ITEM NO. CA5

PUBLIC UTILITY COMMISSION OF OREGON
STAFF REPORT
PUBLIC MEETING DATE: FEBRUARY 7, 2016

REGULAR ____ **CONSENT** __X__ **EFFECTIVE DATE** ____**February 8, 2017**____

DATE: January 17, 2017

TO: Public Utility Commission

FROM: JP Batmale

THROUGH: Jason Eisdorfer and John Crider

SUBJECT: OREGON PUBLIC UTILITY COMMISSION STAFF:
(Docket No. UM 1565) The results of Energy Trust's third-party, economic analysis comparing the residential use of gas furnace systems to heat pump systems.

STAFF RECOMMENDATION:

Staff recommends the Commission accept as compliant with Order No. 15-265 the economic analysis overseen by Energy Trust comparing the use of a heat pump for heating and cooling compared to a natural gas furnace and electric air conditioning.

DISCUSSION:

Issue

Whether the Commission should accept as compliant with Order No. 15-265 the Energy Trust's economic analysis comparing the use of a heat pump for heating and cooling to a natural gas furnace and electric air conditioning.

Applicable Rule or Law

The Energy Trust and the Oregon Public Utility Commission have a grant agreement "to control the manner in which the Energy Trust will receive and expend funds for the Statutory Purposes in conformity with the requirement and intent of the Statute [ORS 757.612]."[1]

1 Recital D, Page 1. Grant Agreement between ETO and OPUC dated December 1, 2005.

In the grant agreement, the term "Conservation" has the meaning given it under OAR 860-027-0310(1), which includes fuel switching as a conservation measure.

Oregon Administrative Rule (OAR) 860-027-0310(1)(a) defines "Conservation" as any reduction in electric power or natural gas consumption as the result of increases in efficiency of energy use, production, or distribution. The same rule specifies that conservation also includes cost-effective fuel switching.

In OAR 860-027-0310(1)(b) "Fuel switching" is defined as any substitution of one type of energy or fuel for another.

In OAR 860-027-0310(1)(c) "Cost-effective" is defined in part as having "the meaning given that term in OAR 860-030-0010." In turn, OAR 860-030-0010 references ORS 469.631(4) which defines, *"Cost-effective" to mean "that an energy conservation measure that provides or saves a specific amount of energy during its life cycle results in the lowest present value of delivered energy costs of any available alternative..."*

The Commission opened Docket UM 1565, Investigation of Fuel Switching and Cross Fuel Energy Issues, in March 2013, the Commission concluded the docket with Order No. 13-104 and listed three specific findings related to Energy Trust's delivery of heat pump incentives.

- The Energy Trust has the discretion to provide the heat pump incentive to all customers, regardless of their heating source.
- The Energy Trust must revise its messaging and marketing activities related to the high-efficiency heat pump incentive and clarify its fuel switching policies consistent with the terms of this order.
- The Energy Trust must use an independent surveying entity to collect additional information about natural gas customers who receive the heat pump incentive.

In addition to these items, the Commission indicated it would revisit these decisions in early 2015 once Energy Trust had completed the third-party survey in Order No. 13-104.

In September 2015 the Commission issued Order No. 15-265 adopting Staff's recommendation to take no action regarding Order No. 13-104, without prejudice to Northwest Natural Gas Company. .

Order No. 15-265 included direction to Energy Trust to do two things. The Commission directed Energy Trust to:

1. Provide an economic analysis of the use of a heat pump for heating and cooling compared to the use of a standard natural gas furnace and electric air conditioning unit.
2. Provide information about possible high-efficiency air conditioning incentives.

Analysis

Background

Staff first notes that Orders 13-104 and 15-265 arose from an investigation in Docket No. 1565, which was opened in 2011, Northwest Natural Gas (NW Natural) raised questions about fuel switching as related to energy efficiency incentives. NW Natural contended that the absence of incentives for gas furnaces was leading to fuel switching. Energy Trust of Oregon (Energy Trust) maintained that its heat pump incentives were only relevant after the ratepayer has chosen to install a heat pump and only motivate installation of a higher efficiency model.

In January 2016 Energy Trust began the process of scoping the report required under Order No. 15-265 with Staff and with PGE, PAC, NWN, and CNG as a stakeholder review group. In March 2016, Energy Trust released a draft statement of work (SOW) to stakeholders. After several rounds of communications and at least two drafts, Energy Trust and the stakeholders finalized the SOW for the contract to research and write the report. In late April 2016 SBW Consulting Inc. (SBW) was selected through an open RFP process conducted by Energy Trust. Given the scope of work and the modeling runs required the contract amount was for $30,428. In August 2016, the first draft of the report was completed and reviewed by stakeholders for comments. Energy Trust worked with SBW and the stakeholders throughout September 2016 to edit the report and address concerns. The final report was submitted to Commission Staff in October 2016. Stakeholders had an opportunity to provide a last round of comments and in December 2016 the report was finalized and submitted to OPUC Staff.

Report's Findings

SBW's economic analysis was based on modelling the life-cycle cost (LCC) of the relevant HVAC systems and their life-cycle energy costs (LCEC). All life-cycle analysis is from the point of view of the home owner. SBW used the Regional Technical Forum's building energy simulation software, Simple Energy & Enthalpy Model (SEEM), to model estimated energy usage used by the LCC and LCEC analysis for the eight different types of systems.

The list below details the types of systems modeled:

1. New Gas Furnace[2] with New Central Air Conditioner (AC)[3]
2. Existing Gas Furnace[4] with New Central AC
3. Constant or Dual Speed Air-Source Heat Pump (ASHP)[5] with Electric Resistance
4. ASHP with Existing Gas Furnace
5. ASHP with New Gas Furnace
6. Variable Speed Air-Source Heat Pump (VSHP) [6] with Electric Resistance
7. VSHP with Existing Gas Furnace
8. VSHP with New Gas Furnace

Both types of air-source heat pumps require backup heat sources. Energy Trust, with stakeholder review group approval, selected three types of backup heat sources based on the homeowner survey conducted under UM 1565 and submitted to the Commission previously under Order No.15-265.

The life-cycle analysis for each of the eight modelled systems utilized eleven discreet elements in their calculation, with the analysis taking place over a 25-year term. In addition, SBW attempted to develop a range of typical outcomes across three different scenarios that would impact energy use.

Life Cycle Analysis Elements		
Financial Parameters	Useful Life	Term
Initial Costs	Install Costs	Tax Credits
Incentives	Maintenance Costs	Replacement Costs
Salvage Value	Energy Costs	

Scenarios
OR Region
Home Type
Shell Level

The graphic below represents a high-level overview of the economic analysis comparing the use of a heat pump and a natural gas furnace with air conditioning.

[2] New Gas Furnace Efficiency = AFUE 95. Based on 2014 market report from Navigant to Energy Trust. See pg. 3 of SBW report.
[3] New Air Conditioner Efficiency was based on data from RTF.
[4] Existing Gas Furnace Efficiency = AFUE 86. Based on regional average found in 2011 Residential Building Stock Assessment.
[5] Constant or Dual Speed Air-Source Heat Pump = HSPF 9.2/SEER 16. Based on Energy Trust program data.
[6] Variable Speed Air-Source Heat Pump = HSPF 12/SEER 18. Based on Energy Trust program data.

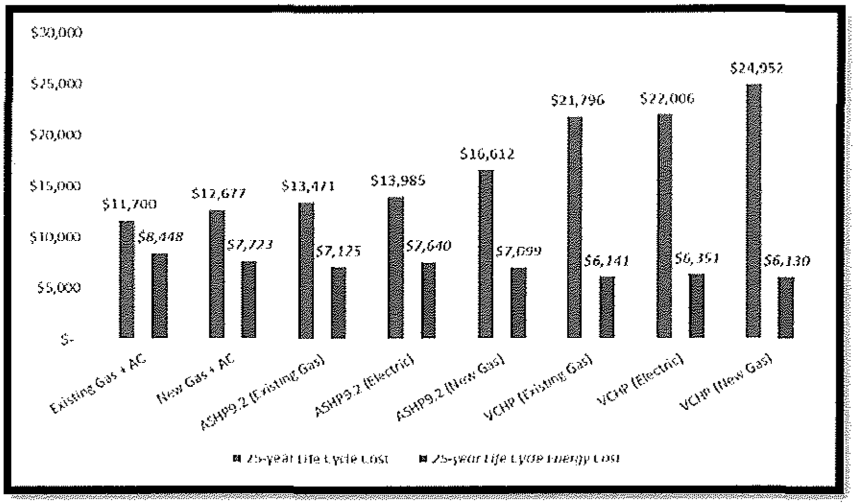


Figure 1: Average Life Cycle Total Costs and Life Cycle Energy Cost for the Systems Studied

The numbers for each of the eight modelled systems above reflect an overall average for the state. Overall averages were weighted by the population in Energy Trust territory. Given the low weight assigned to the eastern part of the state, the average results above reflect more of a moderate climate. SBW also developed a range of possible LCC outcomes for each modelled system.

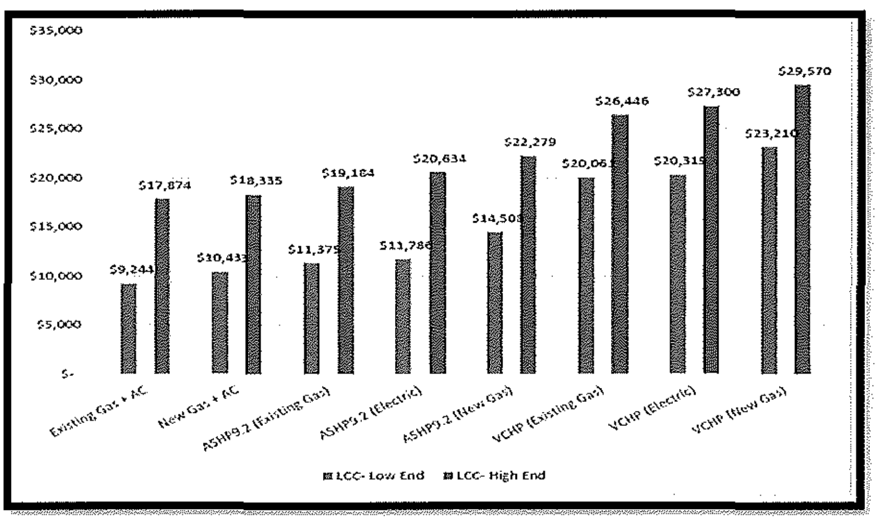


Figure 2: Range of Life Cycle Costs Depending on Energy Use for System Studied

Across all of the analysis conducted, looking at the eight types of systems and using agreed upon efficiencies, standards of operation, measure life, term length, costs home type, and customers by region, SBW's report found that generally:

- Gas furnace options had the lowest overall LCC.
- In colder climates gas furnace options were more cost competitive due to the need for backup heat.
- Heat pump technology had marginally lower operating costs in many cases with VSHP having the lowest overall energy costs.
- Heat pump technology tended to have the highest LCCs due to high initial costs.

Stakeholder Comments
Energy Trust conducted an open and collaborative process convening a stakeholder review group to scope, review and finalize this report. Stakeholders were able to use multiple opportunities to provide guidance and feedback to Energy Trust and SBW. While the amount of communication and coordination did delay the launch and added to the scope of this economic analysis report the final result was generally well received by stakeholders. Stakeholders had an opportunity to comment upon the final report, review any changes made to the final report based on their feedback. All comments and Energy Trust's responses are included in appendices to the report.

PGE suggested three changes to SBW's analysis. The main area of concern for PGE was in SBW's treatment of equipment life and the depreciated salvage value within the LCC. PGE noted that SBW's approach was inconsistent with regional practices for determining measure cost-effectiveness. Energy Trust responded that the approach used by SBW allowed for consistent treatment across of different types of equipment with a variety of measure lives over the 25-year term of the LCC analysis. Depreciation was done consistently on a linear basis due to an absence of depreciation information on this type of residential equipment.

NW Natural had three key concerns and thirteen other issues or comments on the report. The key concerns were:

- Inconsistent use of installed furnace and AC system costs.
- The estimation of natural gas use in SEEM overstates NW Natural's observed natural gas usage among their customers.
- The average heat pump system efficiency does not represent the average efficiency in the Oregon marketplace but rather the average efficiency of those systems represented by Energy Trust

NW Natural supported each of its concerns with a fair amount of research and analysis. Energy Trust addressed all concerns, issues and comments with changes to the final report or in explanations to stakeholders. With regards to inconsistent installed cost, Energy Trust and SBW changed the final report to address this concern.

With regard to NW Natural's concern regarding the overstatement of gas usage by SEEM, Energy Trust did agree that SEEM had limitations related to extrapolating gas results from its energy usage calculations. The RTF had worked to calibrate SEEM calculations to more accurately represent regional electric usage by households using data from regional utilities. SEEM has not undergone a similar process of calibration for natural gas. Instead, SEEM uses industry standards to convert modeled energy usage into estimated gas usage by representative average homes. NW Natural presented their own internal analysis of customer gas usage that was in fact less than the SEEM results.

From a process perspective, Energy Trust did note that all stakeholders were informed in the beginning that SEEM would be used as the energy modeling software for this economic analysis. SBW selected SEEM as its energy modeling software because of its familiarity with SEEM and the wide adoption of SEEM across the Pacific Northwest and in California for modeling and analyzing residential energy usage.

Energy Trust did approach SBW about adjusting the scope of its work to calibrate SEEM results using actual NW Natural billing data, as NW Natural suggested in its September comments. SBW informed Energy Trust that such work would significantly delay the completion of the project and increase the cost of the contract due to the required extensive interactions among the various utilities and other stakeholders.

