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Next Step Homes Pilot Phases 2 and 3 Summary

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Abstract

This report provides a summary of activities, outcomes, and lessons learned during NEEA's Next Step Homes Pilot (Pilot) Phases 2 and 3, a Ratings Accuracy Study, and an Energy Ratings Index (ERI) Variability Study. The primary purpose of this report is to provide a historical reference of activities and core learnings. This report does not provide an evaluation of Pilot activities that occurred during 2013 through 2020.

Descriptions of Phase 2, the Ratings Accuracy Study, Phase 3, and the ERI Variability Study are followed by discussions of lessons learned that informed a variety of technical trainings and resources, code advancement proposals, and the development of Standard Protocol/ Performance Path. Phase 1 is briefly summarized, and references to the current Standard Protocol/Performance Path offering are limited. Appendix A lists technical resources, data files, and other reports from the Pilot and is referenced throughout this report. Appendices B, D, and F include copies of the specification used in each Pilot phase. Appendix H contains a quality assurance checklist for Phase 3, and Appendix I provides a summarized list of training informed by findings in the Pilot. Design guidelines developed and provided to Phase 2 and 3 participants are included in Appendices J, K, L, and M.

NEEA's Residential New Homes Program has gone through several naming conventions over the years, both internally and externally. This report uses the term "initiative" to reflect the naming used for all the efforts during the Pilot. "Initiative staff" refers to NEEA Residential New Homes Program staff and contracted, third party, program implementation support (CLEAResult) working for NEEA's Residential New Homes Program.

Introduction

The Northwest Energy Efficiency Alliance (NEEA) began a residential new homes market transformation initiative in 2004 to advance residential code and building practices throughout the Northwest. From 2004 through 2016, the initiative used the Northwest ENERGY STAR Homes (NWESH) certification (a Northwest variant of the EPA's national ENERGY STAR Homes program) to define requirements and provide oversight to ensure homes were at least 15% more efficient than if built to code.[1] As other branded home certification programs began to lift off across the nation and within the Northwest, NEEA determined that a singular method to measure residential home performance through a single branded certification program could be a limitation in the future, and many of the "easy" measures had been adopted into codes. In 2010, the Next Step Homes Pilot project (Pilot) was born with an outlook toward the next 3-4 code cycles (9-12 years).[2]

The Pilot was designed to identify challenges, best practices, and the most cost-effective methods to achieve higher performance and greater savings in residential new construction. The Pilot explored a range of possible energy code measures and examined how best to leverage performance ratings such as the Residential Energy Services Network (RESNET) Home Energy Rating System (HERS) Index Score or the Energy Trust of Oregon's EPS approach to measure and encourage potential energy and building improvements. The Pilot grew over time to consist of three phases, each of which had a different number of participating homes and different sub-metering plans on equipment and/or the surrounding indoor/outdoor environment. Each phase had slightly different building specifications, informed by lessons learned, to get homes performing up to 20-40% more efficiently than the current code. Component-level specifications were designed to represent the next significant step up in efficiency for each home component (windows, walls, ventilation, heating equipment, etc.). Strategies included significantly tighter home envelopes that incorporated advanced wall construction methods, increased insulation and more efficient windows, advanced HVAC systems, such as ductless heating and cooling systems and heat recovery ventilators (HRVs), and hot water solutions such as heat pump water heaters.[3]

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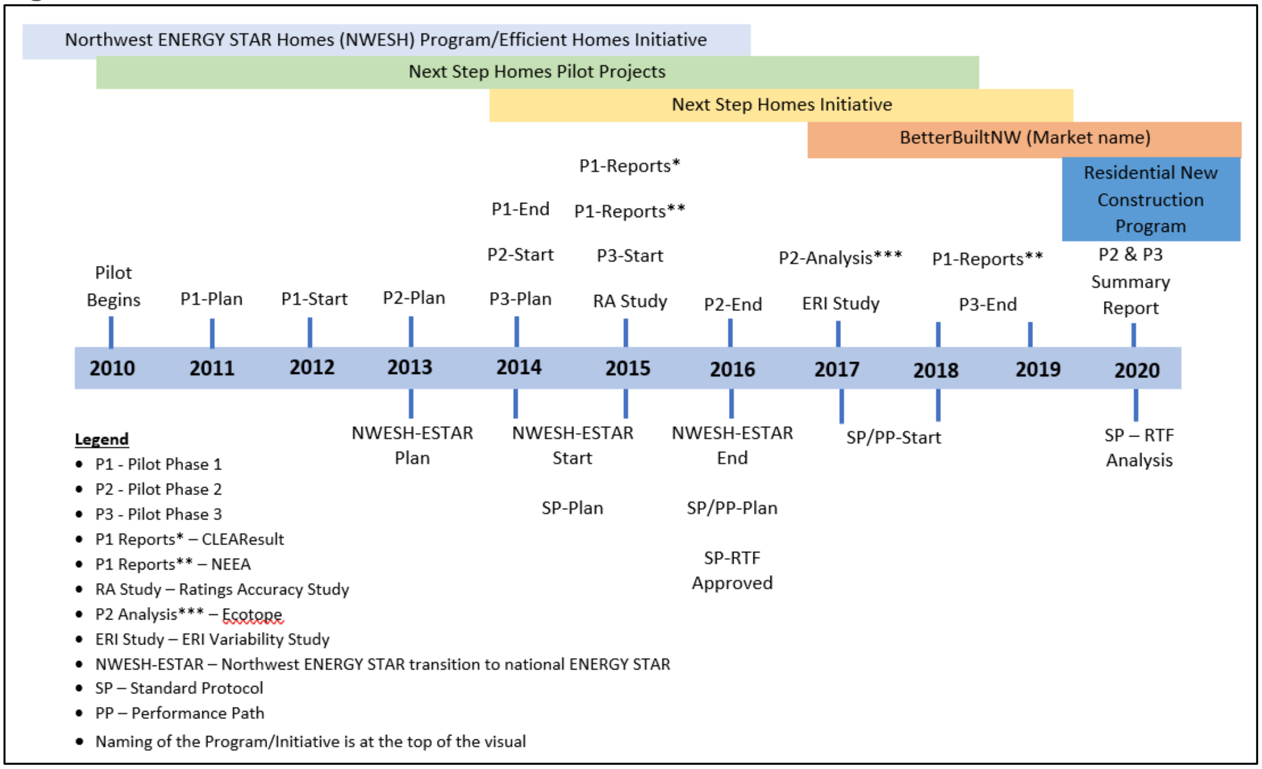
[1] Northwest ENERGY STAR Homes Retrospective Report
[2] Next Step Homes Pilot Phase 1 Executive Summary
[3] Next Step Homes Phase 1 Executive Summary, Annual Reports by CLEAResult

While implementing successive phases of the Pilot, NEEA's residential new homes initiative was also transferring oversight and implementation of ENERGY STAR home certifications from NWESH back to the national EPA program, and developing the Standard Protocol/Performance Path offering with the Northwest Power and Conservation Council's Regional Technical Forum (RTF) and Bonneville Power Administration (BPA). The Pilot also served as a bridging transition from a single branded home certification program (NWESH) to a new way for Northwest utilities to claim savings and pay incentives for all levels of above-code building regardless of the certification program in which the builder may be participating. Additionally, some initiative activities overlapped and supported separate efforts, such as the Sanden CO_2 equipment pilot and updates to the HVAC ST software (previously known as SpecPro). Figure 1 outlines the major milestones of the initiative's activities starting in 2010. NEEA's Residential New Homes Program has gone through several naming conventions over the years, both internally and externally. This report uses the term "initiative" to reflect the naming used for all the efforts during the Next Step Homes Pilot Project. The naming conventions are included at the top of Figure 1.

Figure 1. Initiative Milestones and Names 2010-2020



Phase 1

Phase 1 set the stage for many of the refined learnings and much of the market strategy development within the new homes initiative after its establishment in 2010. The initiative developed an advanced specification in 2011, then recruited 12 builders to participate. After its official kickoff in 2012, the builders tested the “Next Step Homes Specification” and helped to determine the “what’s next” and the most cost-effective ways to build a home that would achieve the greatest savings.[4, 5] The Phase 1 specification and summary of participating homes are available in Appendices B and C, respectively. Information about Phase 1 within this report is limited because it was previously summarized in other project reports.

At the time, the Pilot objectives were to take energy-efficient homebuilding to a higher level with strategies including (a) tighter home envelopes that incorporated advanced framing techniques, increased insulation, and more efficient windows, (b) advanced HVAC systems, such as ductless heating and cooling systems and heat recovery ventilators (HRVs), and (c) hot water solutions such as heat pump water heaters, that together deliver increased comfort, better indoor air quality, and lower monthly energy costs to homeowners.[6] Additionally, the Pilot sought to explore a specification that at the time NEEA believed was a reasonable end-state for residential energy codes.

[The NSH project] provided builders participating in Phase 1 with financial incentives, and also provided deep technical consulting on each home. Homes were issued SiteSage data loggers to facilitate monitoring of several circuits and channels for 13 months. Builders provided cost data and feedback on their participation (roundtables and interviews).[7, 8] The initiative created several marketing and promotional materials for Phase 1, including a Pilot Book, homeowner brochures, and a video commercial highlighting the benefits of living in a super-efficient home (Puget Sound Energy branded and non-branded versions).[9]

For more technical insights on Phase 1 homes, refer to the following unpublished reports:

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4 Pilot Project Positioning
5 Next Step Homes Pilot History-NEEA internal
6 Next Step Homes Pilot History-NEEA internal
7 Annual Reports by CLEAResult
8 Next Step Homes Builder Focus Groups Report
9 Annual Reports by CLEAResult; Marketing Items with NEEA

- CLEAResult: Unique per-home reports (12) summarizing participation and technical findings during the construction period
- NEEA: Unique per-home reports (10) with detailed analysis of the SiteSage logger data, modeled data, and other home components; CLEAResult supported with an Executive Summary and Meta-Analysis

Phase 2

Phase 2 began in 2013 with a review of key takeaways from Phase 1 to adjust the specification and the approach used to recruit and support builders. RESNET certified raters (Raters) did not have an active role in Phase 2 unless they were already working with the participating builder. Home Energy Rating System (HERS) Raters are individuals certified by an accredited Rating Provider to inspect and test a home in order to evaluate each of the minimum rated features and complete a Home Energy Rating according to the RESNET Standards. CLEAResult developed the Phase 2 specification (Appendix D) and accompanying design guidelines (Appendices J, K, L, and M) based on project logs, modeling, frequently asked questions from builders, and data monitoring from Phase 1. In addition to highlighting best practices, the design guidelines were intended to be flexible, refine learnings, and demonstrate that high-efficiency building could be achieved without substantial changes in a builder's standard practice.

The following implementation activities were completed in Phase 2:[10]

- Targeted builder outreach and recruitment
- Project review, selection, and enrollment
- Specification review and negotiation
- Facilitation of builder and homeowner participation agreements
- HRV ducting and data logger infrastructure design
- Technical consulting and training
- Field verification
- Energy modeling
- Quality assurance
- Data logger installation
- Builder and Rater incentive processing
- Collection of builder cost data and participant feedback
- Home tour hosting

[10] Annual Reports by CLEAResult

Recruitment and Participating Homes

Recruitment efforts focused on achieving project diversity and exploring new markets, as well as incorporating systems and shell components not included in Phase 1 homes. CLEAResult tracked, vetted, and enrolled projects based on characteristics such as location, climate, builder type, and utility territory, as well as home size, systems, shell design, and geometry. Builders were offered and issued financial incentives for participating. Twenty-eight homes participated in Phase 2. Several homes received other program certifications, such as NWESH or Built Green.

During Phase 2, the initiative hosted five Pilot home tours with more than 460 attendees, including utilities, builders, code officials, and future homeowners. These home tours (a) showcased NEEA's work on the Pilot, (b) demonstrated the advanced technologies and construction techniques, and (c) generated interest for new utility incentive and savings programs based on the Pilot specification. [11]

Technical Support

Phase 2 required extensive hands-on technical consulting directly to builders and their subcontractors throughout the entire construction process from design through final commissioning. CLEAResult's technical support included:

- Pre-construction and design consulting
- Plan reviews
- Technical tool development (i.e., range hood depressurization calculator)
- Load calculations
- Shell analysis
- HVAC design
- Energy modeling
- 1:1 support
- Field visits
- Training with necessary trades
- Final commissioning

All technical support aimed to help builders meet the stringent specifications and design guidelines, while ensuring builders made thoughtful and well-integrated design decisions. Lessons learned through this level of technical support laid some of the foundations for the

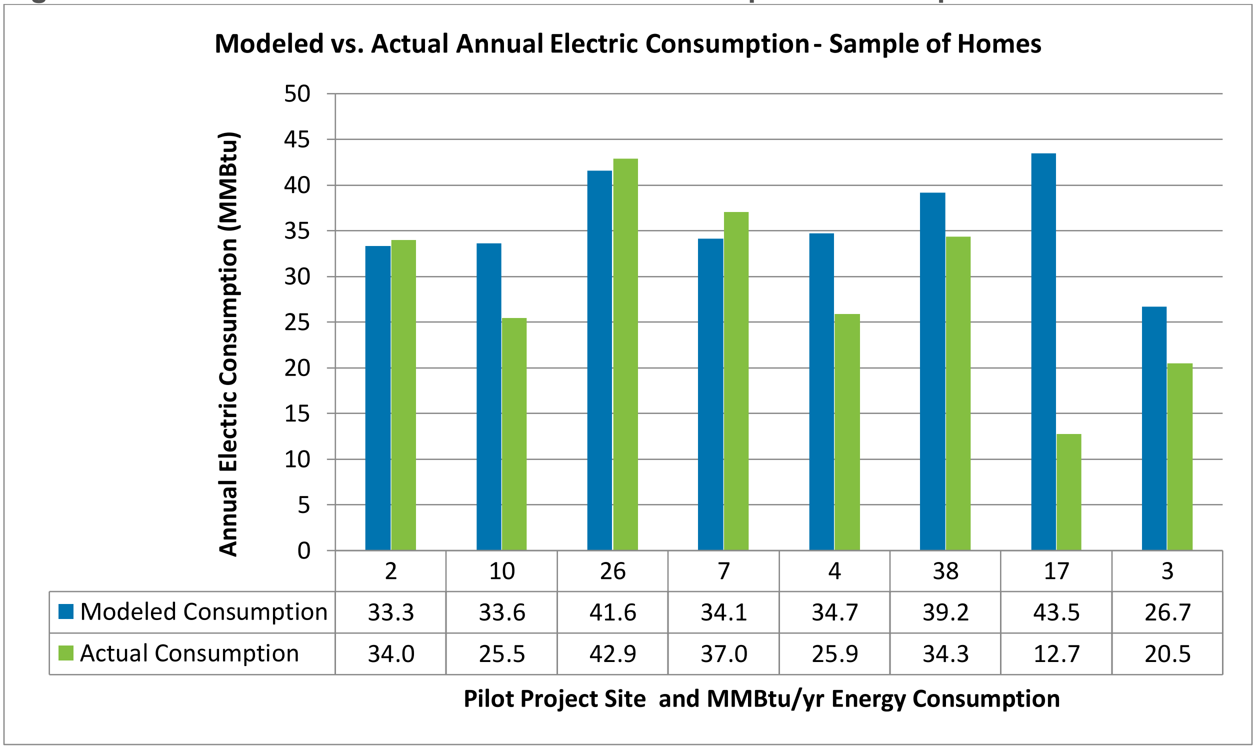
[11] Phase 2 Tracker, AXIS Data

Standard Protocol/Performance Path offering. The Lessons Learned section provides additional information.

Energy Modeling

CLEAResult completed energy modeling for Phase 2 homes in order to capture modeled savings results for comparison against billing data and metered consumption by NEEA. Phase 2 homes were modeled in NW REM/*Rate*™ (a Northwest variant of the REM/*Rate* software) per the methods prescribed under the NWESH program, and relied on participating builders to provide necessary information for modeling, such as: plans, equipment selection and performance curves, typical performance testing results, and any planned unique home characteristics. In order to assess general alignment of modeled to actual performance, CLEAResult compared modeled annual electric consumption against metered electric energy consumption for a subset of Phase 1 and 2 homes for which one year of complete metered data was available. See Figure 2 below for an example of analysis output.

Figure 2. Modeled vs. Actual Annual Electric Consumption for Sample of Homes



	2	10	26	7	4	38	17	3
Modeled Consumption	33.3	33.6	41.6	34.1	34.7	39.2	43.5	26.7
Actual Consumption	34.0	25.5	42.9	37.0	25.9	34.3	12.7	20.5

Submetering/Data Loggers

Phase 2 used the same submetering data loggers as were used in Phase 1. These were PowerWise loggers using the SiteSage analytics and reporting software platform. Several loggers were installed in the homes and performed detailed data collection on the following:[12]

- Room to room temperatures (°F) and relative humidity (%)
- Outdoor temperature (°F) and relative humidity (%)
- Electric circuit-level energy metering for domestic hot water, HVAC, and other key equipment
- Temperature (°F) and flow meters on domestic hot water equipment (gallons)
- Temperature (°F) and relative humidity (%) metered on HRV ports

CLEAResult collaborated with Washington State University (WSU) and NEEA to install loggers across all Phase 2 homes that agreed to participate in this aspect of the Pilot (two of the 28 Phase 2 homeowners declined data loggers). Participating homeowners and initiative staff were provided access to the SiteSage software to review and analyze the data. Goals of the submetering and detailed data collection in Phase 2 were to help inform efficacy of measures installed, identify nuanced interactions across measures, and ultimately to help develop additional guidelines for code advancement and Standard Protocol/Performance Path development.

