditioning during the summer cooling season played a major role, since we observed that homes that used cooling equipment appeared to save less electricity than those with no cooling. It is not clear why homes with cooling usage saved somewhat less electricity, but it may be correlated with other housing characteristics linked to lower savings, such as use of supplemental heating fuels. We recommend that Energy Trust claim electricity savings for ceiling, floor, and wall insulation measures installed in gas-heated homes. New deemed savings values can be based on the results of this study, with the savings estimates divided by the typical project sizes to provide an estimate of savings per square foot. The updated electricity savings estimates per square foot of insulation installed in gas heated homes, by insulation type, are listed in Table 7, below.

Table 7: Estimated electricity savings, in kWh, per square foot of insulation installed in gas heated homes, by insulation measure

Measure	Annual Savings Estimate (kWh)	Average Insulation Quantity (Sq. Ft.)	Estimated Savings Per Sq. Ft. of Insulation
Ceiling	110	810	0.14
Floor	150	800	0.19

Wall	80	640	0.13

We recommend conducting a thorough review of program rules and installation requirements for insulation measures in electric-heated homes to determine what was driving the lower-than-expected savings. More thorough screening for supplemental fuels, like wood and gas, may be necessary to improve insulation measure electricity savings. However, screening out homes with supplemental fuel use may be counter to Energy Trust's DEI efforts, as many rural residents use wood stoves to supplement their electric heating systems. Alternatively, offsets in wood use could be quantified and valued as non-energy benefits. Whether or not program rules and requirements are updated, we recommend a period of increased training and quality control visits to ensure that contractors are enforcing program rules and meeting current installation requirements.

If cost-effectiveness constraints become an issue, especially in electric-heated homes, Energy Trust could screen new measures based on baseline energy usage. Low-usage homes saved less energy, on average, than moderate- and high-usage homes. If new insulation measures were developed focused on moderate- and high-usage homes, higher levels of savings could be claimed. However, this could be counter to Energy Trust's DEI efforts, as many low-income residents and people of color reside in homes that use less energy but could still benefit from improved insulation. This is often because low-income households sacrifice comfort to save money on their utility bills. When insulation is installed in such homes, the energy savings potential is simply lower, although residents may realize large benefits in terms of increasing their comfort level without impacting their utility bills.

Future research on insulation measures should focus on refining savings estimates per square foot of insulation installed, improving savings estimates for electric-heated homes, quantifying savings by heating system type, particularly in electric-heated homes, quantifying savings for heating zone 2, and attempting to quantify potential cooling savings. These issues are difficult to research because there are either a small number of projects each year to draw from or the expected savings are small and would thus require large sample sizes, and/or access to high-frequency electricity meter data, to quantify.

APPENDIX A: COMPLETE SUMMARY OF RESULTS

This appendix provides a complete summary of the results presented in the report above. In Table 6, below, we summarize the electricity savings results for the insulation measure scenarios analyzed above for electric-heated homes. In Tables 7 and 8, we summarize the gas and electricity savings results, respectively, for gas-heated homes. Results are provided in annual kWh and therm savings for homes that installed an insulation measure from 2013 to 2018. For context, additional information like precision, sample size, and annual energy usage is also provided.

Table 8: Electricity savings for electric-heated homes by insulation measure for all analysis groups