NW Natural also suggested that its concern about overstating gas usage could be addressed by reducing the natural gas usage by 30 percent based on NW Natural's internal data and billing analysis provided in its comments.

With regards to heat pump system efficiency, Energy Trust did not change the report. Instead Energy Trust chose to explain the decision to use only the data on the systems they incent. Energy Trust felt that this docket and the question that launched this report were in relation to its heat pump program. Assessing the entire Oregon market expanded the scope of the report beyond the docket and what SBW was contracted to analyze.

With regards to NW natural's thirteen other comments, edits and questions please see the report's appendices. In conclusion, NW Natural was appreciative of the work done but still felt that technical aspects regarding natural gas consumption should be better addressed.

Staff Comments
The process to produce this report relied on an extensive amount of collaboration. All stakeholders appear to be appreciative of the process to produce this report and the work that went into it. Given the comparative nature in conducting an economic analysis of disparate types of technology, the available tools for the analysis and the positions of the stakeholders, Staff found that Energy Trust and the consultant SBW did a good job balancing many tradeoffs. The results, while not absolutely definitive, are useful in addressing the Commission's questions regarding the comparative economics of heating and cooling when using a heat pump system or a natural gas furnace system combined with air conditioning.

NW Natural's observation about the overstatement of natural gas usage was the comment of greatest concern to staff. Energy Trust consulted with Commission Staff regarding options to address this issue when it was raised. Upon learning of the trade-offs in addressing NW Natural's concern Staff determined that while the report's analysis could be improved the use of SEEM was sufficient and fair given the requirements of the Commission, the budget and time spent to date, and the results themselves. While Staff understands and to some extent agrees with NW Natural's concern regarding SEEM's technical limitations Staff finds:

- The report's results were reasonable given the technical limitations of SEEM.
- NW Natural's concerns about SEEM's technical limitations could have been raised earlier in the process.
- NW Natural's proposed solution to reduce gas usage by 30 percent in certain instances, based on NW Natural's own analysis, has spillover effects as stakeholders and utilities involved would want to review NW Natural analysis before accepting this action. Further, others may have, in turn, requested a similar level of customization, potentially adding even more cost and time to the analysis.

Conclusion

Staff finds the economic comparison of heat pumps and furnaces combined with new air conditioning units in this report fair, thorough and complete. The report meets the needs of the Commission as expressed in Order No. 15-265. Staff appreciates the time, effort, and expertise contributed by all of the stakeholders in UM 1565 to deliver this complex report in just under one year.

PROPOSED COMMISSION MOTION:

Accept as compliant with Order No. 15-265 the attached economic analysis overseen by Energy Trust comparing the use of a heat pump for heating and cooling compared to a natural gas furnace and electric air conditioning.

UM 1565 Economic Analysis Comparing Heat Pumps Systems to Furnace Systems

ECONOMIC COMPARISON OF RESIDENTIAL GAS FURNACE AND HEAT PUMP SYSTEMS

Submitted to **Energy Trust of Oregon**

Submitted by **SBW CONSULTING, INC.**
2820 Northup Way, Suite 230
Bellevue, WA 98004

December 15th, 2016

ENERGY + WATER + EFFICIENCY

EXECUTIVE SUMMARY

The Oregon Public Utilities Commission (OPUC) directed the Energy Trust of Oregon (Energy Trust) to prepare an economic analysis comparing the use of residential gas furnace systems with heat pump systems (OPUC *UM 1565 Order No. 15-265*). Energy Trust contracted with SBW Consulting, Inc. (SBW) to perform the analysis.

SBW developed a life cycle comparison of the relevant HVAC systems. SBW estimated the *average* life cycle costs (LCC's) for an Oregon homeowner, for each of the following HVAC systems. Efficiency levels for the heat pump systems are based on those incentivized in Energy Trust's heat pump program. Efficiency levels for the gas systems are based on Oregon averages.

- New gas furnace plus new central air-conditioning (AC)
- Existing gas furnace plus new central AC
- Constant speed air-source heat pump (ASHP) with existing gas furnace backup
- Constant speed ASHP with new gas furnace backup
- Constant speed ASHP with electric resistance backup
- Variable speed air-source heat pump (VSHP) with existing gas furnace backup
- VSHP with new gas furnace heat backup
- VSHP with electric resistance backup

SBW also modeled the *range* of typical LCC's by varying the expected annual heating and cooling energy use. Heat and cooling energy use was estimated with the SEEM simulation model and varied based on home construction details, insulation levels and the climatic location. These variations on heating and cooling energy use were used to estimate high, low and average LCC's, as well as life-cycle energy costs, for each HVAC system.

The modeled average LCC's are shown below for each of the HVAC systems. Also shown are the life-cycle energy costs for each system. The system with the lowest LCC is the one with the highest energy costs, due to the relatively low initial costs for this system. The systems with the lowest energy costs have the highest LCC's due to relatively high initial costs. All systems were modeled for a 25-year term.

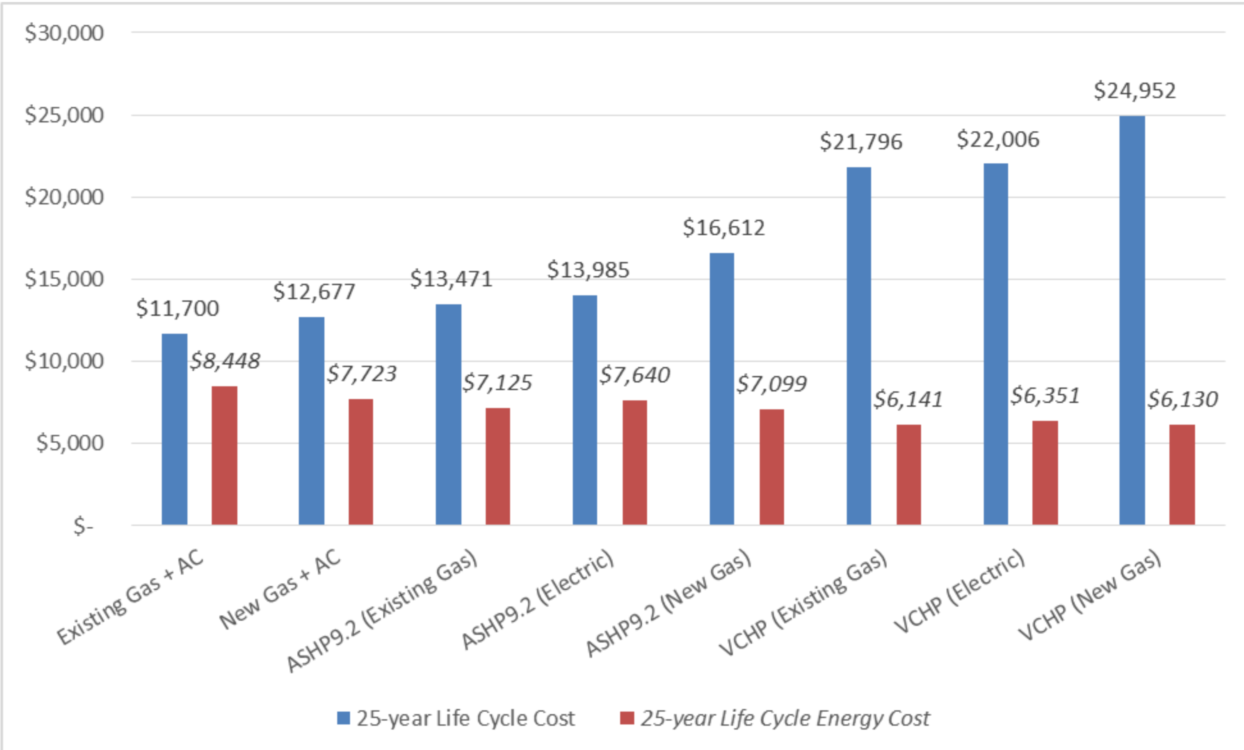


Figure 1: Average Life Cycle Total Costs and Life Cycle Energy Costs for Systems Studied

The range of LCC's for each of the systems is shown below. The higher costs are attributable to higher energy costs due to colder climate, larger home, and/or poorly insulated home.

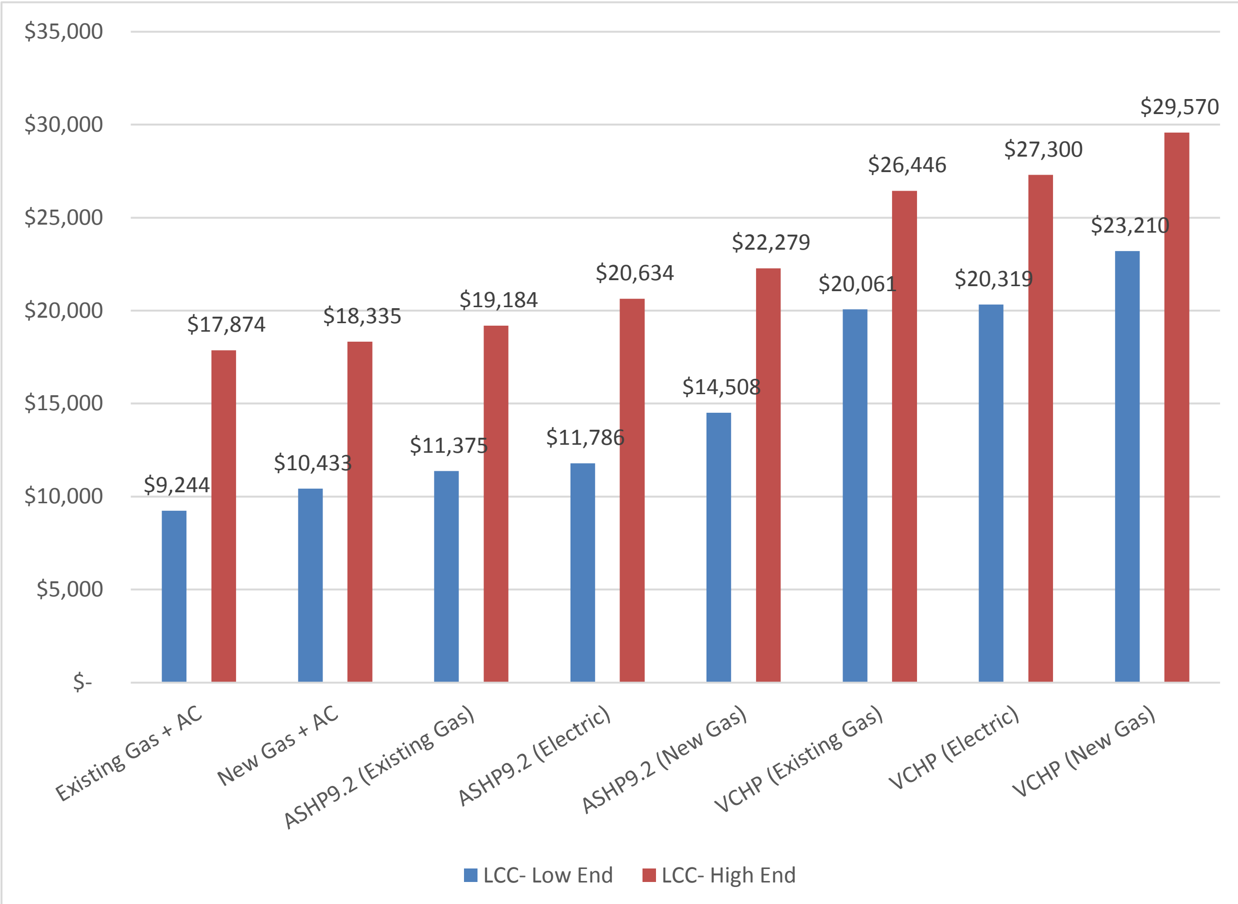


Figure 2: Range of Life Cycle Costs Depending on Energy Use for Systems Studied

The system with the lowest LCC was the existing gas furnace plus new AC. The average LCC for the new gas furnace option was an average of 8% greater, and the average LCC for the heat pump with existing gas backup was 15% greater than the lowest cost option. The VSHP systems were significantly greater in LCC, though energy costs were lowest for these systems.

Table of Contents

1. INTRODUCTION

The Oregon Public Utilities Commission (OPUC) directed the Energy Trust of Oregon (Energy Trust) to prepare an economic analysis comparing the use of residential gas furnace systems with heat pump systems (OPUC *UM 1565 Order No. 15-265*). Energy Trust contracted with SBW Consulting to perform the analysis.

A previous study[1] as part of this docket surveyed homeowners who have switched from a gas furnace to an electric heat pump as their primary home heating system. Homeowners were asked the reasons for making the switch. Homeowners were also asked what kind of heating system provided their backup heat. Responses to this latter question informed the choice of HVAC systems to include in the present analysis.

SBW developed a life cycle cost (LCC) comparison of the relevant HVAC systems. The life cycle analysis is from the point of view of the homeowner. Methodology and results are presented in this report.

[1] http://edocs.puc.state.or.us/efdocs/HAD/um1565had125453.pdf

2. Methodology

A life cycle cost (LCC) analysis includes a number of elements and assumptions. This section describes the components of the analysis.

2.1. Approach

The actual LCC experienced by a homeowner will depend on many factors, including the following.

- Installation costs
- Maintenance costs
- HVAC system life span (sometimes referred to as Estimated Useful Life or EUL)
- Thermostat setpoints and other occupant behaviors
- HVAC system efficiency
- Weather
- Home "shell" parameters, including insulation, window U-factor, air infiltration, and duct leakage
- Home construction details, such as size of the home, number of stories, and amount of window space
- Heating and cooling energy costs
- Homeowner discount rate

SBW's approach is to use estimates of average values for the following.

