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Next Step Homes Phase 1: Savings Validation

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1 Executive Summary

NEEA has been working to improve energy efficiency in new construction with its Efficient Homes Initiative. Next Step Homes (NSH) project initiative embodies this effort and aims to bring current advanced technologies and building practices for adoption into code during the next 3-4 code cycles (9-12 years).

The NSH initiative[1] is currently being tested to identify challenges, best practices, incremental costs and overall performance. NEEA completed Phase 1 of the project in 2014, which included 12 homes that were built to the NSH benchmark specification throughout the Northwest region. Sub-metering of these homes and several major systems continued for a year following construction completion to understand how the efficient features of these homes continued to perform.

The goal of the effort by Energy 350 was to assess the quality and reliability of the savings estimates provided by the implementation team for the 12 pilot homes included in Phase 1 of the initiative. Our savings validation approach was to compare modeled results of the as-built homes to both a modeled code baseline home and to NEEA's benchmark specification. We decided on this model based approach to provide an apples to apples comparison between a theoretical code home and the as-built home, and to eliminate the influence that occupant behavior has on actual energy use.

To build the models we used the commercially available home rating software, REM/Rate that had been recently modified to better reflect conditions of the Pacific Northwest. This NW version of REM/Rate was used to both model the as-built conditions, as well as a comparable code home, labeled a User Defined Reference Home (UDRH) for each of the pilot homes. A separate UDRH was also created based on NEEA's benchmark specification document that lists a set of minimum performance factors required for homes enrolled in this pilot. Our team analyzed savings from this baseline to determine how far builders went above the benchmark specification.

Through performing this analysis we were able to make a number of observations on the impact of the NSH initiative and how savings were realized in each home. For all 12 homes, builders were able to meet the NSH guideline specifications for the maximum area weighted heat transfer coefficient (UA) of 300 btu/hr-°F for homes in Climate Zone 1, and 200 btu/hr-°F for homes in Climate Zone 2. While moving the ducts inside contributed to the majority of savings in one home, the remaining 11 homes experienced the majority of savings due to the substantial reduction in infiltration and the added insulation to above-grade walls. For 6 out of the 11 homes, above-grade walls were the largest contributor to savings, with these homes saving an average of 26% above their respective code baselines. For the other 5 homes, infiltration reduction was the largest contributor to savings and yielded an average of 33% above a code baseline.

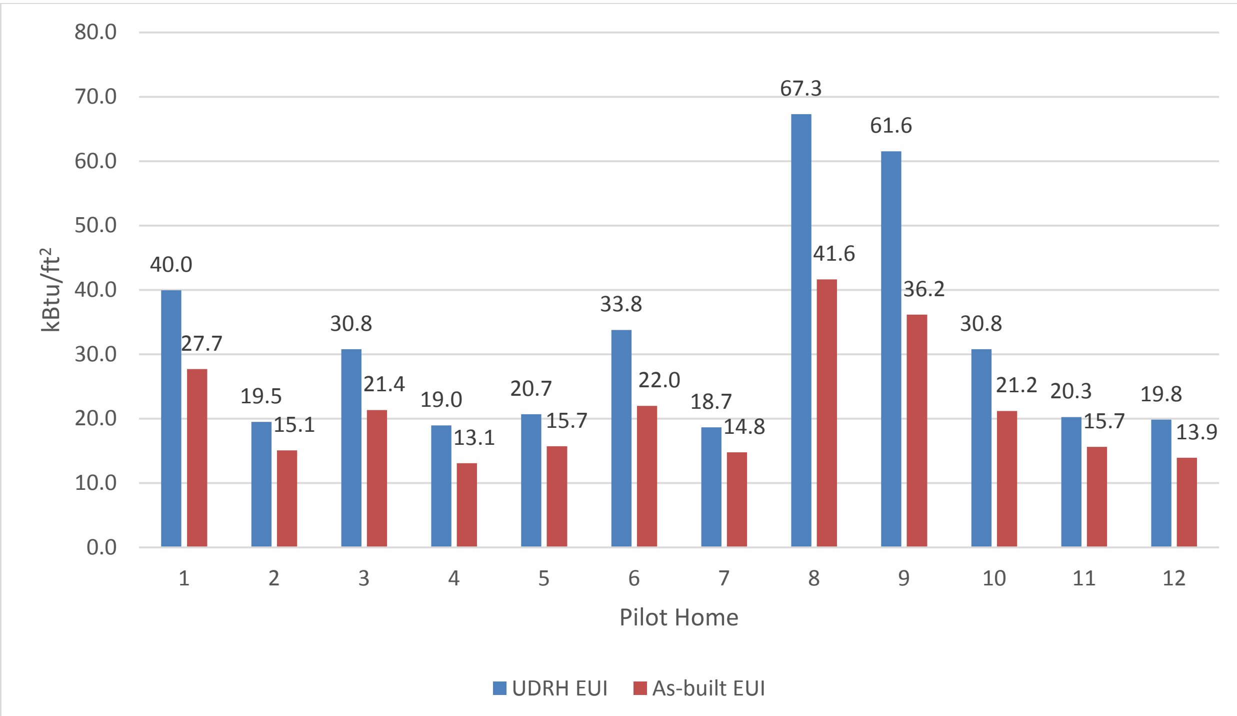
Overall we verified that the savings for the Phase 1 of the Next Step Homes initiative averaged 30% beyond an equivalent code home, with one home in the pilot indicating

[1] NSH initiative details see Appendix C

savings that were 41% beyond a comparable code home. Additionally, all 12 builders constructed homes that went beyond the minimum performance requirements laid out in the benchmark specification document. Pilot homes averaged 19% beyond the benchmark specification, with one home surpassing the maximum envelope UA value listed in the performance specification by 46%.

The chart below provides a summary of the changes in Energy Use Intensity (EUI) for all 12 as-built pilot homes and their equivalent baseline UDRH as modeled by NW REM/Rate.

Figure 1. As-Built NSH Home Compared to UDRH Energy Use Intensity (EUI)



A summary of consumption for all homes and percent savings above an equivalent code UDRH and benchmark specification is also given in the table below.

Table 1. Summary of Consumption and Percent Savings Above an Equivalent UDRH

Pilot Home	State	Square Footage	UDRH kWh	Proposed kWh	UDRH Therms	Proposed Therms	kWh Savings	Therm Savings	UDRH EUI	As-built EUI	Savings Beyond Code	Savings Beyond Benchmark Spec
1	WA	1,404	4,309	3,985	414	253	324	161	40.0	27.7	31%	14%
2	WA	1,644	9,403	7,267			2,136		19.5	15.1	23%	23%
3	WA	1,226	11,065	7,675			3,390		30.8	21.4	31%	22%
4	WA	1,966	10,942	7,536			3,406		19.0	13.1	31%	24%
5	WA	1,969	11,943	9,089			2,854		20.7	15.7	24%	20%
6	WA	2,590	7,803	6,743	609	340	1,060	269	33.8	22.0	35%	15%
7	WA	2,190	11,977	9,493			2,484		18.7	14.8	21%	11%
8	MT	1,610	8,635	7,459	789	416	1,176	373	67.3	41.6	38%	12%
9	MT	1,052	5,467	4,466	461	228	1,001	233	61.6	36.2	41%	15%
10	OR	1,603	8,686	6,387	197	122	2,299	75	30.8	21.2	31%	23%
11	OR	2,730	12,121	8,420	140	140	3,701	0	20.3	15.7	23%	18%
12	OR	1,800	10,465	7,346			3,119		19.8	13.9	30%	27%

2 Overview of Modeling Approach

2.1 Next Step Homes Modeling Approach

The modeling approach we used relied on comparing modeled results of the as-built homes to modeled code baseline homes. With respect to the NSH as-built homes, this validation effort incorporated a modified version of the commercially available home rating software, REM/Rate. A unique Northwest version of this software package was recently developed by CLEAResult[2] and vetted by the Regional Technical Forum (RTF)[3].

Energy 350 met with CLEAResult to discuss the availability of data to support this modeling effort. CLEAResult indicated that existing REM/Rate models were available for each of the 12 homes in the pilot study and that they could be made available for our savings validation effort. In addition to the 12 as-built models completed in the pilot project, CLEAResult also produced simplified pilot project reports for each of these homes. These reports highlighted home characteristics, key lessons learned from talking with the builder, and a comparison of incremental costs based on as-built conditions compared to standard practice costs. We used information included in these reports to true-up each REM/Rate model and ensure as-built conditions were accurately captured.

2.2 Baseline Home Modeling Method

REM/Rate requires the creation of a User-Defined Reference Home (UDRH) as the baseline home that each as-built model is compared against. We developed a UDRH using inputs that differ from the as-built home compiled in a script file that was referenced by REM/Rate during the energy analysis process. The model produced a summary report which listed the energy consumption by building component for both the UDRH and as-built home. We developed a unique script file for each home in the NSH pilot, and the list of these default values used in each file can be found in the Appendix.

Our discussions with NEEA during project kickoff indicated that state codes in place during the period of construction were to be used as the baselines for the pilot homes. Furthermore, we were not to include market effects, such as EnergyStar home penetration rates in each state in the baseline because the objective of this validation was to obtain a straight savings estimate compared to code. As such, we were able to use a direct interpretation of the building codes to develop baseline consumption estimates. Since these homes were built between 2012-2014 and codes in each state have changed since then, we used the following codes in place at the time of construction to represent the baseline UDRH of each home:

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[2] CLEAResult is the implementation contractor for NSH.

[3] Part of the NSH program is predicated on the use of a market accessible home rating software. REM/Rate fits that bill. However historically, the Northwest region has relied on SEEM, a single zone model that is more attuned to the Northwest building conditions. In order to address the two objectives of using an accessible rating package that accounts for the region's particular needs, REM/Rate was modified and this "NW" version of REM/Rate was vetted by the Regional Technical Forum (RTF) to compare results. Findings indicated that the NW version more closely aligns with SEEM than the national REM/Rate version does.

- Oregon – 2011 Oregon Residential Specialty Code (ORSC)
- Montana – 2009 International Energy Conservation Code (IECC)
- Idaho[4] – 2009 International Energy Conservation Code (IECC)
- Washington – 2009 Washington State Energy Code (WSEC)
    - Seattle – 2009 WSEC with Seattle amendments

For the two homes that were built in MT, we relied on a straight adoption of 2009 MT Energy code based on IECC standards with Montana amendments. This code spells out prescriptive requirements for all building components and equipment so that any home built in MT relies on a single code baseline.

For homes built in OR and WA however, both state codes allow a "menu of options" for the builder to choose from to meet code compliance, and therefore we needed to establish a *likely* baseline case for each home. In WA, the builder is required to pick from a pre-defined list of conservation options and to build in compliance with the selected option(s)[5]. To comply with code in OR, a builder must choose both a conservation measure and an envelope measure from two pre-defined lists[6] and build in compliance with those selected options.

Because a builder could choose to implement a variety of measures to comply with code in these two states, each home has the potential to be built to a different baseline. For past regional analysis that looked at savings of EnergyStar homes compared to code homes, determining a baseline in OR and WA required analysts to either choose the single most likely compliance path, (actually two compliance paths depending on an electric resistance home or a forced-air furnace home) or to analyze all the various compliance path combinations to arrive at a weighted average consumption for a code home. As the homes built for the NSH pilot employed many different advanced building techniques, they were eligible to meet many potential code compliance paths, and picking the correct code baseline path would not always be straightforward.

In order to assist with code baselines for homes built in OR and WA we first relied on work that has been done through the RTF, where the region opined on the most likely code paths builders would choose for OR and WA homes. This provided us with a ranking of the conservation measures chosen to achieve compliance based on least-cost options to serve as a proxy for the most popular choices among builders. We also opted to use the as-built features and costs of each NSH home in OR and WA to help determine which code compliance path was most likely taken. Using the pilot project reports of each home provided by the implementation team, we reviewed which elements were already considered "standard practice" by each particular builder. Our assumption was that builders who consider a certain building component, such as using a Ductless Heat Pump as standard practice are likely to use that feature to comply with code since there would be no associated incremental costs to do so. Similarly, when one of the as-built homes presented

[4] While no homes were built in Idaho during this pilot phase, the applicable state code at the time of the project would be the 2009 IECC.
[5] Table 9.1 in the 2009 WSEC lists the varying credits associated with each option. A total of 1 credit is required and typically a builder only needs to implement one of the pre-defined options to achieve this goal.
[6] Table N1101.1(2) in the 2011 ORSC.

a variety of possible choices that could be used for code compliance, we looked at which element was the lowest-cost to the builder to implement. We relied upon incremental costs provided by the builder of each home and listed in the home's pilot project report for this information.

Based on our analysis of the pilot project reports and regional work done by the RTF we chose an appropriate baseline pathway for each home built in OR and WA. The applicable code pathway and chosen compliance options for these homes are given in the tables below along with the reason for choosing each selected compliance path.

Table 2. Code Pathway and Chosen Compliance Options for Washington and Oregon Homes

WASHINGTON HOMES				
Pilot Home	**City**	**Baseline Code Path**	**Baseline Code Option**	**Reasoning**
1	Seattle	Forced Air Path	1a - High Eff. HVAC	- Code notes state using Option 1a to comply based on high efficiency boiler
2	Bainbridge Island	Radiant	5b - High Eff. DHW	- Building indicated high efficiency water heating as standard practice, and cost to increase to HPWH is less than other incremental costs listed
3	Seattle	Radiant	6 - Small Dwelling Unit	- Very little information given, and home qualifies for this path based on sqft listed in verification report - Code notes state using Option 1a, however that would require a FAF baseline. Effect of using Option 6 vs 1a doesn't result in varying savings claimed since a 92% FAF would be baseline already
4	Vancouver	Radiant	1c - High Eff. DHP	- Building indicated DHP was standard practice
5	Kennewick	Radiant	5b - High Eff. DHW	- Building indicated high efficiency water heating as standard practice, and cost to increase to HPWH is less than other incremental costs listed
6	Kent	Radiant	5b - High Eff. DHW	- Building indicated high efficiency water heating as standard practice, and cost to increase to tankless water heater is less than other incremental costs listed

7	Olympia	Radiant	1c - High Eff. DHP	- Builder indicated a negative incremental cost for standard practice dual-DHP system because new system required only 1 DHP.

OREGON HOMES

Pilot Home	City	Baseline Code Options	Reasoning
10	Eugene	Conservation A - High Efficiency HVAC; Envelope 5 - Building Tightness Testing, Ventilation & Duct Testing	- Builder indicated standard HVAC is 2-stage ASHP; - Code requirements for air sealing home are considered easily achievable targets and spot ventilation can be used to comply with ventilation code
11	Portland	Conservation D - Tankless; Envelope 5 - Building Tightness Testing, Ventilation & Duct Testing	- Builder indicated 0.81 EF tankless DHW as standard build which would comply with code; - Code requirements for air sealing home are considered easily achievable targets and spot ventilation can be used to comply with ventilation code
12	Corvallis	Conservation C - Ductless Heat Pump; Envelope 5 - Building Tightness Testing, Ventilation & Duct Testing	- Builder indicated a small cost increase for DHP over standard High Efficiency Forced Air Furnace w/ducts; - Code requirements for air sealing home are considered easily achievable targets and spot ventilation can be used to comply with ventilation code

Once we chose these compliance paths, we contacted the implementation team to ensure our assumptions over the likely code path were sound. After receiving feedback and approval from the implementation team, we began constructing an individual UDRH script file for each home that took into account the chosen code pathways. When modeled, a home that complied with code using the options listed in the tables above did not receive any savings for that component in the as-built model.

3 Analysis Observations

3.1 Model Inputs Compared to Pilot Project Reports

We were able to verify envelope measures in REM/Rate since assembly values are a core component of the model's materials library and can be broken apart to study input details. We verified that the same envelope assembly U-factors and material libraries were used across all homes in the pilot, resulting in a reliable estimate of energy consumption related to envelope improvements. Furthermore, these assembly U-factors were found to be closely in line with industry accepted documents such as the Super Good Cents Heat Loss Reference Manual and ASHRAE Handbook – Fundamentals, both used by the Regional Technical Forum (RTF) for residential envelope savings estimations.

To verify infiltration reductions we relied on the as-built home post construction blower door test that was required as part of the specification and referenced in each pilot project report. While minor differences were found in 4 out of the 12 as-built models provided by the implementation team compared to the pilot project reports, the overall impact on savings was minimal. For 3 of these 4 homes, a 34% difference for the as-built infiltration value compared to the pilot project report value only resulted in a 1% savings change for the home compared to code. This finding suggests that the implementation team was sufficiently accurate in their estimation compared to the final as-built test.

Using REM/Rate to estimate savings was straightforward for envelope and infiltration improvements. However the more unique energy saving elements of the NSH specification related to mechanical systems and domestic hot water services required either workarounds by the implementation team, or were not included in the analysis. This is because REM/Rate provides a limited set of inputs for mechanical systems, and while envelope upgrades are mainly a function of area and heat transfer rate, advanced mechanical systems have controls logic and operational nuances that could not easily be incorporated into the software model. In some instances, the implementation team created a workaround to attempt to incorporate this feature, such as increasing the Energy Factor (EF) of a water heater to account for the inclusion of a drain waste heat recovery system. In other cases, the potential savings resulting from a system were simply left out of the analysis because they could not easily be incorporated into the model, as was the case for 5 homes using demand pumping loops on the hot water system.