In 2017, NEEA contracted with Ecotope to review and analyze data collected by the SiteSage data loggers. Ecotope reviewed data for sites across Phase 1 and Phase 2. Determining whether additional findings exist for the Phase 1 homes, other than those identified in the Phase 1 reports created by NEEA and CLEAResult, is an activity for further research. Figures 3, 4, and 5 are examples of the data analysis conducted by Ecotope. The Ecotope-provided analysis and notes offer more on its findings.[13, 14, 15]

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[12] Next Step Homes Pilot Projects Data Files List – PowerWise (Ecotope)
[13] Next Step Homes Notes (Ecotope)
[14] Merge NSH Summary Document – Ran on 2017-12-18 (Ecotope)
[15] Next Step Homes Pilot Home Results v3 2017-12-18 (Ecotope)

Figure 3. Example of Phase 2 Analysis

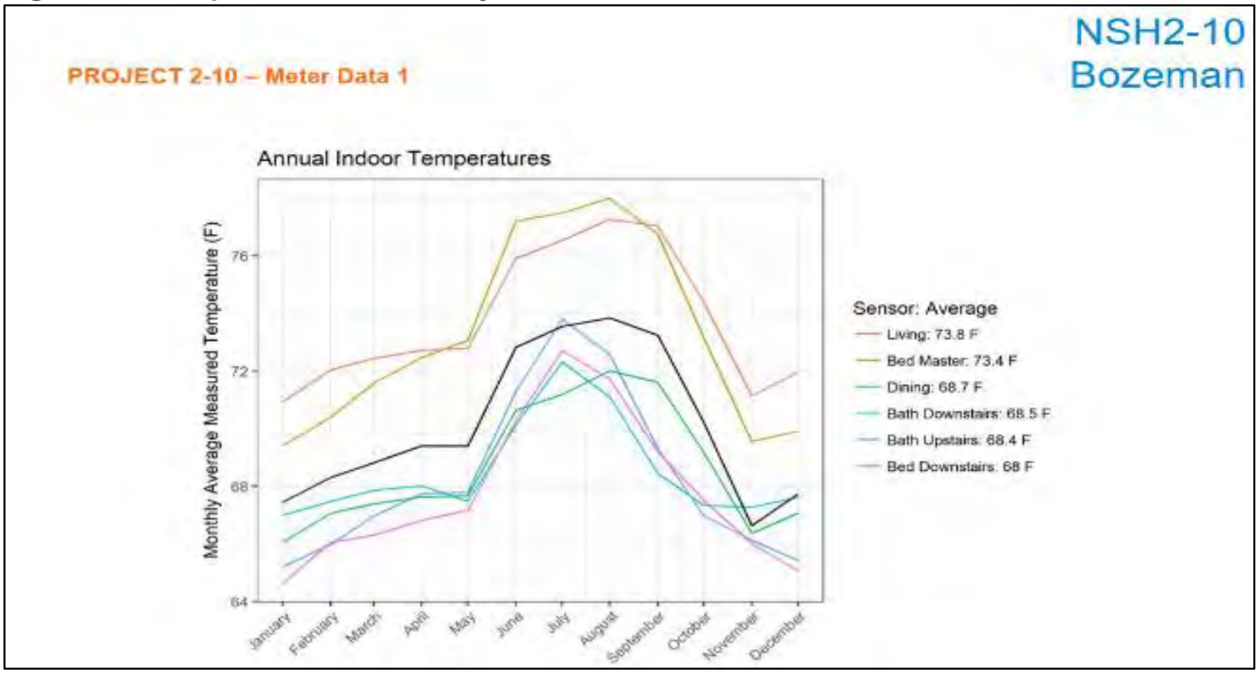


Figure 4. Example of Phase 2 Analysis

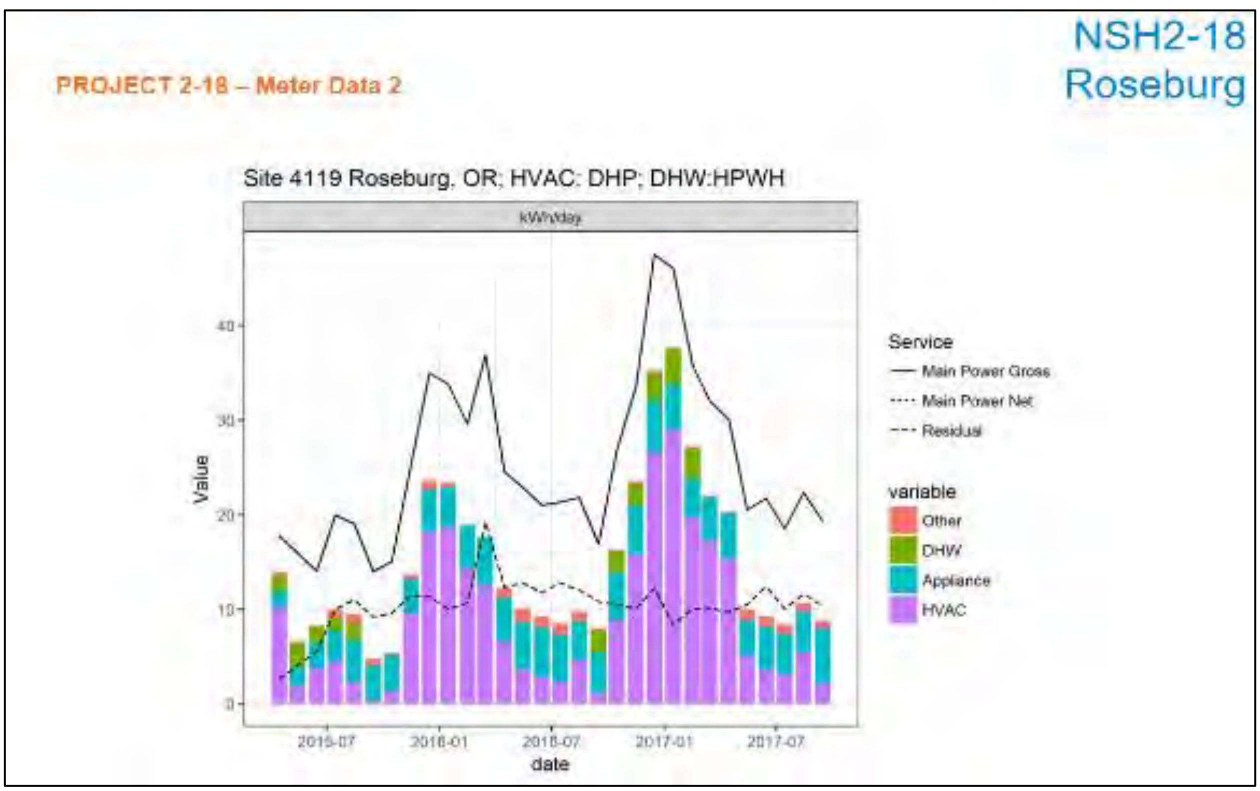
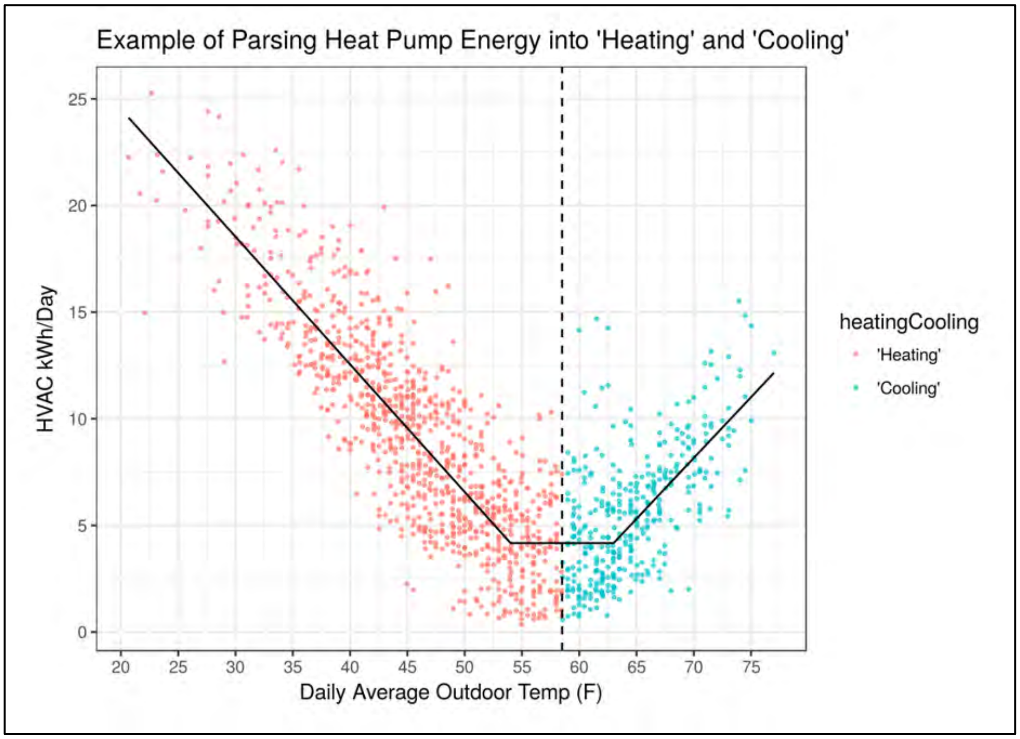


Figure 5. Example of Phase 2 Analysis



Builder Survey

The initiative gathered builder participant feedback from Phase 2 builders. While many of the builders participating in Phase 2 were familiar and experienced with above-code building practices and techniques, most still experienced some challenges meeting the Phase 2 specifications. Items listed below summarize the primary successes and challenges experienced by Phase 2 builders. Phase 3 did not include a builder participant survey.[16]

Many builders or their contractors experienced challenges with:

- HVAC and HRV ducting and design
- HRV technology
- Hot water plumbing design
- Hot water recirculation loop and drain water heat recovery systems
- Staggered stud exterior wall framing
- Double wall framing

[16] Phase 2 Builder Survey Responses

- Different air sealing techniques
- Additional exterior insulation
- Windows not fitting due to wall thickness (framing + added insulation)
- Appropriate space for mechanical equipment
- Communication and language barriers with trades
- Lack of training and knowledge from trades on advanced construction practices (e.g., framers, siders, drywallers, insulation installers, plumbers, foundation contractors)
- Weather
- Sourcing uncommon equipment and materials
- New technology not being UL listed (early HRVs)
- New technology failing (TACO pumps)

Some builders shared that additional communications with their contractors, staff, and the initiative technical support team would have helped them understand and implement these requirements. Many builders expressed that additional training to trades on advanced construction practices is needed in several parts of the region.

Those who sought additional support for troubleshooting a variety of issues greatly appreciated the technical consulting provided by the initiative and other market partners, such as WSU and equipment manufacturers (e.g., Mitsubishi, Panasonic, Zender). Given additional guidance and technical consulting, some builders shared that their perceptions of new technology or construction practices changed because they found them easier to implement than initially anticipated.

Many builders mentioned that their standard build timeline was not significantly extended to meet the Phase 2 spec; some said it took only a few extra days to a few weeks longer than their normal build schedule. Some builders were concerned with the added costs for the advanced equipment and construction practices.

Ratings Accuracy Study

The ratings accuracy study was conducted in 2015 as a supplemental project that reviewed whether modeled energy savings could be used as a common benchmark for all above-code homes. Leveraging findings from Phase 1, early lessons learned in Phase 2, and the in-progress NWESH transition to the National ENERGY STAR certification program, the primary objectives of this study were to 1) determine the variability of home energy raters to consistently estimate home energy usage with REM/*Rate*, and 2) to develop a set of criteria and guidelines for training and program requirements that would minimize Rater variability and improve overall Rater accuracy. Lessons learned supported the role of Raters in Phase 3, improved modeling practices, and informed the Standard Protocol/Performance Path modeling guidelines and file QA processes.

For the ratings accuracy study, NEEA commissioned eight Northwest Raters to field test and model the same 12 homes for cross comparison. Raters used the Northwest version of the REM/*Rate* energy modeling software. Each Rater was given the same set of drawings and information about the homes and asked to generate complete home energy ratings for each home.

The ratings accuracy study final report provides observations of field testing and data collection processes, file QA findings, and the modeled results in two ways: (1) as provided by Raters and (2) after simple QA on most impactful components. Figures 6 and 7 show how energy modeling guidelines and targeted QA bring greater consistency to home energy modeling practices and energy performance estimates. Initiative staff leveraged these findings in several training materials, and the findings were central to the Standard Protocol/Performance Path onboarding training and modeling guidelines provided by the initiative in 2017.[17, 18]

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[17] Ratings Accuracy Study final report
[18] Standard Protocol/Performance Path Onboarding Training

Figure 6. Energy Model File Results, Before and After Modifications

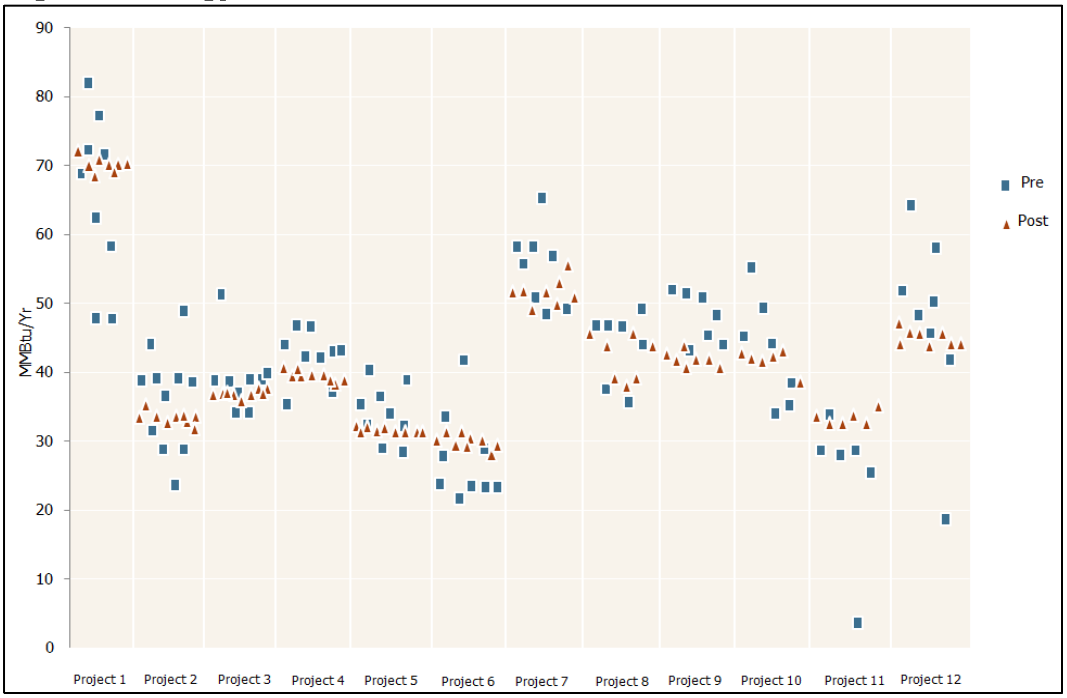
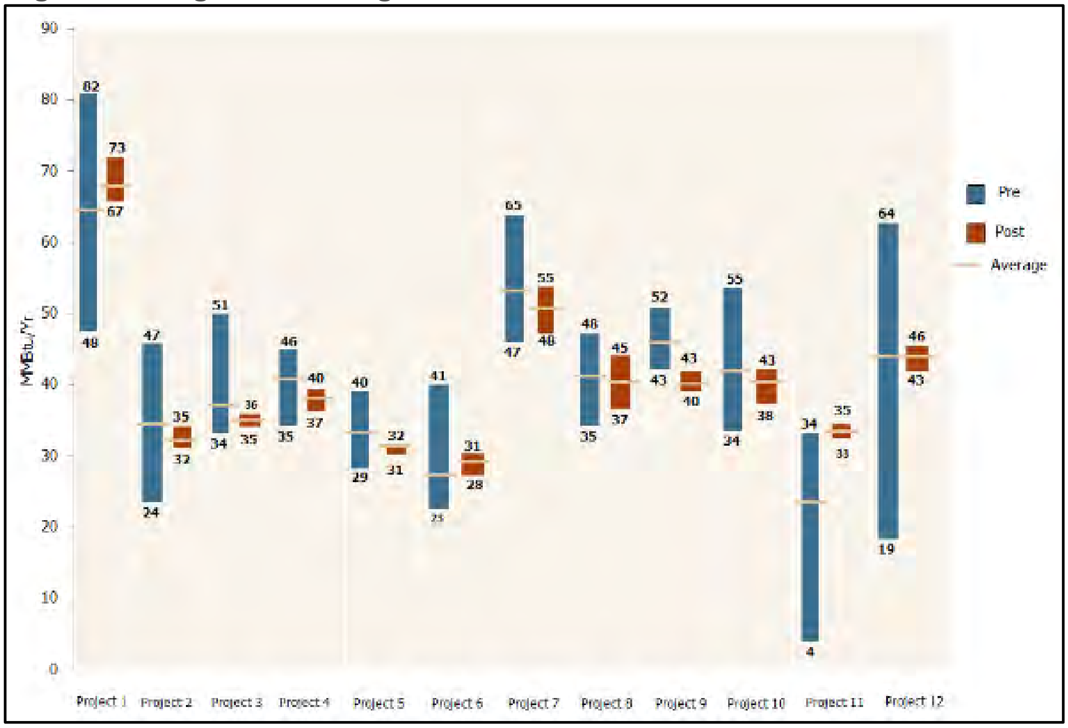


Figure 7. Range and Average Results, Pre and Post Modifications



Phase 3

Phase 3 objectives were to scale up participation, test and refine features for the Standard Protocol/Performance Path so that it could be scaled up for widespread use by utilities, and to further empower Raters to take on a larger role with builders through additional design consulting services and continued participation in above-code programs. Initiative staff infused lessons learned from Phase 2 and the ratings accuracy study into the Phase 3 approach and roll-out. The initiative developed two tiers of specifications, Minimum and Reach (Appendix F), to offer greater flexibility to builders, increase participation, and to align with other performance rating and certification programs gaining traction in the region. Initiative-funded incentives were not available in Phase 3. CLEAResult shifted to an oversight role for the Pilot and focused support efforts toward Raters, utilities, and continued development of the Standard Protocol/Performance Path.