Measure	Group	N[1]	Baseline Annual Usage[2]	Est. Heating Usage[2]	Est. Cooling Usage[2]	Est. Annual Savings[3]	Absolute Precision[4]	% Savings[5]	Reliability Rating[6]
Overall Savings									
Ceiling	All	354	15,600	5,690	760	810	310	5.2%	Moderate
Ceiling, Floor	All	82	15,180	6,070	670	1,240	830	8.1%	Low
Floor	All	216	16,240	5,750	510	490	490	3.0%	Very Low
All	All	731	15,650	5,790	650	780	230	5.0%	Moderate
Savings by Heating Zone									
Ceiling	HZ 1	341	15,600	5,700	770	790	320	5.1%	Moderate
	HZ 2*	--	--	--	--	--	--	--	--
Ceiling, Floor	HZ 1	80	15,080	6,070	690	1,280	840	8.5%	Low
	HZ 2*	--	--	--	--	--	--	--	--
Floor	HZ 1	211	16,160	5,670	520	490	500	3.0%	Very Low
	HZ 2*	--	--	--	--	--	--	--	--
All	HZ 1	709	15,600	5,750	650	770	240	4.9%	Moderate
	HZ 2*	--	--	--	--	--	--	--	--
Savings by Home Size									
Ceiling	<1,400	109	12,460	5,260	520	600	520	4.8%	Low
	1,400-2,199	144	16,280	5,600	730	960	510	5.9%	Low
	2,200+	80	18,170	5,840	1,120	960	650	5.3%	Low
Ceiling, Floor	<1,400*	--	--	--	--	--	--	--	--
	1,400-2,199*	--	--	--	--	--	--	--	--
	2,200+*	--	--	--	--	--	--	--	--
Floor	<1,400	83	13,470	5,140	390	860	820	6.3%	Low
	1,400-2,199	82	16,910	6,110	590	670	700	4.0%	Very Low
	2,200+	43	19,410	5,720	640	-410	1,280	-2.1%	Very Low
All	<1,400	259	12,940	5,200	430	740	390	5.7%	Low
	1,400-2,199	287	16,350	5,800	730	840	350	5.1%	Moderate
	2,200+	148	18,600	6,370	880	860	620	4.6%	Low
Savings by Home Age									
Ceiling	1875-1949	55	13,730	4,890	410	210	520	1.6%	Very Low
	1950-1969	120	15,350	5,730	590	870	640	5.7%	Low
	1970+	179	16,350	5,910	990	960	400	5.9%	Moderate
Ceiling, Floor	1875-1949*	--	--	--	--	--	--	--	--
	1950-1969*	--	--	--	--	--	--	--	--
	1970+	46	16,110	6,430	870	1,880	1,200	11.7%	Very Low
Floor	1875-1949*	--	--	--	--	--	--	--	--
	1950-1969	57	14,200	5,490	550	380	930	2.7%	Very Low

Measure	Group	N[1]	Baseline Annual Usage[2]	Est. Heating Usage[2]	Est. Cooling Usage[2]	Est. Annual Savings[3]	Absolute Precision[4]	% Savings[5]	Reliability Rating[6]
	1970+	125	17,470	5,980	540	520	620	3.0%	Very Low
All	1875-1949	137	13,970	5,550	390	570	460	4.1%	Low
	1950-1969	232	14,890	5,620	530	730	450	4.9%	Low
	1970+	362	16,780	6,000	820	880	330	5.3%	Moderate
Savings by Use of Cooling									
Ceiling	Cooling	157	16,210	5,680	1,680	810	430	5.0%	Low
	No Cooling	197	15,120	5,700	30	820	430	5.4%	Low
Ceiling, Floor	Cooling*	--	--	--	--	--	--	--	--
	No Cooling	49	14,450	6,230	20	1,500	1,290	10.4%	Very Low
Floor	Cooling	85	16,370	5,320	1,270	-240	690	-1.5%	Moderate
	No Cooling	131	16,150	6,020	10	960	660	5.9%	Low
All	Cooling	311	16,170	5,680	1,490	480	310	3.0%	Low
	No Cooling	420	15,270	5,880	20	990	340	6.5%	Moderate
Savings by Annual kWh Usage									
Ceiling	<11,500 kWh	114	8,070	2,730	540	-710	420	-8.8%	Moderate
	11,500-18,000 kWh	123	14,850	5,220	640	850	400	5.7%	Moderate
	18,000+ kWh	117	23,740	9,100	1,100	2,270	650	9.5%	Moderate
Ceiling, Floor	<11,500 kWh*	--	--	--	--	--	--	--	--
	11,500-18,000 kWh*	--	--	--	--	--	--	--	--
	18,000+ kWh*	--	--	--	--	--	--	--	--
Floor	<11,500 kWh	63	8,360	2,800	300	-690	590	-8.2%	Low
	11,500-18,000 kWh	89	14,840	5,380	490	390	510	2.6%	Very Low
	18,000+ kWh	64	25,930	9,150	730	1,780	1,330	6.9%	Low
All	<11,500 kWh	236	8,150	2,840	440	-660	280	-8.1%	Very High
	11,500-18,000 kWh	267	14,910	5,330	550	630	270	4.2%	Moderate
	18,000+ kWh	228	24,300	9,410	980	2,430	570	10.0%	Moderate
Savings by Program Year									
Ceiling	2013-2014	102	16,260	6,110	580	760	660	4.7%	Low
	2015-2016	117	16,070	5,420	1,020	1,090	500	6.8%	Moderate
	2017-2018	135	14,700	5,620	680	610	470	4.2%	Low
Ceiling, Floor	2013-2014*	--	--	--	--	--	--	--	--
	2015-2016*	--	--	--	--	--	--	--	--
	2017-2018*	--	--	--	--	--	--	--	--
Floor	2013-2014	87	16,210	6,770	410	500	940	3.1%	Very Low
	2015-2016	75	16,090	4,410	760	200	780	1.2%	Very Low
	2017-2018	54	16,480	5,960	310	870	580	5.3%	Low
All	2013-2014	249	16,040	6,350	540	870	500	5.4%	Low
	2015-2016	238	15,840	5,090	870	750	380	4.7%	Low
	2017-2018	244	15,080	5,910	540	710	310	4.7%	Moderate