In general, the pilot project reports we reviewed matched the model inputs with the homes exhibiting only minor differences between the two. Though we found conditions in the reports that did not exactly match inputs included in the REM/Rate models for all of the homes, this was likely due to missed updates in the models after homes were completed with as-built information, or a simple modeling oversight. While every home exhibited slight differences, all the variations we found were relatively minor and did not alter estimated savings significantly, indicating that the implementation team captured the most significant inputs correctly. The bolded cells in the summary table below indicate which inputs we chose to model as part of the savings validation effort and the resulting differences caused in terms of impact on overall savings for the home.

Table 3. Model Inputs Compared to Pilot Project Reports and Impact on Savings

Pilot Home	Model Input	Pilot Project Report Input	Change Made	Impact on Savings
1	Combi Furnace: 90% AFUE	**Combi Furnace: 95% AFUE**	Changed to Manufacturer rating of 95% AFUE	7 therm decrease
2	AG Wall U-Factor: U-0.031	**AG Wall U-Factor: U-0.030**	Changed to reflect insulation type	No noticeable change
	Infiltration: 3.0 ACH50	**Infiltration: 2.7 ACH50**	Changed to match pilot project report ACH	1% more savings over code
3	**Windows: U-0.20**	Windows: U-0.29	Left at U-0.20 since product could not be verified	4% more savings over code
4	**Windows: U-0.245**	Windows: U-0.16	Left at U-0.245 since product could not be verified	2% less savings over code
	Sqft: 2,201	**Sqft: 1,966**	Changed to match pilot project report sqft	2% more savings over code
	DHW EF: 2.25	**DHW EF: 1.9**	All other ATI66 models are 1.9 EF	1% less savings over code
5	Cuft: 18,712	**Cuft: 17,717**	Changed to match pilot project report cuft	No noticeable change
	Infiltration: 1.5 ACH50	**Infiltration: 1.83 ACH50**	Changed to match pilot project report 1.83 ACH	No noticeable change
6	**Windows: U-0.245**	Windows: U-0.28	Left at U-0.245 since product could not be verified	2% more savings over code
	Infiltration: 959 CFM50	**Infiltration: 2.64 ACH50**	Equivalent, however changed to match	No noticeable change
7	**Windows: U-0.22**	Windows: U-0.25	Left at U-0.22 since product could not be verified	1% more savings over code
	Infiltration: 767 CFM50	**Infiltration: 2.28 ACH50**	Equivalent, however changed to match	No noticeable change
8	**Furnace: 96% AFUE**	Furnace: 94% AFUE	Left at 96% AFUE	No noticeable change
	Duct Leakage: 100 CFM50	Duct Leakage: 311 CFM50	Left as 100 CFM50 since ducts inside conditioned space	No noticeable change
9	**DHW EF: 0.95**	DHW EF: 0.94	Left at 0.95 EF	No noticeable change
	Windows: U-0.24	Windows: U-0.297	Left at U-0.24 since product could not be verified	2% more savings over code
10	Infiltration: 675 CFM50	**Infiltration: 2.81 ACH50**	Equivalent, however changed to match	No noticeable change
	Windows: U-0.25	Windows: U-0.22	Left at U-0.25 since product could not be verified	1% less savings over code
11	Cuft: 23,630	**Cuft: 25,960**	Changed to match pilot project report cuft	1% less savings over code
	Wall Insulation: R-0 Continuous; R-30 BIB	**Wall Insulation: R-10 Continuous; R-20 BIB**	Changed to match pilot project report description	1% more savings over code
	Infiltration: 2.0 ACH50	**Infiltration: 1.55 ACH50**	Changed to match pilot project report ACH	No noticeable change
12	Lighting: 80% CFL	**Lighting: 100% CFL**	Changed to 100% to match pilot project report	No noticeable change
	DHW EF: 2.2	**DHW EF: 1.9**	All other ATI66 models are 1.9 EF	1% less savings over code
	Infiltration: 2.0 ACH50	**Infiltration: 2.68 ACH50**	Changed to match pilot project report ACH	1% less savings over code

To decide on which components to change and which to leave as-is to perform our savings validation, we relied on the claimed observations from the pilot project reports whenever possible, especially with regards to the final infiltration test numbers, as these were assumed to represent the final conditions of the home. However for some components, such as window U-factors, neither the pilot project reports nor the initial REM/Rate models provided detailed information on actual window models used, and therefore we chose to leave the original model inputs unchanged. While some window U-factors were notably different, due to the relatively small total area of the home, a change in window U-factor either up or down did not result in a large difference in consumption overall. Ultimately, the decision to change an input or leave it as-is did not greatly affect the total estimated savings from each home as the differences we found between the two sources were minor.

3.2 Modeling Complexities and Input Errors

Although REM/Rate provides a simplified method of entering individual building components and mechanical systems, the software has limitations when trying to model more complex advanced building practices. We found that envelope properties were relatively easy to enter, and the implementation team consistently applied the correct heat transfer rate U-factors to the building envelope assemblies. Furthermore, the envelope construction assemblies closely matched the pilot project reports. While we did not attempt to verify total areas for each component compared to as-built documents, the total square footage in each model matched the square footage in the pilot project reports in all cases except one, (shown in the preceding table) indicating that overall component areas were likely correct.

However, the application of several advanced energy savings techniques used by the pilot home builders were not possible to model in the software without making large assumptions and implementing workarounds. We commonly found these more advanced techniques to reside in the design of the mechanical and domestic hot water systems rather than in the envelope construction. As an example, the NSH specification requires implementation of a demand pumping loop in lieu of a core layout with a limited distribution system for the domestic hot water. Savings stem from the reduction of continuous pumping during periods of no water use, and this feature was present in 5 out of the 12 homes according to pilot project reports. However, the current version of REM/Rate cannot model this feature as there is no input that allows for schedule adjustment to assist with modeling Domestic Hot Water (DHW) demand. Therefore, while savings may exist for this feature, we verified that these savings are not being included in the models currently.

Another case of modeling complexity occurred when looking at Pilot Home #4. In this home, the pilot project report stated that a Ductless Heat Pump (DHP) was used to condition the home alongside a Heat Recovery Ventilator (HRV) equipped with an auxiliary heating device. Although DHPs are typically sized to handle the majority of the heating load of the home and are supplemented by small wall heaters, these pilot homes exhibit very small loads and therefore are not likely to require any supplemental heat. Nevertheless, the builder included an auxiliary heater in this home to compensate for the possibility of cold spots in those rooms. Installing an auxiliary heater in the ventilation system is a cheaper way to achieve this and could alleviate the need for wall heaters in these rooms. However the implementation team did not include this auxiliary heating system in the REM/Rate model for this home and instead assumed the DHP would handle the entire heating load. Even if the auxiliary heating system was included in the model, it is unlikely that the software could correctly account for this scenario due to the schedule limitations for mechanical equipment. While we could select the use of an auto-sized auxiliary heater for the DHP system, we could not assign differing schedules to these pieces of equipment nor could we assign the auxiliary heat to the HRV. In this instance, the schedule of operation for the main DHP unit and HRV system are different and this runtime difference would be required to accurately model complete heating energy consumption for this home. REM/Rate does not easily allow for this option to be included, it was left out of our modeling runs which may result in an overestimation of savings for Pilot Home #4.

For lighting systems, REM/Rate allows a very limited input to specify efficient lighting systems. Instead of allowing a Lighting Power Density (LPD) value to be entered, the software allows only a "percent CFL" or "percent Fluorescent[7]" value to be entered. In this way, the use of LED lamps cannot be accurately included as there is no wattage input to allow for adjustment currently. For the validation effort, we used the CFL input to represent an LED lamp to attempt to account for the wattage reduction of efficient fixtures. In reviewing the models, we found that lighting values were incorrectly entered for all homes, with a default of 0% CFL and 10% Fluorescent entered. We corrected the CFL input to reflect the as-built conditions specified in the pilot project reports for each home (a default of 100% was used if no percentage was given on the pilot project report).

3.3 As-Built Home Construction Techniques

All homes in the pilot, regardless of the geographic location, utilized a combination of high efficiency equipment, a well-insulated envelope, and tight construction techniques paired with a whole home ventilation system. All of these individual construction techniques typically surpass minimum code requirements. However, a significant number of the builders indicated several construction elements that they considered standard practice, notably ceiling insulation and efficient lighting. While this could suggest that the NSH specification may not go far enough to encourage these builders to explore advanced solutions in these areas, it should be noted that virtually all builders in this pilot effort already build to EnergyStar certification levels or higher. (Refer to section 3.7 for discussion of builder influence on savings). Nonetheless, we found several builders in the pilot who indicated that their standard practice building components already met levels required as part of the NSH specifications. The summary table below indicates components that each builder specified as standard practice which were equivalent or better than the NSH specification requirements.

[7] REM/Rate uses the "Fluorescent" input to represent the percentage of pin-based CFL lamps only and assigns a similar wattage to CFL lamps.

Table 4. Builder Specified Standard Practice Components Meeting NSH Specifications

Pilot Home	Walls	Ceilings	Windows	Floors	Infiltration	HVAC	DHW	Lighting
1		X				X		X
2		X		X				X
3		X		X				X
4	X	X	X	X				X
5	X	X	X					X
6		X		X				X
7		X		X		X		X
8		X				X		
9		X			*a*		X	X
10	X	X	X				X	X
11		X					X	X
12						X		

a. Builder suggested standard practice was to seal to 3.0 ACH_{50}, which is close to the NSH specification requirements of 2.0 ACH_{50} and was the lowest of all builders in this pilot phase.

In almost all cases, efficient lighting and ceiling insulation values met the NSH specification and were also considered standard practice. While builders often went beyond the minimum specifications to drive the total home UA level down, the NSH specification requirements for those building components did not appear to be driving this cohort of builders to extend far beyond their standard practice.

Even though builders in this pilot typically build efficient homes, many of the builders did experience issues during construction that required assistance from the implementation team. In most cases, technical support was needed to solve issues of occupant comfort, resulting from incorrect DHP settings, or an incorrect installation of a Heat Recovery Ventilator (HRV). All builders who provided interviews stated that they were grateful for the technical support the implementation team provided to ensure the project met the NSH specifications and that the home occupants were satisfied.

While several builders (4 out of 12) stated that the NSH envelope specifications were the most difficult to meet, the majority of builders noted issues with installation or operation of the advanced mechanical systems. Our assessment of the pilot project reports indicated that many of these problems were resolved with help from the implementation team, however unresolved problems that remain in these homes could lead to a wide variation in energy consumption over time.

3.4 Energy Performance by Component

While all homes in the pilot were able to perform well beyond current energy codes and utilized a variety of methods to meet the NSH specification, we found that the reduced consumption for most homes was due largely to upgraded features from only a handful of components. For each home we attempted to determine the main contribution to savings according to the REM/Rate model.

To derive the home component that contributed most to savings for each home, we relied on the REM/Rate output file that details Energy Use Intensities (EUIs) of each component for both the UDRH and as-built home. We calculated the percent change of each as-built home component EUI compared to its UDRH baseline component EUI. This percent change was then multiplied by the percent that each component contributes to the overall home EUI (component EUI divided by total home EUI) to weight the effect of the change on the overall as-built home. This provides us with a weighted average change in EUI by building component.

Using the methodology described above we found that infiltration reduction through tighter construction standards provided the largest percentage of savings in 5 out of the 12 homes, in large part due to the lenient code minimum levels that they are measured from. Although only 50% of the homes were able to meet the NSH performance spec, of ≤ 2.0 ACH_{50}, all homes significantly reduced their infiltration rates below code requirements. The summary table below indicates the percent infiltration reduction over code for each home.

Table 5. Comparison of Infiltration Rates: As-Built vs. Code

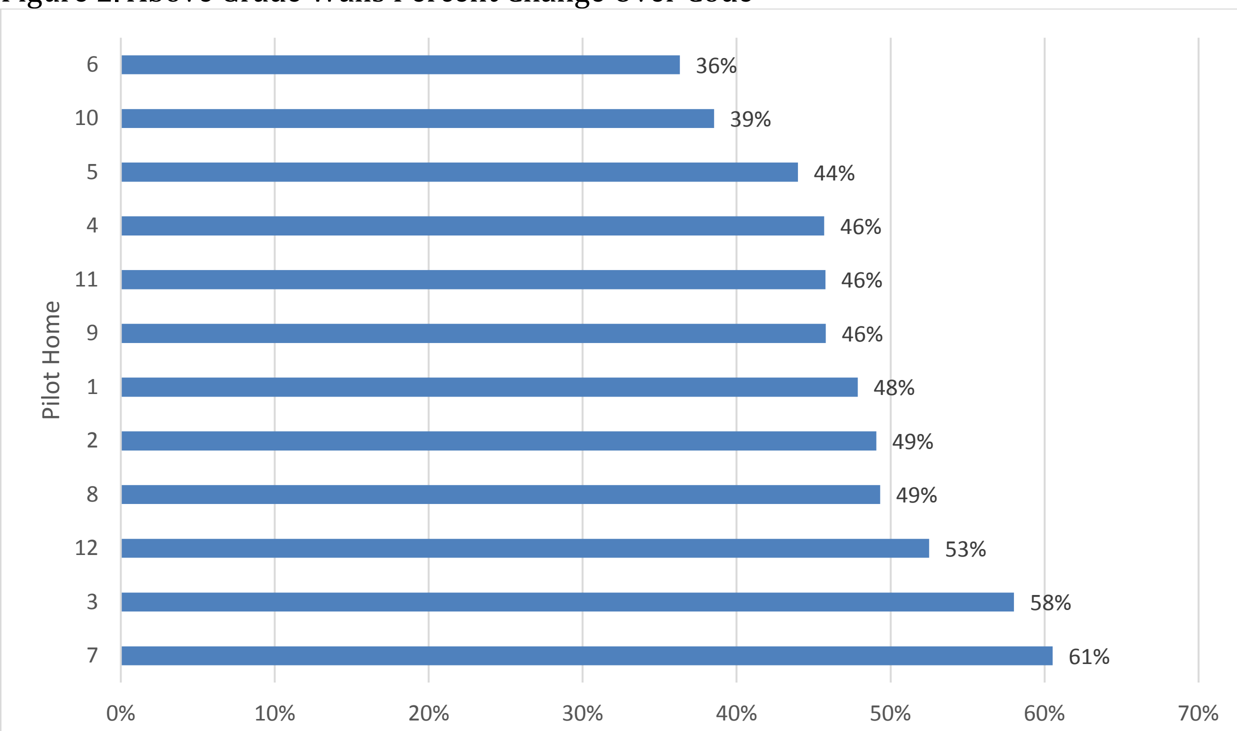
Pilot Home	City	State	As-Built Infiltration	Code Infiltration Rate	Percent Infiltration Reduction
1	Seattle	WA	1.80	6.0	70%
2	Bainbridge Island	WA	**2.70**	6.0	55%
3	Seattle	WA	**2.30**	6.0	62%
4	Vancouver	WA	0.25	6.0	96%
5	Kennewick	WA	1.83	6.0	70%
6	Kent	WA	**2.64**	6.0	56%
7	Olympia	WA	**2.28**	6.0	62%
8	Whitefish	MT	1.31	4.0	67%
9	Billings	MT	0.92	4.0	77%
10	Eugene	OR	**2.81**	6.0	53%
11	Portland	OR	1.55	6.0	74%
12	Corvallis	OR	**2.68**	6.0	55%

Bolded Infiltration rates did not meet the NSH specification threshold of ≤ 2.0 ACH_{50}

These final air infiltration rates were responsible for significant heating energy reduction in each home, even when not quite meeting the NSH performance specification. In particular, the savings for MT homes are significant due to the extremely low infiltration rates achieved by the builders despite stringent code allowance levels of 4.0 ACH_{50} to which they were compared.

The second largest contributor to savings after infiltration reduction is additional insulation on the above-grade walls. Two-thirds of the builders indicated that the NSH specification requirement of U-0.035 in Climate Zone 1 (U-0.030 in Climate Zone 2/3) required significant added cost to implement. Only 3 out of the 12 builders indicated that wall insulation levels required by the NSH specification were similar to standard practice. As with infiltration savings, the savings realization for above-grade walls is most likely caused by the relatively lenient code requirements of each state, allowing a baseline wall insulation value of U-0.060 in climate zone 1, and U-0.057 in climate zone 2. As seen in the summary chart below, the component level reduction for above-grade walls over the code baseline for each home is substantial.

Figure 2. Above Grade Walls Percent Change Over Code



3.5 Savings Beyond Code

Our validation effort indicated that the NSH homes in this pilot phase all performed well beyond homes that are built to minimally comply with code, and that the implementation team effectively captured these performance inputs correctly in the models. Our findings showed that the average as-built home in this pilot phase saved approximately 30% over a comparable code level home, with the lowest savings being 19% and the highest being 41%. As stated above, increased above-grade wall insulation and infiltration reduction were consistently seen as the largest contributors to savings, and the implementation team correctly captured these elements in the as-built models.

A summary of changes for each home is shown in the table below, including the applicable building code and compliance path (if required), kWh and therm savings, total savings beyond code, and the building component that contributed most to savings for each home.