- Weather (using Typical Meteorological Year (TMY3) data for three Oregon cities)
- Initial costs
- HVAC system life spans
- Thermostat settings

In addition, we show the expected range of typical LCC's by varying the following parameters, each of which has a significant impact on annual energy usage.

- Location in Oregon
- Home shell parameters
- Home construction details

We modeled the impact of variations in these parameters using the building energy simulation software used in the Pacific Northwest by the Regional Technical Forum (RTF), the Simple Energy and Enthalpy Model (SEEM) developed by Ecotope, Inc.[2] SEEM models the heating and cooling *load*, and infers input energy use according to HVAC system parameters such as efficiency level and duct losses. SEEM has been calibrated for electric heating and cooling systems using utility bills. SEEM has not been calibrated for gas furnaces. SEEM instructions state, “For Gas Furnace, use FUR [electric furnace code] and apply AFUE to output.”[3] This is the approach used here.

2.2. HVAC Systems Analyzed

This analysis performed here assumes that the customer’s existing HVAC system is a gas furnace without AC. It is reasonable to assume that in some of these cases, the existing gas furnace is not at the end of its useful life, and in other cases the furnace needs to be replaced. For this reason SBW modeled the LCC of the following two gas HVAC system scenarios.

- New gas furnace, together with a new central AC system. The efficiency assumed for the furnace (AFUE 95) was based on market data for systems sold as reported in the Energy Trust 2014 HVAC Market Update.[4] The efficiency level of the AC system was based on assumptions used by the Regional Technical Forum (RTF) as part of the RTF’s heat pump measure.[5]
- Existing gas furnace, together with a new central AC system. The efficiency of the furnace (AFUE 86) was based on the average found in the regional Residential Building Stock Assessment (RBSA).[6]

SBW examined records of heat pump systems that received Energy Trust incentives. These incentives encourage the purchase of higher than average efficiency heat pumps. Energy Trust program data showed two distinct classes of air source heat pumps – constant speed and variable speed (also known as variable capacity). These classes differ significantly in performance and price. We modeled the following two types of heat pump.

- Constant or dual speed air-source heat pump with the average efficiency level found in Energy Trust program data from 2015-16 for this class of heat pump (HSPF 9.2/SEER 16). We used the abbreviation ASHP to refer to this system.
- Variable speed air-source heat pump (VSHP) with efficiency level determined by the simulation software. The SEEM model of a VSHP is based on actual VSHP performance curves, but it is a limitation of the SEEM model that it does not provide a simple mechanism

[2] http://rtf.nwcouncil.org/measures/support/SEEM/Default.asp

[3] http://rtf.nwcouncil.org/measures/support/SEEM/SEEM97.zip, SEEM workbook, tab “Reference”

[4] Navigant Consulting, 2014 HVAC Market Update, Energy Trust of Oregon, 2014, http://energytrust.org/library/reports/HVAC_Market_Update_140527.pdf

[5] http://rtf.nwcouncil.org/measures/res/ResSFExistingHVAC_v4_1.xlsm

[6] David Baylon et al, 2011 Residential Building Stock Assessment: Single Family Characteristics and Energy Use, Ecotope, NEEA, 2012

to vary the efficiency level of the VSHP. The level provided (HSPF 12/SEER 18) is higher than most of those actually installed according to program data. This model represents the high-end of air-source heat pump available on the market today.[7]

A heat pump system requires a backup heating source. According to the survey of homeowners, the following three backup systems were common[8]. SBW modeled both heat pumps with each of these backup systems, making a total of six heat pump systems.

- Electric resistance
- Existing gas furnace
- New gas furnace

2.3. LCC Components

A life cycle study involves a number of elements and assumptions. The components of this study are described in this section.

2.3.1. Financial Parameters

Energy Trust provided these financial parameters, which we used in all LCC calculations.

- Real discount rate = 4.5%
- Inflation rate = 1.9%

2.3.2. Equipment Effective Useful Life (EUL)

Table 1 shows the standard EUL's assumed by Energy Trust for HVAC equipment. The true EUL for the VSHP may differ from that of a standard ASHP – the variable speed control may cause less wear on the motor and compressor. However, the VSHP is relatively new technology and we do not have a basis for changing its EUL from that assumed by Energy Trust for the ASHP. The "existing gas furnace" is modeled as having half of its EUL (12.5 years) remaining.

Table 1: Equipment Effective Useful Life (EUL)

Equipment	EUL (years)
Gas furnace	25
Central AC	18
ASHP	18
VSHP	18

[7] Energy Trust's 2014 HVAC Market Study found that Heat Pumps with HSPF 9.5 or higher occupied a small portion of the overall Oregon heat pump market (3%-13%), but Energy Trust has seen a trend of the program volume of these high efficiency heat pumps increasing in more recent years

[8] http://edocs.puc.state.or.us/efdocs/HAD/um1565had125453.pdf

2.3.3. Term of Study

The term of this study is the EUL of the gas furnace – 25 years. Equipment with a shorter EUL will need to be replaced during the study as described below. This equipment will have useful life remaining at the end of the term of study, and a salvage value is assigned to those units.

2.3.4. Initial Costs

Initial costs include installation labor and materials, as well as Energy Trust rebates and federal and state tax credits.

2.3.4.1. Installation costs

RTF workbooks were the main source used to determine installation costs.[9,10] This provided a single, regionally-accepted, source for all of the HVAC systems. We used the RTF “midpoint” values to arrive at single values for each of the systems. We also used online sources to verify that RTF values were within the range of costs reported by other sources.[11,12] In the case of a new AC system, the RTF value was significantly lower than that found from online sources.[13] However, we used the RTF value for the AC system cost in order to use a consistent source for all HVAC systems.

2.3.4.2. Tax credits

The state of Oregon and the federal government offer tax credits for efficient residential HVAC systems. The relevant tax credits are described below.

Gas Systems

The state of Oregon provides a $352 tax credit for a gas furnace with AFUE between 95 and 96.9.[14] The new gas furnace modeled in this study qualifies for this incentive, and this benefit was included as part of the initial cost for this system. The federal government provides a $200 credit for this system.[15] The AC system which we modeled (SEER 14.5) did not qualify for any tax credits.

[9] http://rtf.nwcouncil.org/measures/support/files/RTFStandardInformationWorkbook_v2_6.xlsx

[10] http://rtf.nwcouncil.org/measures/res/ResSFExistingHVAC_v4.xlsm

[11] http://www.improvenet.com/r/costs-and-prices/heat-pump-installation-cost-estimator

[12] http://www.homeadvisor.com/cost/heating-and-cooling/install-a-furnace/

[13] http://www.homeadvisor.com/cost/heating-and-cooling/install-an-ac-unit/

[14] http://www.oregon.gov/energy/cons/docs/RETC_Rates_2016.pdf

[15] https://www.energystar.gov/about/federal_tax_credits/natural_gas_propane_oil_furnace

Heat Pump Systems

Oregon provides an $800 tax credit for heat pumps with HSPF of 9.5 or greater. According to Energy Trust program data, 33% of incented ASHP's in 2015-16 had HSPF greater than or equal to 9.5. We assigned a tax credit to these heat pumps of 33% of $800. Oregon provides a $1000 tax credit for heat pumps with HSPF of 12 or greater. The modeled VSHP's meet this criterion, and we assigned a benefit in that amount for the VSHP's.

Heat pumps are eligible for a federal tax credit of $300 if the HSPF is greater than 8.5 and the SEER is greater than 15.[16] Both ASHP and VSHP systems qualify for this credit.

2.3.4.3. Energy Trust Incentives

When a non-electric heating system is replaced with a heat pump, Energy Trust provides an incentive of $250 for a heat pump with HSPF greater than or equal to 9.0, and $500 with HSPF greater than or equal to 9.5.[17] The ASHP modeled here qualifies for the $250 incentive, and the VSHP qualifies for the $500 incentive.

2.3.5. Maintenance Costs

Maintenance practices vary widely in the residential sector. Researchers investigating fault detection noted:[18]

> Current residential HVAC maintenance practices face many challenges and opportunities for enhancement. Traditionally, these practices are open to varying interpretations and are reactive in nature. Homeowners typically do not have maintenance contracts established for regular servicing of their HVAC equipment. Homeowners usually call in for maintenance after their equipment fails. HVAC service contractors are then placed in reactionary situations, requiring them to assess and resolve issues chaotically and rapidly. Often, current repair and maintenance practices are not necessarily aimed at bringing HVAC equipment back up to optimum efficiency levels. In addition, some variables influencing HVAC performance (equipment type, faults, indoor/outdoor conditions, etc.) are largely uncontrollable in the field and present their own unique challenges for accurately assessing and resolving maintenance issues.

In most years, maintenance costs would be zero, but at a cost in system efficiency that would be difficult to quantify for all systems. At irregular intervals, repair costs would be incurred.

An alternative to quantifying the degradation in performance and the irregular repair costs would be to quantify the annual costs necessary to maintain the equipment efficiency levels. However, we could not locate sources for these costs for all the systems. The Northwest Power and Conservation Council (NWPCC) studied the issue in 2012, and did provide an estimate of

---

[16] https://www.energystar.gov/about/federal_tax_credits/air_source_heat_pumps

[17] http://energytrust.org/residential/incentives/heating-and-cooling/heatpumps1

[18] http://aceee.org/files/proceedings/2014/data/papers/1-471.pdf

annual maintenance costs for both gas and heat pump systems, but did not identify a source or the nature of the expenses.[19] A study by Oak Ridge National Lab (ORNL) provided estimates of annual expenses and identified the nature of the expenses, but the study is from 1986.[20] Heat pump technology has advanced considerably since that time and therefore the ORNL estimates were not seen as representative of the maintenance costs for heat pumps installed today. ACEEE compared life cycle costs of gas furnace and heat pump systems but did not include annual maintenance costs.[21]

Maintenance costs are not necessarily insignificant. However, they will be substantially less than initial costs and life-cycle energy costs. Furthermore, all system types will incur costs that are at least of the same order of magnitude. In the absence of good data, it was decided to omit maintenance costs from the analysis.

2.3.6. Replacement Costs

Several of the HVAC systems in the study reach the end of their useful lives during the term of the study. The heat pump and AC systems are modeled as being replaced after 18 years. The existing gas furnace is modeled as being replaced after 12.5 years, half of its full useful life.

HVAC systems are modeled as being replaced by the same type of system. The cost for all replacement systems is the same in real terms as the initial cost for the system. The LCC cost is the present value of this replacement cost.

2.3.7. Salvage Value

At the end of the term of study, most of the systems have remaining useful life. A salvage value is credited to the LCC for these systems. The salvage value is based on the assumption that the system loses value in a linear fashion from its initial cost to its final value of zero at the end of its useful life. For example, a system that has half of its useful life remaining at the end of the study period will be credited with half of its original value in real terms. The salvage value is the present value of this value remaining at the end of the term of study.

2.3.8. Energy Costs

Annual energy usage was derived with SEEM, as noted above. The RTF has developed considerable support tools for SEEM simulations, including Unit Energy Savings (UES) measure workbooks that incorporate assumptions about typical Northwest residential building construction. SEEM results have been calibrated to electric energy bills for a sample of homes.

---

[19] Direct Use of Natural Gas, Council Document 2012-01, https://www.nwcouncil.org/media/30071/2012_01.pdf Appendix D DUGAppendixD_LCCSystemSummaries_110411.xlsx

[20] V.C. Mei and E.A. Nephew, Life-Cycle Cost Analysis of Residential Heat Pumps and Alternative HVAC Systems, Oak Ridge National Laboratory, 1987, http://web.ornl.gov/info/reports/1987/3445602795456.pdf

[21] Steven Nadel, Comparative Energy Use of Residential Gas Furnaces and Electric Heat Pumps, ACEEE, 2016, http://aceee.org/comparative-energy-use-residential-furnaces-and

Ecotope and the RTF have developed three standard home prototypes, and weighting factors to apply to each of them to estimate results for the "average" case. We used these prototypes along with the weighted average case for this study.

SEEM includes models for the following HVAC systems.

- Electric furnace with ducts
- Central AC
- ASHP
- VSHP

Results for gas furnaces are obtained by applying the efficiency of the gas furnace to the results for the modeled electric furnace.

2.3.8.1. Location Differences

We selected three regions in Oregon in order to model the impact of weather, and also of utility rates, on the LCC results. We used TMY3[22] weather for three Oregon cities in simulating home energy use. We also estimated energy prices for each of these regions, as the utility rates vary with location. The following table shows the city locations modeled. The heating and cooling degree day values give an idea of the difference in weather between the regions. Where a city represents a region with more than one gas utility, the utility rate used is the simple average of the rates for the two utilities.

Table 2: Regions modeled, with utilities

City	Heating Degree Days	Cooling Degree Days	Electric Utility	Gas Utility
Redmond	6583	204	PacifiCorp	Cascade Natural Gas/Avista
Portland	4187	367	Portland General Electric	Northwest Natural Gas
Medford	4530	601	PacifiCorp	Avista

Some results are reported on a location basis, and some results are reported for the overall Oregon average case. The overall average case is the weighted average of the above regions. Gas and electric utility territories do not completely overlap, so there is no exact way to derive a weight for each region. Based on inspection of the utility territory maps, counties were selected as belonging to one of the regions represented by the cities shown above. The county populations were summed to provide the weights for each region. Results are shown in the following table. Given the low weight assigned to the eastern part of the state, average results can be expected to reflect a moderate climate.