Implementation activities completed by CLEAResult in Phase 3 included:[19]

- Targeted Rater outreach and recruitment
- Facilitation of builder and homeowner participation agreements
- Technical consulting and training
- Quality assurance
- Facilitation of data logger installations and retrieval
- Collection of participant feedback
- Home tour hosting
- Management and definition of AXIS development (described in the AXIS Database section)
- Completion of AXIS entry of Phase 1 and 2 homes

Recruitment and Participating Homes

In 2015, the initiative evaluated capacity across the region to identify underserved markets, markets where top-tier Raters and builders existed, as well as areas with sufficient new construction activity, certification program participation, and utility interest. After creating a Rater and Builder Engagement Plan, the initiative completed targeted outreach and selected 14

[19] Annual Reports by CLEAResult

Raters to participate based on their technical expertise, interest, regional coverage, and potential or active builder clients. After providing training and tools to these Raters, and creating value proposition flyers to use with builders, the initiative enrolled 79 homes into Phase 3 throughout 2015-2016. Financial incentives were not offered in Phase 3.

Technical Support

Technical support for Phase 3 shifted to supporting and empowering Raters as expert consultants to their builders. CLEAResult provided three Rater onboarding training sessions focused on Pre-Construction Support, Calculating Performance, and Commissioning. These trainings not only directly enhanced above-code construction to Pilot specification, they also filled gaps in RESNET's Standards 380 and 301 for Rater support and training. In particular, commissioning of HRVs and kitchen fan depressurization impacts are not addressed in Standard 380. After onboarding training, CLEAResult served as technical consultant/backup to Raters on the following:

- New equipment types
- Meeting Pilot specifications
- Modeling unique home configurations and advanced equipment
- What to look for in the field
- Commissioning support
- AXIS database entry

CLEAResult also leveraged and refined the use of the AXIS QA module to communicate and record file and field QA findings. The method and items of focus (Appendix H) defined in Phase 3 QA ultimately informed the foundations for Standard Protocol/Performance Path QA. The Lessons Learned section describes these activities in greater detail.

Energy Modeling

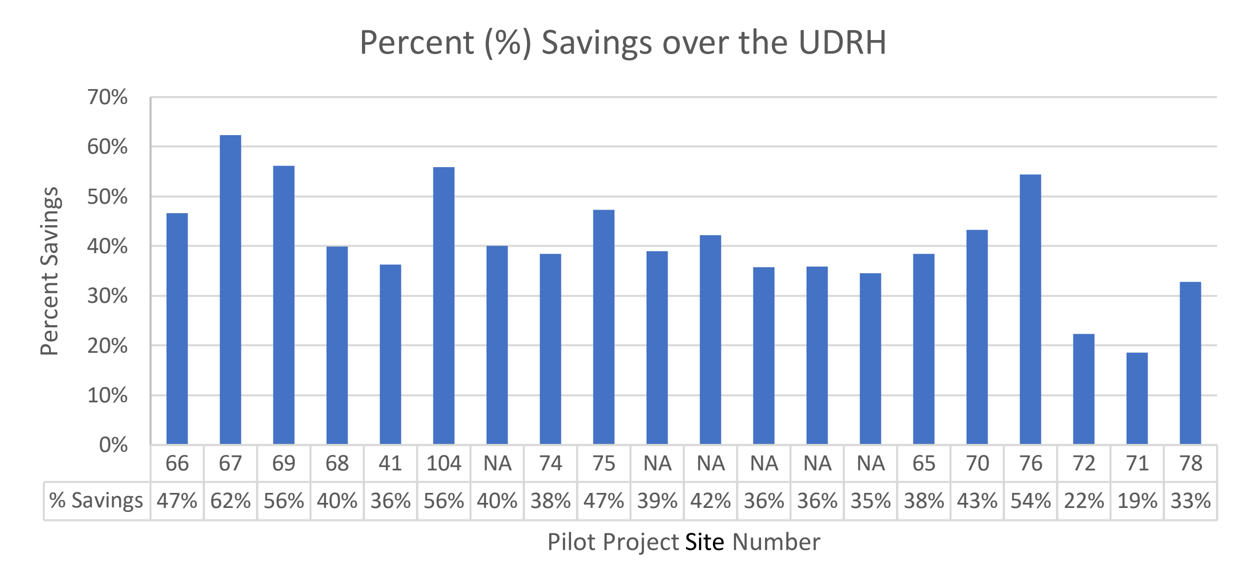
In support of the Standard Protocol/Performance Path and to promote greater confidence in modeled energy savings, the initiative completed additional analyses and revisions to the modeling guidelines, incorporating best practices discovered in earlier phases of the Pilot and the ratings accuracy study.[20] Raters participating in Phase 3 used NW REM/*Rate* and were trained on the updated modeling practices, which were also applied retroactively to Phase 2

[20] Phase III Modeling Guidelines

homes. These efforts served as a road test for the modeling guidelines and helped streamline QA protocols for the Standard Protocol/Performance Path.

The initiative analyzed a sample of 20 homes, checking modeled savings outputs and results against the User-Defined Reference Homes (UDRH). Figure 8 shows the as-built home's % improvement over the UDRH. Unfortunately, several of the projects did not complete their participation with the Pilot (indicated by NA in the project site number).

Figure 8. Percent Improvement over UDRH, Sample of Phase 3 Homes



Submetering/Data Loggers

The initiative streamlined the submetering and data logger strategy in Phase 3 to focus on elements to support and validate the Standard Protocol/Performance Path, and minimize cost and complexity for participating Raters, builders, and homeowners. Instead of implementing detailed equipment submetering, as in Phases 1 and 2, the initiative used HOBO loggers in Phase 3 to gather only temperature and relative humidity data. As sites completed construction and became occupied, the initiative configured and shipped an indoor and an outdoor data logger to each site for which the homeowner signed an agreement, for installation by an onsite point person. Fifty-four of the 79 homes received loggers; 25 homeowners either declined the loggers or did not return their homeowner agreements.

One logger was installed inside the main body of each home to gather indoor temperature and relative humidity. One logger was installed outside the home to gather outdoor temperature. For multiple participating homes in the same neighborhood/vicinity, only one outdoor logger was used across those homes. The initiative intended to use these data in conjunction with billing data to create a regression analysis for each site, then to compare the findings to modeled energy consumption results.

As sites completed the 14-month logging period, initiative staff retrieved loggers and extracted data. Logger retrieval began in 2017 and continued through early 2019. The logger-extracted data include:

- A folder for each property with the address name as the folder name
- A .hobo file (accessible by using HOBOware to open this file and use its functions)
- A .xlsx file, which was generated using exported data from HOBOware along with a plot of the data for quick visual reference. This file shows the raw data collected and allows for further analysis using Excel instead of HOBOware.
- A .txt file, created using the "export details" function from within HOBOware. This file contains various statistical information from the data along with important dates, the data logger serial number, and other useful information.[21]

The loggers and data downloads for 38 of the Phase 3 sites were packaged and returned to NEEA at the end of 2019 for additional analysis.[22, 23] The remaining homes in Phase 3 either did not initially receive loggers, or the homeowners did not return the loggers. Figure 9 shows an example of the HOBO data, including the temperature (black) and relative humidity (blue) captured results. The Future Research section describes opportunities for additional analysis.

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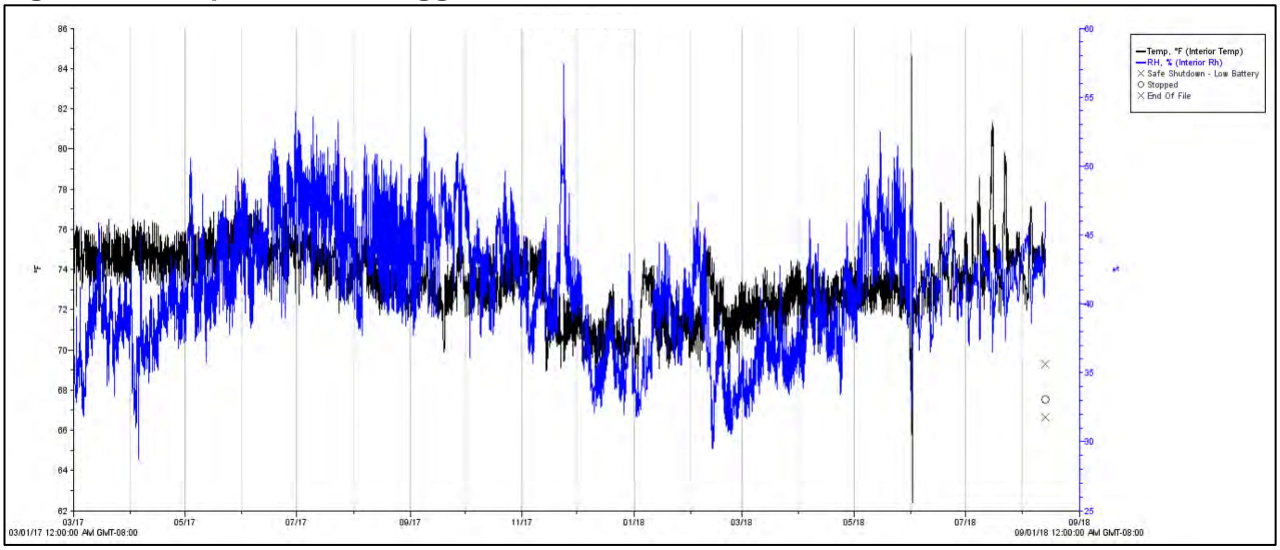
[21] Explanation of downloaded data and loggers for NSH Phase III
[22] Annual Reports by CLEAResult
[23] Phase III Metering Equipment Inventory

Figure 9. Example of Hobo Logger Data



AXIS Database

In 2013, NEEA began using the AXIS database, developed by Pivotal Energy Solutions, to capture and record project data from NWESH Program. As the Program evolved and NWESH came to a close, NEEA expanded its use of the AXIS database to capture other voluntary certification program home data (e.g., National Green Building Standard and National ENERGY STAR). The purpose of this expanded use of the AXIS database was to support other utility incentive programs and generate market evidence of increasing energy efficiency in new residential homes. This evidence supports both NEEA's market transformation program evaluation and proposals for increase energy codes.

The increased number of homes and Rater participation in Phase 3 led initiative staff to create a new Pilot-specific AXIS database program. As Raters submitted data and the initiative began using the new AXIS QA module, the CLEAResult team retroactively entered data for the Phase 1 and 2 homes to ensure all Pilot homes and respective modeling files and other data were centrally located and more accessible to NEEA and utilities.

The initiative staff also created a new program in AXIS, the Standard Protocol/Performance Path Program, which incorporated advanced savings calculations, additional data validations, and updated features within a QA module.

Energy Rating Index Variability Study

In 2017, NEEA and CLEAResult completed an Energy Ratings Index (ERI) Variability Study that examined whether using a RESNET Home Energy Rating System (HERS) Index Score constituted a viable method for energy code compliance.

At the time, the RESNET home energy rating community was becoming increasingly involved in residential energy code compliance. The national ENERGY STAR Certified Homes program (versions 3 and 3.1) began requiring verification by a RESNET HERS Rater, and the 2015 International Energy Conservation Code (2015 IECC) included two pathways whereby HERS Raters can determine whether a home is compliant with the energy code: The Energy Rating Index (ERI) path and the Performance Path. Given the increased involvement of the Rater community in energy code compliance and given that a home's compliance with the energy code could now be determined by the home's HERS Index Score, the initiative sought to verify that HERS Index Scores are consistent and replicable.[24]

The ERI Variability Report provided an understanding of the level of variation within a set of RESNET HERS assessments. The report highlighted the level of variation in HERS Index Scores and other pertinent metrics for two new, unoccupied homes in the Pacific Northwest: one in Portland, Oregon, and the other in Lake Stevens, Washington. For each home, initiative staff asked five local Raters to perform an independent assessment of the home just prior to occupancy, create an energy model in REM/*Rate*, and report the projected HERS Index Score and pertinent findings/recommendations for the home.

Data collected in this study demonstrated the level of variation in reported performance across multiple Raters on the same home. This information was intended to provide the Department of Energy (DOE) a more detailed understanding of the reliability of the HERS Index Score as a code compliance tool and to guide future training, quality oversight, and code development efforts.[25] Figures 10 and 11 are examples of findings provided in the report.

At the time of the report, the ERI and HERS were essentially the same. Beginning in 2018, the ERI and HERS began to diverge due to the means for calculating ventilation, and more importantly, which version of Standard 301 is referenced. ERI still references Standard 301-

[24] 2017 ERI Variability Study Report
[25] 2017 ERI Variability Study Report

2014, while HERS references later versions of the ANSI-approved standard. Lessons learned from the ERI Variability Report may no longer reflect current impacts of using the ERI path for code compliance.

Figure 10. Example of ERI Variability Findings

Overview - Portland, OR site

	HERS Score	Software Version	Cost of Rating	Weather Location	Conditioned Area	Volume
Rater 1	83	15.3	$660	Portland, OR	1,405	12,767
Rater 2	82	15.3	$300	Portland, OR	1,422	13,290
Rater 3	86	15.3	$300	Portland, OR	1,405	11,942
Rater 4	86	15.3	$325	Portland, OR	1,405	12,786
Rater 5	88	15.3	$550	Portland, OR	1,443	14,144

Figure 11. Example of ERI Variability Findings

Estimated Annual Energy - Lake Stevens, WA site

	HERS Score	EUI (kBtu/ft^2)	Total Cons (MMbtu)	Heating Cons (kWh)	Heating Cons (Therms)	DHW Cons (Therms)	L&A Cons (kWh)	L&A Cons (Therms)
Rater 6	76	18.83	55.01	353.5	387.65	128.73	11139.6	0.00
Rater 7	71	28.20	82.37	966.9	589.98	130.44	6962.9	80.09
Rater 8	79	28.47	83.17	1111.8	514.18	257.06	7183.5	36.10
Rater 9	75	23.24	69.80	978.2	489.81	142.71	9047.1	36.10
Rater 10	74	21.60	64.57	649.9	491.63	125.72	9041.7	0.00

Training Materials and Resources

Significant outcomes of the Pilot were the development of the Standard Protocol/Performance Path and several types of technical training and resources leveraging lessons learned to promote best practices for advanced performance homes.[26] As the Pilot progressed, the initiative incorporated institutional knowledge gained through the participating homes and adjusted its training strategy to include:

- Collaborating with additional market partners and participating in market training opportunities as they arose. This allowed the initiative to meet partners where they were, improve attendance, and reduce resources needed from the initiative.
- Adopting a more holistic approach with ties across training, technical tools, Pilot home tours, Home Efficiency Forum (HEF) and direct consulting to Providers, Raters, builders, and manufacturers.
- Encouraging and partnering with other organizations (including national training institutes, Home Certification Programs, manufacturers, and Providers) to co-brand and promote initiative-created technical materials.

The initiative team disseminated lessons learned in the Pilot through multiple paths; the three most prominent paths were (1) individual training events (e.g., webinars and in-person training), (2) Rater, builder, and contractor QA/QC discussions, and (3) the annual Home Efficiency Forum (HEF) event. NEEA hosted the annual HEF event (previously known as Verifier/Rater Boot Camp) from 2012 through 2019 as a two-day conference that distilled technical design, product installation, and energy modeling lessons learned into subject matter-specific training sessions delivered to audiences of Raters, builders, designers, utilities, and product manufacturers. A secondary goal of the annual conference was to provide a space for exchanging ideas and best practices through peer-to-peer sharing and networking opportunities designed to enhance the community of excellence that had emerged in the new residential construction market.

In 2016, the initiative shifted its Rater, builder, and contractor training efforts by encouraging and recruiting more market partners to deliver training at HEF and other events. Several different speakers began attending the HEF event to showcase their findings and perspectives

[26] Annual Reports by CLEAResult, Training Trackers by CLEAResult

within the new homes market. The initiative also attempted to transfer several training sessions to NEEA's online Learning Management System (LMS) (with Advanced Energy) and began offering more builder-centric training (with Earth Advantage). The initiative continued to encourage the market to use initiative-created materials through "co-branding" (partner puts their logo on the materials) and increased promotion of several other market-led training events with regional organizations such as Sustainable Connections and Built Green, as well as national events such as the RESNET conference.[27]

The following sections highlight, by year of introduction, new trainings and resources that were based on or included lessons learned from the Pilot. Many of the practice areas addressed in these trainings remained consistent, while training content evolved as additional knowledge was gained via Pilot implementation. Appendix I provides a full list of the training sessions and materials leveraging Pilot lessons learned, which were delivered by CLEAResult at HEF and through other venues.[28]

2014

Starting in Phase 1, the initiative developed five new trainings that were offered at the 2014 Boot Camp event (subsequently rebranded as "Home Efficiency Forum"), listed below. In addition to the technical training, the initiative also supported builders and contractors with technical detail sheets for quick reference in the field. The initiative also created homeowner-facing materials such as flyers and a video commercial in partnership with Puget Sound Energy, then created a non-utility-branded version of the commercial for use across the region.

- HRV/ERV Design and Commissioning
- HVAC Design for Low-Load Homes
- Thermal Enclosure: Efficient Walls
- Thermal Enclosure: Airtightness
- High Efficiency Water Heating and Plumbing

2015–2016

Moving into Phase 2, the initiative gathered feedback from builders, Raters, and other market actors on common challenges experienced with utilizing advanced practices and emerging

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[27] Initiative Annual Reports, CLEAResult
[28] Training and Home Efficiency Forum Trackers, CLEAResult

technologies promulgated in the Pilot. For example, builders consistently encountered challenges or indicated steeper learning curves with items such as: HRV distribution system design and commissioning, advanced wall construction detailing, hot water demand recirculation and plumbing layout design, sequencing and coordinating trades, and adapting HVAC design and system selection for the low loads of a Next Step Home.