Table 6. Summary of Consumption and Percent Savings Above an Equivalent Code UDRH

Pilot Home	Applicable Code Baseline	Compliance Path	UDRH EUI (kbtu/sqft)	As-built EUI (kbtu/sqft)	kWh savings	Therm savings	Main Savings Contribution	% Savings Beyond Code
1	2009 Seattle EC	1a - High Eff. HVAC	40.0	27.7	324	161	Above Grade Walls	31%
2	2009 WSEC	5b - High Eff. DHW	19.5	15.1	2,136	0	Above Grade Walls	23%
3	2009 Seattle EC	6 - Small Dwelling Unit	30.8	21.4	3,390	0	Infiltration	31%
4	2009 WSEC	1c - High Eff. DHP	19.0	13.1	3,406	0	Infiltration	31%
5	2009 WSEC	5b - High Eff. DHW	20.7	15.7	2,854	0	Above Grade Walls	24%
6	2009 WSEC	5b - High Eff. DHW	33.8	22.0	1,060	269	Ducts	35%
7	2009 WSEC	1c - High Eff. DHP	18.7	14.8	2,484	0	Above Grade Walls	21%
8	2009 IECC	N/A	67.3	41.6	1,176	373	Infiltration	38%
9	2009 IECC	N/A	61.6	36.2	1,001	233	Infiltration	41%
10	2011 ORSC	A - High Efficiency HVAC; 5 - Building Tightness Testing, Ventilation & Duct Testing	30.8	21.2	2,299	75	Above Grade Walls	31%
11	2011 ORSC	D - Tankless; 5 - Building Tightness Testing, Ventilation & Duct Testing	20.3	15.7	3,701	0	Infiltration	23%
12	2011 ORSC	C - Ductless Heat Pump; 5 - Building Tightness Testing, Ventilation & Duct Testing	19.8	13.9	3,119	0	Above Grade Walls	30%

3.6 Savings Beyond NSH Benchmark Specification

After we developed a code-based UDRH file for each home and validated the as-built home inputs with the pilot project reports, we then created a separate UDRH file that reflected the minimum performance requirements outlined in the NSH draft specification. (Refer to Appendix for specification details.) Using the NSH specification as the UDRH for each home allowed us to calculate how far each builder went beyond the specification.

An interesting finding in the models was the difficulty meeting the NSH performance specification crawlspace (i.e. floor) U-factor requirement. Currently listed at U-0.025 in the specification, this value is not readily obtained with only R-38 batts and 12" deep TJI joists as the specification suggests. A resulting U-factor of 0.029 was used in the REM/Rate models for 11 pilot homes instead of the U-0.025 value required as part of the specification. Thus we were not able to verify that any of the pilot homes achieved this level of performance for the floor insulation component with the exception of pilot home #10 which employed 1.5" of spray foam in addition to R-38 insulation.

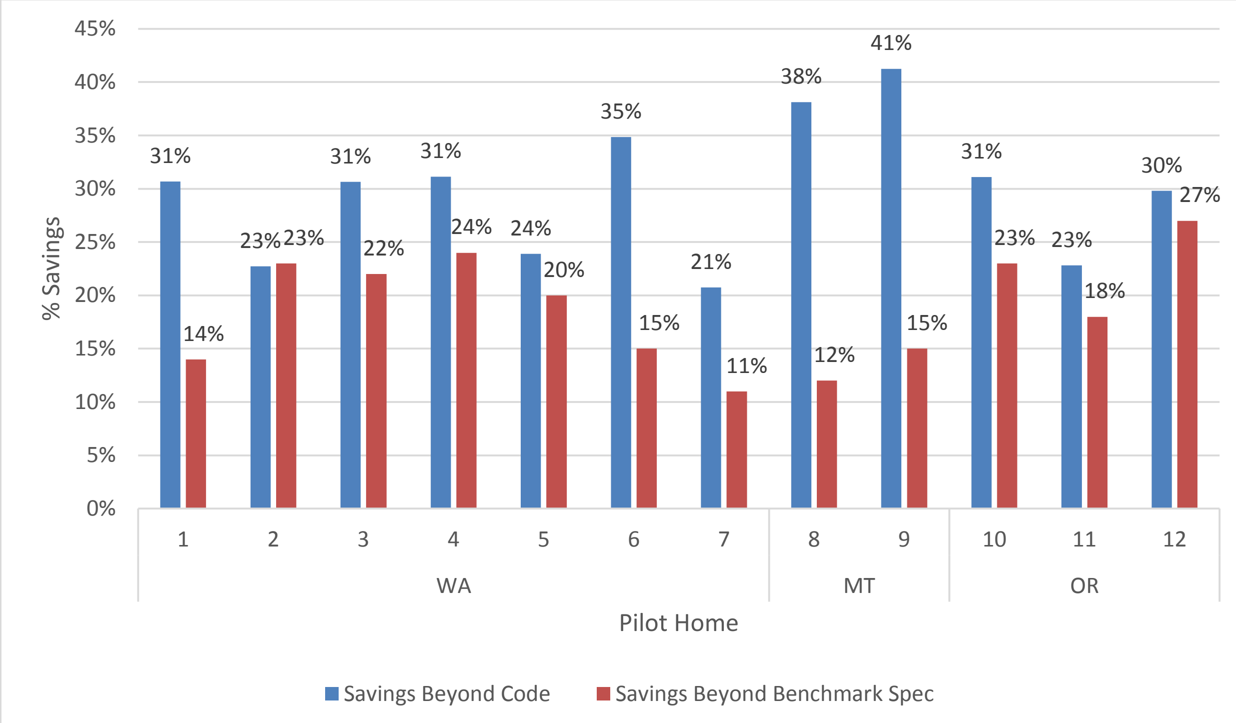
NEEA indicated that the specification in place during the Phase 1 pilot is similar to the current draft specification proposed for Phase 2, however the maximum envelope UA level was 300 btu/hr-°F for homes in Climate Zone 1, and 200 btu/hr-°F for homes in Climate Zone 2/3. While we validated that all homes in this pilot met the minimum envelope UA values set forth in the Phase 1 specification, several homes would not meet the proposed Phase 2 envelope UA requirement of [150 + (30 x Number of Bedrooms)] in btu/hr-°F. A summary of the Phase 1 and Phase 2 UA levels and calculated UA value for each as-built home is given in the table below, with bolded cells indicating which homes would not meet the Phase 2 maximum envelope UA threshold.

Table 7. Summary of Phase 1 and Phase 2 UA Levels

Pilot Home	City	State	Bedrooms	Phase 1 NSH UA (btu/hr-°F)	Phase 2 NSH UA (btu/hr-°F)	Calculated UA (btu/hr-°F)
1	Seattle	WA	2	300	210	198.4
2	Bainbridge Island	WA	3	300	240	202.7
3	Seattle	WA	3	300	240	163.3
4	Vancouver	WA	4	300	270	201.6
5	Kennewick	WA	3	200	240	172.6
6	Kent	WA	3	300	240	**280.3**
7	Olympia	WA	3	300	240	175.4
8	Whitefish	MT	2	200	210	185.7
9	Billings	MT	2	200	210	90.3
10	Eugene	OR	2	300	210	**234.8**
11	Portland	OR	4	300	270	**294.6**
12	Corvallis	OR	3	300	240	180.5

We also found that most builders went well beyond specification for building components, and achieved an average of 19% (11% min, 27% max) savings beyond the minimum performance specification. The table below shows the percent increase of each as-built home beyond the NSH specification compared with the savings beyond code for that same home.

Figure 3. Savings Beyond Code and NSH Specification



3.7 Builder Influence on Savings

The approach we took to quantify savings for this validation relied on a model-to-model comparison and not a comparison of model-to-utility data. Therefore there is no builder influence on the savings estimations since the REM/Rate model assumes perfect construction[8] is occurring that matches the inputs. However, it is expected that builders who routinely build efficient homes that meet stricter performance requirements are better equipped to properly construct these homes, and would show higher savings through a billing analysis compared to builders who more commonly construct homes near code performance levels. In this way, builders who do not routinely employ advanced building techniques may be able to meet the NSH specification as per the model. But compared to efficient home builders, actual home performance may vary more with a market-based builder cohort since many of these advanced construction techniques were said to require careful oversight and implementation during this pilot phase (in particular, proper air sealing and HRV installation and commissioning).

[8] Perfect Construction is a term used to convey that the input U-factor (or R-value) for any component is modeled as such, whereas actual construction may result in varying component U-factors depending on material selection, builder practices, and site conditions.

4 Market Effects for Consideration

Through discussions with NEEA at the start of this project, we were advised that accounting for market effects (such as efficient home penetration in the new homes market) was not necessary as part of this validation effort. However we believe several known market effects should be included in the models due to the significant presence they have had in the Northwest prior to the pilot homes being built and for their implications regarding savings potential from the NSH program. While the inclusion of these market effects may have a small impact on home performance overall, ignoring these well-known market effects and relying on a simplified approach will overstate savings for these homes.

The most notable market effects are equipment efficiency standards in which all three state codes defer to the federal standards. In the case of a forced-air furnace, this translates to a 78% AFUE which has been the standard gas-fired furnace efficiency rating since 1987. A market transformation study conducted by Summit Blue on behalf of Energy Trust of Oregon in 2009 sought to show whether the natural gas furnace market had been transformed. The findings indicated that due to several factors, including the prevalence of tax credits and utility program incentives, the gas furnace market in Washington and Oregon had been transformed to a 90% AFUE furnace as early as 2007. Today, many utility efficiency programs use a market adjusted AFUE baseline for gas furnaces as opposed to the federal standard.

A similar argument is made for the Heat Pump market. While federal standards require heat pump efficiencies to be 7.7 HSPF and 13 SEER, a similar market transformation study completed in 2009 for Energy Trust of Oregon showed that the average air-source heat pump efficiency was 8.5 HSPF and 14 SEER in both Washington and Oregon. Similar to gas furnaces, many Northwest utility efficiency programs use an 8.5 HSPF and 14 SEER heat pump as a baseline. Therefore, we recommend that both heating equipment types in Oregon and Washington homes use the market average efficiency in the UDRH in lieu of the federal standard, which has all but disappeared in the new construction market in the Northwest.

Conversely, while these HVAC equipment market effects have been seen primarily in the OR and WA metro areas of the Pacific Northwest region, we found less evidence to suggest that these efficiency levels persist in Montana and Idaho territories. Due to a lack of data, we recommend keeping the efficiency levels for the Montana homes in this pilot to the current federal standards, which are 80 AFUE[9] for a gas furnace and 7.7 HSPF/13 SEER for an air-source heat pump.

While specifying equipment efficiencies at the market adjusted levels would provide for a more conservative estimate of savings in the modeling, our results indicated a very modest difference in home energy consumption overall. Therefore, we opted to include the market affected equipment efficiencies in our UDRH baseline models in lieu of the federal

[9] While the federal standard is actually 78% AFUE, distributors sell 80% AFUE gas furnaces as the minimum.

standards allowed by state code to produce savings estimates that are more closely aligned with the Northwest market.

Infiltration reduction is another source of large energy savings seen in all pilot homes. However the default code values for air leakage are generous in Oregon and Washington compared to the average leakage rate in the new homes market. Because this has such a large impact on the savings being claimed for each home, we looked for information on market averages for air infiltration rates.

Several recent studies that looked at EnergyStar homes compared to a controlled baseline group have shown that infiltration rates may be lower on average than current code allows. A 2010 KEMA study that looked at EnergyStar new homes constructed from 2004-2005 and compared them to a control group of approximately 600 homes constructed during that same period. The baseline infiltration rate for the Northwest was 5.87 ACH_{50}, indicating that in 2004 builders were already constructing homes tighter than the code requires today. A 2007 RLW report found similar limits for the same 2004-2005 program years, and separated out the results by each state as shown in the table below.

Table 8. Infiltration Rates Code vs. Builder Practice

System Type	State	ACH		ACH50		ACH50 divided by 20		n
		Average	EB	Average	EB	Average	EB	
Central Systems	ID	0.39	0.04	4.9	0.4	0.24	0.02	44
	MT	0.47	0.28	5.8	2.6	0.29	0.13	4
	OR	0.5	0.06	6.6	0.7	0.33	0.04	113
	WA	0.41	0.02	5.3	0.3	0.26	0.02	83
	Overall	**0.44**	**0.03**	**5.6**	**0.3**	**0.28**	**0.02**	**244**

Ultimately we determined that average infiltration rates of new homes built today are likely lower compared to the code allowed levels. However the reports we found were for homes built over a decade ago, and we were unsure whether similar construction practices existed today in the new homes market. Without more updated evidence to support current air infiltration rates, we modeled the code allowance levels in the UDRH files for all 12 pilot homes instead of adjusting for any market effects.

5 Site Level Review

We produced a detailed site level summary of the savings validation efforts for each home. We used the REM/Rate models provided to us by CLEAResult in concert with the pilot project summaries of each home. We did not conduct site visits as part of this effort and therefore were reliant upon the information provided to us from the implementation team to conduct the analysis.

Although each home was unique in its construction and component modeling, we developed several assumptions when modeling recurring conditions for each home. Notable examples are given below:

- If a home used a DHP and the standard practice system was noted to be electric resistance, no penalty was taken for duct leakage to the outside as allowed by code.
- For homes that required a code compliant path option to be selected, no savings were attributed to elements of that path between the UDRH and the as-built home.
- The REM/Rate default heat transfer paths for the envelope were used by selecting the “quick-fill site-built” input instead of defining individual layers and path heat transfer rates.
- If a home did not include a door in the as-built model, a code compliant door (U-0.20) was assumed.
- Setpoint temperatures were left the same for the UDRH and as-built homes, at 68°F heating and 78°F cooling.
- No credit was taken for efficient appliances. Both the UDRH homes and as-built homes referenced the same appliance energy consumption values.
- Because lighting values were entered incorrectly in all models, we used the pilot project reports to determine % efficient lighting. If a percentage was not given in the report, we defaulted to 100% efficient lighting in the revised model.

5.1 Pilot Home #1 – Seattle, WA Summary

Pilot Home #1 is a 2-story modern house located in Seattle, WA. Totaling 1,400 ft^2 and built on a vented crawlspace, the structure uses a two-zone radiant heating system served by an on-demand gas condensing tankless water heater. Highlights of this home are shown in the table below.

Table 9. Pilot Home #1 – Seattle, WA Summary

Pilot Home	Applicable Code Baseline	Compliance Path	UDRH EUI (kbtu/sqft)	As-built EUI (kbtu/sqft)	kWh savings	Therm savings	Main Savings Contribution	% Savings Beyond Code
1	2009 Seattle Energy Code	1a – High eff HVAC	40.0	27.7	324	161	Above-Grade Walls	31%

5.2 Pilot Home #2 – Bainbridge Island, WA Summary

Pilot Home #2 is a 2-story modern house located on Bainbridge Island, WA. Totaling 1,644 ft^2 and built on a conditioned crawlspace, the home uses a single zone DHP to deliver air to all zones and a Heat Pump Water Heater (HPWH) for domestic hot water service. Highlights of this home are shown in the table below.

Table 10. Pilot Home #2 – Bainbridge Island, WA Summary

Pilot Home	Applicable Code Baseline	Compliance Path	UDRH EUI (kbtu/sqft)	As-built EUI (kbtu/sqft)	kWh savings	Therm savings	Main Savings Contribution	% Savings Beyond Code
2	2009 WSEC	5b - High Eff. DHW	19.5	15.1	2,136	N/A	Above-Grade Walls	23%

5.3 Pilot Home #3 – Seattle, WA Summary

Pilot Home #3 is a 2-story modern house located in Seattle, WA. Totaling 1,226ft^2 and built on a vented crawlspace, the structure uses hydronic slab heat with a Daikin Altherma combined appliance to both condition the home and provide domestic hot water service. Highlights of this home are shown in the table below.

Table 11. Pilot Home #3 – Seattle, WA Summary

Pilot Home	Applicable Code Baseline	Compliance Path	UDRH EUI (kbtu/sqft)	As-built EUI (kbtu/sqft)	kWh savings	Therm savings	Main Savings Contribution	% Savings Beyond Code
3	2009 Seattle Energy Code	6 - Small Dwelling Unit	30.8	21.3	3,390	N/A	Infiltration	31%

5.4 Pilot Home #4 – Vancouver, WA Summary

Pilot Home #4 is a 2-story traditional house located in Vancouver, WA. Totaling 1,966 ft^2 and built on a vented crawlspace, the structure uses a single zone DHP with auxiliary fan-aided distribution to deliver air to the outer zones and a heat pump water heater for domestic hot water service. Highlights of this home are shown in the table below.

Table 12. Pilot Home #4 – Vancouver, WA Summary

Pilot Home	Applicable Code Baseline	Compliance Path	UDRH EUI (kbtu/sqft)	As-built EUI (kbtu/sqft)	kWh savings	Therm savings	Main Savings Contribution	% Savings Beyond Code
4	2009 WSEC	1c - High Eff. DHP	19.0	13.1	3,406	N/A	Infiltration	31%

5.4.1 Outstanding issues

The mechanical system employed in this home uses a single zone DHP coupled with an auxiliary heater in the HRV distribution system to provide heat to the remote zones.

Currently there is no data available to determine whether this method produces sufficient heat to condition those zones comfortably. Since most homes with DHP systems use electric resistance heaters to serve remote zones, this method would further reduce the electric consumption if occupants found it as effective as wall heaters.

5.5 Pilot Home #5 – Kennewick, WA Summary

Pilot Home #5 is a 2-story traditional ranch located in Kennewick, WA. Totaling 1,969 ft^2 and built on an insulated slab, the structure uses a single zone DHP to deliver conditioned air to the main zone of the home and a second ducted-DHP to provide conditioned air to several other zones. A 66-gallon heat pump water heater is used for domestic hot water service. Highlights of this home are shown in the table below.