[22] http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/

Table 3: Regional weights

Region	Weight
Portland	66%
Redmond	9%
Medford	25%

Utility Rates

The utility rates used for each region are shown in the table. The rates were found on utility websites. The low electric rate applies to usage under 1000 kWh per month; the high rate applies after that limit. Since this study is investigating the conversion from a gas system to an electric system, we assumed that any use over 1000 kWh in a month is due to electric space conditioning, and applied the higher rate to space conditioning where total usage exceeded 1000 kWh/month. SEEM only reports heating and cooling electrical usage, so we estimated the proportion of monthly electric usage that goes to space conditioning with additional simulations for Portland using Energy Plus.[23] These simulations were used to derive a relationship between annual energy use and monthly use over 1000 kWh. With these simulations we estimated that space-conditioning annual use over 2500 kWh should be assigned the higher rate.[24]

Table 4: Regional Utility Rates

Region	Electric Rate Low ($/kWh)	Electric Rate High ($/kWh)	Gas Rate ($/therm)
Weighted Average	$0.10394	$0.11548	$0.97830
Portland	$0.10601[25]	$0.11323	$0.93513[26]
Redmond	$0.09988[27]	$0.11988	$0.97[28,29]
Medford	$0.09988[30]	$0.11988	$1.09611[31]

23 https://beopt.nrel.gov/

24 See analysis in ETO_HVAC_Costs.xlsm, tab "Monthly kWh > 1000"

25 https://www.portlandgeneral.com/our-company/regulatory-documents/tariff

26 https://www.nwnatural.com/uploadedFiles/252ai%286%29.pdf

27 https://www.pacificpower.net/content/dam/pacific_power/doc/About_Us/Rates_Regulation/Oregon/Approved_Tariffs/Oregon_Price_Summary.pdf

28 http://www.cngc.com/docs/default-source/rates-tariffs/0101_residential_service_rate.pdf?sfvrsn=24

29 https://www.avistautilities.com/services/energypricing/or/curgas/Documents/OR_G_shortcuts_5.1.16.pdf

30 https://www.pacificpower.net/content/dam/pacific_power/doc/About_Us/Rates_Regulation/Oregon/Approved_Tariffs/Oregon_Price_Summary.pdf

31 https://www.avistautilities.com/services/energypricing/or/curgas/Documents/OR_G_shortcuts_5.1.16.pdf

2.3.8.2. Differences in Home Construction

The RTF provides three home prototypes for use with SEEM. The prototypes represent typical home construction in the Pacific Northwest. The RTF also provides weighting factors to apply to each prototype such that the weighted results are representative of overall regional single-family home energy use. The prototypes are free-standing single family construction with floor areas of 1,344, 2,200, and 2,688 square feet. All prototypes include an attic. The smaller prototypes have a crawl space; the largest has a basement. The 2688 square foot prototype has two stories; the 2200 square foot prototype has a partial second story. Modeled energy usage is actually greater in the 2,200 square foot home than in the 2,688 square foot model, because the heating and cooling ducts are inside conditioned space only in the larger model, and therefore duct leakage is not lost energy.

SBW simulated each HVAC system with each of the three home prototypes.

2.3.8.3. Differences in Home Shell

Shell parameters greatly affect a home's energy consumption. These parameters include insulation, window heat losses, air infiltration, and duct leakage. In order to find the range of energy consumption in typical homes, SBW varied the shell parameters in simulations for each of the HVAC systems and each of the home prototypes. The table below shows the parameters varied. The values were derived from the RBSA report and from SEEM defaults. We used the RTF default air infiltration value in all simulations.

Table 5: Home Shell Parameters

Shell Level	Wall Insulation R-value	Ceiling Insulation R-value	Floor Insulation R-value	Window U-factor	Duct Leakage, %
Poor	5.3	2.6	6.5	1.04	13.5%
Average	11	25	18	0.49	12%
Good	19	49	28	0.28	6%

2.4. Scenarios

For each HVAC system, SBW ran simulations for each city (3), prototype (3) and shell level (3). SEEM outputs were converted from electric kWh to gas therms for the gas furnace primary systems and backup systems by applying the furnace efficiency factor described in Section 2.2. Average Oregon results were obtained by applying the regional weights from Table 3. Average home prototype results were obtained using the RTF prototype weights.

With this process the following results are obtained for each HVAC system.

- Overall average – Weighted average weather, home prototype weighted average, and average shell

- Regional impact – Range of LCC's that result from varying the region and using the average home prototype and the average shell
- Shell impact – Range of LCC's that result from varying the shell and using the average region and average home prototype
- Home prototype impact – Range of LCC's that result from varying the prototype and using the average region and average shell
- Overall range – The minimum and maximum LCC's across all these results

3. RESULTS

The following tables and charts show modeling results. In general, the gas furnace options have the lowest life cycle costs, with ASHP systems with electric or existing gas furnace backup as the next lowest options. The gas furnace options are more cost competitive in the colder climate, reflecting the need to use more backup heat (which is less efficient than a heat pump) in a colder climate. The VSHP options have the lowest energy costs but the highest LCC's due to high initial costs.

3.1. Initial Costs

Initial costs include installation labor and materials, as well as various incentives – a rebate from Energy Trust, an Oregon tax credit, and a federal tax credit. The assumption is that the homeowner received all incentives for which they were eligible. The table shows the initial cost assumptions used in the analysis, in 2016 dollars.

Table 6: Initial Costs (2016 Dollars)

HVAC System	Backup System	Installation	Rebate	Oregon Tax Credit	Federal Tax Credit
New Gas + AC	Gas	$ (5,124)	$ -	$ 352	$ 200
Existing Gas + AC	Gas	$ (1,957)	$ -	$ -	$ -
ASHP9.2	New Gas	$ (9,158)	$ 250	$ 268	$ 300
ASHP9.2	Existing Gas	$ (5,991)	$ 250	$ 268	$ 300
ASHP9.2	Electric	$ (5,991)	$ 250	$ 268	$ 300
VCHP	New Gas	$ (17,766)	$ 500	$ 1,000	$ 300
VCHP	Existing Gas	$ (14,599)	$ 500	$ 1,000	$ 300
VCHP	Electric	$ (14,599)	$ 500	$ 1,000	$ 300

3.2. Replacement and Salvage Costs

Each of the systems analyzed involved a major replacement at some point during the 25 year term, and each of the systems had some useful life at the end of the term. The following table shows the net present value of the replacement and salvage costs for each of the systems, in 2016 dollars.

Table 7: Net Present Value of Replacement and Salvage Costs (2016 Dollars)

HVAC System	Backup System	Replacement	Salvage	Total
New Gas + AC	Gas	$ (631)	$ 249	$ (383)
Existing Gas + AC	Gas	$ (2,075)	$ 781	$ (1,294)
ASHP9.2	New Gas	$ (1,933)	$ 761	$ (1,172)
ASHP9.2	Existing Gas	$ (1,933)	$ 761	$ (1,172)

HVAC System	Backup System	Replacement	Salvage	Total
ASHP9.2	Electric	$ (1,933)	$ 761	$ (1,172)
VCHP	New Gas	$ (4,711)	$ 1,854	$ (2,856)
VCHP	Existing Gas	$ (4,711)	$ 1,854	$ (2,856)
VCHP	Electric	$ (4,711)	$ 1,854	$ (2,856)

3.3. Average Annual Energy Use and Costs

Modeled annual energy use is shown below for the average case, which assumes the following:

- Weighted average region
- Weighted average home prototype
- Average shell parameters

The range of annual energy use and costs is shown in Appendix A.6.

Table 8: Average Annual Energy Use and Costs (2016 Dollars)

HVAC System	Annual Electric kWh	Annual Gas Therms	Annual Electric Cost	Annual Gas Cost
Existing Gas + AC	902	611	$ 94	$ 598
New Gas + AC	902	550	$ 94	$ 538
ASHP9.2 (Existing Gas)	5,116	22	$ 562	$ 21
ASHP9.2 (Electric)	5,666	-	$ 625	$ -
ASHP9.2 (New Gas)	5,116	20	$ 562	$ 19
VCHP (Existing Gas)	4,527	9	$ 494	$ 9
VCHP (Electric)	4,752	-	$ 520	$ -
VCHP (New Gas)	4,527	8	$ 494	$ 8

3.4. Average Life Cycle Costs

The estimate of the average life cycle costs is based on the initial, replacement, and salvage costs shown above, and simulated energy costs assuming the following:

- Weighted average region
- Weighted average home prototype
- Average shell parameters

As shown below (results are also presented in tabular form in the Appendices), the system with the lowest overall LCC has the highest life cycle energy costs, due to the low initial costs for the “existing gas furnace + AC” option. The gas furnace and ASHP systems are close in overall LCC, with the exception that the ASHP with a new gas furnace as backup has a higher LCC than the other ASHP options. The VCHP systems have the lowest energy costs, but the highest LCC's.

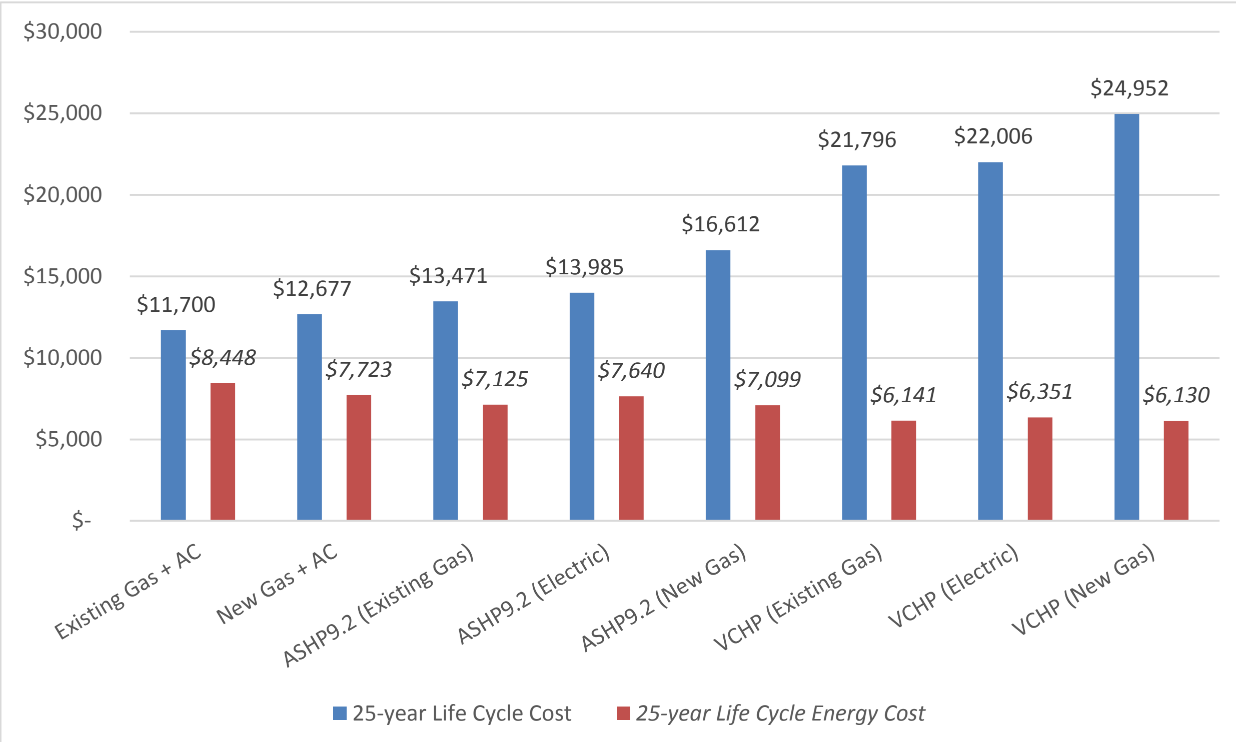


Figure 3: Total Life Cycle Costs and Life Cycle Energy Costs (2016 Dollars)

3.5. Impact of Location on LCC

The following chart shows the city location impact on LCC. These are the simulated results for the weighted average home prototype and the average shell level. The low end of the range applies to Portland, due to the warmer climate. The high end applies to Redmond in all cases except the "Existing Gas + AC" system, which applies to Medford (the higher cost of AC in Medford compared with Redmond is the reason). The ASHP options are more cost competitive in the more moderate climate, while both gas options are more cost competitive in the colder climate.