* This category is not reported due to an insufficient sample size (n <40).

[1] N is the final treatment group sample size available for each analysis. Only measure categories with n ≥40 are reported, so the sample sizes for individual measure categories do not sum to equal the "All" measures category. The "All" measures category includes less prevalent insulation measure not reported separately.
[2] The estimated weather normalized total annual electricity usage, heating usage, and cooling usage in kWh during the baseline.
[3] The estimated weather normalized annual electricity savings in kWh, using TMY3 weather data, after removal of effects observed in the matched comparison group.
[4] Absolute precision of the savings estimate at the 90 percent confidence level.
[5] Energy savings as a percentage of the weather normalized baseline annual usage.
[6] Reliability rating of the savings estimate, based on relative precision and sample size.

Table 9: Gas savings for gas-heated homes by insulation measure for all analysis groups

Measure	Group	N[1]	Baseline Annual Usage[2]	Est. Heating Usage[2]	Est. Annual Savings[3]	Absolute Precision[4]	% Savings[5]	Reliability Rating[6]
Savings Overall								
Ceiling	All	1,070	692	567	93	7	13.5%	Very High
Ceiling, Floor	All	236	713	591	156	17	21.9%	High
Ceiling, Wall	All	125	616	500	136	26	22.1%	High
Floor	All	244	700	563	75	14	10.7%	High
Wall	All	125	558	449	53	15	9.5%	Moderate
All	All	1,848	678	555	100	5	14.7%	Very High
Savings by Heating Zone								
Ceiling	HZ 1	1,048	689	564	91	7	13.3%	Very High
	HZ 2*	--	--	--	--	--	--	--
Ceiling, Floor	HZ 1	232	710	591	155	17	21.9%	High
	HZ 2*	--	--	--	--	--	--	--
Ceiling, Wall	HZ 1	125	616	500	136	26	22.1%	High
	HZ 2*	--	--	--	--	--	--	--
Floor	HZ 1	239	695	560	74	14	10.6%	High
	HZ 2*	--	--	--	--	--	--	--
Wall	HZ 1	125	558	449	53	15	9.5%	Moderate
	HZ 2*	--	--	--	--	--	--	--
All	HZ 1	1,817	676	553	99	5	14.6%	Very High
	HZ 2*	--	--	--	--	--	--	--
Savings by Home Size								
Ceiling	<1,400	258	510	421	72	11	14.1%	High
	1,400-2,199	426	687	566	107	11	15.6%	Very High
	2,200+	301	867	702	93	16	10.7%	High
Ceiling, Floor	<1,400	80	585	484	161	28	27.6%	Moderate
	1,400-2,199	100	735	610	159	26	21.7%	Moderate
	2,200+	40	901	737	166	39	18.4%	Very Low
Ceiling, Wall	<1,400*	--	--	--	--	--	--	--
	1,400-2,199	48	654	547	148	49	22.6%	Very Low
	2,200+*	--	--	--	--	--	--	--
Floor	<1,400	82	545	451	63	22	11.6%	Moderate
	1,400-2,199	94	735	587	95	25	13.0%	Moderate
	2,200+	63	848	670	67	23	7.9%	Low
Wall	<1,400	50	499	403	53	18	10.6%	Low
	1,400-2,199	42	551	446	40	31	7.3%	Very Low