Table 13. Pilot Home #5 – Kennewick, WA Summary

Pilot Home	Applicable Code Baseline	Compliance Path	UDRH EUI (kbtu/sqft)	As-built EUI (kbtu/sqft)	kWh savings	Therm savings	Main Savings Contribution	% Savings Beyond Code
5	2009 WSEC	5b - High Eff. DHW	20.7	15.7	2,854	N/A	Above-Grade Walls	24%

5.6 Pilot Home #6 – Kent, WA Summary

Pilot Home #6 is a 2-story traditional located in Kent, WA. Totaling 2,590 ft^2 and built on a vented crawlspace, the structure uses a 2-stage gas furnace to deliver conditioned air to the main zone of the home and a gas tankless water heater is used for domestic hot water service. Highlights of this home are shown in the table below.

Table 14. Pilot Home #6 – Kennewick, WA Summary

Pilot Home	Applicable Code Baseline	Compliance Path	UDRH EUI (kbtu/sqft)	As-built EUI (kbtu/sqft)	kWh savings	Therm savings	Main Savings Contribution	% Savings Beyond Code
6	2009 WSEC	5b - High Eff. DHW	33.8	22.0	1,060	269	Ducts	35%

5.7 Pilot Home #7 – Olympia, WA Summary

Pilot Home #7 is a 2-story timber frame home located in Olympia, WA. Totaling 2,190 ft^2 and built on a basement, the structure uses a single zone DHP unit downstairs and electric resistance upstairs in the bedrooms to deliver conditioned air to all zones of the home. A high efficiency electric water heater combined with solar water heating is used for domestic hot water service. Highlights of this home are shown in the table below.

Table 15. Pilot Home #8 – Olympia, WA Summary

Pilot Home	Applicable Code Baseline	Compliance Path	UDRH EUI (kbtu/sqft)	As-built EUI (kbtu/sqft)	kWh savings	Therm savings	Main Savings Contribution	% Savings Beyond Code
7	2009 WSEC	1c - High Eff. DHP	18.7	14.8	2,484	N/A	Above-Grade Walls	21%

5.8 Pilot Home #8 – Whitefish, MT Summary

Pilot Home #8 is a single-story ranch home located in Whitefish, MT. Totaling 1,610 ft^2 and built on a conditioned crawlspace, the structure uses high efficiency 2-stage gas furnace to deliver conditioned air to all zones of the home, and a high efficiency electric water heater with drain water heat recovery for domestic hot water service. Highlights of this home are shown in the table below.

Table 16. Pilot Home #8 – Whitefish, MT Summary

Pilot Home	Applicable Code Baseline	Compliance Path	UDRH EUI (kbtu/sqft)	As-built EUI (kbtu/sqft)	kWh savings	Therm savings	Main Savings Contribution	% Savings Beyond Code
8	2009 IECC	N/A	67.3	41.6	1,176	393	Infiltration	38%

5.8.1 Outstanding issues

The pilot home uses a high efficiency electric water heater coupled with drain waste heat recovery. However REM/Rate does not currently have an input to calculate savings from this advanced feature, and therefore savings are not being attributed to this feature. Our conversations with NEEA indicated that this standard high efficiency tank was allowed to be used in the pilot because it incorporated a drain waste heat recovery system and would therefore likely perform closer to a HPWH COP. However this added savings is not reflected in the model currently, and therefore savings for the DHW use in this home are understated.

5.9 Pilot Home #9 – Billings, MT Summary

Pilot Home #9 is a single-story ranch home located in Billings, MT. Totaling 1,052 ft^2 and built on a slab on grade, the structure uses four-zone hydronic heating system and ducted-DHPs during the shoulder months to deliver conditioned air to all zones of the home. A tankless gas water heater provides domestic hot water service. Highlights of this home are shown in the table below.

Table 17. Pilot Home #9 – Billings, MT Summary

Pilot Home	Applicable Code Baseline	Compliance Path	UDRH EUI (kbtu/sqft)	As-built EUI (kbtu/sqft)	kWh savings	Therm savings	Main Savings Contribution	% Savings Beyond Code
9	2009 IECC	N/A	61.6	36.2	1,001	233	Infiltration	41%

5.9.1 Outstanding issues

Although the pilot home uses 80% efficient lighting compared with 50% in the UDRH home, a slight increase in the lighting and appliance load was seen. Despite the appliances being locked out in both models (i.e. no credit is taken for efficient appliances) the pilot home consumes approximately 100kWh/yr more energy in the lighting and appliances. We could not resolve this issue during the analysis phase.

5.10 Pilot Home #10 – Eugene, OR Summary

Pilot Home #6 is a single-story ranch home located in Eugene, OR. Totaling 1,603 ft^2 and built on a vented crawlspace, the structure uses a two-stage Air-Source Heat Pump (ASHP) to deliver conditioned air to all zones of the home. A tankless gas water heater provides domestic hot water service. Highlights of this home are shown in the table below.

Table 18. Pilot Home #10 – Eugene, OR Summary

Pilot Home	Applicable Code Baseline	Compliance Path	UDRH EUI (kbtu /sqft)	As-built EUI (kbtu/ sqft)	kWh savings	Therm savings	Main Savings Contribution	% Savings Beyond Code
10	2011 ORSC	A - High Efficiency HVAC; 5 - Bldg. Tightness, Ventilation & Duct Testing	30.8	21.2	2,319	75	Above-Grade Walls	31%

5.11 Pilot Home #11 – Portland, OR Summary

Pilot Home #11 is a 2-story traditional home located in Portland, OR. Totaling 2,730 ft^2 and built on a vented crawlspace, the structure uses two ducted-DHP's to deliver conditioned air to all zones of the home, and a tankless gas water heater for domestic hot water service. Highlights of this home are shown in the table below.

Table 19. Pilot Home #11 – Portland, OR Summary

Pilot Home	Applicable Code Baseline	Compliance Path	UDRH EUI (kbtu/ sqft)	As-built EUI (kbtu/ sqft)	kWh savings	Therm savings	Main Savings Contribution	% Savings Beyond Code
11	2011 ORSC	D - Tankless; 5 - Bldg. Tightness, Ventilation & Duct Testing	20.3	15.7	3,701	0	Infiltration	23%

5.12 Pilot Home #12 – Corvallis, OR Summary

Pilot Home #12 is a 2-story traditional home located in Corvallis, OR. Totaling 1,800 ft^2 and built on a vented crawlspace, the structure uses two DHP's to deliver conditioned air to all zones of the home, and a HPWH for domestic hot water service. Highlights of this home are shown in the table below.

Table 20. Pilot Home #12 – Corvallis, OR Summary

Pilot Home	Applicable Code Baseline	Compliance Path	UDRH EUI (kbtu/ sqft)	As-built EUI (kbtu/ sqft)	kWh savings	Therm savings	Main Savings Contribution	% Savings Beyond Code
12	2011 ORSC	C - Ductless Heat Pump; 5 – Bldg. Tightness, Ventilation & Duct Testing	19.8	13.9	3,119	N/A	Above-Grade Walls	30%

6 Conclusion

Our findings indicate that the implementation team captured the most critical elements of savings estimation correctly within the REM/Rate modeling. While we perceived minor discrepancies in the models compared to what was detailed in the pilot project reports, these differences did not constitute a large swing in savings, especially for the two largest contributors of savings for the pilot: infiltration reduction and above-grade wall insulation.

The average NSH pilot home in Phase 1 was able to save over 30% beyond an equivalent code home baseline, indicating that the specification targets are obtainable by this cohort of builders. Furthermore, builders were able to exceed the NSH specification by an average of 19% and all homes met the target UA levels required during the pilot. Almost all builders in the pilot saw the implementation team as a technical resource and received assistance on several elements that led to better home construction and operation overall.

A key element to the success of the program was NEEA's education of builders during construction, even those who routinely built efficient homes, to ensure proper application and installation of envelope and mechanical systems. For future pilots, implementation staff should focus both their modeling efforts and builder education on infiltration reduction and insulation installation on above-grade walls since those elements achieved the majority of savings for the 12 pilot homes. Additionally, our review of the pilot project reports showed that the majority of builders found the HRV systems to be a recurring problem and will likely require future assistance by implementation staff to ensure proper installation and operation. While these systems appeared to be modeled correctly by the implementation team in REM/Rate, the success or failure of their installation in the field has the capacity to greatly impact heating energy consumption.

While a billing analysis was not performed as part of this effort to test the accuracy of the REM/Rate modeling software compared to real world conditions, the use of REM/Rate to model NSH pilot homes in the future appears to be a satisfactory choice so long as several important improvements are made. As homes that strive to perform well beyond code are built, more advanced construction techniques are likely to be employed and will require flexible inputs to model consumption correctly. If NEEA is interested in using the NW REM/Rate software to evaluate savings potential for future NSH projects, we recommend several modifications to the software (or at a minimum, the development of modeling guidelines) to allow home features to be modeled consistently across all homes instead of requesting modelers to make judgment calls or workaround solutions.

Below we suggest several recommendations that we believe would strengthen the program efficacy and savings estimation for future NSH pilots:

- Allow for mechanical equipment (and DHW systems) to be scheduled individually in REM/Rate to capture savings from demand reduction measures and for equipment that operates independently from the main thermostat setbacks.
- Implementation staff should note the home features that were not modeled in REM/Rate within the model file itself for future reference. Additionally, note whether the efficiency of a system has been purposefully modified to include other

aspects of energy savings that are not able to be modeled in REM/Rate. (ex. increased water heater efficiency to account for drain waste heat recovery energy savings)

- The NSH crawlspace U-factor requirement is not able to be met with R-38 batts and 12” deep TJI joists alone. A resulting U-factor of 0.029 was used in the REM/Rate models for 11 pilot homes instead of the U-0.025 value required as part of the specification. Only one home was able to achieve the NSH specification U-factor level by incorporating 1.5” of spray foam over the R-38 insulation. We recommend revising this requirement in the specification to either allow an equivalent U-factor for wood framed floors with R-38 batts or specifying alternative methods of insulating crawlspace floors to U-0.025.
- Allow a total home LPD, or fixture wattage input, to be available in REM/Rate to account for the increasing mix of CFL and LED lamps found in most new homes.
- Most builders complained about the expense and installation challenges associated with the Zehnder HRV unit. While the specification does not state specific manufacturers, most builders stated that alternate HRV’s could be used that met target performance requirements and maintained occupant comfort. As this component represented a small portion of the overall energy savings in the homes, we recommend revisiting the requirements of this device in the NSH specification to ensure multiple manufacturer options exist.
- Minimize error by fixing certain construction types in the REM/Rate library for common building components. For example, double 2x4 walls were used on several homes, however cavity space varied in the inputs even when blown-in insulation was used across several homes. This has an effect on the overall U-factor of the assembly, and can be specified ahead of time in a REM/Rate library to minimize input errors.

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8 Appendices

Appendix A – Next Step Homes Model Details

Appendix B – UDRH Script Files

Appendix C – Next Step Homes Specification

Appendix A – Next Step Homes Model Details

Pilot Home #1 – Seattle, WA

Details behind the highlights

- The pilot home claims that LED lights were installed in the Pilot Project Report. The modeled lighting was initially comprised of 10% fluorescent lights and 0% CFLs. The UDRH model assumes lighting is comprised of 0% fluorescent and 50% CFLs. The model does not allow for LED lighting input. The as-built model was updated to assume 100% CFLs and 0% fluorescent as a proxy for LED energy consumption.
- The pilot home uses a small buffer tank served by an electric water heater to eliminate the 'cold water sandwich' that often occurs in combined systems. There is no credit taken between the pilot and code home buffer tank, however this tank does contribute to increased energy use in the pilot home compared to a code home that does not have both gas and electric DHW.
- The modern design of this home includes a glazing area ratio to square footage of over 38 percent. This leads to high heating energy consumption in the UDRH home due to the higher U-value of the windows allowed and the larger percentage of wall area that they encompass. Builder was still able to keep as-built home within NSH specification UA limits by increasing other envelope components.
- Improved above-grade wall insulation, efficient windows and tighter air sealing return the most heating energy savings for the home.
- The pilot home uses a Heat Recovery Ventilator (HRV). With the HRV, the fan runs 24/7 and is rated at 32W. The UDRH exhaust fan is rated at 27W and runs 3.5 hrs/day to simulate spot ventilation from a bathroom and kitchen fan.

Figure A1. Pilot Home #1 Fuel Use Summary – kWh/yr

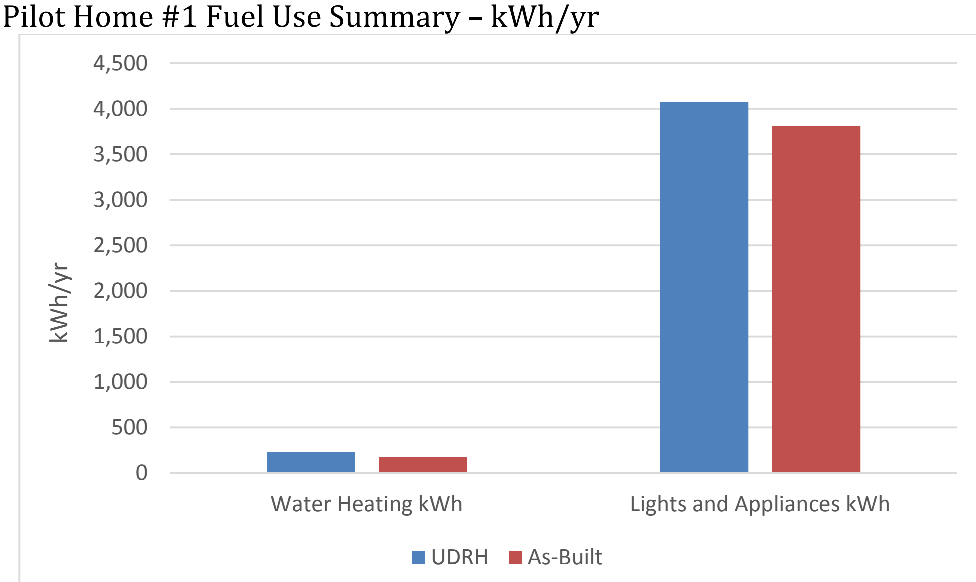
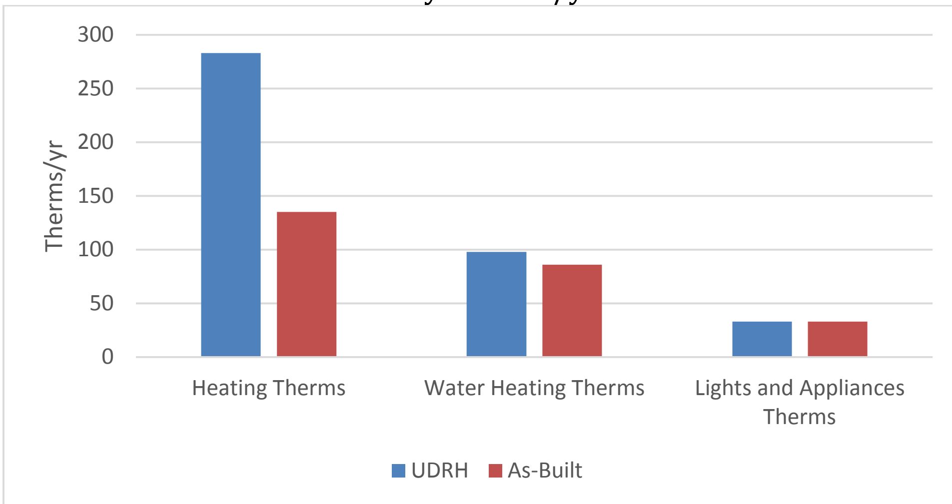
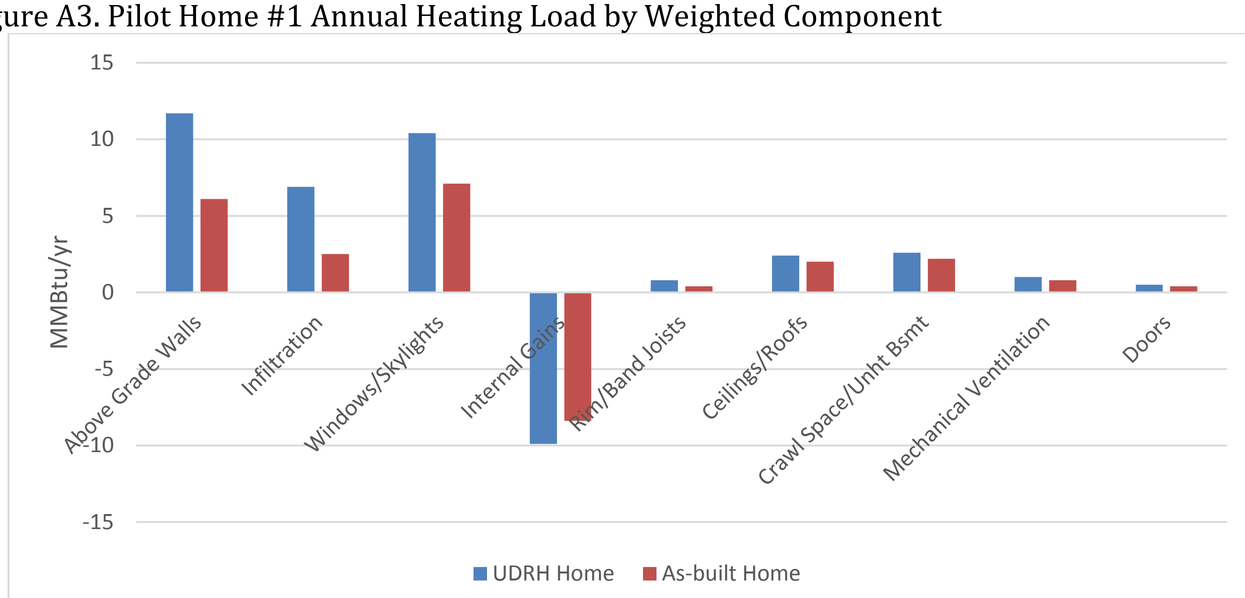


Figure A2. Pilot Home #1 Fuel Use Summary Therms/yr



While most of the savings for this home are from a reduction of the heating load, by far the largest contributor to those savings comes from the above-grade wall insulation which is 2x6 advanced framing with 3 inches of rigid exterior insulation, giving the wall assembly a total of R-35. The pilot project report indicated that due to the high use of glazing in this home, the U-factor for the walls was intentionally lowered to meet the NSH specification UA limit. Because a code home does not dictate a maximum glazing percentage, the as-built home is compared to a code home with similar window square footage, creating more savings for that component. The figure below shows the contribution of savings by each component[10].