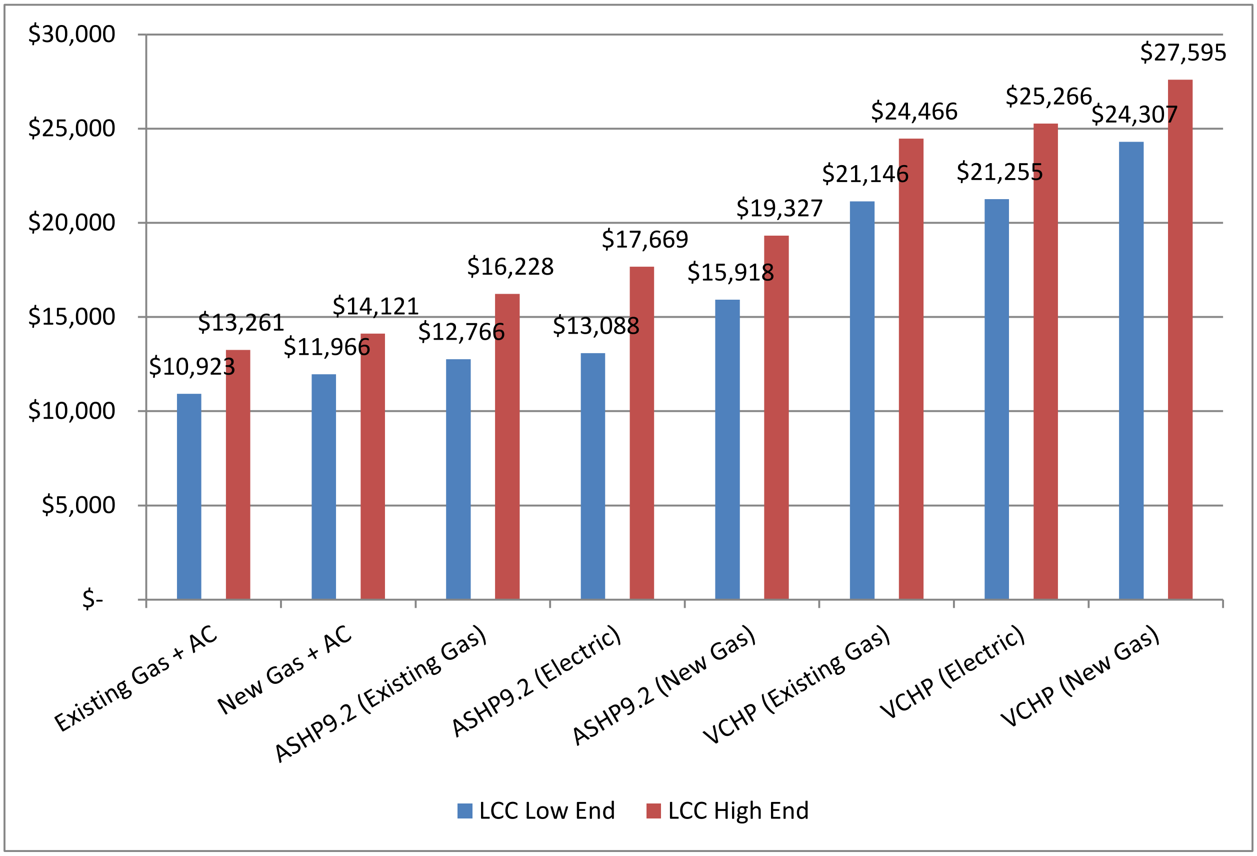


Figure 4: Location Variation in LCC (2016 Dollars)

3.6. Impact of Home Prototype on LCC

The following chart shows the impact of varying the home prototype on the LCC. These results are for the weighted average region and the average shell level. The low end of the cost range is for the prototype with the smallest floor area (1,344 square feet). The high end is for the prototype with the highest annual usage, which is a split level home with a 2,200 square foot floor area.

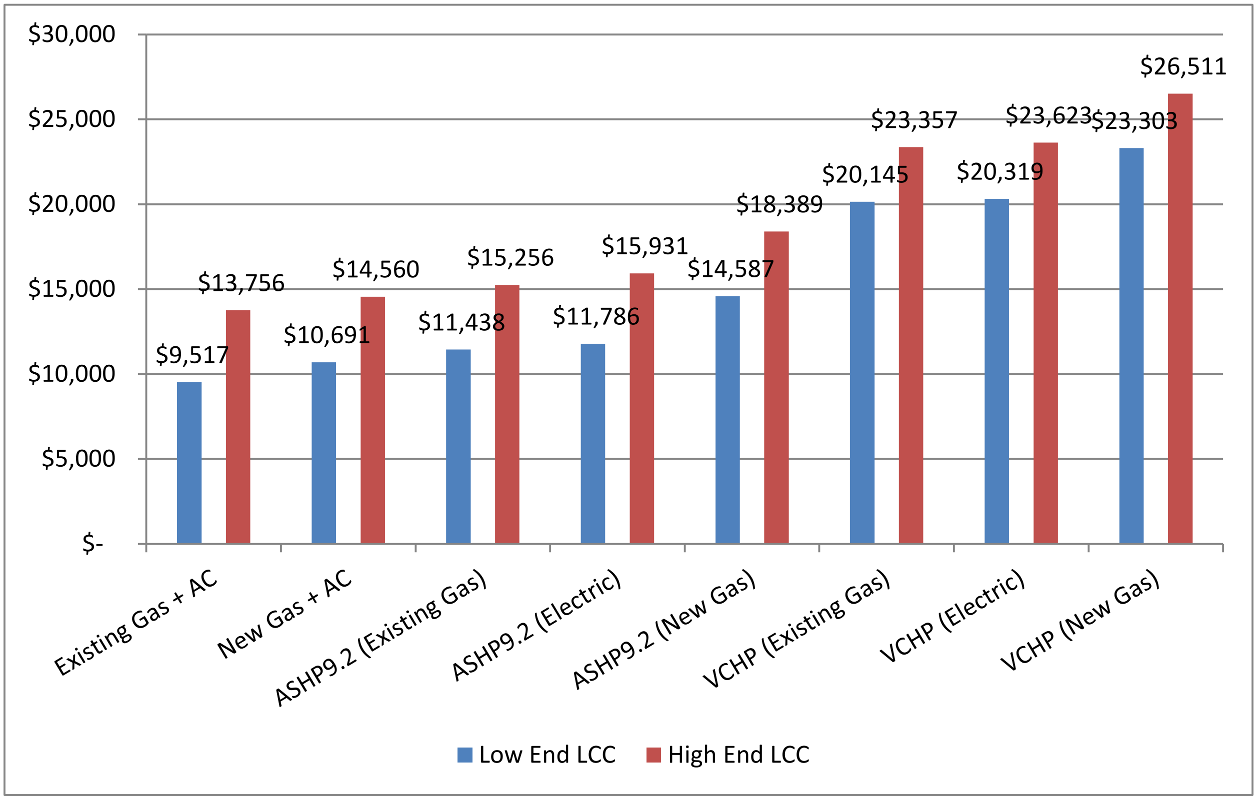


Figure 5: Home Prototype Variation in LCC (2016 Dollars)

3.7. Impact of Shell on LCC

The impact of poor vs. good shell on the LCC is shown in the following chart. For these simulations, the region is the overall weighted average region, and the home prototype is the weighted average prototype. The shell level has a greater impact on the LCC than region or home prototype.

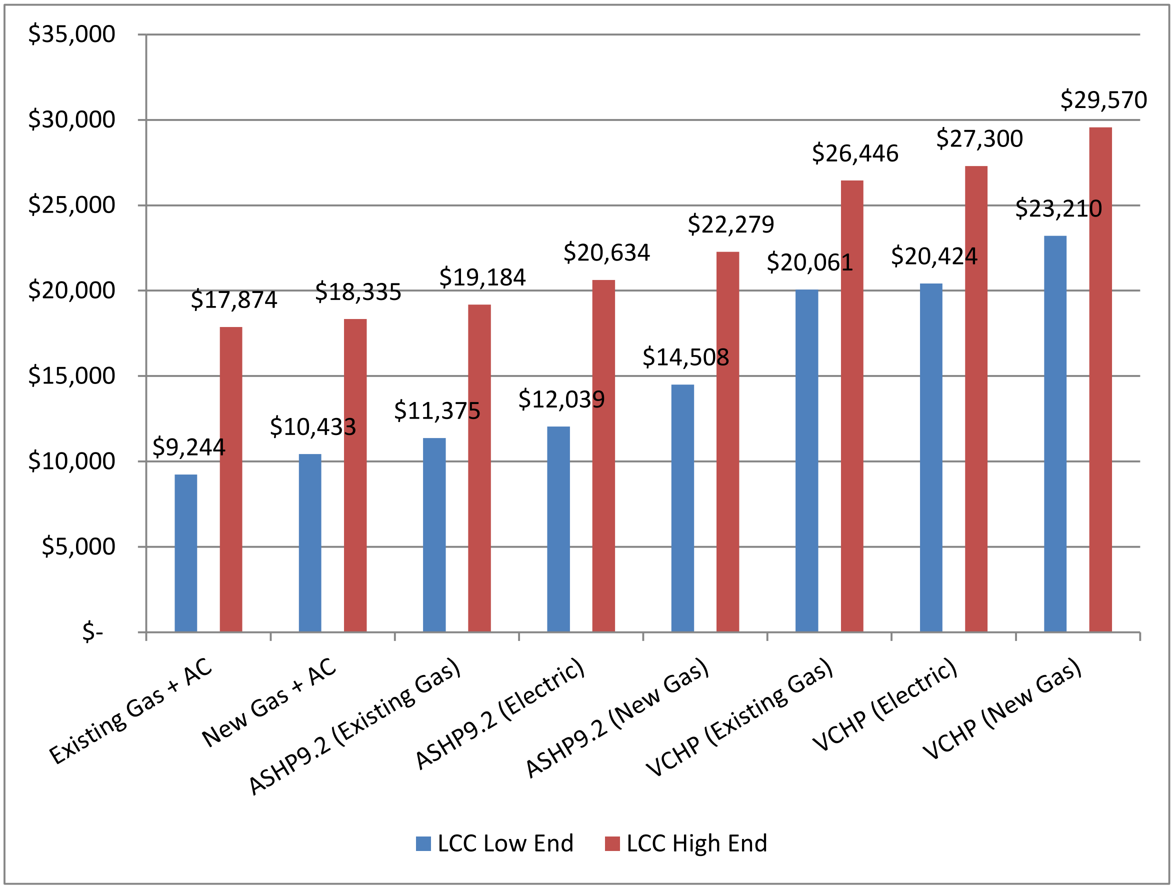


Figure 6: Shell Insulation Level Variation in LCC (2016 Dollars)

3.8. Overall Range of LCC

The following chart shows the range across all the simulations. The low end values are the lowest LCC values found for each system, and the high end values are the highest LCC values found for each system.

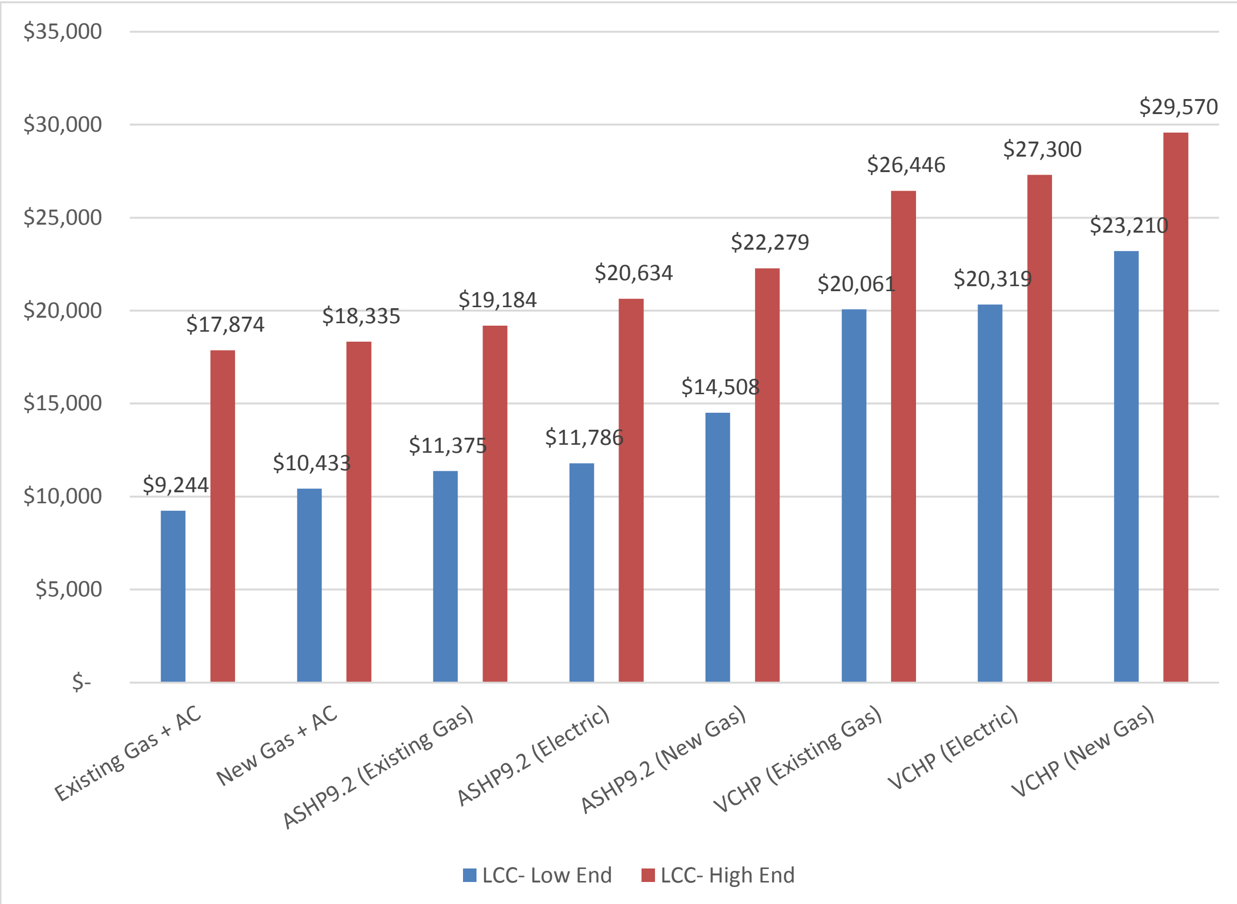


Figure 7: Overall Range of Variation in LCC (2016 Dollars)

APPENDICES

A. Results in Tabular Form

The results presented above in graphical form are presented here in table form.