Measure	Group	N[1]	Baseline Annual Usage[2]	Est. Heating Usage[2]	Est. Annual Savings[3]	Absolute Precision[4]	% Savings[5]	Reliability Rating[6]
	2,200+*	--	--	--	--	--	--	--
All	<1,400	525	526	434	90	9	17.1%	Very High
	1,400-2,199	724	688	564	112	9	16.2%	Very High
	2,200+	475	839	678	95	12	11.3%	High
Savings by Home Age								
Ceiling	1875-1949	261	650	545	76	14	11.6%	High
	1950-1969	342	651	550	100	11	15.3%	High
	1970+	467	745	591	98	11	13.2%	High
Ceiling, Floor	1875-1949*	--	--	--	--	--	--	--
	1950-1969	72	671	568	180	33	26.8%	Low
	1970+	128	743	612	160	22	21.5%	High
Ceiling, Wall	1875-1949	53	604	480	135	33	22.3%	Low
	1950-1969	54	601	509	130	45	21.6%	Low
	1970+*	--	--	--	--	--	--	--
Floor	1875-1949	49	660	526	83	32	12.6%	Very Low
	1950-1969	72	631	519	61	21	9.6%	Low
	1970+	123	755	603	79	21	10.5%	Moderate
Wall	1875-1949	64	591	475	61	22	10.3%	Low
	1950-1969	53	526	423	36	21	6.8%	Low
	1970+*	--	--	--	--	--	--	--
All	1875-1949	490	638	526	84	10	13.2%	High
	1950-1969	605	634	531	102	9	16.1%	Very High
	1970+	753	741	592	108	9	14.5%	Very High
Savings by Annual Therm Usage								
Ceiling	<530 therms	336	390	332	36	8	9.2%	Moderate
	530-759 therms	364	639	521	87	10	13.6%	High
	760+ therms	370	1,017	818	151	14	14.8%	Very High
Ceiling, Floor	<530 therms	63	389	323	61	23	15.7%	Low
	530-759 therms	81	647	532	165	23	25.5%	Moderate
	760+ therms	92	992	821	212	32	21.4%	Moderate
Ceiling, Wall	<530 therms	55	398	335	72	24	18.2%	Low
	530-759 therms	41	638	503	137	39	21.5%	Very Low
	760+ therms*	--	--	--	--	--	--	--
Floor	<530 therms	70	382	308	8	18	2.1%	Very Low
	530-759 therms	90	648	526	65	21	10.0%	Moderate
	760+ therms	84	1,019	809	140	26	13.7%	Moderate
Wall	<530 therms	67	391	340	28	19	7.1%	Low
	530-759 therms*	--	--	--	--	--	--	--
	760+ therms*	--	--	--	--	--	--	--
All	<530 therms	614	390	329	39	6	10.0%	High
	530-759 therms	629	641	520	96	8	15.0%	Very High
	760+ therms	605	1,010	814	165	12	16.3%	Very High
Savings by Program Year								
Ceiling	2013-2014	243	687	561	92	13	13.4%	High
	2015-2016	388	691	546	94	12	13.6%	High
	2017-2018	439	695	588	93	11	13.3%	High
Ceiling, Floor	2013-2014	59	720	590	149	37	20.8%	Low
	2015-2016	84	685	551	145	28	21.1%	Moderate
	2017-2018	93	733	626	170	27	23.2%	Moderate
	2013-2014*	--	--	--	--	--	--	--