Based on this feedback and the experience of the Pilot team in interacting with builders, Raters, and trades, the initiative adapted training content over time and also developed three new technical posters to address key design and installation areas. These posters were printed on weather-resistant materials and distributed to partners throughout the region. Electronic versions of the posters were picked up and promoted by nationally-recognized training institutions, such as Construction Instruction. The posters released in 2015 were:

- HRV System Best Practices
- Mini-Split Technology in New Construction
- Thermal Enclosure: Efficient Walls and Airtightness

Moving into Phase 3, the initiative developed additional Rater trainings, created another technical poster, and continued to share best practices and insights from the Pilot in a variety of training avenues such as sessions at the NW Passive House conference, ACI Northwest conference, Built Green conference, Home Performance conference, Energy Trust of Oregon Trade Ally events, utility-sponsored local sessions, online webinars, and at the initiative's annual Home Energy Forum. The initiative continued promoting co-branding technical resources and supported other market partner training that included lessons learned from the Pilot. Technical training for Phase 3 included:

- Rater pre-construction support
- Rater calculating performance
- Rater commissioning
- Poster: Thermal Enclosure Best Practices

Although Raters greatly increased their knowledge and expertise over the years of the Pilot, they often asked the initiative to consult on advanced systems such as HRV selection and installation, DHP system design, and drain waste heat recovery. Some possibilities for the ongoing technical support provided to Raters during Phase 3:

- The Raters were not being compensated by NEEA for the extra time and work needed to participate in Phase 3
- They wanted quick answers on unfamiliar equipment
- They trusted the free technical advice provided by the initiative

The Raters also sought specific modeling guidance on obscure equipment or building assemblies that were not included in the modeling guidelines, to ensure they were meeting the intent of the stringent modeling guidelines. Over time, and in partnership with the Energy Trust of Oregon's EPS program, the initiative developed additional modeling resources such as the Equipment Modeling Flow Chart and an Equipment Selection for Modern Times training.

2017–2019

With the launch of Standard Protocol/Performance Path in 2017, the Rater and utility onboarding training included several lessons and findings informed by the Pilot and the ratings accuracy study. Raters were required to attend or view this onboarding training before participating in utility programs leveraging the Standard Protocol/Performance Path framework.

In 2018 and 2019, the initiative continued developing, promoting, and partnering with other organizations to deliver advanced training informed by lessons learned from the Pilot and early Standard Protocol/Performance Path projects. Most of the 2019 HEF training sessions were delivered by market partners.

Lessons Learned

Technical Lessons for Home Construction

The following sections highlight the technical lessons learned throughout the Pilot on products and home construction design techniques. These findings were identified by CLEAResult during home construction in Phase 2, during which CLEAResult provided builders with extensive technical consulting.[29, 30, 31, 32] Combining these findings with Ecotope's Phase 2 data logger analysis and the yet-to-be completed Phase 3 data analysis is an activity for future research and may yield additional valuable lessons learned.

HVAC

The HVAC design guidelines provided to Phase 2 and 3 participants are described in Appendix J. The HRV and other ventilation design guidelines are described in Appendix E. Phase 2 homes informing these findings were projects 14, 15, 16, 17, 19, 20, 21, 25, 28, 31, 32, 33, 34, 35, 36, 37, 39, and 40.

- HVAC pre-construction design and coordination may be the most important design phase topic of all the mechanical systems encountered A poorly-designed system or a system that did not follow any form of preconstruction design often resulted in HVAC systems that did not perform correctly, had poor flow rates, or was oversized.
- The interconnectivity of HVAC systems with other systems is important to understand and emphasize with builders and contractors. A poorly-performing HVAC system can and did throw off other systems within some of the homes that were part of Phase 2.
- Many HRVs installed in Pilot homes either did not meet the recovery or fan efficacy requirements or were not installed according to pilot specifications. (However, the impacted sites were not excluded from the Pilot because of this.) Continued training efforts are needed to support ventilation understanding and proper installation.
- High-performance products such as heat recovery ventilators (HRVs) present the biggest challenges for achieving predicted performance. While the program developed a variety of technical tools and training to assist partners with best practices, further

[29] CLEAResult internal notes
[30] Phase 2 Tracker
[31] Design Guidelines
[32] Annual Reports by CLEAResult

engagement with manufacturers and distributors will be needed to offer product-specific guidance through market-led training. In-person, in the field, and hands-on trainings can all serve as important and effective ways to help the market understand the various types of ventilation systems and how to properly install them into different home types.

- In addition to the complexity of installation for some systems, the homeowner user experience can also present challenges without a proper tutorial from a knowledgeable builder or contractor. Educating home buyers on how to use and maintain these systems is just as important as educating contractors on proper installation techniques. Improper use, or lack of use, can potentially lead to systems not working correctly, callbacks, or failure down the line. (WSU has since proposed, and provided for voluntary use, updated Energy Code documentation stickers for homes in Washington that better identify commissioning results and recommend homeowner education).

Additionally, several sites in Phases 2 and 3 were part of a Sanden equipment pilot that was coordinated with NEEA, Bonneville Power Administration, and WSU. Refer to the Sanden pilot reports for technical findings and outcomes on Sanden equipment.

Water

The domestic hot water and other water design guidelines provided to Pilot Phase 2 and 3 participants are in Appendix L. Phase 2 homes informing these findings were projects 13, 14, 15, 18, 19, 20, 21, 28, 32, and 34.

- Water resource accessibility, cost, and management have become important aspects of overall building design in the region. In general, the potential for water cost savings through water efficiency measures can be quite high. In addition to the importance of focusing on efficiency of the water heating system, water management is particularly vital in the Pacific Northwest. Homes with well-thought-out and effective water management systems in place will not only function better and have fewer issues with mold and construction degradation, they will have increased longevity compared to those that do not.
- Some newer technologies entering the market are not only challenging to sell to customers; they are also challenging in terms of educating code officials on why they meet certain code requirements. Recirculation pumps seemed to present a particular challenge for some builders, homeowners, and contractors. Many issues with recirculation pumps in the field led to homeowner dissatisfaction. Training on these

technologies and their controls may be helpful for plumbers and builders alike and may result in systems that work more effectively.

Shell/Envelope

The initiative did not provide specific shell/envelope design guidelines and instead referred Raters and builders to the thermal enclosure technical posters developed by CLEAResult for the initiative (see the Training Materials and Resources section). Builders were encouraged to choose their own approaches to meet the specific shell/envelope requirements identified within the Pilot specification. Phase 2 homes informing these findings were projects 15, 17, 32, 34, 36, 37, 38, and 39.

- Countless ways exist to address shell and envelope construction and insulation. Pilot homes demonstrated success using several insulation and air sealing techniques. Well-trained insulators with attention to detail during insulation and air sealing led to tight homes with low blower door testing results. Some challenges that occurred were due to code requirements around fire suppression and use of new materials such as phase change materials on low load homes.

Other Technical Findings

Feedback from Phases 1 and 2 repeatedly pointed to the need for pre-construction meetings, pre-drywall inspections, and frequent communication among all parties involved to ensure the home was progressing toward meeting Pilot goals. Pre-construction planning and coordination is essential as high-performance systems in high-performance homes are complicated and interconnected. As a result of these findings, the initiative trained and required Raters to host an integrated design charrette with the builder and key trades before construction began. The training was provided in the Rater Pre-Construction Support webinar as part of the Phase 3 Rater onboarding series (See the Training Materials and Resources section). The initiative also provided guidelines for this activity, which are listed in Appendix M.

Other miscellaneous technical findings from Phase 2 homes are summarized below. Phase 2 homes informing these findings were projects 14, 15, 20, 22, 23, 24, 25, 26, 27, and 30.

- Using fly ash in concrete mix can corrode plumbing parts.
- Additional heat sources in bathrooms should be considered (i.e., heated towel racks, heated toilet seats, heated floors).
- Additional energy-intensive equipment must be considered (i.e., hot tubs, saunas, patio fireplace, data server rooms, EV charging).

Submetering/Data Loggers

For this report, lessons learned with the submetering/data loggers are limited to CLEAResult's involvement with deploying loggers to homes and assisting with some analysis activities.[33]

In all phases of the Pilot, some homeowners did not agree to installation of the data loggers within their homes; the homeowner either indicated their stance on the homeowner agreement or didn't return the agreement. This points to a possible need for improved homeowner and builder engagement to ensure their understanding of the purpose and goals of Pilot activities.

CLEAResult, WSU, and NEEA staff were responsible for installing the loggers in Phases 1 and 2 given the complicated submetering plans and the need for several SiteSage sensors on equipment and individual electrical circuits. In Phase 3, the initiative relied on Raters and builders to install the simpler HOBO loggers, which yielded mixed results. The HOBO loggers had to be pre-programmed with a start date and in several instances, the loggers were not installed in a timely manner. At times, the initiative needed to have repeated check-ins with Raters and builders to encourage logger installations.

Current Initiative staff do not know whether all SiteSage loggers from Phases 1 and 2 were decommissioned and returned; this is an item for further research. The Phase 3 HOBO loggers were retrieved, with mixed results. The loggers were installed for nearly two years and some homes became unresponsive. The initiative mailed letters to the homeowners explaining what the loggers looked like and where they were likely installed (one indoors, one outdoors), and included a pre-paid envelope for the homeowners to mail the loggers back, yet several homes still did not return the loggers. The initiative attempted to make additional contact with the homeowners via information provided on their agreement, yet some contact information had

[33] Annual Reports, CLEAResult

changed, and some homes had changed ownership. This points to the possible need for additional and ongoing homeowner engagement throughout the entire Pilot period.

Regarding CLEAResult's involvement in data analysis activities, the team identified a few challenges, as described below.

With the SiteSage loggers:

- Builders and homeowners made several requests to the initiative to provide real-time analysis on HVAC system design and performance, water heater performance, drain waste recovery units, and solar thermal systems. The builders and/or homeowners either did not have access to the SiteSage platform or they weren't able to identify meaningful results. Fulfilling these requests often involved analyzing significant amounts of minute-level data from several Pilot sites with similar characteristics to provide accurate and meaningful results. This points to the possibility of too much data precluding real-time analysis.
- At times, the loggers would fail or experience software licensing issues, which CLEAResult actively notified NEEA and WSU to troubleshoot.

With the HOBO loggers:

- Initiative staff could not tell whether the logger actually recorded data until it was retrieved, batteries replaced (when needed), and was plugged into the HOBOware software to download.
- Several loggers had dead batteries upon retrieval.
- These loggers only recorded temperature and relative humidity. Identifying whether the homes sustained relatively stable indoor temperatures, regardless of outdoor temperatures, could be a key potential takeaway. Additionally, comparing temperatures and relative humidity against the home's annual energy use could help determine weather-related impacts and whether the home's building practices actually resulted in energy savings. However, without pairing to the home's actual energy consumption data (utility data), there may be limited value to using these data.

Overall, the findings around deploying and retrieving data loggers point to the need for ongoing and continued engagement touchpoints with all Pilot participants to ensure understanding and successful participation. The lessons learned from logger data analysis activities within this report are limited as CLEAResult had limited involvement in this area of work.

Energy Modeling

During the Pilot, the use of residential energy modeling for program certification was a relatively new activity for the Northwest. Historically, Both the NWESH and Energy Trust of Oregon EPS certifications, savings estimates, and utility incentives were based on deemed savings values and prescriptive building specifications. New "performance" options using energy modeling software (e.g., REM/*Rate*) to generate savings estimates and determine compliance were introduced to the region around the same time as the launch of the Pilot in 2013.

The ratings accuracy study completed in 2015 shed light on the inconsistencies in rating and energy modeling practices throughout the region and highlighted the need for significant modeling guidelines and targeted QA to bring greater consistency to home energy modeling and rating.[34] However, even with detailed modeling guidelines, some Raters still needed additional assistance following or interpreting the guidelines to build an accurate energy model of a home (see the following Quality Assurance section).

The subsequent ERI Variability study completed in 2017 found significant variance in the characterization of home features, as well as resulting energy model outputs and identified disharmony among HERS Index Scores, ERI, and other energy metrics. Energy model outputs for the Lake Stevens home exhibited as much as 51% variance in annual energy consumption and energy use intensity (EUI) with only an 11% corresponding change in the HERS Index Score. Additionally, Raters' field inspection and testing protocols reflected a wide range of rigor, awareness, and prioritization of home features and performance testing protocols. Raters' processes, data collection, and energy modeling methods seemed to be heavily influenced by the prevalence of above-code certification and utility programs in their respective markets. The additional quality assurance rigor these certification and utility programs provide could contribute to greater consistency among Raters with the application of simplified and standardized data collection methods. While additional quality assurance on energy model inputs can drive better modeling accuracy, variances in field data collection methods should be addressed through training and field QA.[35] These findings also led to enhancements and alterations of QA practices for the Standard Protocol/Performance Path.

Beyond the Pilot and study findings, residential home energy modeling continues to evolve in the market. Tools such as REM/*Rate*—although it is the oldest and most prevalent tool used for home energy modeling and ratings—can be challenging for utility programs to align with due to

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[34] Ratings Accuracy Study

[35] ERI Variability Study

unknowns in calculation methods, impacts from the variety of data inputs, and lack of awareness and coordination with software development updates. To reduce variability of results, NEEA and Energy Trust of Oregon have required Raters to use specific versions of REM/*Rate*, User-Defined Reference Homes (UDRHs), and modeling guidelines.

During Standard Protocol/Performance Path development, the initiative team intended to use modeled energy results to capture all utility-claimable savings. However, given the depth of market knowledge in many of the energy measures defined by the Regional Technical Forum (RTF), the RTF chose to use only the modeled heating and cooling savings and UDRH whole-home consumption values produced by REM/*Rate* in addition to RTF-approved deemed savings values for appliances, water heating, and lighting. NEEA worked with the RTF to add a few additional measures, such as Smart Thermostats.

Data collected from the Pilot and early submittals in the Standard Protocol/Performance Path were intended to inform the RTF's review of the standard protocol. In 2020, data for roughly 3,000 homes (many of which were Energy Trust of Oregon EPS participating homes) served as the basis for an RTF review, which resulted in (1) the acceptance of REM/*Rate* modeled results for heating and cooling savings and (2) updating the deemed savings for appliances, lighting, and water heating. However, the RTF concluded that the homes within the dataset were either too similar in design or the data were too inconclusive to generate a clear evaluation of the full REM/*Rate* software tool and modeled results. The RTF decided to postpone adjustment and additional review of the Standard Protocol/Performance Path until 2021.

Quality Assurance

During Phase 2, the initiative provided extensive technical support to builders and visited sites multiple times to provide on-site education at various stages of the construction timeline. The initiative completed the REM/*Rate* energy modeling and was also responsible for final commissioning and testing. Initiative staff created no formal file and field QA plan for Phase 2.

The activities and learnings from Phase 2 and the ratings accuracy study influenced much of the Phase 3 QA plan, focusing on Raters who were responsible for data entry, energy models, and working with builders to remediate issues. Phase 3 QA activities revealed several lessons learned with Raters. Even with onboarding training, detailed modeling guidelines, and the availability of one-on-one consulting with initiative staff, Raters often overlooked specific modeling details, did not provide field data, had errors in AXIS entry, did not assist with homeowner agreements, and in some cases, did not ensure projects met minimum Pilot specifications. Additionally, some Phase 3 Raters became unresponsive, while others indicated that the additional Pilot requirements were well beyond their normal scope of work with builders and home certification programs.

Phase 3 asked for preliminary and final file QA on all projects and used the AXIS QA module. The Phase 3 File QA Checklist is in Appendix H. While AXIS proved to be an effective tool for communicating corrections needed and for returning files, the initiative had to provide additional AXIS training to several Raters. Raters also needed additional training on REM/*Rate* and the use of UDRHs, as these types of reference homes differ from how many of the home certification programs use energy modeling software.

Raters often did not use the initiative-provided field data collection form, which they considered yet another document to fill out and submit on top of their “normal” scope of work with builders. Raters and Home Certification Programs often have their own field collection tools and methods. To ease the burden, the initiative allowed Raters to submit field data in whatever format worked best for the Rater. However, Raters still found submitting field verification data to be a challenge.[36]

The initiative evolved File and Field QA methods over the Pilot phases. The lessons learned and findings of the ratings accuracy study, the ERI Variability study, and the Phase 2 and Phase 3 QA activities informed initial QA methods for the Standard Protocol/Performance Path. QA requirements for the Standard Protocol/Performance Path prioritized the key components and targeted data reviews, rather than specific formatting or exactness of values. Only a few key data points were checked for matching values across the REM/*Rate* files, AXIS database fields, and any field inspection documents. If the homes met minimum specifications, were modeled according to the modeling guidelines, and yielded no glaring concerns, they were passed through QA.[37]

Overall, a key lesson learned through QA activities by the initiative and in collaboration with the Energy Trust of Oregon EPS program points to the fact that QA provided in other market above-code programs such as RESNET HERS, ENERGY STAR, and Built Green are not sufficient for utility incentive programs in this region. Even though homes benefit from participating in above-code programs, they fall short in QA protocols. The initiative team recently identified that the QA protocols defined by the initiative and in collaboration with other regional stakeholders are now influencing local RESNET providers and programs such as Built Green to enhance their QA

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[36] Annual Reports by CLEAResult

[37] Phase 3 QA Checklist, Annual Reports by CLEAResult

activities (e.g., Built Green's 2021 checklist now gives additional credit for participating in a utility or other program that employs quality control on 5% or more of the submitted projects.

AXIS Database

The AXIS Database became part of the NEEA effort in 2013 and was primarily used for the NWESH program. Expanded use of AXIS for the Pilot began in 2015 with Phase 3. The use of AXIS for the Standard Protocol/Performance Path began in 2017.

The NWESH program provided Raters and builders specific and required checklists for use in the field, whereas the Pilot did not. Many other home certification programs in which Raters and builders participate have their own checklists and data requirements; therefore, the initiative tried to design the Pilot's AXIS program with minimal data entry requirements in order to be flexible and coexist with the variety of field data collection methods and checklists. Yet, even with minimal data entry, several Phase 3 Raters held negative opinions toward the use of AXIS because it was yet another software requirement on top of their normal services and participation with builders. In addition to AXIS training webinars, the teams provided several additional one-on-one training opportunities to Raters. In some cases, the CLEAResult team had to complete the data entry on behalf of the Rater because the Rater was unable or unwilling to finish the AXIS entry.[38]

Although discussions of Standard Protocol/Performance Path AXIS developments are beyond the scope of this report, a brief summary and key lessons learned regarding the AXIS database follows.