A.1. Average LCC Results

This table shows the estimate of the average life cycle costs, based on the initial, replacement, and salvage costs shown above, and simulated energy costs assuming the following:

- Weighted average region
- Weighted average home prototype
- Average shell parameters

Table 9: Average LCC (2016 Dollars)

HVAC System	LCC	25-year Life Cycle Energy Costs
Existing Gas + AC	$ 11,700	$8,448
New Gas + AC	$ 12,677	$7,723
ASHP9.2 (Existing Gas)	$ 13,471	$7,125
ASHP9.2 (Electric)	$ 13,985	$7,640
ASHP9.2 (New Gas)	$ 16,612	$7,099
VCHP (Existing Gas)	$ 21,796	$6,141
VCHP (Electric)	$ 22,006	$6,351
VCHP (New Gas)	$ 24,952	$6,130

A.2. Impact of Location on LCC

The following table shows the city location impact on LCC. These are the simulated results for the weighted average home prototype and the average shell level. The low end of the range applies to Portland, due to the warmer climate. The high end applies to Redmond in all cases except the “Existing Gas + AC” system, which applies to Medford (the higher cost of AC in Medford compared with Redmond is the reason).

Table 10: Impact of Location on LCC (2016 Dollars)

HVAC System	LCC Low End of Cost Range	LCC High End of Cost Range
Existing Gas + AC	$ 10,923	$ 13,261
New Gas + AC	$ 11,966	$ 14,121
ASHP9.2 (Existing Gas)	$ 12,766	$ 16,228
ASHP9.2 (Electric)	$ 13,088	$ 17,669
ASHP9.2 (New Gas)	$ 15,918	$ 19,327
VCHP (Existing Gas)	$ 21,146	$ 24,466
VCHP (Electric)	$ 21,255	$ 25,266
VCHP (New Gas)	$ 24,307	$ 27,595

A.3. Impact of Home Prototype on LCC

The following table shows the impact of varying the home prototype on the LCC. These results are for the weighted average region and the average shell level. The low end of the cost range is for the prototype with the smallest floor area (1,344 square feet). The high end is for the prototype with the highest annual usage, which is a split level home with a 2,200 square foot floor area.

Table 11: Impact of Home Prototype on LCC (2016 Dollars)

HVAC System	LCC Low End of Cost Range	LCC High End of Cost Range
Existing Gas + AC	$ 9,517	$ 13,756
New Gas + AC	$ 10,691	$ 14,560
ASHP9.2 (Existing Gas)	$ 11,438	$ 15,256
ASHP9.2 (Electric)	$ 11,786	$ 15,931
ASHP9.2 (New Gas)	$ 14,587	$ 18,389
VCHP (Existing Gas)	$ 20,145	$ 23,357
VCHP (Electric)	$ 20,319	$ 23,623
VCHP (New Gas)	$ 23,303	$ 26,511

A.4. Impact of Shell on LCC

The impact of poor vs. good shell on the LCC is shown in the following table. For these simulations, the region is the overall weighted average region, and the home prototype is the weighted average prototype.

Table 12: Impact of Shell on LCC (2016 Dollars)

HVAC System	LCC Low End of Cost Range	LCC High End of Cost Range
Existing Gas + AC	$ 9,244	$ 17,874
New Gas + AC	$ 10,433	$ 18,335
ASHP9.2 (Existing Gas)	$ 11,375	$ 19,184
ASHP9.2 (Electric)	$ 12,039	$ 20,634
ASHP9.2 (New Gas)	$ 14,508	$ 22,279
VCHP (Existing Gas)	$ 20,061	$ 26,446
VCHP (Electric)	$ 20,424	$ 27,300
VCHP (New Gas)	$ 23,210	$ 29,570

A.5. Overall LCC Range

The following table shows the range across all the simulations. The low end values are the lowest LCC values found for each system, and the high end values are the highest LCC values found for each system.

Table 13: Overall Range of LCC (2016 Dollars)

HVAC System	LCC Low End of Cost Range	LCC High End of Cost Range
Existing Gas + AC	$ 9,244	$ 17,874
New Gas + AC	$ 10,433	$ 18,335
ASHP9.2 (Existing Gas)	$ 11,375	$ 19,184
ASHP9.2 (Electric)	$ 11,786	$ 20,634
ASHP9.2 (New Gas)	$ 14,508	$ 22,279
VCHP (Existing Gas)	$ 20,061	$ 26,446
VCHP (Electric)	$ 20,319	$ 27,300
VCHP (New Gas)	$ 23,210	$ 29,570

A.6. Overall Range of Annual Energy Use

The following table shows the low and high end (as determined by LCC's) of annual energy use across all the scenarios modeled.

Table 14: Overall Range of Annual Energy Use

HVAC System	Low End of Range		High End of Range	
	kWh	Therms	kWh	Therms
Existing Gas + AC	644	433	1,667	1,047
New Gas + AC	644	390	1,667	943
ASHP9.2 (Existing Gas)	3,576	28	8,831	61
ASHP9.2 (Electric)	4,106	-	10,380	-
ASHP9.2 (New Gas)	3,576	25	8,831	55
VCHP (Existing Gas)	3,243	15	7,593	36
VCHP (Electric)	3,556	-	8,506	-
VCHP (New Gas)	3,243	14	7,593	33

A.7. Overall Range of Annual Energy Costs

The following table shows the low and high end (as determined by LCC's) of annual energy costs across all the scenarios modeled.

Table 15: Overall Range of Annual Energy Costs

HVAC System	Low End of Range		High End of Range	
	Electric	Gas	Electric	Gas
Existing Gas + AC	$ 67	$ 424	$ 173	$ 1,024
New Gas + AC	$ 67	$ 382	$ 173	$ 922
ASHP9.2 (Existing Gas)	$ 384	$ 28	$ 991	$ 60
ASHP9.2 (Electric)	$ 445	$ -	$ 1,170	$ -
ASHP9.2 (New Gas)	$ 384	$ 25	$ 991	$ 54
VCHP (Existing Gas)	$ 346	$ 15	$ 848	$ 35
VCHP (Electric)	$ 382	$ -	$ 953	$ -
VCHP (New Gas)	$ 346	$ 14	$ 848	$ 32

B. Stakeholder Comments on Final Draft of Report and Energy Trust Responses

UM 1565 Order No. 15-265 HVAC Cost Study- Stakeholder Comments and Energy Trust responses

PGE Comments-

1. Equipment Life & Salvage Value-
   The use of a salvage value is both problematic and inconsistent with how cost-effectiveness is typically approached for EE programs. Using a linear depreciation ignores the time value of money by equally distributing the costs across the measure life. Use of a salvage value therefore unrealistically values assets with a large amount of remaining useful life.
   In order to evaluate measures on a level playing field, we suggest that we approach this issue similarly to how the RTF looks at early replacement versus replace on burnout. In this case, analysis is restricted to the life of the new measure. In the case of an early replacement measure, the baseline is the existing technology for the remaining useful life of the measure and then steps up the new technology for the remainder of the EUL of the new technology. We recommend that this be set to the 18 year life of the AC/HP, since these are the actual technologies being evaluated.
   Even if the analysis were to remain in its current form, it also appears that the "net replacement cost" is not being discounted when calculating the LCC. This is leading to inconsistent comparisons between measures with replacements.

   We would also suggest that the RUL of the furnace be set to 1/3 the EUL, consistent with RTF and CPUC methodologies for early replacement measures.

2. In the appendix we'd like to see a new table after A.1 which shows for each system the annual consumption for electricity and gas. SEEM reports this. For the all-electric options there will be only kWh use for the rest there will be therms and kWh.

3. Variable speed heat pumps-
   SEEM does not provide a simple mechanism to vary the efficiency level of the VSHP. We understand that more investigation into VSHPs needs to be done, and we like the report to acknowledge that more analysis needs to be done to accurately estimate the energy consumption for VSHPs. We believe that part load performance and the ability to have a much lower backup heat lockout significantly reduces energy consumption in VSHP systems.

Energy Trust Response to PGE comments-

1. Salvage value approach;
   Both Energy Trust and the consultant who performed the analysis, SBW, feel that the method used for estimating the *salvage value* of equipment with remaining useful life at the end of the analysis period is consistent between different types of equipment, is consistent with standard approaches for estimating salvage value, and also addresses the time value of money properly. Salvage values are presented in the results workbook as *present values,* and the calculations used to discount current prices can be seen on the tab named "Installation Costs", in cells N18:N21, contained within the "ETO_HVAC_Costs" results workbook that was distributed on 8/19/16.
   Since the estimated useful life (EUL) of a gas furnaces is 25 years, which is longer than the EUL of a heat pump (18 years), the term of the analysis is necessarily 25 years in order to account for the entire life cycle costs of the furnace. This also means that a new heat pump will need to be purchased in year 18 in the 'new heat pump' case. Similarly, a new gas furnace will need to be purchased in year 12.5 in the case 'existing gas furnace' case. In both of these cases, the equipment purchased in years 12.5 or year 18 will have remaining useful life (RUL) at the end of the analysis period, which represents some value to the consumer. Both types of equipment are depreciated linearly since we do not have any other information available about the depreciation schedules of these types of equipment. The linearly depreciated value is then converted into present value terms using a discount rate of 6.49%. We've double checked that replacement costs *are* being discounted, and so we are confident that the comparison between measures with different replacement schedules is balanced.

   Energy Trust agrees with the consultant, SBW's opinion that the RUL of a gas furnace should remain at 1/2 of its EUL rather than 1/3 of its EUL. In the case where this assumption applies (existing gas furnace case), the customer *keeps* the gas furnace until the end of its EUL, and does not retire it early, so it would not make sense to apply an early retirement approach here. Additionally, we find the following logic to support our selection of ½ the EUL rather than 1/3 of the gas furnace EUL; if an existing gas furnace has only 1/3 or less of its EUL remaining at the time the customer decides to install AC, the customer would likely have decided to purchase a new heating system rather than keep their existing system in place.

2. Variable Speed Heat Pumps;
   The consultant, SBW, agreed to insert a note in the report indicating that SEEM's ability to model Variable Speed Heat Pumps usage is limited to only a few efficiency levels of equipment. SBW did not think we should include language that says "more analysis needs to be done" in the context of this report because that could be interpreted as saying that the analysis performed for this report was not complete. Rather, the consultant will include report language noting that the SEEM model was unable to exactly estimate the usage for the specific level of VSHP efficiency that was found in the Energy Trust program and instead used a different level of heat pump efficiency that the model *was* able to handle.

3. An appendix showing annual consumption for both gas and electric energy will be added to the report.

NW Natural Key Concerns-

1. The inconsistent use of installed system costs likely overstates the upfront investment of the furnace/A/C combination options relative to the heat pump options
2. The convention used to estimate natural gas usage from SEEM model results for an electric furnace in this study significantly overstates actual usage when compared to an empirical estimation of actual NW Natural customer billed usage
3. The statement in the report that "SBW's approach is to make a good estimate of the "average" homeowner LCC" is not an accurate depiction of the analysis because the heat pump system the "average" homeowner installs (HSPF 8.5) is not analyzed in the report

Energy Trust Response to NW Natural Key Concerns-

1. Inconsistent use of installed cost;
   We agree that the installation cost for an AC unit was treated inconsistently compared to the costs used for heat pumps and gas furnaces. We have instructed SBW to change the installation cost for the AC unit to the value found in the RTF workbook and to *not* average the RTF value and the online sources identified in the draft report. SBW will also investigate the possible spreadsheet error that was called out in NWN's comments under key concern #1 to ensure that the midpoint RTF cost value is being used for all system types.

2. Estimated gas furnace consumption is too high;
   We understand the point that is being made with this comment and understand the concern that NW Natural has stated related to how natural gas usage is modeled using SEEM. While we disagree with the statement that "SEEM is only a model of electricity usage", since it is a model of energy usage, we do agree and recognize that SEEM has not been calibrated to actual natural gas usage in the same way that it has been calibrated to actual electric usage. In consulting with SBW it was determined to be an expensive addition to project scope and would also add significant time to the project to either calibrate the SEEM model to actual NWN billing data or simply to utilize NWN billing data. Additionally, Energy Trust and SBW would need to do something similar with the electric utilities and the other gas utilities given that SEEM does not use any utility's specific data but rather has been calibrated around an aggregation of RBSA data and data from the region's utilities. When presenting both options to OPUC Staff as possible additions to SBW's analysis OPUC Staff was against both options because of the cost and time impacts would more than likely not result in any deeper clarity to the analysis and that the opportunity to challenge the data used by SEEM was during the project's scope development. We point out that SEEM was agreed to by all stakeholders as the model that would be used for determining energy usage, for both electricity and natural gas, when the work plan was developed at the beginning of the project. The consultant has been instructed to double check the factors used to convert

modeled energy use from SEEM to natural gas usage. However, introducing a new method for estimating natural gas usage at this point in the project will be not pursued.

3. The 'average' homeowner LCC is not being modeled for the heat pump systems;
   It has been deemed beyond the scope of this project to include the 8.5 HSPF heat pump system that NW Natural recommends including in order to represent the 'average' homeowner LCC for a heat pump. The docket and this question are related to Energy Trust's heat pump program, and so it was determined with input from stakeholders and the OPUC that the *program* average heat pump would be studied for this analysis.
   Regarding NW Natural's minimum recommendations;
   - We do not agree to include this suggested pie chart because it is beyond the scope of this report to describe the heat pump market beyond Energy Trust's program. The 2014 HVAC Market Update report is mentioned in a three places in the report, and a footnote specifically describes the market share of 9.5+ HSPF units found from that report, at NW Natural's request. We will hyperlink the footnote referencing this 2014 HVAC market report but do not find it prudent to spend more effort or time describing the findings of that report here when those are readily available online.
   - Again, it is beyond the scope of this report to include judgments about the LCC for heat pumps not studied in this analysis.
   - Agree to remove the 'average homeowner' language used on page 2. The referenced language will be changed to say;

     SBW's approach is to use estimates of average values for the following;

     - *Weather (using Typical Meteorological Year (TMY3) data for three Oregon cities)*
     - *Initial costs*
     - *HVAC system life spans*
     - *Thermostat settings*

NW Natural Other Concerns and Questions: (Energy Trust Responses in Blue)

Page ii: States that heat and cooling energy use was estimated with the SEEM simulation model, though this isn't entirely accurate for the gas systems

> We believe this comment is addressed with our response to key concern #1 above. Energy use was estimated using SEEM, and that model output was converted to electric and natural gas use.