Measure	Group	N[1]	Baseline Annual Usage[2]	Est. Heating Usage[2]	Est. Annual Savings[3]	Absolute Precision[4]	% Savings[5]	Reliability Rating[6]
Ceiling, Wall	2015-2016*	--	--	--	--	--	--	--
	2017-2018	49	605	514	152	49	25.2%	Very Low
Floor	2013-2014	169	700	563	76	16	10.8%	Moderate
	2015-2016	54	753	601	85	28	11.3%	Low
	2017-2018*	--	--	--	--	--	--	--
Wall	2013-2014	86	572	463	51	19	9.0%	Moderate
	2015-2016*	--	--	--	--	--	--	--
	2017-2018*	--	--	--	--	--	--	--
All	2013-2014	613	671	544	90	9	13.4%	Very High
	2015-2016	608	680	538	101	10	14.9%	Very High
	2017-2018	627	684	581	108	10	15.8%	Very High

* This category is not reported due to an insufficient sample size (n <40).

[1] N is the final treatment group sample size available for each analysis. Only measure categories with n ≥40 are reported, so the sample sizes for individual measure categories do not sum to equal the "All" measures category. The "All" measures category includes less prevalent insulation measure not reported separately.

[2] The estimated weather normalized total annual gas usage and heating usage in therms during the baseline period.

[3] The estimated weather normalized annual gas savings in therms, using TMY3 weather data, after removal of effects observed in the matched comparison group.

[4] Absolute precision of the savings estimate at the 90 percent confidence level.

[5] Energy savings as a percentage of the weather normalized baseline annual usage.

[6] Reliability rating of the savings estimate, based on relative precision and sample size.

Table 10: Electricity savings for gas-heated homes by insulation measure for all analysis groups

Measure	Group	N[1]	Baseline Annual Usage[2]	Est. Heating Usage[2]	Est. Cooling Usage[2]	Est. Annual Savings[3]	Absolute Precision[4]	% Savings[5]	Reliability Rating[6]
Overall Savings									
Ceiling	All	835	9,120	1,670	830	110	140	1.2%	Very Low
Ceiling, Floor	All	181	8,330	1,660	750	250	330	3.1%	Very Low
Ceiling, Wall	All	109	8,440	1,590	550	530	480	6.3%	Low
Floor	All	215	9,770	1,770	760	150	370	1.5%	Very Low
Wall	All	108	9,460	1,820	450	80	430	0.8%	Very Low
All	All	1,491	9,070	1,690	750	160	120	1.8%	Low
Savings by Heating Zone									
Ceiling	HZ 1	827	9,090	1,660	830	120	140	1.4%	Very Low
	HZ 2*	--	--	--	--	--	--	--	--
Ceiling, Floor	HZ 1	178	8,400	1,680	770	290	330	3.5%	Very Low
	HZ 2*	--	--	--	--	--	--	--	--
Ceiling, Wall	HZ 1	109	8,440	1,590	550	530	480	6.3%	Low
	HZ 2*	--	--	--	--	--	--	--	--
Floor	HZ 1	212	9,780	1,760	770	150	380	1.5%	Very Low
	HZ 2*	--	--	--	--	--	--	--	--
Wall	HZ 1	108	9,460	1,820	450	80	430	0.8%	Very Low
	HZ 2*	--	--	--	--	--	--	--	--
All	HZ 1	1,477	9,060	1,690	760	170	120	1.9%	Low
	HZ 2*	--	--	--	--	--	--	--	--