Figure A3. Pilot Home #1 Annual Heating Load by Weighted Component



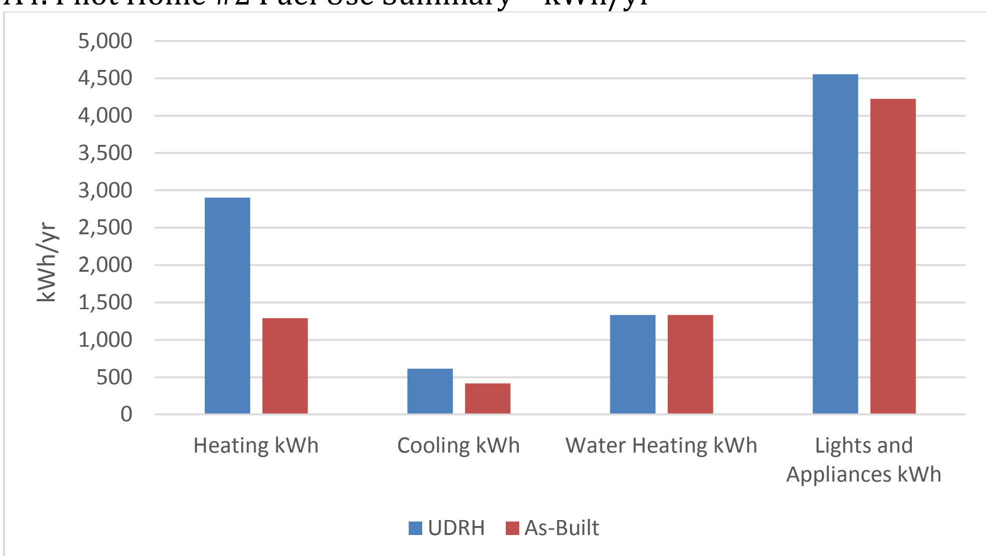
[10] Components that are not shown in the graph are still present in both homes though they do not contribute to savings beyond a code home.

Pilot Home #2 – Bainbridge Island, WA

Details behind the highlights

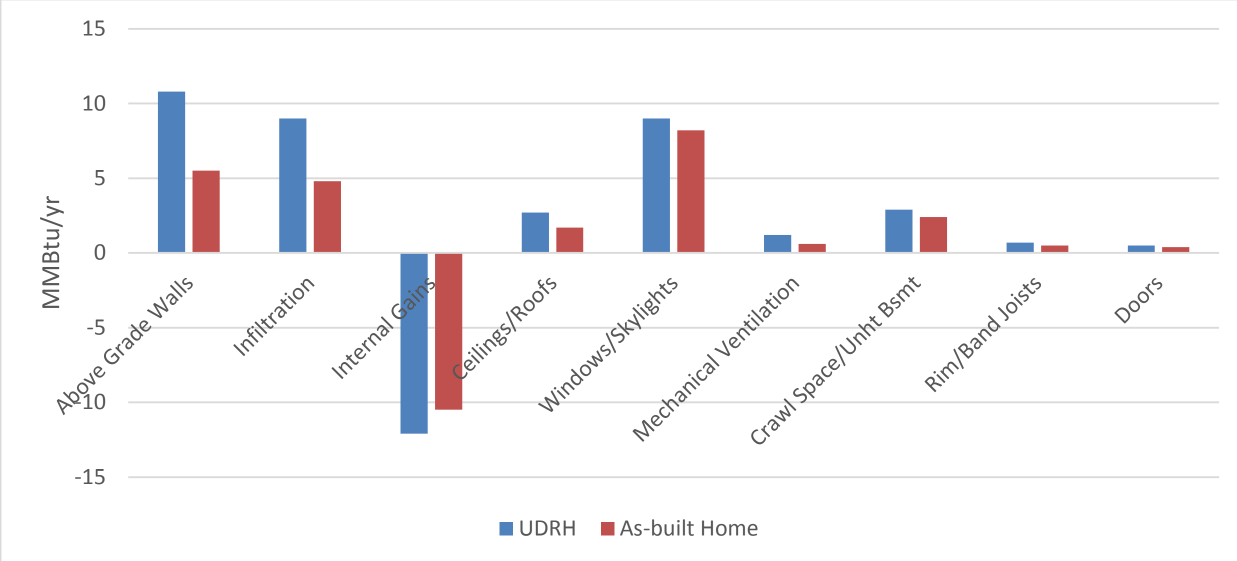
- The pilot and UDRH home did not have any inputs for doors, however the Pilot Project Report claims a cost difference of $1,500 for efficient doors with a U-0.28. With no inputs defined, each model uses default values of U-0.20 and therefore there are no savings being claimed for more efficient doors.
- The pilot home claims that LED lights were installed in the Pilot Project Report. The modeled lighting was initially comprised of 10% fluorescent lights and 0% CFLs. The UDRH model assumes lighting is comprised of 0% fluorescent and 50% CFLs. The model does not allow for LED lighting input. The as-built model was updated to assume 100% CFLs and 0% fluorescent as a proxy for LED energy consumption.
- The pilot home uses a Heat Recovery Ventilator (HRV). With the HRV, the fan runs 24/7 and is rated at 32W. The UDRH exhaust fan is rated at 27W and runs 3.5 hrs/day to simulate spot ventilation from a bathroom and kitchen fan.
- The original REM/Rate file had a continuous R-5.5 value for the above-grade walls, and a 3.5" cavity. However the builder indicated using 1/2" rigid XPS insulation which carries an R-3 rating, and a double 2x4 wall which has an 8" cavity. Making these changes decreased the wall U-factor from U-0.031 to U-0.030.

Figure A4. Pilot Home #2 Fuel Use Summary – kWh/yr



While most of the savings for this home are from a reduction of the heating load, by far the largest contributor to those savings comes from the above-grade walls which were double 2x4 walls with 1/2" of rigid insulation. While the builder expressed concern over the air sealing at the tops of the walls, the home still realized significant savings from reduced infiltration compared to the code allowable level of 6.0 ACH_{50}.

Figure A5. Pilot Home #2 Annual Heating Load by Weighted Component

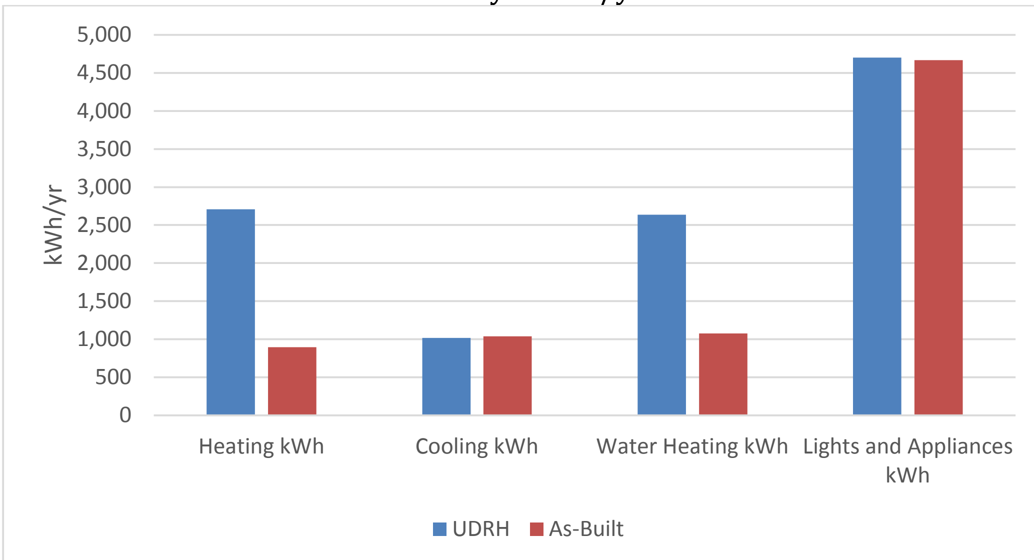


Pilot Home #3 – Seattle, WA

Details behind the highlights

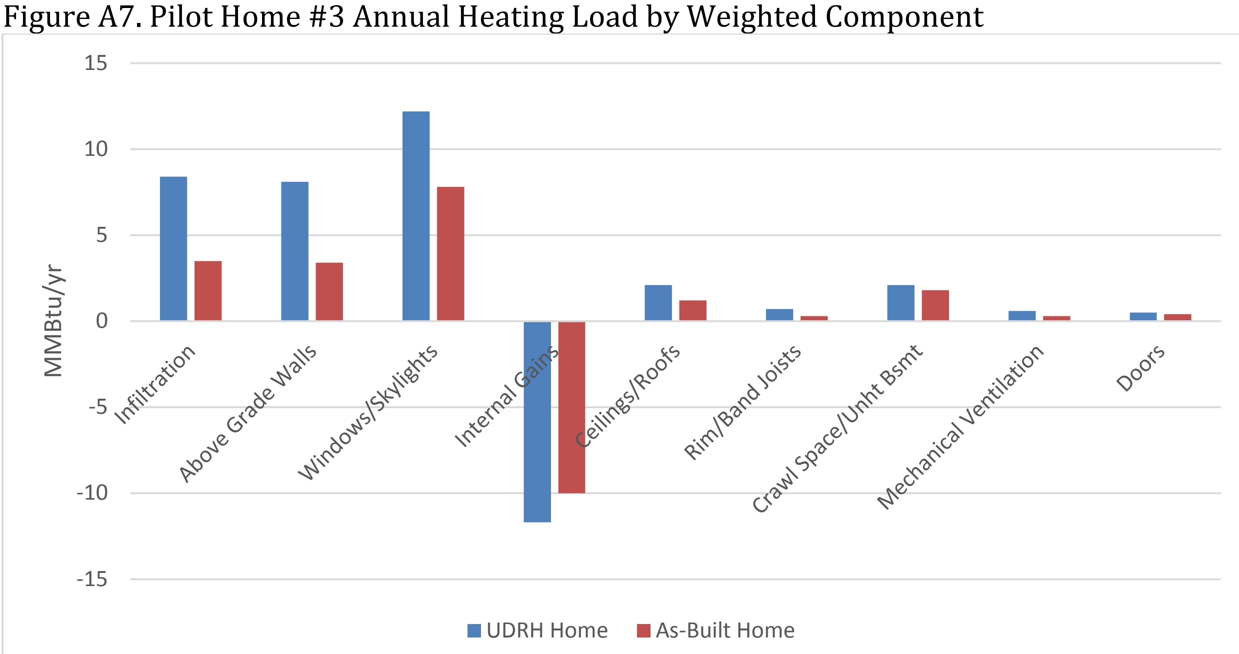
- Very little detail has been provided for this home, however the builder commented that the Dow weather-resistant barrier used to air seal the exterior wall was instrumental in achieving the low infiltration rate.
- The pilot home claims that LED lights were installed in the Pilot Project Report. The modeled lighting was initially comprised of 10% fluorescent lights and 80% CFLs. The UDRH model assumes lighting is comprised of 0% fluorescent and 50% CFLs. The model does not allow for LED lighting input. The as-built model was updated to assume 100% CFLs and 0% fluorescent as a proxy for LED energy consumption.
- The pilot home uses a Heat Recovery Ventilator (HRV). With the HRV, the fan runs 24/7 and is rated at 32W. The UDRH exhaust fan is rated at 27W and runs 3.5 hrs/day to simulate spot ventilation from a bathroom and kitchen fan.
- Double 2x4 above-grade wall U-factor is inconsistent with other homes that use this type of construction. Cavity space is listed as 3.5 inches, however if blown-in insulation was used, the insulation thickness is increased, which affects wall assembly U-factor. Not enough details were provided to warrant change.

Figure A6. Pilot Home #3 Fuel Use Summary – kWh/yr



An interview with the builder of this home was not provided. However similar to several other pilot homes, above wall insulation and infiltration reduction measures were the main contributors to savings. The above-grade walls were constructed of double 2x4 walls, however little insulation details were provided. We could also not verify the window U-factor, which was modeled at U-0.20 even though the pilot project summary indicated window U-factors were close to U-0.29. Due to a lack of information, we left the window U-factor at 0.20, though use of the higher U-0.029 value would only result in lowering overall home savings by 4%.

Figure A7. Pilot Home #3 Annual Heating Load by Weighted Component

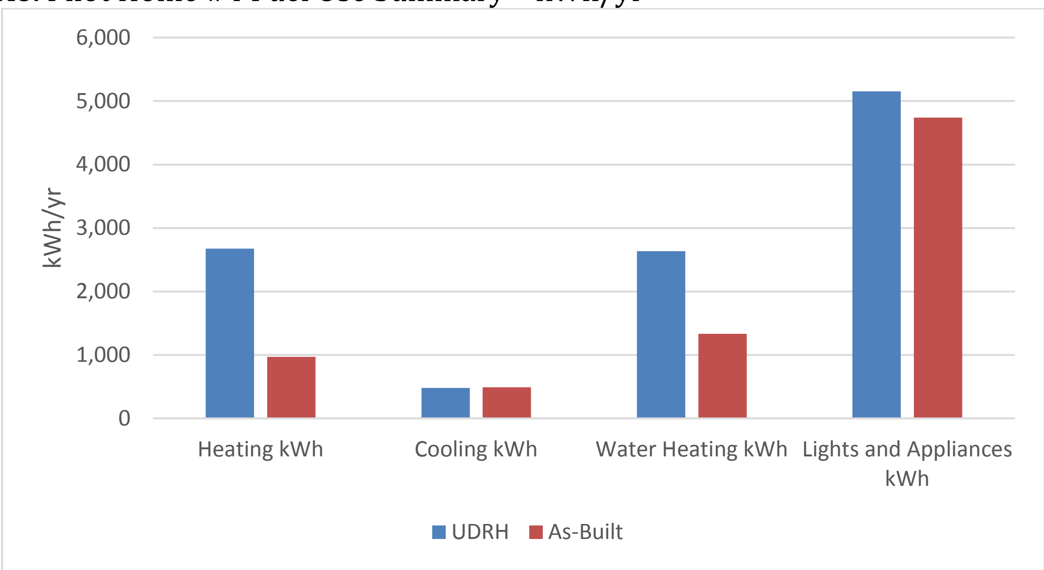


Pilot Home #4 – Vancouver, WA

Details behind the highlights

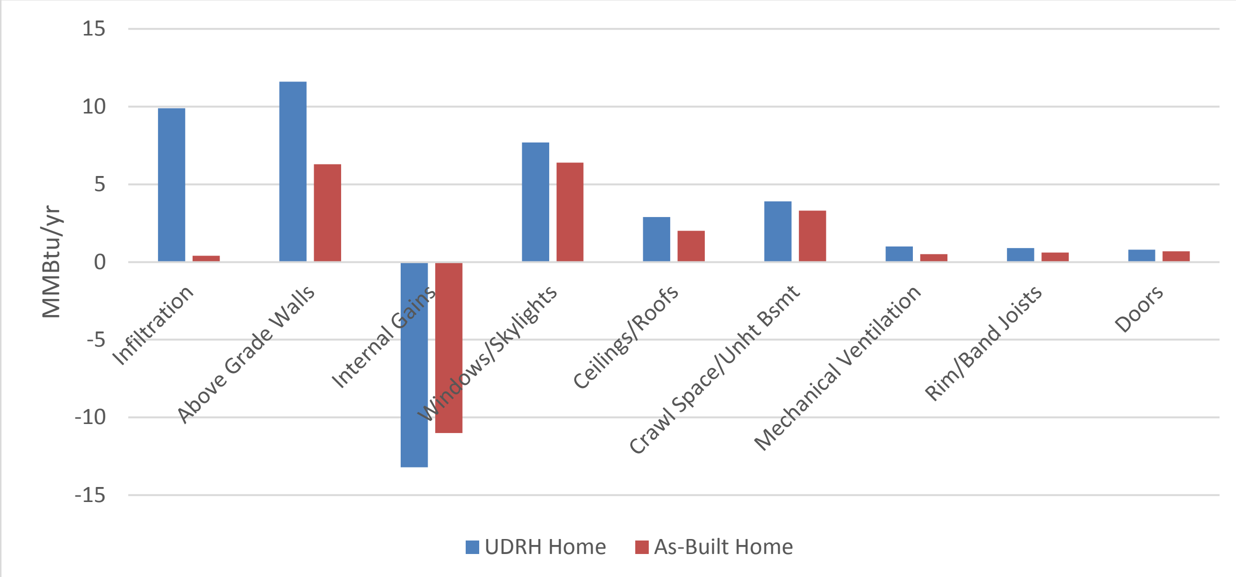
- The pilot home has a very low infiltration rate of 0.25 ACH_{50} whereas the UDRH home has an allowable infiltration rate of 6.0 ACH_{50}. The improved infiltration rate above code results in a 9.5 MMBtu/yr reduction in heating load from this measure alone.
- The pilot home claims that LED lights were installed in the Pilot Project Report. The modeled lighting was initially comprised of 10% fluorescent lights and 0% CFLs. The UDRH model assumes lighting is comprised of 0% fluorescent and 50% CFLs. The model does not allow for LED lighting input. The as-built model was updated to assume 100% CFLs and 0% fluorescent as a proxy for LED energy consumption.
- The pilot home uses a Heat Recovery Ventilator (HRV). With the HRV, the fan runs 24/7 and is rated at 32W. The UDRH exhaust fan is rated at 27W and runs 3.5 hrs/day to simulate spot ventilation from a bathroom and kitchen fan.