As the initiative began coordinating with Bonneville Power Administration while awaiting the RTF's approval of Standard Protocol, the teams were prepping development activities for AXIS. However, the savings calculations and methods approved by the RTF in late 2016 were significantly different from those for which the teams were planning (see the Energy Modeling Lessons Learned section).

Upon RTF approval of Standard Protocol, NEEA began the following activities: (1) coordinating with Snohomish PUD as the first utility interested in launching an updated incentive program using the new methods, (2) working with the RTF to approve a few additional measures for savings, and (3) coordinating with Bonneville Power Administration on its new Performance Path offering. While these activities were occurring, the CLEAResult and Pivotal Energy

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[38] Annual Reports by CLEAResult

Solutions teams quickly pivoted to redefine, develop, test, and launch the new Standard Protocol/Performance Path AXIS database program by late April 2017, in time for Snohomish's PUD program launch.

Rater and builder participation in Snohomish's new program were initially low. It was not until the October 2017 launch of Bonneville Power Administration's Performance Path offering (leveraging Standard Protocol) and Clark Public Utilities' new incentive program that the initiative began seeing homes come through, providing real-world results of the complex AXIS program and Standard Protocol/Performance Path savings calculator developments. Unfortunately, home results were not calculating correctly, which led to NEEA and the initiative shutting down the AXIS program, completing several rounds of calculator updates and testing, regaining trust with utilities and key market partners, then relaunching the program out to the market.[39]

The most valuable lessons learned from AXIS development for Standard Protocol/Performance Path are that compressed development timelines are challenging and complex energy savings calculators can be difficult to translate into software solutions.

Participant Recruitment

During all phases of the Pilot, participant recruitment efforts, either by CLEAResult or by Raters, were most effective with builders already familiar with and including advanced practices and technologies in their homes, as opposed to builders who were new to above-code construction.

In Phase 2, builder participation often hinged on the financial incentive offsetting the incremental costs of the extra equipment or construction practices, which ultimately limited the level of advanced measures in some projects. For other builders, having access to the robust equipment, energy monitoring data, and extra technical support was enough to warrant participation.

In Phase 3, which offered limited monitoring and no financial incentives, several builders and Raters ultimately chose not to participate. The initiative determined that the lack of incentives, an above-average-priced housing market, and a labor shortage caused participation in the Pilot to be a lower priority. Some Raters also determined that the extra energy modeling, AXIS entry, and additional support to builders was above and beyond what they were normally providing to their builder clients at the time. There were also concerns that Pilot requirements misaligned

[39] Annual Reports by CLEAResult

with other established certification programs in the region beyond NWESH and Energy Trust EPS, such as the Built Green program. Several sites could not move forward due to unresponsive Raters, builders, or build schedules delayed beyond the timeline of Phase 3.

Future Research

While this report focused on providing both a historical summary of Pilot activities and a few highlights on lessons learned, several items are worth continued exploration and further research.

Future research items specific to the Pilot are:

- Phase 2 analysis
  - Re-engage with Ecotope's analysis activities; Ecotope identified a few items for further investigation
  - Pair Ecotope findings with CLEAResult findings
  - Pair Ecotope and CLEAResult findings with Annual Savings estimates
- Identify activities and complete Phase 3 analysis
- Make final determinations on capturing utility billing data for participating homes

Future research activities specific to technical practices are:

- Evolving the design guidelines that were provided to Pilot participants (Appendices J, K, L, and M)
- Encourage more adoption and/or identify additional alignment of technical practices recommended by Home Certification Programs
- Identify additional means of collaboration and alignment across several local, regional, and national market influencers and programs
- Gather additional cost data from builders and trades to further define the most cost-effective technology and construction practices

Regarding code advancement activities, CLEAResult recommends continuing discussions with others on code advancement possibilities, as well as evaluating the code items on which to focus. The CLEAResult team reported on the following exploratory activities surrounding code engagement:[40]

- The Pilot was an effort to introduce adoption of advanced building products and practices to advance state codes.
- In 2016, CLEAResult engaged with WSU on the potential use of User Defined Reference Homes (UDRHs) created for the Pilot and Standard Protocol/Performance

[40] Initiative Annual Reports by CLEAResult

Path to determine energy code compliance for homes modeled in REM/*Rate*. If used, this could increase Rater consistency and reduce the burden of documenting code compliance for Raters and builders. At WSU's request, CLEAResult developed and delivered a UDRH based on the requirements stipulated under the Washington code's Chapter R405—Simulated Performance Alternative, accompanied by annotated copies of the code tables.

- In 2017, CLEAResult supported NEEA Codes and Standards by presenting top recommendations to incorporate into future iterations of code. These recommendations covered the most effective and promising design and building practices discovered in the Next Step Homes Pilot, as well as recommendations for implementing performance-based compliance approaches. Specifically, the team's compliance recommendations focused on potential risks of "ERI"-based compliance (i.e., ERI Variability Study) and the Standard Protocol's potential to supplant this mechanism in future Northwest codes. The team continued supporting WSU with options for UDRH files to implement compliance under the WSEC Chapter R405-Simulated Performance Alternative. The team also coordinated communications among the DOE Codes, Standards, and Innovation teams and the Northwest EcoBuilding Guilds' Codes Innovation Database (CIDb), the goal of which is to find the best methods for the region to utilize both the CIDb and Code Briefs available on the Building America Solution Center website.
- Additionally, in 2017, the CLEAResult team responded to Bonneville Power Administration technical inquiries regarding code treatment of ducted and ductless mini-split heat pumps. The team also led follow-up meetings on moving advanced construction practices, technologies, and methods into the next round of code updates in the region, based on historical NWESH and Pilot research and analysis.
- In 2019, the team provided consulting on the Standard Protocol/Performance Path, AXIS, and REM/*Rate* to Chuck Murray from the Washington Department of Commerce, at the request of NEEA. The Washington Department of Commerce encouraged the team to investigate the Performance Path as a potential Washington code-compliance method in 2020 and beyond.

An additional future research activity around code compliance would consist of reevaluating the ERI and HERS options.

Some early findings from the Standard Protocol/Performance Path were reported in CLEAResult's last few years of supporting the initiative (2017-2019). The authors have provided a few of these recommendations again for consideration in future research activities:[41]

- Standard Protocol/Performance Path homes are leaning heavily on simple equipment measures and incremental product upgrades to meet prescribed program eligibility thresholds, rather than implementing further-reaching advanced practices with longer measure lives, such as advanced walls or building with ducts inside.
- Generally, proliferation of the Pilot measures such as envelope upgrades and distributed ventilation is not occurring in Performance Path programs nor being addressed in Northwest alignment discussions with the Bonneville Power Administration, Energy Trust of Oregon, and others. In order to support viability of new construction programs over the next code cycle and to ensure a pipeline of advanced practices for integration into future codes, CLEAResult recommends future development and deployment of strategies to:
    - Accelerate proliferation of Pilot measures by incentivizing builders to continue adoption of those measures—perhaps a redesign of the Performance Path incentive structures could encourage investment in these advanced practices.
    - Explore alternative software approaches and non-modeling alternatives to support utilities in maintaining new homes programs in 2021 and beyond.
    - Address program design needs under Washington State Energy Code change proposals.

Finally, the CLEAResult team briefly considered expanding the Standard Protocol/Performance Path to the multifamily sector, which would require significant effort to define with the RTF and deploy to the market.

[41] Annual Reports by CLEAResult

Closing

In closing, this report does not provide an evaluation of Pilot activities; rather it offers a summary of activities and outcomes that occurred from 2013 through 2019. There were many successes, challenges, findings, and lessons learned through the Next Step Homes Pilot project, many of which ended up in training and technical resources provided to the market (Appendix I) and informed the current Standard Protocol/Performance Path offering. Additional findings through the recommended future research activities could help illuminate additional paths forward for NEEA's Residential New Homes Program.

Appendices

Appendix A: Summary of Background Materials and Reports

Phase 1

Materials

- Specification (Appendix B)
- Summary of participating homes (Appendix C)
- Pilot Project Positioning – for Builders (Referenced in this report)
- Project Tracker
- NSH Pilot History-NEEA internal document (Referenced in this report)
- Customizable Homeowner brochure
- Pilot Book – highlighting projects
- Video Commercial – PSE and non-branded versions, award winning
- NW REM/*Rate* files
- AXIS data

Reports

- For each participating home (unpublished)
    - CLEAResult versions
    - NEEA versions with very detailed analysis
- Meta-Analysis and Executive Summary for NEEA per-home reports (Referenced in this report)
- NEEA Homes Savings Validation Memo (Phase 1, Energy 350)
- Next Step Homes Savings Validation (NSH E350 Report): https://neea.org/img/uploads/next-step-homes-phase-1-savings-validation.pdf
- Next Step Homes Builder Focus Groups: https://neea.org/img/uploads/next-step-home-builder-focus-groups.pdf

Phase 2

Materials

- Specification (Appendix D)
- Summary of participating homes (Appendix E)
- Field Verification Protocols/Field checklist
- Takeoff and Shell Qualifier form
- Cost Data
- Project Tracker (Referenced in this report)
- NW REM/*Rate* files
- AXIS data
- Builder/Homeowner participation agreements
- Design guidelines (Appendices J through M)
- SiteSage Data Loggers/Sensors files
    - Equipment sensors check
    - NEEA_file_manifest (NEEA/Ecotope)
    - NSH Pilot Projects Data Files List – Powerwise (NEEA/Ecotope)
    - Phase 2 metered list (NEEA/Ecotope)
    - SiteSage License Data (NEEA)
- Technical Posters and other training (Referenced in this report, See the Training and Resources Section and Appendix I)

Reports

- Builder Survey Responses (Referenced in this report)
- Lessons Learned Debrief, internal notes (CLEAResult - Referenced in this report)
- Miscellaneous internal notes (NEEA and CLEAResult – Referenced in this report)
- Next Step Homes Notes (Ecotope – Referenced in this report)
- Merge NSH Summary Document – Ran on 2017-12-18 (Ecotope)
- NSH Pilot Home Results v3 2017-12-18 (Ecotope)

Phase 3

Materials

- Specification/Requirements (Appendix F)

- Summary of participating homes (Appendix G)
- Project Tracker (Referenced in this report)
- Phase III Modeling Guidelines (Referenced in this report)
- NW REM/*Rate* files
- AXIS data
- File QA Checklist (Appendix H)
- Field/File QA results
- HOBOWare Data Loggers (Referenced in this report)
    - Data logger overview
    - Data logger downloads
    - Phase III Metering Equipment Inventory
- Builder, Rater, Homeowner participation agreements
- Pilot program AXIS Walkthrough
- Rater Support Webinars (Reference in this report, See the Training and Resources Section and Appendix I)
- Qualified HRVs list
- Range Exhaust Calculator
- Design Guidelines Appendices J through M
- Homebuyer and Builder flyers
- Misc. notes
- Technical Posters and other training (Referenced in this report, See the Training and Resources Section and Appendix I)

Ratings Accuracy Study

- Final report (Referenced in this report)
- Raw data
- Participant feedback

Energy Rating Index (ERI) Variability Study

- Final report (Referenced in this report)

- Raw data

Other Materials and Reports

- All Programs Savings Workbooks, 2016-2018, in collaboration with TRC
- Initiative Annual Reports by CLEAResult, 2013 – 2019 (Referenced in this report)
- Training Trackers and Home Efficiency Forum Trackers (see Training and Resources section, and Appendix I)
- Northwest ENERGY STAR Homes Retrospective Report: https://neea.org/img/uploads/northwest-energy-star-homes-retrospective-report.pdf
- Standard Protocol/Performance Path Onboarding training: https://betterbuiltnw.com/resources/rater-performance-path-overview-webinar-1

Appendix B: Phase 1 Specification

NEEA High Performance Home Spec

Envelope		**Climate Zone 1** **u-value**	**Climate Zones 2&3** **u-value**
Walls:	2x6 16" o.c. w/ 2x2 interior strapping, R23 BIB FG or cellulose insulation; or 2x4 double stud on	**0.035**	**0.030**
Flat Ceilings:	R49 or R60 truss typical, partial raised heel truss in both cases.	**0.025**	**0.017**
Vaulted Ceilings:	2x12 or 12" I-joist 16" o.c. w/ R38 insulation typical, unvented & 3" ext. insulation in zones 2&3	**0.027**	**0.020**
Windows:	Calculated as an area-weighted average. Any SHGC.	**0.25**	**0.25**
Doors:	Calculated as an area-weighted average.	**0.20**	**0.20**
Foundations			
Crawlspace:	12-inch I-joist 16" o.c. , R38 batts typical	**0.025**	**0.025**
Slab:	Zone 1: Thermally isolated inside stem wall (minimum R5 thermal break), R15 on inside of stem wall and footing below slab, plus R15 under the perimeter 4 ft of unheated slab. If slab is heated, minimum R20 under entire slab.	Zones 2&3: Thermally isolated inside stem wall (minimum R5 thermal break), R20 on inside of stem wall and footing below slab, plus R20 under the perimeter 6 ft of unheated slab. If slab is heated, minimum R20 under entire slab.	
Basements:	Zone 1: Any height, R20 wall insulation, fully insulated rim/band joists. If basement floor is less than 4 ft below grade, R15 under the perimeter 4 ft of unheated slab. If slab is heated, minimum R20 under entire slab.	Zones 2&3: Any height, R24 wall insulation, fully insulated rim/band joists. If basement floor is less than 4 ft below grade, R20 under the perimeter 6 ft of unheated slab. If slab is heated, minimum R20 under entire slab.	
Maximum Envelope UA:	Zone 1: **300** Btu/hr-deg F	Zones 2&3: **280** Btu/hr-deg F	
Infiltration:	Maximum **2.0 ACH_{50}**		
HVAC			
HRV/ERV:	Required. Minimum ASE 80% IAW NRC/CSA C439-06. Max electricity use 0.75 watt/cfm at design continuous operating		
System Efficiency:	AFUE: **94%** HSPF: **9.0** EER: **12.0/11.5** COP: **3.0**		
Ducts (if applicable):	Inside (maximum 5% of duct area allowed outside). Minimum duct insulation R4.		
Domestic Hot Water			
Water Heater:	**Electric: Northern Climate HPWH** (if GSHP space conditioning, desuperheater required); **Natural Gas: EF = 0.81**		
Distribution System:	Hot water shall use demand pumping (loop) or core layout. **Note: Continuous or timed domestic hot water circulation is prohibited.**		
Showerheads:	Max flow rate 2.0 gpm		
Lighting			
	Northwest Energy Star (80% of fixtures high efficacy or 0.72 w/sf lpd)		
Appliances			
	Energy Star for DW, Refrigerator-freezer, and/or ceiling fans, if installed		
Inspections/Checklists			
Thermal Bypass	Lighting	Domestic Hot Water Design (adapted as a verification tool for NEEA spec above, under "Distribution System")	
Air Barrier	Blower Door / Duct Leakage		
Blower Door / Duct Leakage			
Domestic Hot Water Design (adapted as a verification tool for NEEA spec above, under "Distribution System")			

Appendix D: Phase 2 Specification

Envelope		Heating Zone 1 u-value	Heating Zones 2&3 u-value
Max. Envelope UA:	150 + (30*Number of Bedrooms) Btu/hr-deg F		
Infiltration:	≤ 2.0 ACH_{50}		
Walls:	2x6 with R23 BIB FG or cellulose insulation + 2" XPS or similar (Heating Zone 1) 2x4 staggered stud on 2x8 plate w/BIB FG or cellulose insulation + 1" XPS or similar (Heating Zones 2&3)	0.035	0.030
Flat Ceilings:	R49 or R60 truss typical, partial raised heel truss in both cases.	0.025	0.017
Vaulted Ceilings:	2x12 or 12" I-joist 16" o.c. w/ R38 insulation typical (Heating Zone 1) 2x12 or 12" I-joist 16" o.c. w/ R38 insulation, unvented + 3" ext. insulation (Heating Zones 2&3)	0.027	0.020
Windows:	Calculated as an area-weighted average. Any SHGC.	0.25	0.25
Doors:	Calculated as an area-weighted average.	0.20	0.20

Foundations			Heating Zone 1 u-value	Heating Zones 2&3 u-value
Crawlspace:	12-inch I-joist 16" o.c. , R38 batts typical		0.025	0.025
Slab:	Zone 1: Thermally isolated inside stem wall (minimum R5 thermal break), R15 on inside of stem wall and footing below slab, plus R15 under the perimeter 4 ft of unheated slab. If slab is heated, minimum R20 under entire slab.	Zones 2&3: Thermally isolated inside stem wall (minimum R5 thermal break), R20 on inside of stem wall and footing below slab, plus R20 under the perimeter 6 ft of unheated slab. If slab is heated, minimum R20 under entire slab.		
Basements:	Zone 1: Any height, R20 wall insulation, fully insulated rim/band joists. If basement floor is less than 4 ft below grade, R15 under the perimeter 4 ft of unheated slab. If slab is heated, minimum R20 under entire slab.	Zones 2&3: Any height, R24 wall insulation, fully insulated rim/band joists. If basement floor is less than 4 ft below grade, R20 under the perimeter 6 ft of unheated slab. If slab is heated, minimum R20 under entire slab.		

HVAC								
HRV/ERV:	Required. Minimum Sensible Recovery (SRE) 80% (IAW NRC/CSA C439-06.) Max electricity use 0.75 watt/cfm at design continuous operating speed (defined as the middle 20% of the operating range). Sized to meet ASHRAE 62.2-2010 rates at middle 20% of operating range.							
System Efficiency:	AFUE:	94%	HSPF:	9.0	EER:	12.0/11.5	COP:	3.0
Ducts (if applicable):	Ducts and Equipment Inside Conditioned Space (maximum 5% of duct area allowed outside). Minimum duct insulation R4.							