Page 2: It may make sense to change the "energy costs" bullet to "heating and cooling energy costs" to make explicit that cooling costs are considered in the analysis

> Yes, this makes sense, we agree and have instructed the consultant to make this change.

Page 3: It might make sense to include in the first paragraph that the SEEM model was developed for electricity usage of electric equipment and does not model natural gas usage

We do not feel that this suggestion is appropriate for the report. SEEM is a model of building energy use, not a model of electric equipment specifically. The RTF description of the model states; "The SEEM program is designed to model small scale residential building **energy use**"

Page 3: What is the reasoning behind the assumption that the customer's existing HVAC system is a gas furnace without AC?

In order to keep the scope of the project reasonable and to avoid excessive spending of ratepayer dollars on this analysis, a limited number of scenarios were selected to be modeled, which were agreed to by stakeholders during work plan development. The reasoning used for selecting gas furnace without AC as the existing HVAC system was influenced by the nature of the docket where this question arose. The question raised by participants in that docket was about customers who wanted air conditioning.

Page 3: Per key concern #3, to give the reader a better idea of the equipment of the average customer, NW Natural recommends a pie chart that shows the efficiencies of furnaces (with the recommendation for furnaces 85% or lower, 85-89%, 90-94% and 95% or greater AFUE for gas furnaces and 8.5 to 8.9, 9.0-9.4, 9.5-11, and greater than 11 HSPF for ducted heat pumps) using data from the 2014 HVAC Market Study. Additionally, footnote 5 notes the share of heat pumps with HSPF's greater than 9.5- does this exclude ductless heat pumps and why is there a range rather than a number?

The same response provided for key concern #3 above applies here as well. The suggested pie chart describing heat pump market shares is beyond the scope of this report and a link to the report where that information is presented is included in this report. Ducted central heatpump systems are the only heatpump systems analyzed as the study attempted to address the comparable operations of gas furnace with central AC cooling.

Page 5: Section 2.3.3- It may be a good idea to point out here that salvage value is provided to systems that still have a useful life at the end of the study horizon

We've instructed the consultant to add this language to the report.

Page 7: Section 2.3.7- it may be a good idea to explain what the last sentence in this paragraph means and its implications to the casual reader with an example along the lines of "Therefore, a system that has half of its useful life remaining at the end of the study period will be credited with half of its original value in real terms."

We've instructed the consultant to also add this language to the report.

Page 8: The last sentence in section 2.3.8.1 states that "where a city represents more than one *gas* utility, the utility rate used is a simple average of the rates for the two utilities." Should it say "electric utility" where it says "gas utility"? This would seem to make better sense as some cities have numerous electric providers, but no cities in Oregon have multiple gas utilities providing service.

The consultant will clean up this language to make it clearer.

Page 8: Table 3 shows a population weighting that seems to understate the "Portland" climate and overstate the "Medford" climate by excluding the populations of the mid-Willamette Valley that are rather populous and have both IOU and LDCs serving them. Grouping the populations of Multnomah, Washington, Clackamas, Marion, Linn, Yamhill, Benton, Polk and Clatsop counties in the Portland climate, the populations of Jackson, Douglas, Josephine, and Klamath counties in the Medford climate and Deschutes and Umatilla county in the Redmond climate gives the following population weighting:

Portland	78%
Medford	15%
Redmond	8%

The consultant will check the population weighting values used for each region against the values suggested by NW Natural.

Page 9: The first paragraph states "the low electric rate applies to usage under 1000 kWh per month; the high rate applies after that limit." The annual energy costs of the heat pump systems are likely underestimated because the analysis assumes that all electric usage is for space heating and cooling so that only if the heating or cooling system used more than 1000 kWh for the month does the higher rate apply in the analysis. This underestimates the higher tiered rate usage associated with the HVAC system. NW Natural believes it is fair to assume that lighting, clothes washing and drying, water heating and other uses are considered to be necessities by customers so that the non-space heating or cooling electric load usage is far greater than the assumed 0 kWh per month. It would be a better approach to take the average electric usage of a home without electric space heating or cooling for each month and add the space heating and cooling usage for a given month to this and assign the tiered rates accordingly.

The consultant stated that they did address electric usage in the way that is being suggested and that this comment represents a misunderstanding of the method that was employed. The consultant will modify the report language to make the method clearer to the reader.

Page 9: Section 2.3.8.2- It may make sense to provide a small description of each of the 3 homes modeled including whether it (1) has any shared walls, (2) is one or two story, (3) has a basement, and (4) has the ducting within the heating envelope.

This suggestion has been passed on to the consultant.

Page 11-12: It is NW Natural's understanding that the primary component of the LCC that is of interest to the Commission is the energy costs of the different heating and cooling systems, while the draft report embeds this section in to the LCC rather than breaking it out like the initial costs and replacement and salvage costs sections (3.1 and 3.2 respectively). NW Natural recommends the energy cost section be made section 3.3 and it include both the assumed annual energy usage (both electric and natural gas usage) and the calculated annual energy costs of each system as this is a major component of the total LCC.

This suggestion has been passed on to the consultant. The consultant will create an alternate version of the results table that includes more detail.

Pages 13-15: The analysis has three categories for each location, home prototype, and shell quality, though and Figures 4, 5, and 6 in the draft report show "highs" and "lows" of each. It may make more sense to add one more bar to each system and label each one. This will give the reader much more information at only a small cost in terms of complication in the graph.

> This suggestion makes sense and does provide additional information for the reader, however we are unfortunately unable to include the suggested graph formats in the final report due to the consultant already reaching their maximum budget amount. The intention for the format of the graphs as they stand currently was to describe the *range* of LCC results that could be found by changing the variables of location, home prototype, and shell quality, and although the suggested format does provide additional contextual information for the reader, that additional information is not deemed necessary for the reader to accurately interpret the results of the analysis.

Appendix: Full Text of Stakeholder Comments

PGE Comments-

We only have one area of the study where we'd like to see adjustments made.

Equipment Life & Salvage Value:

The use of a salvage value is both problematic and inconsistent with how cost-effectiveness is typically approached for EE programs. Using a linear depreciation ignores the time value of money by equally distributing the costs across the measure life. Use of a salvage value therefore unrealistically values assets with a large amount of remaining useful life.

In order to evaluate measures on a level playing field, we suggest that we approach this issue similarly to how the RTF looks at early replacement versus replace on burnout. In this case, analysis is restricted to the life of the new measure. In the case of an early replacement measure, the baseline is the existing technology for the remaining useful life of the measure and then steps up the new technology for the remainder of the EUL of the new technology. We recommend that this be set to the 18 year life of the AC/HP, since these are the actual technologies being evaluated.

Even if the analysis were to remain in its current form, it also appears that the "net replacement cost" is not being discounted when calculating the LCC. This is leading to inconsistent comparisons between measures with replacements.

We would also suggest that the RUL of the furnace be set to 1/3 the EUL, consistent with RTF and CPUC methodologies for early replacement measures.

We also noted a few items that we would like to see addressed, but do not see as critical.

1. Variable speed heat pumps:
    - SEEM does not provide a simple mechanism to vary the efficiency level of the VSHP. We understand that more investigation into VSHPs needs to be done, and we like the report to acknowledge that more analysis needs to be done to accurately estimate the energy consumption for VSHPs. We believe that part load performance and the ability to have a much lower backup heat lockout significantly reduces energy consumption in VSHP systems.
2. In the appendix we'd like to see a new table after A.1 which shows for each system the annual consumption for electricity and gas. SEEM reports this. For the all-electric options there will be only kWh use for the rest there will be therms and kWh.

NW Natural Comments-

NW Natural is appreciative of the work that has been completed on this report and thanks Energy Trust of Oregon for allowing us to provide comments. We understand the amount of work this entails and the number of sources that need to be tapped and assumptions that need to be made to complete an analysis of this sort. While we remain supportive of the overall approach in performing the economic life cycle analysis, we have a number of concerns regarding the assumptions that were used to complete the draft report. We will detail our key concerns first along with suggestions for moving forward, followed by other concerns and questions in the order they appear in the report.

Our key concerns are:

4. The inconsistent use of installed system costs likely overstates the upfront investment of the furnace/A/C combination options relative to the heat pump options
5. The convention used to estimate natural gas usage from SEEM model results for an electric furnace in this study significantly overstates actual usage when compared to an empirical estimation of actual NW Natural customer billed usage
6. The statement in the report that "SBW's approach is to make a good estimate of the "average" homeowner LCC" is not an accurate depiction of the analysis because the heat pump system the "average" homeowner installs (HSPF 8.5) is not analyzed in the report

Key concern #1: Inconsistent source data for installed system costs

Page 5 of SBW's report states:

> RTF workbooks were the main source used to determine installation costs. This provided a single, regionally-accepted, source for all of the HVAC systems. We used the RTF "midpoint" values to arrive at single values for each of the systems. We also used online sources to verify that RTF values were within the range of costs reported by other sources. In the case of a new AC system, the RTF value was significantly lower than that found from online sources, and the value used was the average of the RTF value and that from a representative online source.

Due to the nature of the HVAC industry, NW Natural recognizes the difficulty in sourcing installed equipment costs and that no perfect source is available for this data. However, the approach that was used to estimate installed system costs in the draft analysis is inconsistent in a way that favors the heat pump systems modeled without a compelling reason for using this approach. Additionally, after reviewing the spreadsheets that contain the data and sources used, the paragraph above could be somewhat misleading to a reader who has not reviewed the analysis in depth.

NW Natural believes the decision to average the cost of the air conditioner with the RTF value and that of one online source, but use the RTF value as the sole source for all other equipment modeled, is inappropriate since reputable sources can be found to invalidate the RTF cost estimates for the other equipment analyzed (the heat pump system and the gas furnace) as well. However, given the nature of the HVAC industry, finding a source that can invalidate another source is somewhat expected. While NW

Natural agrees that the cost listed in the RTF worksheet is likely too low for a stand-alone A/C install, there is strong evidence- primarily Energy Trust program install costs and other online sources- that the estimated costs for the standard high efficiency heat pump system costs are also too low.

As the top frequency distribution in Figure 1 below shows, Energy Trust program data indicates that the installed cost of traditional high efficiency heat pumps has been in the $8000 range over the last 3 years for traditional high efficiency heat pumps and regression analysis indicates that the 2016 cost of a 9.2 HSPF heat pump for a 2200 square foot house is estimated to be roughly $9000, or far higher than the ~$6000 figure provided by the RTF and used in the analysis.[32] Additionally, a respected website- homewyse.com- that was not consulted as a source but provides more detailed estimates than the websites used (homeadvisor.com or improvenet.com) indicates that the installed cost of a mid-sized high efficiency heat pump is also in the $9000 range.