Figure A8. Pilot Home #4 Fuel Use Summary – kWh/yr



While most of the savings for this home are from a reduction of the heating load, by far the largest contributor to those savings comes from the infiltration reduction which tested out at 0.25 ACH_{50}, lower than any other home in the pilot program. The builder paid close attention to the tightness of this home by minimizing penetrations through the building envelope and thoroughly sealing any penetrations or gaps. The result is significant heating savings from reduced air infiltration.

Figure A9. Pilot Home #4 Annual Heating Load by Weighted Component

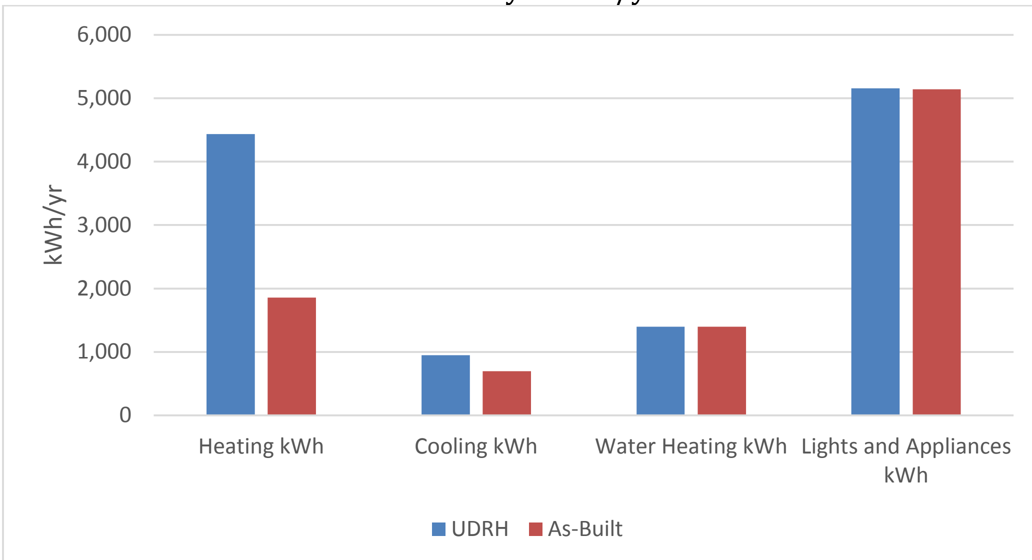


Pilot Home #5 – Kennewick, WA

Details behind the highlights

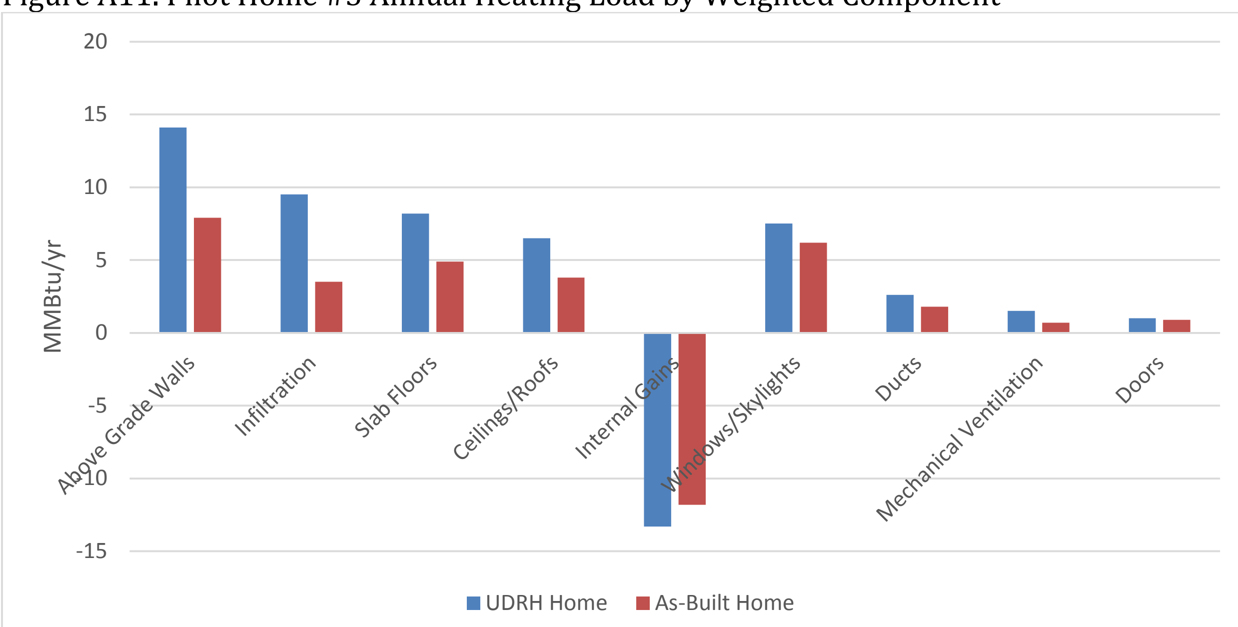
- The pilot home has a low infiltration rate at 1.5 ACH_{50} whereas the UDRH home has an allowable infiltration rate of 6.0 ACH_{50}. The improved infiltration rate above code results in a 6.0 MMBtu/yr reduction in heating load.
- The pilot home claims that LED lights were installed in the Pilot Project Report. The modeled lighting was initially comprised of 10% fluorescent lights and 70% CFLs. The UDRH model assumes lighting is comprised of 0% fluorescent and 50% CFLs. The model does not allow for LED lighting input. The as-built model was updated to assume 100% CFLs and 0% fluorescent as a proxy for LED energy consumption.
- The pilot home uses a Heat Recovery Ventilator (HRV). With the HRV, the fan runs 24/7 and is rated at 32W. The UDRH exhaust fan is rated at 27W and runs 3.5 hrs/day to simulate spot ventilation from a bathroom and kitchen fan.
- Ductless system has small amounts of ductwork and is presumable under attic insulation. Ducts could effectively be insulated to R-68 in this case, however no change was made due to the low impact on overall home savings.

Figure A10. Pilot Home #5 Fuel Use Summary – kWh/yr



While most of the savings for this home are from a reduction of the heating load, by far the largest contributor to those savings comes from the added insulation to above-grade walls which were built as 2x6 w/ advanced framing, including blown-in-batt and R-10 rigid insulation. The builder paid close attention to the tightness of this home by minimizing penetrations through the building envelope and thoroughly sealing any penetrations or gaps. The result is significant heating savings from reduced air infiltration.

Figure A11. Pilot Home #5 Annual Heating Load by Weighted Component

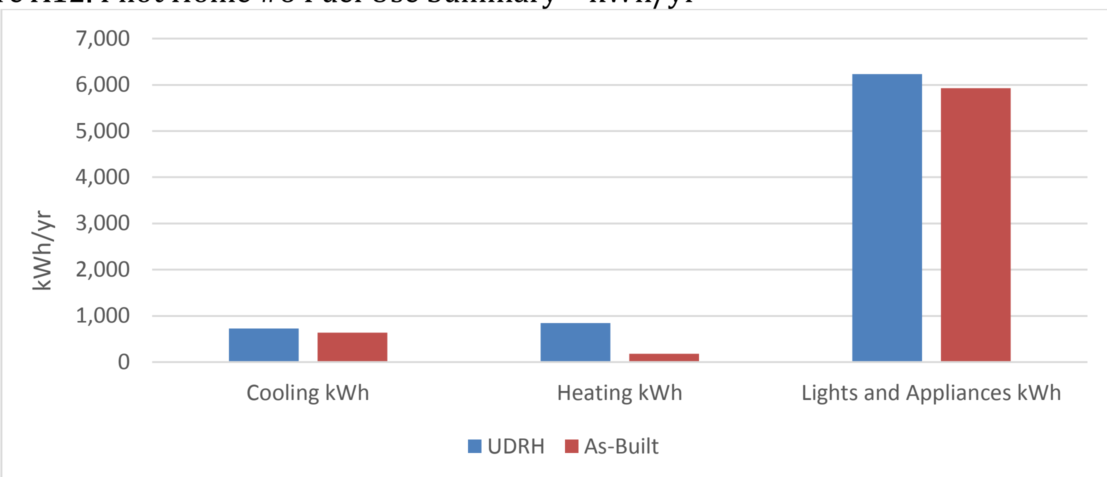


Pilot Home #6 – Kent, WA

Details behind the highlights

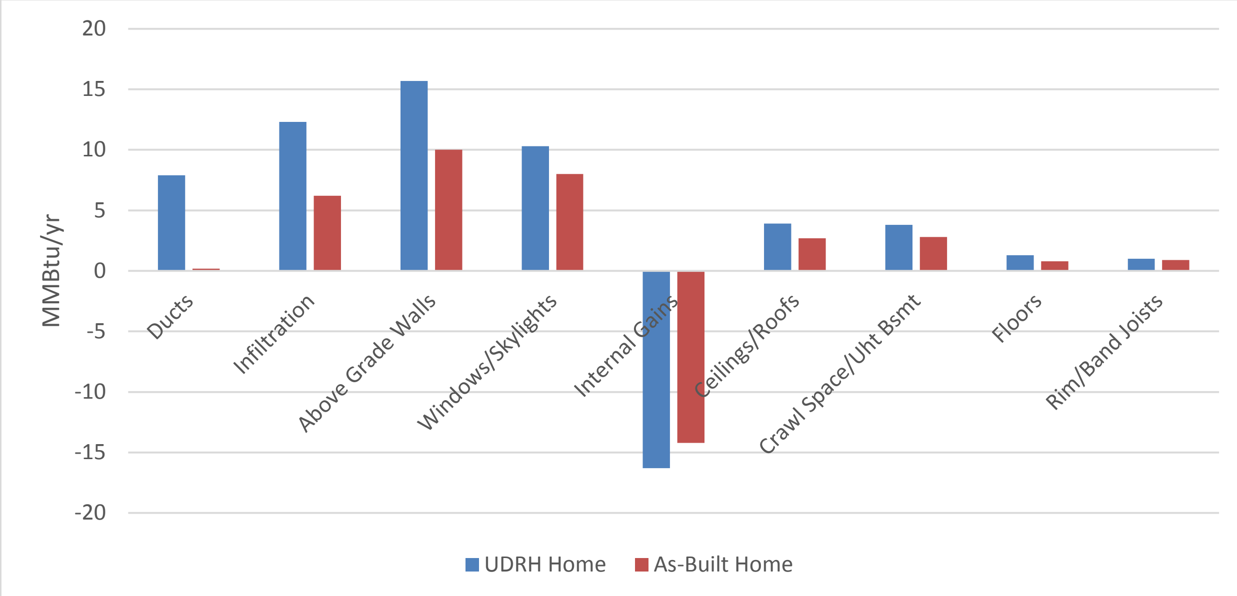
- The UDRH home has a duct leakage to outside rate of 0.06 CFM25/CFA, where the pilot home has a rate of 28 CFM @ 50 Pa. This change leads to the most significant savings compared to the UDRH. This results in heating savings of 7.7 MMBtu/yr.
- The pilot home claims that LED lights were installed in the Pilot Project Report. The modeled lighting was initially comprised of 10% fluorescent lights and 70% CFLs. The UDRH model assumes lighting is comprised of 0% fluorescent and 50% CFLs. The model does not allow for LED lighting input. The as-built model was updated to assume 100% CFLs and 0% fluorescent as a proxy for LED energy consumption.
- The pilot home uses a Heat Recovery Ventilator (HRV). With the HRV, the fan runs 24/7 and is rated at 32W. The UDRH exhaust fan is rated at 27W and runs 3.5 hrs/day to simulate spot ventilation from a bathroom and kitchen fan.

Figure A12. Pilot Home #6 Fuel Use Summary – kWh/yr



While almost all of the savings for this home are from a reduction of the heating load, there were two large contributor to those savings. The first is from moving the ducts inside the conditioned space and a low duct leakage number compared to the code allowable levels. The second comes from infiltration reduction which tested out at 2.64 ACH_{50}. While this is the third highest of the pilot homes, the larger square footage of the home yields significant savings when infiltration levels are reduced compared to code.

Figure A13. Pilot Home #6 Annual Heating Load by Weighted Component

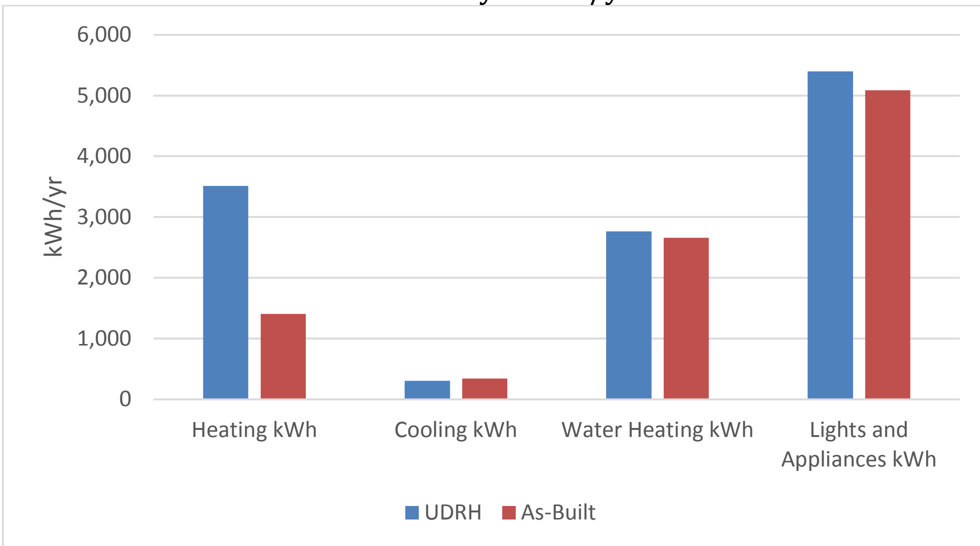


Pilot Home #7 – Olympia, WA

Details behind the highlights

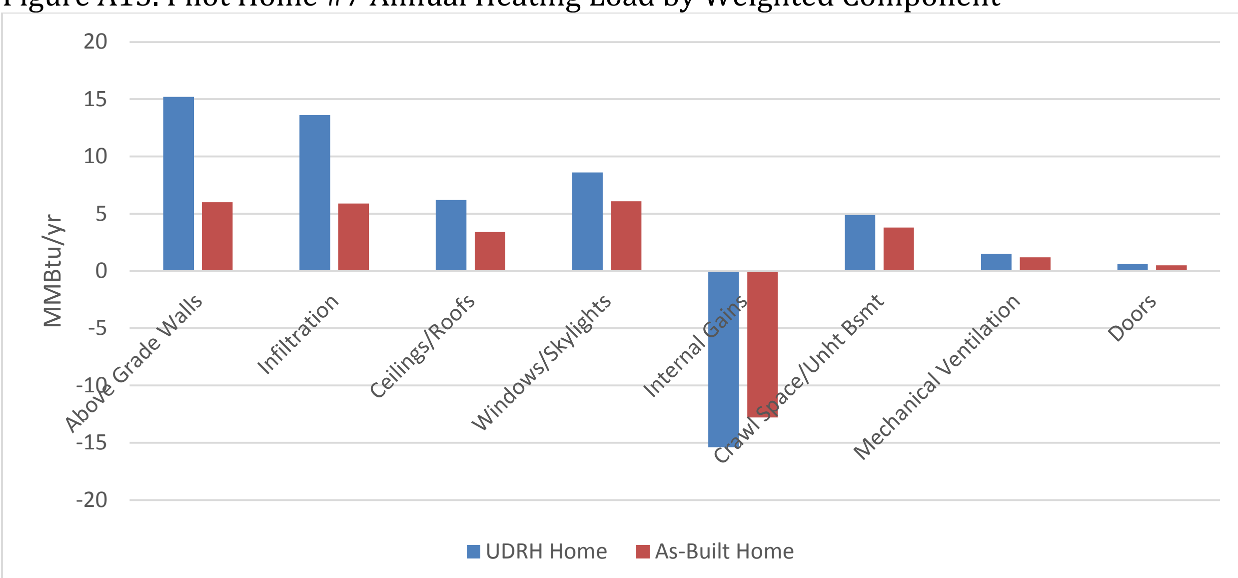
- The pilot home uses 10" SIP panels for the above-grade wall construction. This allows for R-40 of continuous insulation and an extremely low heat transfer rate. This leads to a heating energy savings of 9.2 MMBtu/h.
- The reduction in infiltration leads to significant heating energy savings of 7.7 MMBtu/h. The pilot home has an infiltration rate of 2.28 ACH_{50}, where the UDRH has an infiltration rate of 6.0 ACH_{50}.
- The pilot home claims that LED lights were installed in the Pilot Project Report. The modeled lighting was initially comprised of 10% fluorescent lights and 0% CFLs. The UDRH model assumes lighting is comprised of 0% fluorescent and 50% CFLs. The model does not allow for LED lighting input. The as-built model was updated to assume 100% CFLs and 0% fluorescent as a proxy for LED energy consumption.
- The pilot home uses a Heat Recovery Ventilator (HRV). With the HRV, the fan runs 24/7 and is rated at 32W. The UDRH exhaust fan is rated at 27W and runs 3.5 hrs/day to simulate spot ventilation from a bathroom and kitchen fan.