Domestic Hot Water	
Water Heater:	Electric: ≥ .93 EF electric tank with Drain Water Heat Recovery Unit or Northern Climate HPWH (if GSHP space conditioning, desuperheater required); Natural Gas: EF = 0.81
Distribution System:	Hot water shall use demand pumping (loop) or core layout. For core layout, maximum pipe length of 25 ft or less to any fixture. Note: Continuous or timed domestic hot water circulation is prohibited.
Showerheads:	Max flow rate 2.0 gpm

Lighting
≥ 80% of lamps high efficacy or 0.72 w/sf Lighting Power Density

Appliances
Energy Star qualified dishwasher, refrigerator-freezer, and/or ceiling fans, if installed

Inspections/Checklists
□ Thermal Enclosure Checklist/Air Barrier Inspection
□ HVAC Commissioning and Verification (includes Duct Blaster test where forced air centrally ducted heating systems are in place)
□ Plumbing System Inspection and Verification
□ Blower Door Test
□ Lighting Inspection

Appendix F: Phase 3 Specification

Phase III Requirements – Homes:

- Must be modeled according to New Residential Construction Standard Protocol currently under development, with Rating provided in MMbtu/yr.
- Must be commissioned to Pilot specifications with commissioning reports provided to Pilot for review.
- Must be designed and constructed to minimum requirements below:

Phase III Minimum Requirements	
Integrated Design	Home must be modeled in NW REM/*Rate* and receive MMbtu/yr rating. Builder must participate in pre-construction design meeting/s with key trades: Designer, Rater, HVAC Contractor, Insulator, Framer, and Plumber. Systems and design requirements written into subcontractor scopes of work.
Envelope	Must meet or exceed state energy code. All shell components must meet or exceed code minimums for R- and U- values. Infiltration must meet or exceed code minimum. Where no code minimum exists, infiltration must be $\leq$ 4 ACH_{50}. Infiltration must be tested by a third-party Rater.
Ventilation	Heat Recovery Ventilator (HRV) with $\geq$ 75% SRE, fan efficacy of $\leq$ 0.8 watt/cfm, properly designed & commissioned. A dedicated duct system must: o Deliver supply air to all bedrooms, offices, and other high occupancy areas. o Exhaust air from all bathrooms, kitchens, utility closets, and other locations that generate pollutants/moisture. The HRV unit and ducts between the HRV and interior must be located inside the thermal envelope. Ducts between the HRV and outside must be insulated to R8 or greater. o Contact the program concerning integrating HRV and forced air heating/cooling ducts. o The system must be designed to meet ASHRAE 62.2 2010 flow rates in a medium to low fan speed setting on the unit with constant flow rate targets as follows: • 20 CFM to full bathrooms • 25 CFM to the master bedroom and main body • 15 CFM to other bedrooms and offices o The system must be commissioned at final to ensure whole house ASHRAE 62.2 2010 flow rates are met, the total supply and exhaust flow rates are within 10% of each other meaning the system is balanced, and target flow rates are proportional Homes with kitchen range exhaust rated $\geq$ 400cfm or with an infiltration target of $\leq$ 2.0ACH_{50} may require active makeup air. Must adhere to detailed requirements for delivery of tempered makeup air, based on house volume, rated airflow, and house air tightness – based on the Range Exhaust Calculator.

Heating/AC system	Equipment must meet efficiency requirements and be properly designed & commissioned. Primary heating equipment efficiency levels must meet or exceed: • Electric: ≥ 9.0 HSPF • Gas/Propane: ≥ 92% AFUE Must complete room-by-room load calculation and select appropriately sized equipment. Ductwork must be located inside conditioned space, designed and installed to meet room-by-room flow requirements.
Water Heat Equipment	Equipment must meet or exceed state energy code with properly designed distribution system. Electric: ≥ .93 EF electric tank or heat pump water heater Gas/Propane: Condensing tank or tankless Continuous or timed recirculation systems are prohibited.
Other Requirements	Builder provides homeowner operation and maintenance instructions for all equipment installed in home. Home and systems must be commissioned to Pilot specifications with commissioning reports provided to NEEA. Builder agrees to complete a participation survey and provide construction cost data to NEEA. Homeowner releases 24 months of utility billing data to NEEA for analysis. Homeowner agrees to installation of data logger in main living area for 14 months.
Phase III “Reach” Specifications	
Must meet all Phase III minimum requirements and requirements listed below	
Envelope	Infiltration target of ≤ 2.5 ACH_{50} Must meet overall UA cap **150 + (30*Number of Bedrooms)** Btu/hr-deg F ≥ R-30 wall ≤ U-.25 windows ~ R-60 ceiling
Ventilation	Heat Recovery Ventilator (HRV) with ≥ 80% SRE, fan efficacy of ≤ 0.75 watt/cfm, properly designed & commissioned as noted above. All homes with kitchen range exhaust must adhere to detailed requirements for delivery of tempered makeup air, based on house volume, rated airflow, and house air tightness – based on the Range Exhaust Calculator.
Heating/AC system	High-efficiency equipment, properly designed & commissioned as noted above. • Electric: ≥ 9.0 HSPF • Gas/Propane: > 94% AFUE
Water Heat Equipment	High-efficiency equipment, properly designed distribution system Electric: Northern Climate heat pump water heater or ≥ .93 EF tank with drain water heat recovery Gas/Propane: ≥ .81 EF Hot water runs must be ≤ 20’ from water heater to fixture or system has demand-based recirculation pump with dedicated return line.

Builders may find the following technical tools helpful in the design of their Phase III homes:
Mini-Split Technologies in New Construction
HRV System Best Practices
Thermal Enclosure Poster
Thermal Enclosure: Efficient Walls and Airtightness

Appendix H: Phase 3 File QA Checklist[42]

Type	QA Question
Admin Issue	Were Field Verification Forms Submitted?
Admin Issue	Was the correct UDRH selected, based on location (and heating fuel in WA)?
Admin Issue	Did Rater provide multi-point blower door test results?
Misalignment Issue	Does REM climate location align with address information?
Misalignment Issue	Does REM bedroom count match field checklist or 640S form?
Misalignment Issue	Do the utilities selected in REM match Axis and are correct for region?
Misalignment Issue	Does the REM infiltration value match field checklist value?
Misalignment Issue	Do gas furnace and gas boiler REM entries match actual model number specs?
Misalignment Issue	Do ASHP and DHP REM entries match actual model number specs?
Misalignment Issue	Are fuel fired unit heaters accounted for in REM that are listed in field checklist?
Misalignment Issue	Is water heat accounted for in REM and match actual model number specs?
Misalignment Issue	Mechanical ventilation rate, fan watts, recovery efficiency, and hours/day are accurate to system described in field checklist or 640S form
Misalignment Issue	Are all other appliances and loads present accounted for in REM that are listed in the field checklist?
Modeling Issue	Do conditioned floor areas make sense with conditioned volume?
Modeling Issue	Do floor and ceiling areas make sense to total conditioned floor area?
Modeling Issue	Are window to floor ratios realistic?
Modeling Issue	Do the foundation type and foundation wall assemblies match up and associated correctly?
Modeling Issue	If foundation type is a conditioned basement, is a slab entered and assigned as the thermal boundary?
Modeling Issue	Slab Total Exposed Perimeter is a realistic, non-zero value (should be 50% or more of total perimeter value)?
Modeling Issue	Are the building assembly U-values within reason of assembly description?
Modeling Issue	For DHP homes with supplemental ER heat, was at least 20% of heating load allocated and are all sources accounted for that are listed in the field checklist?
Modeling Issue	Are radiant slabs accounted for in REM?
Modeling Issue	Is strip heat accounted for on conventional heat pumps?
Modeling Issue	Are ducts assigned to all equipment and total 100%?
Modeling Issue	Are appliance entries realistic and look OK?
Spec Issue	Are ducts inside of conditioned space?
Spec Issue	Was the installed HRV on the QPL?
Spec Issue	Is the HRV installed according to the specifications? (Critical exhaust/supply locations, Balancing, terminus, zone flows)
Spec Issue (Reach only)	Does the installed H/AC equipment meet efficiency requirements?
Spec Issue (Reach only)	Does the installed water heater meet efficiency requirements?
Spec Issue (Reach only)	Are program infiltration targets met?
Spec Issue (Reach only)	Does the home meet range exhaust make up air requirements?
Spec Issue (Reach only)	Is the home under the UA cap?

[42] Pilot Phase III Axis Files pipeline and QA updates

Appendix I:Training with Pilot Findings and Lessons Learned

Year	Title	Location/Conference	Primary Audience
2014	Advanced Thermal Enclosure Training	Bellingham, WA	Builders
2014	Emerging Technology Update: Lessons learned from NEEA's Northwest Pilot	Rater Boot Camp (HEF)	Raters
2014	HRV/ERV Design and Commissioning	Rater Boot Camp (HEF)	Raters
2014	Thermal Enclosure: Airtightness	Rater Boot Camp (HEF)	Raters
2014	Thermal Enclosure: Efficient Walls	Rater Boot Camp (HEF)	Raters
2014	High Efficiency Water Heating and Plumbing	Rater Boot Camp (HEF)	Raters
2014	HVAC for Low-Load Homes	Rater Boot Camp (HEF)	Raters
2014	Common Failures: Leading Builders to Solutions	Rater Boot Camp (HEF)	Raters
2014	Advanced HVAC Diagnostics	Rater Boot Camp (HEF)	Raters
2015	HVAC For Above Code Homes	ACI Northwest	Raters
2015	High-Performance Homes	ACI Northwest	Raters
2015	HRVs	ACI Northwest	Raters
2015	DHPs	ACI Northwest	Raters
2015	5 Pilot Home Tours	Various	Utilities
2015	HRV System Best Practices Poster	Poster	All
2015	Mini-Split Technology in New Construction Poster	Poster	All
2015	Thermal Enclosure Best Practices Poster	Poster	All
2015	Thermal Enclosure: Efficient Walls and Airtightness poster	Poster	All
2015	Pilot Rater Webinar Series: Pre-Construction Support	Webinar	Raters
2015	Lessons Learned from the Pilot	Built Green Conference	Builders
2015	Pilot Rater Webinar Series: Calculating Performance Webinar	Webinar	Raters
2015	Pre-Construction Support: Before the Hammer Hits a Nail	Home Efficiency Forum (HEF)	Raters
2015	Quantifying Model Variability: Findings from NEEA's Pilot Rating Project	Home Efficiency Forum (HEF)	Raters
2015	Efficient Hot Water Solutions	Home Efficiency Forum (HEF)	Raters
2015	Panel: Overcoming Cost Barriers to High Performance: Builder Case Studies	Home Efficiency Forum (HEF)	Raters
2015	Lessons Learned from the Pilot	Sustainable Design and Development Conference	Designers
2015	Pilot Rater Webinar Series: Commissioning for Success Webinar	Webinar	Raters
2015	Sanden CO_2 Heat Pumps	Small Planet Workshops	HVAC

2015	Modeling with Confidence: Using REM/*Rate* for Sound Energy Projections	Home Efficiency Forum (HEF)	Raters
2016	Ducted and Ductless Mini-Split Best Practices	Tacoma & Bellingham, WA	HVAC
2016	Keeping Cool, Now and in the Future	Seattle, WA	Raters, Builders
2016	Tackling Current and Future Codes	Olympia, WA	Raters, Builders
2016	Combining HRVs with Ducted Heating Systems	Home Efficiency Forum (HEF)	Raters
2016	Super Insulated Walls	Home Efficiency Forum (HEF)	Raters
2016	Commissioning for High Performance Homes	Home Efficiency Forum (HEF)	Raters
2016	Equipment selection for modern times	Home Efficiency Forum (HEF)	Raters
2016	Integrating Heat Recovery Ventilators (HRVs) and Central Air Handlers	Home Performance Coalition NW	All
2016	Modeling with confidence	Home Performance Coalition NW	All
2016	Efficient walls and how we build them	Home Performance Coalition NW	All
2016	HVAC inspection points we love and the tools that help us measure them	Home Performance Coalition NW	All
2016	Design Evolution of HVAC Systems – Mini Splits measure them	Home Performance Coalition NW	All
2017	New Homes Performance Path for Raters (onboarding)	Webinar - Standard Protocol/Performance Path	Raters
2017	New Homes Performance Path for Utilities (onboarding)	Webinar - Standard Protocol/Performance Path	Utilities
2017	New Homes Performance Path (utility program kick offs)	Snohomish PUD, Puget Sound Energy, Clark PUD, Idaho Power	Raters, Utilities, Builders
2017	Working w/DHPs and other variable capacity Heat Pumps	Home Efficiency Forum (HEF)	Raters
2017	Behind the Construction Trailer - Builder Panel	Home Efficiency Forum (HEF)	Raters
2017	Energy Codes Update	Home Efficiency Forum (HEF)	Raters
2017	Mythbusting Water Heating Opportunities	Home Efficiency Forum (HEF)	Raters
2017	Integrating HRVs into Central Air Handlers	RESNET & HCP & ETO Trade Ally Forums	Raters, All
2017	Got Gas? Low load home solutions with combustion equipment	RESNET & HCP & ETO Trade Ally Forums	Raters, All
2017	Emerging Trends in Building Science	Northwest EcoBuilding Guild Seattle	Raters
2017	Trends in New Construction	Seattle Building Enclosure Coalition	Raters, Builders
2018	New Homes Performance Path - utility program kick off	Idaho Power	Raters, Utility

2018	New Homes Performance Path - several individual onboarding sessions	Online	Raters, Utilities
2018	Where the Air Goes in and Where the Air Comes Out	Home Efficiency Forum (HEF)	Raters
2018	HVAC Technologies for Today's New Homes and Tomorrow	Home Efficiency Forum (HEF)	Raters
2018	A Breath of Fresh Air: Talking about IAQ in Homes, Beyond Ventilation	Home Efficiency Forum (HEF)	Raters
2018	Homes of the Immediate Future - Sensible Approaches in Use Today	Home Efficiency Forum (HEF)	Raters
2018	The Building Science of Efficient Envelopes	Home Efficiency Forum (HEF)	Raters
2019	Most of the 2019 Home Efficiency Forum training sessions were delivered by market partners; sessions that were delivered by and/or included CLEAResult were on other topics not influenced by the Pilot.		

Appendix J: HVAC Design Guidelines

Design Loads[43]

While it is not yet standard practice, all home designs must be analyzed for room-by-room design space heating and cooling loads and ventilation requirements so the specified HVAC systems will provide high levels of comfort and indoor air quality for the occupants. Home design – especially window areas and orientation, and the amount of exterior wall exposure – can result in significant load differences from room to room that often vary by season. These need to be taken into account when designing and specifying the systems that will serve the home.

> Requirement: All project homes shall use a room-by-room design space heating and cooling design load analysis to ensure that heating, cooling and ventilation systems provide adequate conditioning for each room in the home. Project homes that are custom-built per client are not required to directly meet cooling load in each room. All other projects must utilize a conditioning strategy that will meet the heating and cooling loads in each room of the home.
>
> Recommendation: Builder or the HVAC contractor should consider if separate air distribution settings are needed for heating and cooling seasons. Because air flow rates in many Next Step Homes are primarily used to provide fresh air, seasonal load balancing may be more challenging, especially in rooms with large window areas or significant exterior wall exposure, or rooms that are to be heated and cooled indirectly.

Considerations for Low Load Homes[44]

Constructing tight, highly insulated homes creates significant impacts realized in the design of high performance heating and air conditioning systems. Homes with lower heating and cooling loads require smaller quantities of conditioned air by design. This means that many conventionally accepted design assumptions and installation methods will not yield similar results in low load homes as they do in conventional or code-built homes. In fact, using traditional design and installation methods may compromise the overall performance of the

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[43] Next Step Home Design Guidelines FINAL_clean

[44] Low Load Homes Design Guide_5_3_2016

home and its systems. In order to ensure comfort and efficient performance, new approaches must be used. The design and installation practices recommended in this guide are based on the most recent building science knowledge and field research available.

Heating and Cooling Load Calculations[45]

While it is not yet standard practice, all home designs should be analyzed for room-by-room heating and cooling loads so that the specified HVAC systems will provide high levels of comfort and indoor air quality for the occupants. Home design – especially window areas and orientation and the amount of exterior wall exposure – can result in significant load differences from room to room that often vary by season. These differences should be taken into account when designing and specifying the systems that will serve the home. Low Load homes, by their very nature, are designed and constructed to retain heat. Heat generated in the home by occupants and their electronics and appliances, as well as solar gains from windows and glass doors will also be retained – in both the heating *and* cooling seasons. In order to ensure comfort, heat and cooling must be delivered to each room or zone in the home proportional to their respective loads. This requires attention to detail at every step of the process – Load calculation, equipment selection, and distribution system design and installation – in order to result in a truly high performance system.

- Perform a room-by-room load calculation for each and every home or installation to ensure that heating, cooling, and ventilation systems provide adequate conditioning and fresh air to each room in the home.
- Consider whether air distribution settings should be altered for heating and cooling modes. Because heating and cooling air flow rates are lower in tight, well insulated homes, seasonal load balancing may be more challenging, especially in rooms with large windows or significant exterior wall exposure, or rooms that are expected to be heated and cooled indirectly.