Measure	Group	N[1]	Baseline Annual Usage[2]	Est. Heating Usage[2]	Est. Cooling Usage[2]	Est. Annual Savings[3]	Absolute Precision[4]	% Savings[5]	Reliability Rating[6]
Savings by Home Size									
Ceiling	<1,400	216	7,260	1,550	530	420	340	5.8%	Low
	1,400-2,199	321	9,040	1,610	930	160	220	1.8%	Very Low
	2,200+	239	11,040	1,890	970	-180	240	-1.6%	Very High
Ceiling, Floor	<1,400	64	6,660	1,320	570	270	390	4.1%	Very Low
	1,400-2,199	73	8,470	1,760	870	60	680	0.7%	Very Low
	2,200+*	--	--	--	--	--	--	--	--
Ceiling, Wall	<1,400*	--	--	--	--	--	--	--	--
	1,400-2,199	45	7,900	1,670	600	830	850	10.5%	Very Low
	2,200+*	--	--	--	--	--	--	--	--
Floor	<1,400	68	8,380	1,920	530	0	580	0.0%	Very Low
	1,400-2,199	81	8,730	1,540	740	-220	560	-2.5%	Moderate
	2,200+	63	12,660	1,890	1,060	770	850	6.1%	Very Low
Wall	<1,400	45	7,980	1,570	380	-190	500	-2.4%	Very Low
	1,400-2,199*	--	--	--	--	--	--	--	--
	2,200+*	--	--	--	--	--	--	--	--
All	<1,400	435	7,340	1,530	500	260	210	3.6%	Low
	1,400-2,199	569	8,880	1,660	840	180	190	2.0%	Very Low
	2,200+	396	11,340	1,940	930	50	220	0.4%	Very Low
Savings by Home Age									
Ceiling	1875-1949	218	8,060	1,940	600	90	290	1.1%	Very Low
	1950-1969	274	9,770	1,660	820	50	290	0.5%	Very Low
	1970+	343	9,280	1,510	980	180	190	1.9%	Very Low
Ceiling, Floor	1875-1949*	--	--	--	--	--	--	--	--
	1950-1969	59	7,740	1,590	530	-130	840	-1.6%	Low
	1970+	94	8,850	1,660	990	470	300	5.4%	Low
Ceiling, Wall	1875-1949	46	7,660	1,780	490	370	820	4.9%	Very Low
	1950-1969	44	8,950	1,460	640	980	770	10.9%	Very Low
	1970+*	--	--	--	--	--	--	--	--
Floor	1875-1949	44	9,020	1,500	710	-330	670	-3.7%	Very Low
	1950-1969	63	9,190	1,840	560	0	440	0.0%	Very Low
	1970+	108	10,410	1,840	910	430	640	4.1%	Very Low
Wall	1875-1949	54	9,180	1,740	440	230	570	2.5%	Very Low
	1950-1969	46	9,510	2,010	440	-20	760	-0.2%	Very Low
	1970+*	--	--	--	--	--	--	--	--
All	1875-1949	412	8,230	1,790	570	100	210	1.3%	Very Low
	1950-1969	501	9,280	1,700	690	100	220	1.1%	Very Low
	1970+	578	9,480	1,610	940	250	170	2.6%	Low
Savings by Use of Cooling									
Ceiling	Cooling	482	9,760	1,460	1,390	90	180	0.9%	Very Low
	No Cooling	353	8,250	1,960	60	140	240	1.8%	Very Low
Ceiling, Floor	Cooling	99	9,360	1,570	1,320	60	470	0.7%	Very Low
	No Cooling	82	7,090	1,770	70	490	460	6.9%	Low
Ceiling, Wall	Cooling	47	9,520	1,310	1,200	550	830	5.7%	Very Low
	No Cooling	62	7,620	1,800	50	530	560	6.9%	Very Low
Floor	Cooling	104	11,100	1,540	1,500	-30	620	-0.3%	Moderate