Figure A14. Pilot Home #7 Fuel Use Summary – kWh/yr



While almost all of the savings for this home are from a reduction of the heating load, there were two large contributor to those savings. The first is from the above-grade walls that used 10" SIPs to construct a large continuous insulation barrier. The second comes from infiltration reduction which tested out at 2.28 ACH_{50}. Combined, these two components comprise 48% of the total savings for this site.

Figure A15. Pilot Home #7 Annual Heating Load by Weighted Component



Pilot Home #8 – Whitefish, MT

Details behind the highlights

- The reduction in infiltration results in the greatest amount of heating savings by component (7.7 MMBtu/yr). The pilot home uses an infiltration rate of 1.3 ACH_{50} while the UDRH uses an infiltration rate of 4.0 ACH_{50}.
- The pilot project report does not mention a cooling system. The pilot model calculates energy consumption for a 3 ton AC unit rated with a cooling efficiency of 14 SEER. This is the same cooling system modeled in the UDRH model.
- The pilot home uses a Heat Recovery Ventilator (HRV). With the HRV, the fan runs 24/7 and is rated at 32W. The UDRH exhaust fan is rated at 30W and runs 3.5 hrs/day to simulate spot ventilation from a bathroom and kitchen fan.

Figure A16. Pilot Home #8 Fuel Use Summary – kWh/yr

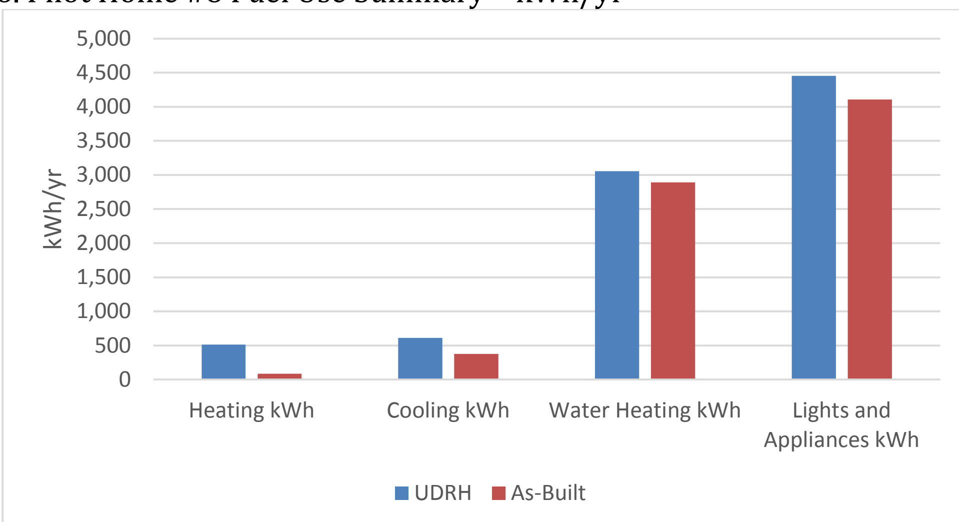
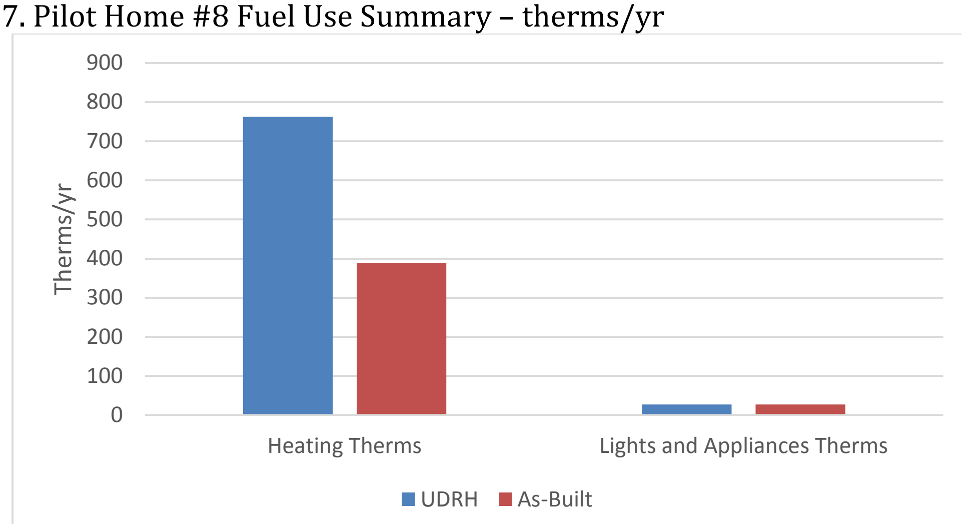
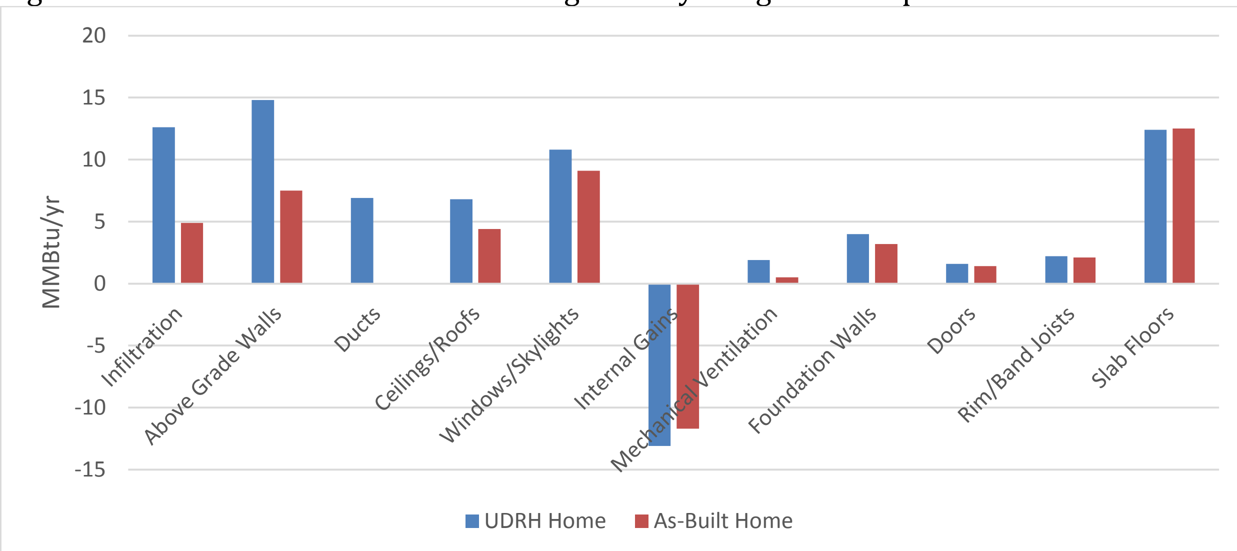


Figure A17. Pilot Home #8 Fuel Use Summary – therms/yr



While almost all of the savings for this home are from a reduction of the heating load, there were two large contributors to those savings. The first is from infiltration reduction which tested out at 1.31 ACH_{50}. The second is from upgrading insulation on the above-grade walls. These two components constitute almost 45% of the total savings of the home, which results in a 41% savings beyond the 2009 MT code when coupled with moving ductwork inside the conditioned space.

Figure A18. Pilot Home #8 Annual Heating Load by Weighted Component



Pilot Home #9 – Billings, MT

Details behind the highlights

- The reduction in infiltration results in the greatest amount heating savings by component (5.6 MMBtu/yr). The pilot home uses an infiltration rate of 0.92 ACH_{50} while the UDRH uses an infiltration rate of 4.0 ACH_{50}.
- The improvement in wall insulation also leads to large heating savings by component (4.9 MMBtu/yr). The pilot home uses a U-factor of 0.029 while the UDRH uses a U-factor of 0.054.
- There is no credit claimed for the 'Sensor-controlled instant loop' demand DHW distribution system.
- The pilot home claims that LED lights were installed in the Pilot Project Report. The modeled lighting was initially comprised of 10% fluorescent lights and 80% CFLs. The UDRH model assumes lighting is comprised of 0% fluorescent and 50% CFLs. The model does not allow for LED lighting input. The as-built model was updated to assume 100% CFLs and 0% fluorescent as a proxy for LED energy consumption.
- The pilot home uses a Heat Recovery Ventilator (HRV). With the HRV, the fan runs 24/7 and is rated at 32W. The UDRH exhaust fan is rated at 27W and runs 3.5 hrs/day to simulate spot ventilation from a bathroom and kitchen fan.

Figure A19. Pilot Home #9 Fuel Use Summary – kWh/yr

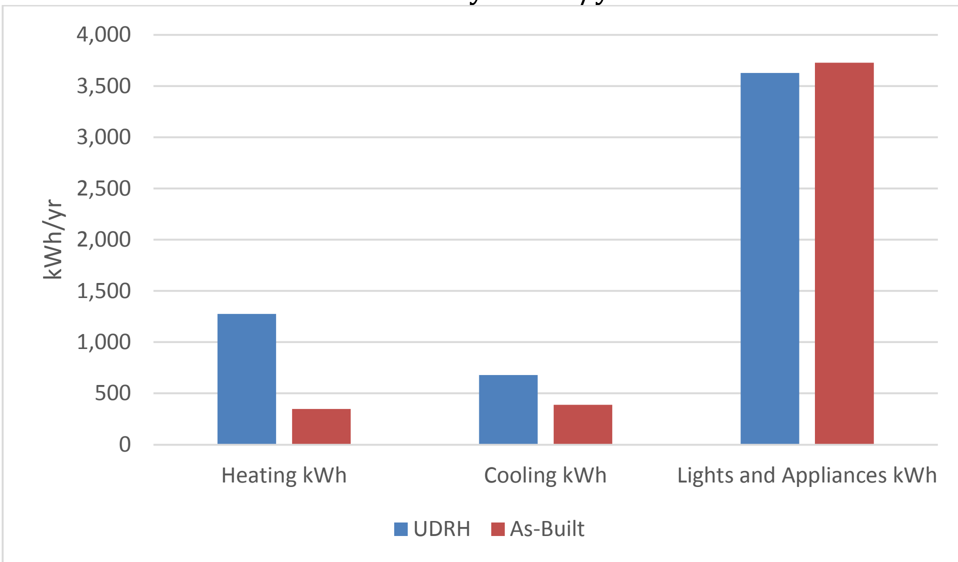
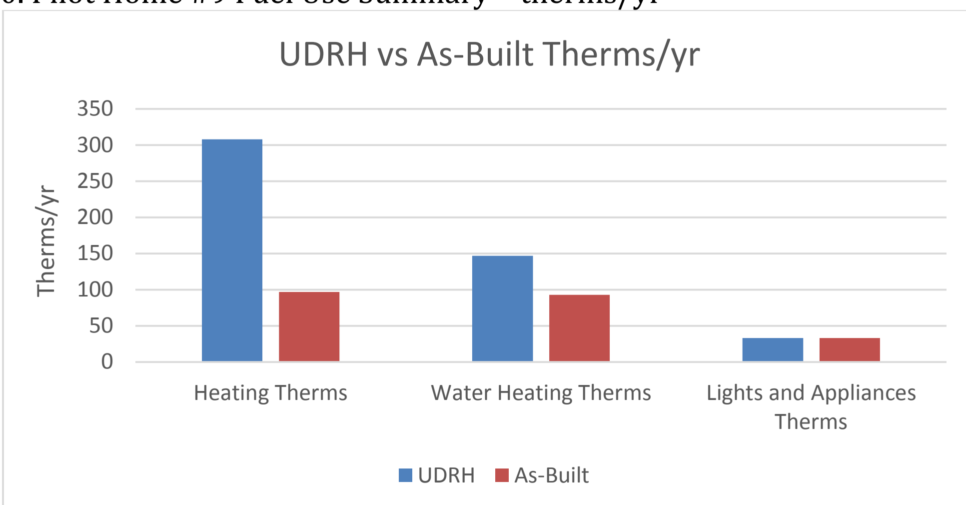
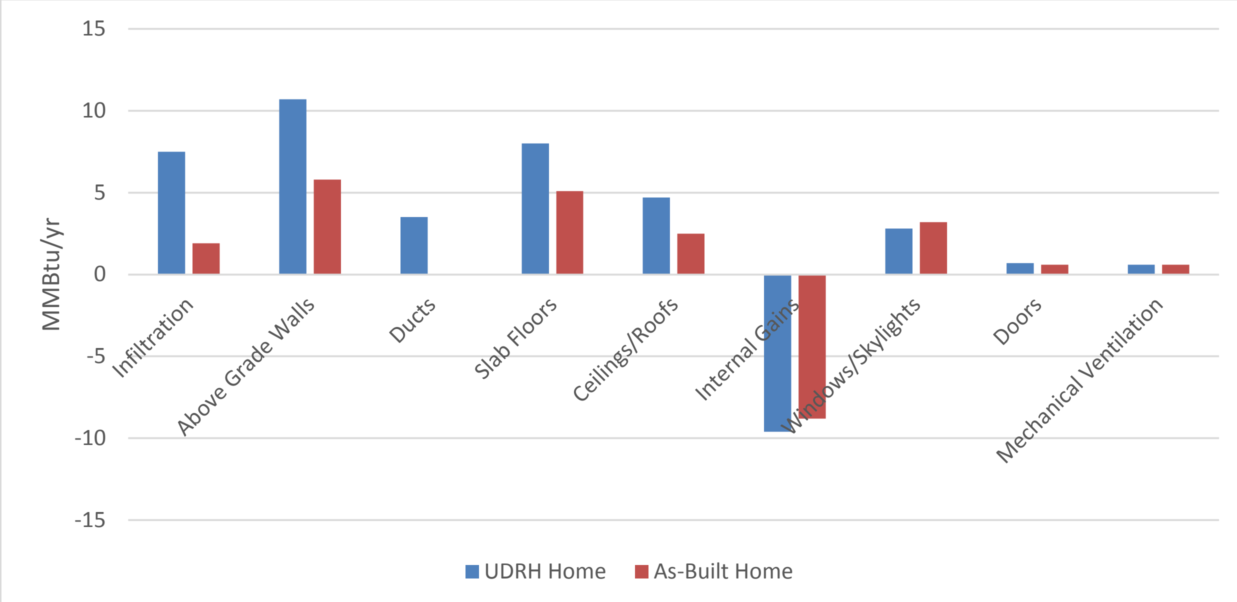


Figure A20. Pilot Home #9 Fuel Use Summary – therms/yr



While almost all of the savings for this home are from a reduction of the heating load, there were two large contributors to those savings. The first comes from infiltration reduction which tested out at 0.92 ACH_{50} and was the second lowest infiltration number in the pilot. The second biggest contributor to the savings was the added insulation to the above-grade walls. This builder used staggered stud walls, comprised of 2x4 and 2x6 studs to achieve an R-35 rating for the wall assembly. These two components constitute almost 62% of the total heating savings for the home, and when coupled with ducts moved inside the conditioned space, results in a 41% savings beyond the 2009 MT code.

Figure A21. Pilot Home #9 Annual Heating Load by Weighted Component



Pilot Home #10 – Eugene, OR

Details behind the highlights

- The improvement in above-grade wall insulation leads to the greatest amount heating savings by component (4.7 MMBtu/yr). The pilot home uses a U-factor of 0.036 while the UDRH uses a U-factor of 0.06.
- The pilot home claims that LED lights were installed in the Pilot Project Report. The modeled lighting was initially comprised of 10% fluorescent lights and 0% CFLs. The UDRH model assumes lighting is comprised of 0% fluorescent and 50% CFLs. The model does not allow for LED lighting input. The as-built model was updated to assume 98% CFLs and 0% fluorescent as a proxy for LED energy consumption.
- The pilot home uses a Heat Recovery Ventilator (HRV). With the HRV, the fan runs 24/7 and is rated at 32W. The UDRH exhaust fan is rated at 27W and runs 3.5 hrs/day to simulate spot ventilation from a bathroom and kitchen fan.
- There is no credit claimed for the 'Sensor-controlled instant loop' demand DHW distribution system.