Ductless Heat Pumps[46, 47]

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[45] Low Load Homes Design Guide_5_3_2016

[46] Low Load Homes Design Guide_5_3_2016

[47] Ductless_Ducted_Minisplit Design and Install Guidelines_New_Res_Con_CR_Final

Ductless heat pumps, often referred to simply as “DHPs”, can be a highly efficient means of heating and cooling any home. Ductless heat pumps are typically equipped with inverter-driven compressors, allowing them to vary their heat and cooling output to serve the fluctuating needs of the home. This provides comfortable, efficient heat by allowing the unit to run nearly continuously, thoroughly mixing the air in the zone the DHP is serving. Some units are equipped with diffusers that can oscillate or direct airflow to hot and cold spots within the room.
Attention must be paid to detailed product information, which is available upon request from most manufacturers. When selecting variable-capacity equipment, it’s important to understand the range and flexibility of capacities the unit can provide. This can vary greatly by product line and model and is particularly critical in homes that are designed to be tight and very well insulated. When the home’s need for heat drops below the equipment’s lowest capacity, sub-optimal performance can result. This degraded performance can come in the form of higher than normal energy use, compromised comfort, and “short-cycling” – a condition characterized by the equipment turning on for short periods, then shutting down again.
When specifying and installing Ductless Heat Pumps, adhere to the following guidance for optimal performance:

- Obtain detailed capacity information from the manufacturer
  - Select equipment with a maximum capacity that meets the Design Heating and Cooling Loads for the home
  - Select equipment with at least a 4:1 ratio between its maximum capacity and minimum capacity at 47f
- Specify an appropriate number of indoor heads to provide for the home’s Design heating and Cooling Loads, with some localized conditioning.
  - In most homes, specifying more than 2 indoor heads will add significant cost to the system without significantly increasing comfort or efficiency
- Provide some means of direct conditioning to bedrooms, offices and other rooms where occupants will spend a significant portion of their time. In most homes, a cost- and performance- optimized system consists of a ductless indoor head in the home’s main living area, augmented by one or more of the following:
  - A ducted mini-split providing direct heat and cooling to remote rooms
  - A smaller indoor head in the Master bedroom suite, bonus room, or main area of the home’s second floor
  - Small (≤750W) thermostat-controlled electric resistance baseboard or wall heaters in remote rooms

- Place and orient indoor heads to take advantage of the long “throw” and thorough mixing they can provide
    - Place in open areas and position the unit to throw the long direction through the space
    - Position larger units to blow down central hallways
- In vaulted or double-height areas, place indoor heads no more than 8’ off the floor
- Do not leave units set to run in “Auto” mode. This setting allows some units to switch freely between heating and cooling modes and can affect efficiency and behavior of the units.

Ducted Mini-Splits[48, 49]

Ducted mini-splits combine the variable capacity and efficient operation of ductless heat pumps with the distribution flexibility of a ducted heating and cooling strategy. Ducted mini-splits are typically equipped with inverter-driven compressors, allowing them to vary their heat and cooling output to serve the fluctuating needs of the home. This provides comfortable, efficient heat by allowing the unit to run nearly continuously, thoroughly mixing the air in the home. Ducted mini-splits are a viable option for most tight, well-insulated new homes. With some attention to detail on the duct installation and distribution capabilities of the unit selected, optimal results can be achieved.

Attention must be paid to detailed product information, which is available upon request from most manufacturers. When selecting variable-capacity equipment, it’s important to understand the range and flexibility of capacities the unit can provide. This can vary greatly by product line and model and is particularly critical in homes that are designed to be tight and very well insulated. When the home’s need for heat drops below the equipment’s lowest capacity, sub-optimal performance can result. This degraded performance can come in the form of higher than normal energy use, compromised comfort, and “short-cycling” – a condition characterized by the equipment turning on for short periods, then shutting down again.

When specifying and installing ducted mini-splits, adhere to the following guidance for optimal performance:

- Obtain detailed capacity information from the manufacturer

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[48] Low Load Homes Design Guide_5_3_2016

[49] Ductless_Ducted_Minisplit Design and Install Guidelines_New_Res_Con_CR_Final

- Select equipment with a maximum capacity that meets the Design Heating and Cooling Loads for the home
    - Select equipment with at least a 4:1 ratio between its maximum capacity and minimum capacity at 47f
- Specify an appropriate number of indoor heads to provide for the home's Design heating and Cooling Loads.
    - In most homes, specifying more than 2 indoor heads will add significant cost to the system without significantly increasing comfort or efficiency
- Locate ductwork and equipment inside the conditioned area of the home
    - Place and orient indoor heads to allow for future maintenance/service
- Design and install ductwork to minimize flow restriction and provide airflow as required by the room-by-room load calculations
    - Use guidance and design factors provided in ACCA Manual D
    - For simplified design guidance, follow the protocols outlined in the EasyDucts design guide
- Adhere to the manufacturer's specifications on static pressure capability and ducting limitations
    - Some units have specific limitations on the length and quantity of ducts while others may simply provide the static pressure capabilities of the air handler fan
- Specify grilles, registers, and diffusers appropriate for each space and application
    - For ceiling registers, select a product with throw that will reach to $\leq$ 5' above finished floor at 120f delivered air temp
- Do not leave units set to run in "Auto" mode. This setting allows some units to switch freely between heating and cooling modes and can affect efficiency and behavior of the units.

Central Air-Source Heat Pumps[50]

Central air-source heat pumps, when properly installed and commissioned; provide efficient, distributed heat and cooling. Central heat pumps use compressors to extract heat from the outdoor air and move that heat inside the home, so the heat pump's capacity diminishes as the outdoor air temperature drops. This type of heat pump relies on electric resistance strip heat

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during colder times when the compressor cannot output enough heat to serve the heat needs of the home. Achieving optimal performance and efficiency with this type of heating system requires minimizing the usage of the strip heat. Oversizing the unit to provide sufficient heat down to lower outdoor temperatures helps minimize strip heat usage and is a good practice, so long as the oversizing will not create issues with short-cycling during less severe weather conditions. Multi-stage heat pump equipment provides flexible capacity – a lower compressor stage to provide sufficient heat for the bulk of the heating hours and a higher compressor stage that can be used as an efficient means of providing extra capacity during cold snaps. In this case, the strip heat would only be used during the very coldest hours of the year, if at all. In order to ensure that use of the strip heat does not compromise the efficiency of an air-source heat pump, controls must be installed which disable the strip heat above specific outdoor temperatures. Commissioning protocols must be performed to verify that the system is utilizing the correct amount of refrigerant and achieving the designed air flows. New products in this category are available that utilize variable-capacity, inverter-driven compressors, similar to those found in ductless heat pumps. These units may perform very efficiently, though there is currently very little field research verifying their performance. Finally, because rooms in low load homes require smaller quantities of conditioned air, grille, register and diffuser selection is important in order to provide proper mixing and de-stratification of the air inside the home. When specifying and installing air-source Heat Pumps, adhere to the following guidance:

- Obtain detailed capacity information from the manufacturer
    - Select high-efficiency equipment with a capacity that meets the design heating and cooling loads for the home
    - Design to a balance point of ≤ 30f
    - Specify multi-stage equipment for any home with a design heat load of < 18 kBtu/hr
- Locate ductwork and equipment inside the conditioned area of the home
- Design and install ductwork to minimize flow restriction and provide airflow as required by the room-by-room load calculations
    - Use guidance and design factors provided in ACCA Manual D
    - For simplified design guidance, follow the protocols outlined in the "EZ Ducts" design guide
- Design grilles, registers, and diffusers appropriate for each space and application
    - For ceiling registers, select a product with throw that will reach to ≤ 5' above finished floor at 120f delivered air temp

- Adhere to Performance-Tested Comfort System (PTCS) standards for installation and equipment commissioning.
    - Verify that outdoor thermostats and strip heat lockouts are correctly wired and functional
- Where programmable thermostats will be used, program with ≤ 3f difference between "set up" and "set back" temperatures.

Gas Furnaces[51]

Modern, high-efficiency gas furnaces can be paired with an air conditioning coil to provide efficient distributed heat and cooling. Most standard gas furnaces are grossly oversized for newly constructed efficient homes, even if the home is quite large and located in a cold climate. As such, modulating or multi-stage furnaces should be specified for all low-load homes to prevent "short-cycling" – a condition characterized by the equipment turning on for short periods, then shutting down again. Short-cycling degrades equipment efficiency as it does not allow the equipment to reach optimal operating conditions prior to shutting down again. Short-cycling can also have negative impacts on occupant comfort and shorten equipment life. Achieving optimal performance and efficiency with a gas furnace is also dependent on distribution efficiency. Installing well-designed and sealed ducts inside the envelope of the home minimizes heat lost to outdoors and unconditioned spaces. Specifying a unit with a high-efficiency air handler fan, equipped with an electronically-commutated motor (ECM) capable of running at various speeds minimizes the fan energy used to distribute conditioned air to the home. Modulating or multi-stage equipment provides flexible capacity –lower heating stages to provide sufficient heat for the bulk of the heating hours and higher stages that can be used as an efficient means of providing extra capacity during cold snaps. This allows the system to run at optimal efficiency under a range of indoor and outdoor conditions. Finally, because rooms in low load homes require smaller quantities of conditioned air, grille, register and diffuser selection is important in order to provide proper mixing and de-stratification of the air inside the home.

When specifying and installing gas furnaces in low load homes, adhere to the following best practices:

- Obtain detailed capacity information from the equipment manufacturer

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- Select a high-efficiency modulating or multi-stage furnace with the lowest high-stage *output* capacity that will meet the home's design heat load.
- Select the model with the lowest low-stage capacity available, preferably ≤ 20 kBtu/hr *output* capacity.
- Select equipment that has an ECM air handler.
  - For systems where ventilation or mixing will be provided by the air handler, program to use the lowest available fan speed for ventilation and select equipment that can deliver its lowest fan speed at < 30w
- Select the smallest cooling equipment with a capacity that will cover the sensible and latent cooling design loads of the home
- Cooling equipment may be added after installation of the furnace. Design as if a cooling coil will be added later.
  - Select equipment with an air handler capable of delivering design airflows at ≤ .7 IWC.

- Locate ductwork and equipment inside the conditioned area of the home
- Design and install ductwork to minimize flow restriction and provide airflow as required by the room-by-room load calculations
  - Design and size ductwork for cooling airflows
  - Design ductwork as if an AC coil will be added, even if there is no AC at the time of install. Design for the added static pressure drop associated with a high-efficiency AC coil.
  - Use guidance and design factors provided in ACCA Manual D
  - For simplified design guidance, follow the protocols outlined in the "EZ Ducts" design guide
- Design grilles, registers, and diffusers appropriate for each space and application
  - For ceiling registers, select a product with throw that will reach to ≤ 5' above finished floor at 120f delivered air temp and low-stage airflows
- Adhere to Performance-Tested Comfort System (PTCS) standards for duct installation and cooling equipment commissioning.
  - Use the Northwest ENERGY STAR Homes Central AC Commissioning & Startup Form: http://www.northwestenergystar.com/sites/default/files/resources/Northwest%20ENERGY%20STAR%20Homes%20Central%20AC%20Commissioning%20Form_6202012.pdf

Hydronic Systems[52]

Because Hydronic heat systems utilize hydronic loops, rather than ductwork, as their means of distribution, they carry a unique set of design and installation considerations. Detailed load calculations and hydronic loop design are necessary to meet the room-by-room heating requirements of the home. In areas where cooling is necessary or desired, the hydronic heating system may be augmented with a small DHP or Ducted Mini-Split for cooling and shoulder-season heating when bringing the entire slab or distribution system up to temperature is not necessary. Because low-load homes require less heat to be delivered to each zone, hydronic systems in low-load homes will heat the slab to much lower temperatures than systems in typical homes. This means that the slab or floor surface may not feel warm to the touch, a key selling point for hydronic systems in more conventional homes. Due to warmer return water temperatures, some condensing hydronic heat sources may not achieve the level of combustion efficiency that they would achieve in a home with higher heat loss. Modern, high-efficiency gas boilers, condensing gas tank or tankless water heaters can work well as a heat source, as can air-to-water heat pumps. New heat pump products coming available in the market utilize CO_2 as a refrigerant to super-heat water that can be used for heating and domestic hot water needs. Electric boilers and standard heat pump water heaters are not recommended as a heat source for hydronic heating systems if energy efficiency and equipment longevity are goals of the system design.

When specifying and installing hydronic heating systems, adhere to the following best practices:

- Select a high-efficiency heat source appropriate for the load
  - Do not utilize a standard electric tank water heater, electric boiler, or typical heat pump water heater as the primary heat source
  - When specifying a condensing gas tank water heater as the heat source, or for systems incorporating solar storage tanks, install the tank inside conditioned space to minimize standby losses.
  - Do not utilize small buffer tanks to eliminate the cold water “sandwich” on combined space heat and domestic hot water systems. This add-on comes at a very high energy penalty, due to constant stand-by losses.

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- For radiant slabs, leave no portion of the slab uninsulated. Insulate the entire slab to ≤ R-20 and include a thermal break of ≥ R-5 at the slab edge, including any portion of the slab that abuts an unconditioned space such as a garage.
- Flush the system annually as part of routine maintenance to prevent scaling. In areas with hard water (≥ 7 grains per gallon), install water softeners inline upstream of the heat source.

Appendix K: Ventilation Design Guidelines

Ventilation System[53, 54]

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Because Next Step Homes are designed to be substantially air-tight, a properly designed, specified, operated and maintained ventilation system is essential for providing a healthy and comfortable indoor environment. Such a system will be balanced, will not adversely affect heating and cooling costs, and will use very little energy to operate. Next Step Homes require a high efficiency heat recovery ventilation system (HRV system) to meet these goals.

Aside from the efficiency specifications, there are a number of Design Guidelines that apply to these systems. Because they are not yet in widespread use, these systems tend to be new to builders, contractors and homeowners, and these guidelines are designed to ensure that the systems are properly designed and specified by the engineer or HVAC contractor, properly installed, and that they are properly operated and maintained by the occupants of the home.

> Requirement: HRV systems shall be designed to exhaust air from all bathrooms, utility spaces, kitchen areas, and other areas of the home where pollutants might be generated. The HRV systems shall deliver filtered fresh air to all bedrooms, offices, the main living area, and other areas where the occupants of the home are expected to spend a significant amount of time. The system shall be designed to deliver the air flow rates required by ASHRAE 62.2-2010 when the home is fully occupied, by using a fan speed in the middle of the range of speed settings provided for the HRV.
>
> Requirement: When an HRV is integrated with a ducted heating/cooling system, supplied fresh air from the HRV will be injected into the HVAC system ductwork in such a way as to deliver fresh air in HVAC system design proportions to each room, and exhaust air to the HRV will be taken directly from the home. If the HRV is set to run continuously to meet ASHRAE 62.2 levels of ventilation and is used to replace bathroom exhaust fans, then exhaust air will be taken directly from all bathrooms and utility spaces. *No exhaust air shall be taken from the return side of the HVAC system ductwork.*
>
> Requirement: HRV/ERVs equipped with defrost function based on recirculation shall have a ducted termination to the recirculation intake port of the HRV in order to provide room-temperature air for this defrost function. *The recirculation intake port shall not take its air from and unconditioned or uninhabitable space.*
>
> Requirement: HRV/ERVs shall not be designed or installed with after-market defrost or tempering measures unless explicitly approved by a project technical advisor.

Requirement: The HRV unit shall be placed in an easily accessible location in the home such that maintenance of the unit is easily accomplished by the occupants of the home (usually through filter and heat exchange core access). HRVs shall not be placed in a vented attic or crawl space.

Requirement: All HRV systems shall be commissioned to verify that design air flows are exhausted from and delivered to each room, that the controls of the system are properly set up and functioning in all modes, and that the system meets ASHRAE 62.2 levels of ventilation in the middle of its capacity range. The controls for the system will be conspicuously labeled as those for the ventilation system.

Requirement: The occupants of the home shall be trained on how to properly operate and maintain the ventilation system. The homeowner must know how to adjust air flow, set a schedule, clean or replace filters, adjust the system for different occupancy modes, and to operate any other special features of the ventilation system. All operation and installation manual(s) for the system will be provided to the occupants as part of the Homeowner Operations Manual. A one-page operating guide shall be provided to help the homeowner with basic operation of the system. The guide will contain language that emphasizes the importance of running the system as specified and potential impacts to health and safety from not doing so.

HRV Volume and Balancing Guidance[55]

- HRV is set to meet ASHRAE or code ventilation whole house requirements on medium or medium low setting. Bruce added low is OK.
- All bathrooms, utility room, and kitchen meet ASHRAE or code ventilation with a combination of HRVs and local exhaust. Must either be capable of meeting continuous standard at medium or medium low setting OR with boost function able to meet intermittent requirements.
- The sum of all supplies should be within 90-110% of the sum of all exhaust readings at high speed or as indicated by manufacturer. Anemometers- Testo, Alnor, or other professional vane anemometer designed to work in the 5-150CFM range.

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[55] HRV Volume and Balancing Guidance

- If balancing dampers are installed at the unit and measuring ports are available, balancing to meet the above should happen first at the air handler and then tuned as possible at the termini. If there are no balancing dampers, add them
- 75% of supply air (+/- 10%) should be distributed amongst bedrooms with a minimum of 12.5 cfm per room when HRV is set to medium or medium low setting.
- Proper homeowner education
- The HRV setting, supply flows per room, exhaust flows per room, and availability of boost functionality should be recorded and listed along with building tightness and other commissioning requirements as set forth by code or above code program.

Kitchen Range Exhaust[56, 57]

Because Next Step Homes are designed to be substantially air-tight, a properly designed, specified, operated and maintained kitchen exhaust fan system is essential. High-capacity exhaust fans (greater than 200 cfm) have the ability to substantially depressurize the home while in operation and under such depressurized conditions may not exhaust the amount of air required to adequately remove range-generated pollutants. In the case of the highest capacity fans (more than 400 cfm), passive make-up ducts are unlikely to provide adequate balancing air flow and prevent significant house depressurization. In addition, field experience has shown that high make-up air flows create occupant discomfort during the winter when delivered to the area anywhere near the cooking range. The use of high capacity kitchen exhaust fans usually requires significant investment in measures to mitigate the tendency of these systems to depressurize the home and underperform in their role of removing cooking-generated pollutants.