Measure	Group	N[1]	Baseline Annual Usage[2]	Est. Heating Usage[2]	Est. Cooling Usage[2]	Est. Annual Savings[3]	Absolute Precision[4]	% Savings[5]	Reliability Rating[6]
	No Cooling	111	8,520	1,980	80	320	430	3.7%	Very Low
Wall	Cooling	49	9,840	1,730	920	20	540	0.2%	Very Low
	No Cooling	59	9,150	1,890	70	120	650	1.4%	Very Low
All	Cooling	800	9,860	1,490	1,350	80	160	0.9%	Very Low
	No Cooling	691	8,140	1,920	60	250	170	3.0%	Low
Savings by Annual kWh Usage									
Ceiling	<6,200 kWh	271	4,460	760	470	-530	150	-11.9%	Very High
	6,200 to 9,999 kWh	265	8,040	1,380	720	-200	180	-2.5%	Very High
	10,000+ kWh	299	14,300	2,750	1,250	970	320	6.8%	Moderate
Ceiling, Floor	<6,200 kWh	72	4,380	860	330	-290	270	-6.6%	Low
	6,200 to 9,999 kWh	54	8,070	1,620	930	-410	800	-5.1%	Low
	10,000+ kWh	55	13,760	2,750	1,140	1,620	570	11.8%	Low
Ceiling, Wall	<6,200 kWh*	--	--	--	--	--	--	--	--
	6,200 to 9,999 kWh	44	7,870	1,560	510	160	340	2.0%	Very Low
	10,000+ kWh*	--	--	--	--	--	--	--	--
Floor	<6,200 kWh	65	4,290	750	350	-900	340	-21.0%	Low
	6,200 to 9,999 kWh	73	8,100	1,270	670	-260	360	-3.3%	Low
	10,000+ kWh	77	15,970	3,100	1,210	1,420	890	8.9%	Low
Wall	<6,200 kWh*	--	--	--	--	--	--	--	--
	6,200 to 9,999 kWh*	--	--	--	--	--	--	--	--
	10,000+ kWh	40	14,460	2,930	460	1,280	940	8.8%	Very Low
All	<6,200 kWh	490	4,420	790	410	-540	110	-12.2%	Very High
	6,200 to 9,999 kWh	493	8,030	1,410	690	-190	150	-2.4%	Very High
	10,000+ kWh	508	14,550	2,830	1,160	1,170	270	8.1%	Moderate
Savings by Program Year									
Ceiling	2013-2014	225	10,230	2,190	760	310	390	3.0%	Very Low
	2015-2016	328	9,440	1,470	900	-20	180	-0.3%	Very High
	2017-2018	282	7,860	1,490	790	120	190	1.5%	Very Low
Ceiling, Floor	2013-2014	48	10,410	2,050	620	540	720	5.2%	Very Low
	2015-2016	64	6,990	1,140	840	360	300	5.2%	Low
	2017-2018	69	8,130	1,870	770	-40	650	-0.5%	Low
Ceiling, Wall	2013-2014*	--	--	--	--	--	--	--	--
	2015-2016*	--	--	--	--	--	--	--	--
	2017-2018	45	7,880	1,410	680	360	360	4.5%	Very Low
Floor	2013-2014	157	10,260	1,920	760	270	490	2.6%	Very Low
	2015-2016	45	8,710	1,220	810	-210	400	-2.4%	Very Low
	2017-2018*	--	--	--	--	--	--	--	--
Wall	2013-2014	77	9,970	2,170	410	-10	580	-0.1%	Low
	2015-2016*	--	--	--	--	--	--	--	--
	2017-2018*	--	--	--	--	--	--	--	--
All	2013-2014	556	10,120	2,080	680	250	240	2.5%	Low
	2015-2016	506	8,960	1,390	830	100	150	1.1%	Very Low
	2017-2018	429	7,820	1,540	770	110	170	1.4%	Very Low

* This category is not reported due to an insufficient sample size (n <40).

[1] N is the final treatment group sample size available for each analysis. Only measure categories with n ≥40 are reported, so the sample sizes for individual measure categories do not sum to equal the "All" measures category. The "All" measures category includes less prevalent insulation measure not reported separately.

[2] The estimated weather normalized total annual electricity usage, heating usage, and cooling usage in kWh during the baseline.

[3] The estimated weather normalized annual electricity savings in kWh, using TMY3 weather data, after removal of effects observed in the matched comparison group.

[4] Absolute precision of the savings estimate at the 90 percent confidence level.

[5] Energy savings as a percentage of the weather normalized baseline annual usage.

[6] Reliability rating of the savings estimate, based on relative precision and sample size.