Figure A22. Pilot Home #10 Fuel Use Summary – kWh/yr

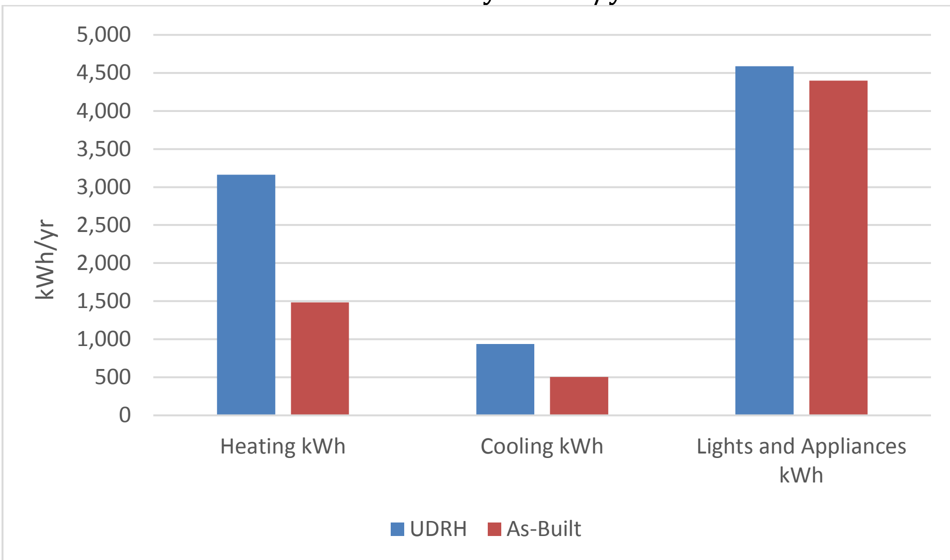
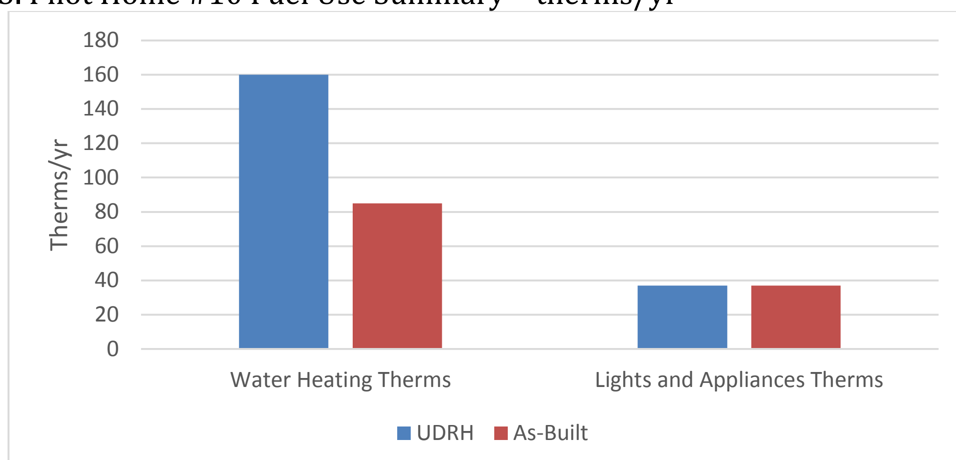
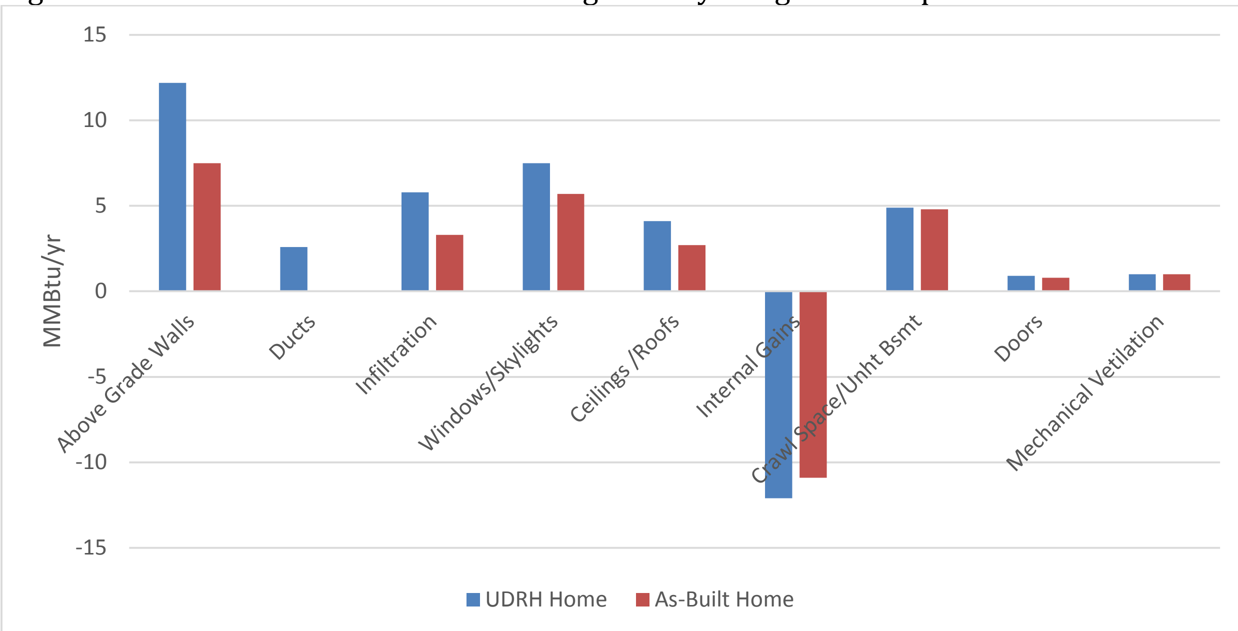


Figure A23. Pilot Home #10 Fuel Use Summary – therms/yr



While almost all of the savings for this home are from a reduction of the heating load, by far the above-grade walls were the largest contributor to those savings. This builder used 2x6 advanced framing with 1" of exterior rigid foam to achieve an R-31 rating for the wall assembly. This component alone constitute almost 45% of the total heating savings for the home and results in a 31% savings beyond the 2011 OR code.

Figure A24. Pilot Home #10 Annual Heating Load by Weighted Component



Pilot Home #11 – Portland, OR

Details behind the highlights

- The reduction in infiltration leads to the greatest amount of heating savings by component (10.8 MMBtu/yr). The pilot home uses an infiltration input of 1.55 ACH_{50} while the UDRH uses an infiltration input of 6.0 ACH_{50}.
- The pilot home claims that LED lights were installed in the Pilot Project Report. The modeled lighting was initially comprised of 10% fluorescent lights and 0% CFLs. The UDRH model assumes lighting is comprised of 0% fluorescent and 50% CFLs. The model does not allow for LED lighting input. The as-built model was updated to assume 98% CFLs and 0% fluorescent as a proxy for LED energy consumption.
- The pilot home uses a Heat Recovery Ventilator (HRV). With the HRV, the fan runs 24/7 and is rated at 32W. The UDRH exhaust fan is rated at 27W and runs 3.5 hrs/day to simulate spot ventilation from a bathroom and kitchen fan.
- There is no credit claimed for the 'Circulating Pump System' DHW distribution system. The cost difference, defined in the pilot project report, between the code and the pilot home is claimed to be $640.

Figure A25. Pilot Home #11 Fuel Use Summary – kWh/yr

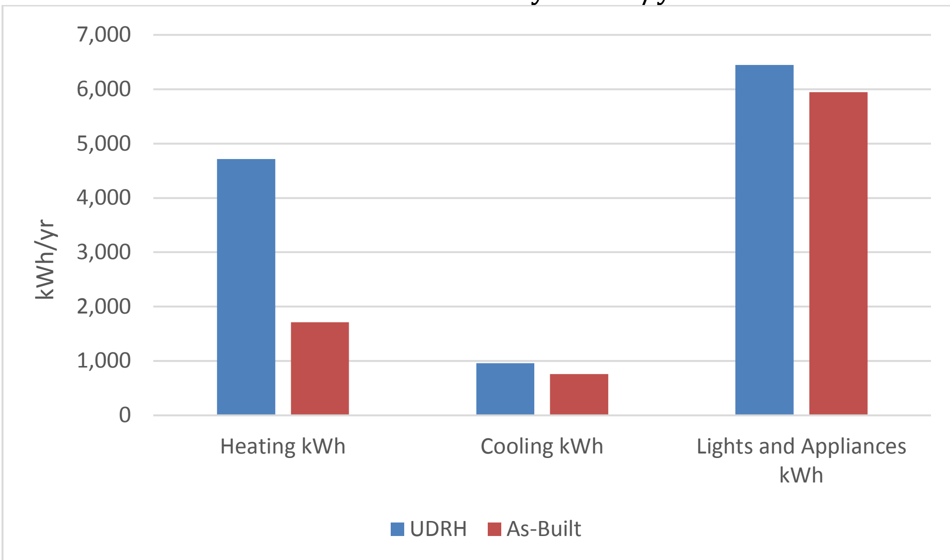
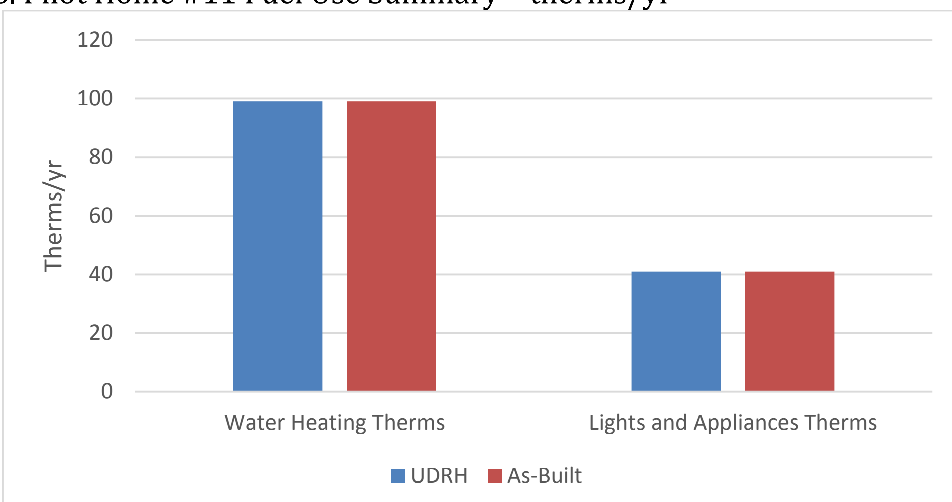
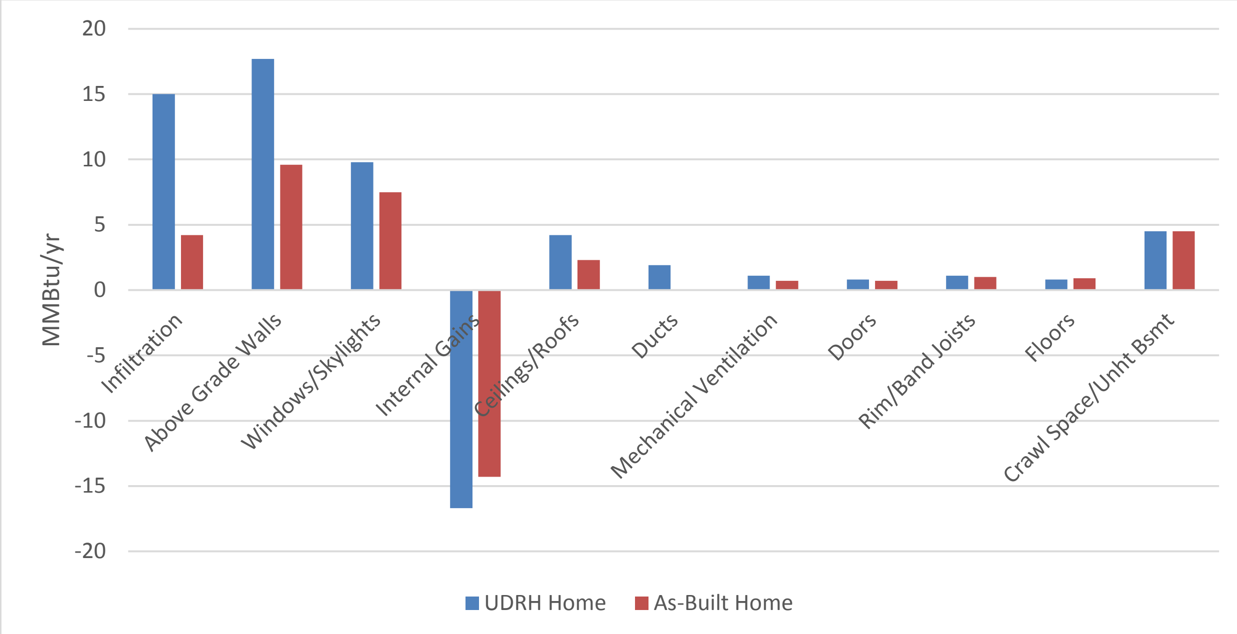


Figure A26. Pilot Home #11 Fuel Use Summary – therms/yr



While almost all of the savings for this home are from a reduction of the heating load, there were two large contributors to those savings. The first comes from infiltration reduction which tested out at 1.55 ACH_{50}. The second biggest contributor to savings was the added insulation to the above-grade walls. This builder used 2x6 advanced frame walls with R-10 rigid insulation to achieve an R-30 rating for the wall assembly. These two components constitute almost 47% of the total heating savings for the home, and resulted in a 23% savings beyond the 2011 OR code.

Figure A27. Pilot Home #11 Annual Heating Load by Weighted Component

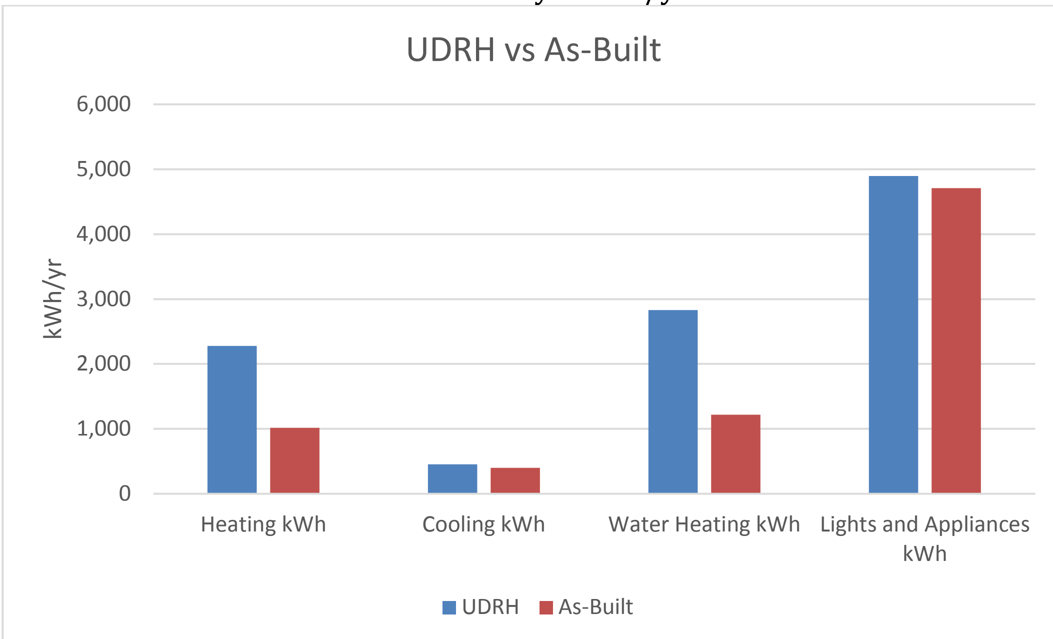


Pilot Home #12 – Corvallis, OR

Details behind the highlights

- The improvement in above-grade wall insulation leads to the greatest amount heating savings by component (6.3 MMBtu/yr). The pilot home uses an 'Above-Grade Wall' U-value input of 0.039 for the garage walls and 0.027 for the house walls. The UDRH uses an 'Above-Grade Wall' input of 0.06 for all walls.
- The pilot home claims that LED lights were installed in the Pilot Project Report. The modeled lighting was initially comprised of 10% fluorescent lights and 0% CFLs. The UDRH model assumes lighting is comprised of 0% fluorescent and 50% CFLs. The model does not allow for LED lighting input. The as-built model was updated to assume 98% CFLs and 0% fluorescent as a proxy for LED energy consumption.
- The pilot home uses a Heat Recovery Ventilator (HRV). With the HRV, the fan runs 24/7 and is rated at 32W. The UDRH exhaust fan is rated at 30W and runs 3.5 hrs/day to simulate spot ventilation from a bathroom and kitchen fan.

Figure A28. Pilot Home #11 Fuel Use Summary – kWh/yr



While almost all of the savings for this home are from a reduction of the heating load, there were two large contributors to those savings. The first comes from the added insulation to the above-grade walls. This builder used 2x8 staggered stud walls to achieve an R-40 rating for the wall assembly. The second is the use of very efficient triple pane windows, with a U-factor of 0.019. These two components, combined with infiltration reduction, constitute almost 53% of the total heating savings for the home, and resulted in a 30% savings beyond the 2011 OR code.

Figure A29. Pilot Home #12 Annual Heating Load by Weighted Component