> Recommendation: Use the smallest range hood or downdraft exhaust fan that will adequately exhaust cooking-generated pollutants from the kitchen.
>
> Requirement: All range hood or downdraft exhaust fans with a capacity greater than the home's target air leakage at a 15 Pa pressure differential with respect to the outside require the provision of tempered (heated) balancing air flow as needed

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to ensure a pressure differential of no greater than 10 Pa with respect to outside, interlocked with the range hood or downdraft fan. A thermostatically controlled electric resistance duct heater, with sufficient capacity to deliver air no cooler than 60°F at winter design conditions, shall be provided and set to temper incoming make-up air when Outdoor Ambient air temperature is below 45f unless other means of tempering are available. The use of an active (electrically activated), gasketed damper, interlocked with the range hood or downdraft fan, is required to be used for all make-up air ducts. Make-up air shall be delivered to an area of the main body of the home that is not a high occupancy area (kitchen, living room, rec room, or similar).The homeowner's operations manual will provide information on the make-up air system and the need to periodically examine and clean, as necessary, the inlet air screens for this system, which shall be easily accessible for maintenance.

The NEEA Make-up Air Calculator, available from a project Technical Advisor will be used to compute the necessary amount of make-up air. Where the make-up air flow required is ≤10% of the range hood or downdraft fan's rated flow, no make-up air provision is required.

Appendix L: Water Design Guidelines

Domestic Hot Water Systems[58, 59]

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Domestic water heating is usually the second-largest energy end use in a home. Energy efficiency of a home's hot water system is a function of both the energy efficiency of the home's water heater and the efficiency of the hot water distribution system. Heat loss in pipes, wasted water, and wasted heat down the drain can be dramatically reduced. Based on field experience to date, certain practices in this area are clearly effective in saving energy, and others have proven to actually increase energy use. The provisions of this section are focused on all of these practices.

Recommended: Wherever physically possible, use a drain water heat recovery system to recover half or more of the energy in the hot water going down the drain during household showers. The ideal configuration requires about a 6-foot vertical drop in the wastewater line below the bathroom(s), and would ideally capture the drain water flows from all of the home's showers. Talk to a Next Step Homes technical team advisor for details on how to implement this measure.

Requirement: The home's plumbing layout shall be a core layout (no hot water runs longer than 20 feet from the water heater to a fixture) or have a demand-pumping loop design. This provision is required to prevent the waste of large amounts of hot water (10,000 gallons per year or more in many larger homes) in waiting for hot water to arrive at fixtures that are remote from the water heater. Talk to a Next Step Homes technical team advisor for details on how to implement this measure.

Prohibited: Continuous or timed domestic hot water circulation. Both of these unfortunate practices waste significant amounts of energy. A demand-pumping system will perform the same service with no energy wasted.

Prohibited: The use of an electric resistance buffer tank downstream of a natural gas-fired on-demand water heater. This practice, used to mitigate the "cold water sandwich" effect that can occur with many short-duration hot water draws, not only adds significant cost to the hot water system, but wastes energy. Such buffer tanks typically use more than 1,000 kWh of electricity per year, more than offsetting the energy savings associated with the on-demand water heater.

Plumbing layout[60]

Flow rates are generally low and simultaneity is much smaller than assumed in current plumbing codes, therefore updating plumbing size requirements and allowing small bore structure plumbing is now appropriate. The ideal hot water distribution system:

- Has the smallest volume (length and smallest “possible” diameter) of pipe from the **source of hot water** to the plumbing fixture or appliance
    - Locate the “sources” of hot water close to the uses
        - Sometimes the source of hot water is a water heater or boiler, sometimes it is the trunk line or the supply portion of a circulation loop or a heat traced pipe.
        - Sometimes more than one water heater or more than one hot water distribution system is needed. Sometimes both.
    - Keep the volume from the source(s) to the uses small
        - This is critical when the volume per event is small and time between events is long; for example hand washing in restrooms in office buildings.
        - New washing machines and dishwashers have flow rates while filling of less than 1.5 gpm, so they are similar to faucets and showers.
        - Fixture branch piping (twigs) should contain less than 2 cups from the trunk line to the fixture fittings or appliances.
- Sometimes the **source of hot water** is the water heater, sometimes a trunk line
    - Select water heaters (or boilers) matched to these uses and patterns
        - Pay attention to the lowest flow rates and the smallest volumes – which happen with great frequency- as well as to the peaks – which happen much less often.
        - Maintain this water heater so it lasts a very long time.
- For a given layout (floor plan) of hot water locations the system will have:
    - Minimize pressure drop and optimize velocity in the piping
        - Size fixture branch piping (twigs) in accordance with the flow rate of the fixture fitting or appliance that it serves.
            - The shortest buildable trunk line
            - Few or no branches

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        - The shortest buildable twigs
    - Use wide radius sweeps or bend the pipe into “swoops” instead of using hard 90-degree elbows wherever possible.
- Not recommended: plumbing manifold systems are not recommended unless each run is capable of being 10 feet or less

Recirculation[61]

Water conservation goes hand in hand with energy efficiency. Research shows that hot water use is generally extremely variable within and among households. Demand-based recirculation is a simple means of preventing wasted water while waiting on hot water to arrive at a fixture. This makes timed continuous and learning recirculation pumps less value than they may initially appear. This can also save heat energy when compared to timed or continuous run recirculation systems and can prevent long wait times for hot water therefore increasing homeowner satisfaction. With demand-based systems, when hot water is needed, the homeowner triggers the system through a variety of means, and then the system automatically shuts down when a thermistor detects hot water at the fixture or back at the circulator. If the system is triggered and there is still hot water in the line, the system will not recirculate. Considerations and requirements for installing these systems:

- **Requirement:** For “Reach” specification level homes only, demand-based recirculation is required if hot water runs are ≥ 20’ from the water heater to the farthest fixture, measured along the water pipe.
- **Requirement:** Continuous or time recirculation systems are prohibited.
- The circulator must be sized according to the number of stories of the home (head), supply and return pipe length, recirculation time, and return line diameter. Most manufacturers publish pump performance curves and tables to makes this easy.
- For on-demand water heaters, ensure that the GPM flow rate of the installed circulator is high enough to engage the water heater. Pump manufacturers will usually call out if their circulator is intended for use with these types of water heaters. Some on-demand water heaters have built-in circulators that are triggered when a fixture is opened. These do not satisfy the requirements of demand-based recirculation. Demand-based circulation systems can be installed on on-demand water heaters with built-in circulators.

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- Manifold plumbing systems are not good candidates for on-demand recirculation. See more information in the “Hot Water Distribution” section about issues and the energy impacts of central manifold plumbing systems.
- Methods of initiation:
    - **Hardwired momentary contact switches:** Typically doorbell buttons, these only require the user to press once and doesn’t require the switch be flipped back off. This system is typically the most reliable and easiest for the homeowner, but takes planning and labor at rough wiring stage.
    - **Wireless switches:** A reliable solution where the circulator is triggered by a remote switch. Switches have a limited range, but a repeater can be used to help strengthen the signal. A plug under a sink can be installed for the repeater. Multiple switches can be located around the home and replacements are easy to get. Homeowner education is critical as the wireless switches can get lost or put in a drawer.
    - **Wireless motion sensors:** If you want a wireless system without the hassle of switches or want a more hands free approach, a motion sensor system may be worth considering. Motion sensors can have a tendency to cause recirculation cycles when hot water is not needed, but removes the need for the homeowner to actively press a button, which may often not get used.
- System types:
    - **Under-the-sink with no dedicated return line (good):** This system is best for retrofit situations or homes that only have one fixture that is far from the water heater. The unit is installed under the sink and bridges the hot and cold shut off valves. When the circulator is triggered, it returns un-tempered hot water into the cold water line until a thermistor in the unit reaches temperature. Cut off temperatures can be adjusted. A plug is needed under the sink. Be aware that some circulators run fairly loud and may be heard if in a bathroom vanity.

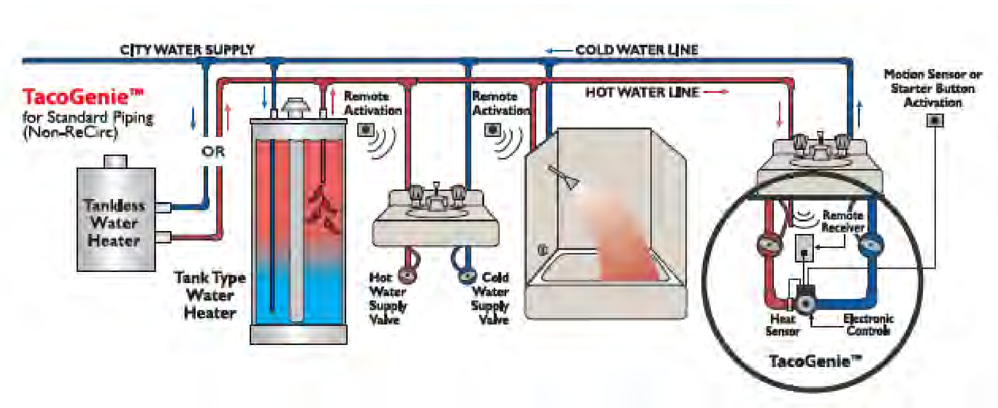

Figure 1.

- **Dedicated return line with internal thermistor (better):** This system requires a dedicated return line and the circulator is located at the water heater. A thermistor is built into the pump housing. Hot water must be pumped all the way back to the water heater before flow is stopped.

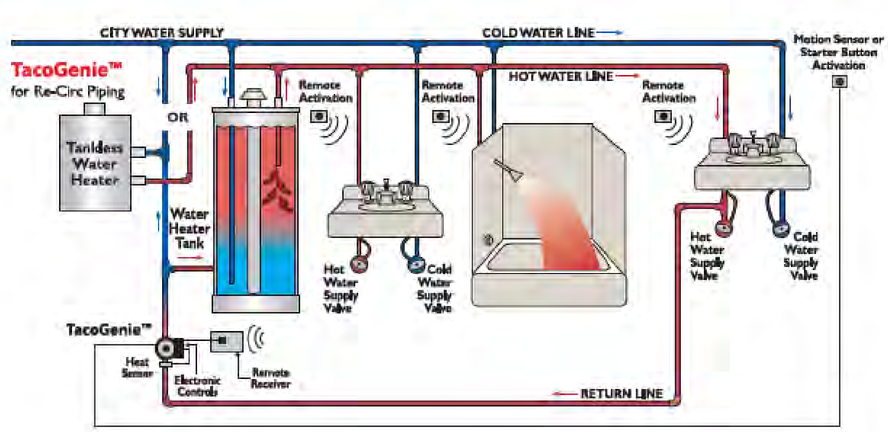

Figure 2.

- **Dedicated return line with remote thermistor (best):** This system is similar to the system above, except the thermistor is not integrated into the pump housing and can be located at the last fixture on the loop. This prevents hot water from having to travel down the return line before satisfying the thermistor. Care must be taken when placing the thermistor depending on how the home is plumbed and where the trunk and twigs terminate.

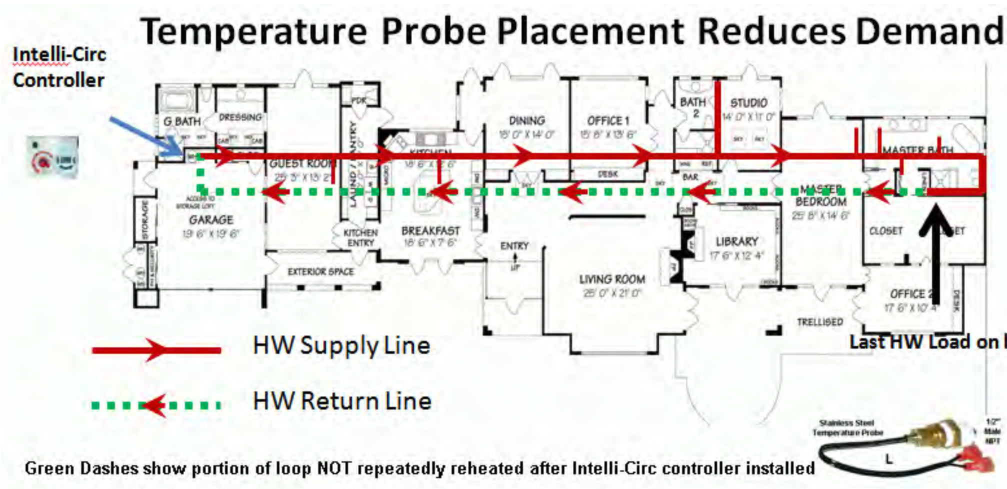

Figure 3.

Manufacturers[62]

These are only some of the manufacturers. Many more systems are available and approved for use as long as they adhere to the goals of the Design Guidelines.

- **ACT D'Mand, Metlund D'Mand, Taco Genie** – Can be plumbed as an under-the-sink unit or installed with a dedicated return line. The pump housing has a built in thermistor, so once the pump senses hot water has returned, it clicks off. Can be hard wired or each manufacturer has a wireless kit.
    - ACT system: http://www.gothotwater.com/ >$500
    - Taco system: http://www.taco-hvac.com/products.html?current_category=59_> $400
    - Remote kit with push buttons or motion sensors, receiver, repeater ± $100

- **RedyTemp Controls** – This is a controller that operates a standard circulator. Can be hard wired or order the wireless kit or motion sensor directly from RedyTemp. Another advantage of this system is the included thermistor is separate, which must be plumbed in. This enables you to put it at the last fixture in the loop, saving even more heat energy.
    - http://www.redytemp.com/efficienthotwatercirculation.htm

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- TLC-X1-115 - $189, standard recirculator not included. Another $75 for wireless package.

- **Chilipepper** - Can be plumbed as an under-the-sink unit or installed with a dedicated return line. The pump contains a thermistor. The pump is VERY loud and not recommend for an under-the-sink placement. - $189
  - http://www.chilipepperapp.com/howit.htm

Insulation[63]

We've learned that hot water events are clustered together within windows of opportunity based on the schedules of the occupants. Insulated pipes maintain the heat in the pipes between short intervals of uses.

- **Requirements**
  - Insulate all of it because the patterns of use are so variable and likely to changes over the life of the piping within the building
  - Pipe insulation wall thickness should be at least the same as the diameter of the pipe it's insulating (1/2 inch diameter pipe should have at least ½ thick insulation).

Appliances[64]

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When considering appliances and/or equipment, please use the following guidance:

- Utilize (hot) water use efficient fixture fittings and appliances
    - Lower flow rate faucets and showers and lower fill volume washing machines and dishwashers will be more satisfactory to consumers when installed in conjunction with the hot water distribution system described above.
    - In areas with low pressure, specify pressure compensating aerators, particularly for showers.
- Capture waste heat from hot water running down the drain and use it to preheat incoming cold water
    - Preheat the cold water going to the water heater(s)
    - Preheat the cold water going to the shower(s)
    - Preheat the cold water going to both the water heater(s) and the shower(s)
    - The potential savings involved look something like:
        - Captures 40-80% of the temperature drop
        - **Recommended:** Balance flow – saves more than unequal flow.

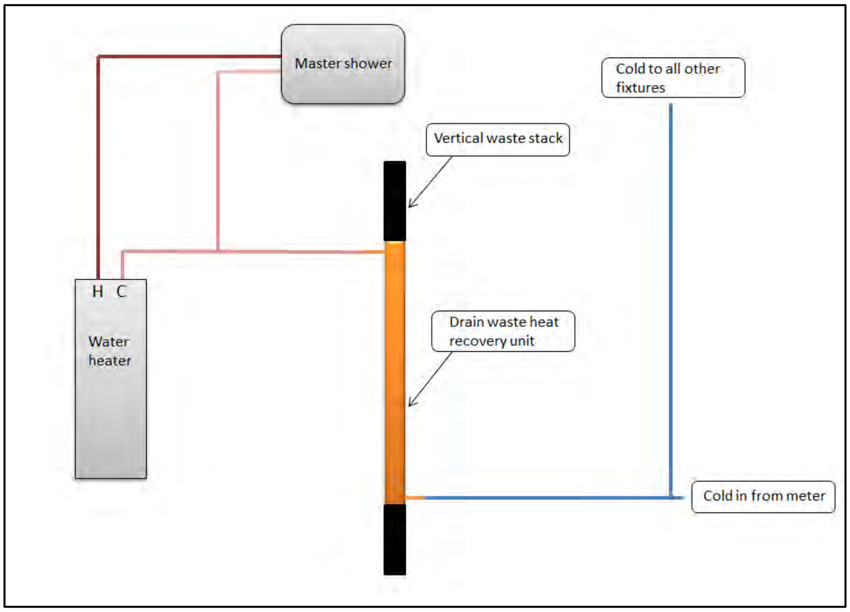

Figure 4.

Appendix M: Other Design Guidelines

Homeowner Operation Manual[65]

Success with Advanced Performance Homes requires proper design, installation and operation of critical elements. While other portions of the Design Guide and the Specifications focus on the design and installation of key elements, the Homeowner Operation Manual addresses post install operation and maintenance of the home and its mechanical elements by the homeowner. Even the best installed systems will do little for the home and its occupants if not properly operated and maintained.

> Required: Homeowner Operation Manual (or O & M guidebook) must accompany each home in the pilot program. These manuals should contain operation manuals from equipment, ventilation education and operational materials, general building maintenance requirements for the home and equipment, tips and tricks for best operation of systems (such as use of the demand pump system for hot water) and any other pertinent information necessary for Homeowner awareness of the home's comfort, ventilation, and hot water systems.

Integrated Design (Pre-Construction Support)[66]

Complicated and interconnected systems in high performance homes demand that designers, builders, and contractors work together. Prior to construction, the Builder, Rater, HVAC contractor, Insulator, and Plumber meet in an Integrated Design Charrette to ensure interdependencies are identified and understood. In the case of custom homes, the Builder, Designer, Purchasing agent, and homeowner meet to ensure home is modeled and scopes of work written to achieve systems approaches.

> Requirement: Each project home requires a pre-construction meeting or integrated design charrette before construction begins. In the case of a builder participating with multiple homes of the same floor plan (with the same equipment/systems and construction assemblies) only one design charrette is required for each floor plan.

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Because orientation affects load differences from room to room that vary by season, especially window areas and the amount of exterior wall exposure, each project home of the same floor plan must use a room-by-room design space heating and cooling design load analysis to ensure that heating, cooling and ventilation systems provide adequate conditioning for each room in the home.