Figure 1: Installed Costs of Heat Pumps Incented by Energy Trust of Oregon

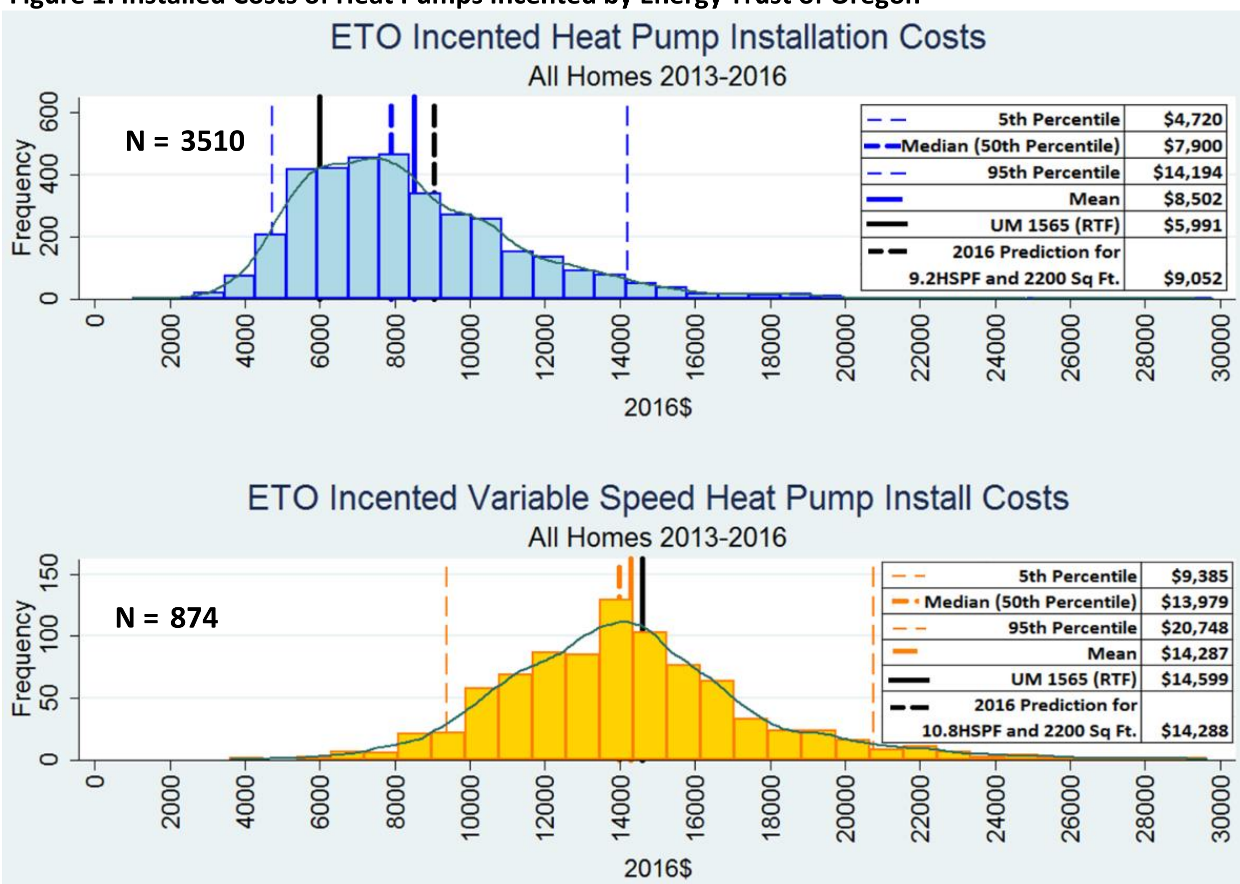


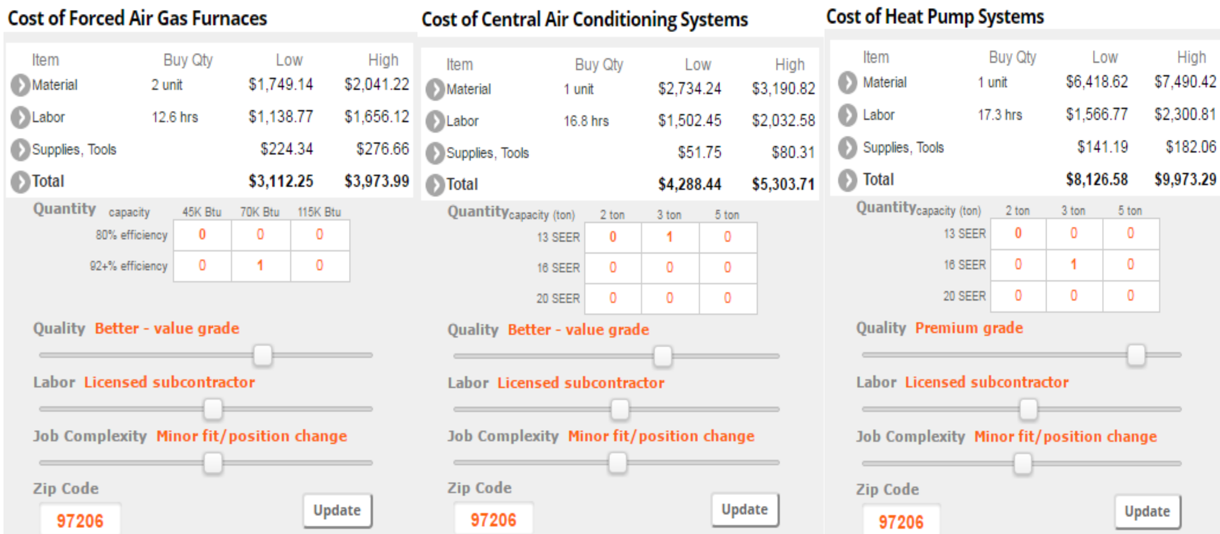
Figure 2 shows the costs for stand-alone furnace, air conditioner, and heat pump installations from homewyse.com with markers that are consistent with the systems modeled in the draft report.[33] While these figures seem to validate the furnace figure in the RTF worksheet and indicate the air conditioner and heat pump costs are too low, this again is a single source and it is not surprising that not all sources

32 The regression results are provided along with these comments.

33 Note that it is not possible to single out the cost of the high efficiency heat pumps modeled in the analysis on homeadvisor.com or improvenet.com though it is on homewyse.com. Also note that “premium grade” is chosen for the heat pump system since the HSPF 9.2 system modeled in the analysis is a high efficiency system that is not the normal system installed.

line up. Furthermore, this points out one of the primary reasons that the RTF figure may show a lower figure for the air conditioner system than the online sources: stand-alone air conditioner installs, which from reading the descriptions of the estimates of the online sources seems to be what they are providing estimates for, are likely to be much more expensive than installs that are combined with a furnace install, which is what is what appears to be estimated by the RTF and is what is modeled in this analysis for the new gas and a/c system.[34]

Figure 2: Homewyse.com Stand-Alone HVAV Install Costs for Mid-Sized Systems



Cost of Forced Air Gas Furnaces

Item	Buy Qty	Low	High
Material	2 unit	$1,749.14	$2,041.22
Labor	12.6 hrs	$1,138.77	$1,656.12
Supplies, Tools		$224.34	$276.66
Total		$3,112.25	$3,973.99

Quantity capacity	45K Btu	70K Btu	115K Btu
80% efficiency	0	0	0
92+% efficiency	0	1	0

Quality Better - value grade
Labor Licensed subcontractor
Job Complexity Minor fit/position change
Zip Code 97206 Update

Cost of Central Air Conditioning Systems

Item	Buy Qty	Low	High
Material	1 unit	$2,734.24	$3,190.82
Labor	16.8 hrs	$1,502.45	$2,032.58
Supplies, Tools		$51.75	$80.31
Total		$4,288.44	$5,303.71

Quantity capacity (ton)	2 ton	3 ton	5 ton
13 SEER	0	1	0
16 SEER	0	0	0
20 SEER	0	0	0

Quality Better - value grade
Labor Licensed subcontractor
Job Complexity Minor fit/position change
Zip Code 97206 Update

Cost of Heat Pump Systems

Item	Buy Qty	Low	High
Material	1 unit	$6,418.62	$7,490.42
Labor	17.3 hrs	$1,566.77	$2,300.81
Supplies, Tools		$141.19	$182.06
Total		$8,126.58	$9,973.29

Quantity capacity (ton)	2 ton	3 ton	5 ton
13 SEER	0	0	0
16 SEER	0	1	0
20 SEER	0	0	0

Quality Premium grade
Labor Licensed subcontractor
Job Complexity Minor fit/position change
Zip Code 97206 Update

The RTF spreadsheet referenced as the source of the install cost data states that the sole source of all of the estimates come from one contractor from 2012[35] and while the contractor estimate approach is valid, it is typically considered a next-best option to a dataset of actual costs from the field with a large sample size, which the Energy Trust has for high efficiency heat pumps and provided with the spreadsheets that generated the results of the report. However, given that no perfect source exists and, as the report points out, the Northwest Power and Conservation Council is a “regionally-accepted” organization for cost estimates and RTF values are used extensively by the Energy Trust, NW Natural recommends the statement in the draft report that the RTF “provide(s) a single, regionally-accepted, source for all HVAC systems” be given full credence and the RTF values be used for all system costs.

Lastly, while it is likely a simple spreadsheet error, the “high” as opposed to “midpoint” installed cost[36] was used for the gas furnace estimate and the system-size weighted average was used for the installed cost of the heat pump systems even though the draft report states “we used the RTF “midpoint” values to arrive at single values for each of the systems.” At a minimum the “midpoint” installed cost should be

[34] http://www.homewyse.com/costs/cost_of_heat_pump_systems.html
http://www.homewyse.com/costs/cost_of_forced_air_gas_furnaces.html
http://www.homewyse.com/costs/cost_of_central_air_conditioning_systems.html

[35] The RTF spreadsheet detailing install costs states “(t)he method chosen (to estimate installed equipment costs) was to get bids from a single contractor (Mark Jerome). Data from the Energy Trust were also reviewed, but there was too much variation in the data.” Note that variation within a dataset is not generally evidence the dataset is inaccurate or faulty, and given the HVAC market a strong case could be made that it would be more surprising if there were very little variation in install costs of heat pumps.

[36] Which we are assuming is the “Most Likely” value referenced in the RTF spreadsheet (as opposed to the “High” or “Low” or values) as there is not a “midpoint” category

used for the gas furnace and since the system-size weighting is not described in the RTF worksheet it is recommended that mid-sized system cost figures be used for all equipment.

When the suggested changes to assumed install costs of HVAC systems are made, Table 6 from page 11 of the draft report would be updated to the figures shown on the left of Table 1 below (where the original install costs assumed in the draft report on page 11 are shown on the right):

Table 1: Updated System Install Cost Figures vs. Installed Cost Figures from Draft Results

HVAC System	Backup System	Installation	Rebate	OR Tax Credit	Fed Tax Credit	HVAC System	Backup System	Installation	Rebate	OR Tax Credit	Fed Tax Credit
New Gas + AC	Gas	$ 5,279	$ -	$ 352	$ 200	New Gas + AC	Gas	$ 6,281	$ -	$ 352	$ 200
Existing Gas + AC	Gas	$ 1,957	$ -	$ -	$ -	Existing Gas + AC	Gas	$ 2,866	$ -	$ -	$ -
ASHP9.2	New Gas	$ 9,372	$ 250	$ 268	$ 300	ASHP9.2	New Gas	$ 9,406	$ 250	$ 268	$ 300
ASHP9.2	Existing Gas	$ 6,173	$ 250	$ 268	$ 300	ASHP9.2	Existing Gas	$ 5,991	$ 250	$ 268	$ 300
ASHP9.2	Electric	$ 6,173	$ 250	$ 268	$ 300	ASHP9.2	Electric	$ 5,991	$ 250	$ 268	$ 300
VCHP	New Gas	$ 17,766	$ 500	$ 1,000	$ 300	VCHP	New Gas	$ 18,013	$ 500	$ 1,000	$ 300
VCHP	Existing Gas	$ 14,599	$ 500	$ 1,000	$ 300	VCHP	Existing Gas	$ 14,599	$ 500	$ 1,000	$ 300
VCHP	Electric	$ 14,599	$ 500	$ 1,000	$ 300	VCHP	Electric	$ 14,599	$ 500	$ 1,000	$ 300

The spreadsheets that contain the analysis for this report with the suggested changes made by NW Natural highlighted in yellow accompany this report.

Key concern #2: Estimated gas furnace natural gas consumption is too high

The report uses SEEM model runs to estimate electric furnace electricity usage and then converts this consumption to gas usage through an efficiency factor. While SEEM is a respected model for estimating electricity consumption that is calibrated with actual equipment usage, SEEM is only a model of electricity usage and the conversion of electric furnace usage to gas furnace usage methodology employed in the report has not been calibrated with actual natural gas furnace usage. NW Natural understands why this approach was taken given that there is no natural gas equivalent of the Northwest Power and Conservation Council, and no region-specific natural gas usage model equivalent to SEEM exists. However, after reviewing the spreadsheets, NW Natural noticed that the assumed Portland usage of natural gas furnaces seemed much higher than the average gas consumption of its residential customers for their space heating needs (assumed Portland usage in the report for a 95% efficient gas furnace for space heat is 524 therms per year whereas average space heating usage of all NW Natural customers is closer to 350 therms per year). Consequently, NW Natural looked to calibrate the gas usage figures provided from the SEEM output to gas conversion methodology employed in the report and found gas usage from actual customers with the type of homes analyzed in the report to be much lower than the figures used in the analysis.

To validate the assumed natural gas annual usage for the Portland area, NW Natural collected billing data from residential customers that use gas furnaces for space heating but have no other gas fired equipment in the home (they do not have natural gas water heaters or natural gas cooking)[37] for the following types of homes to correspond with the home types analyzed in the report:

[37] This excluded most of NW Natural's customers as most customers use natural gas for either their water heating or cooking needs, and often both

- Small- Homes smaller than 1800 square feet without a basement to represent the 1344 ft^2 home with a crawl space
- Medium- Homes between 1800 and 2400 ft^2 without a basement to represent the 2200 ft^2 home with a crawlspace[38]
- Large- Homes between 2400 and 2900 ft^2 with a basement to represent the 2688 ft^2 home with a basement

NW Natural split this data into residential single-family conversion homes (existing homes that convert from oil, propane, wood, or electricity to natural gas for their space heating needs) and residential single-family new construction homes since the year 2000[39] and estimated weather normalized usage from actual usage for these customers. The results are found in Table 2 below:

Table 2: Weather Normalized Annual Gas Space Heating Usage of NWN Customer by Home Size

Home Size	Customer Type	Count	Average Square Feet	Basement?	Weather Normalized Annual Gas Use (therms)
large	Conversion	1346	2623	Yes	422.3
large	New Home	1	2832	Yes	253.8
medium	Conversion	20	2051	No	402.8
medium	New Home	1	1858	No	208.1
small	Conversion	101	1300	No	338.3
small	New Home	29	1442	No	223.9

Conversion homes are expected to use much more gas than new homes as their shells are presumably poorer and this held true. However, after restricting the billing data to homes that do not have any other natural gas equipment other than a furnace and to the home types considered in this analysis there were not a statistically significant number of new construction homes in each category. Consequently, NW Natural feels it may be appropriate to consider natural gas conversion customers only in this analysis to assure that annual natural gas usage is not underestimated but represents actual usage better than the methodology employed in the report. If anything, considering the conversion customer usage only will overstate expected natural gas usage, not only because new construction home usage is much lower than for conversion homes and because conversion homes are existing homes with poorer shells, but also because it is unlikely that the average efficiency of the furnaces is as high as the 95% efficient unit that the analysis is modeling.

Note from Table 2 that if home size is weighted equally, the average weather normalized annual usage for space heating with a gas furnace in the Willamette Valley is 387.8 therms per year, though the mid-sized home with a crawl space uses 402.8 therms per year, much less than the home-size weighted usage of 582 therms per year from an existing furnace (86%) or 524 therms per year from a new 95% efficient furnace included in the draft report's analysis from the SEEM electric furnace to gas usage calculation. In fact, actual usage from conversion mid-sized homes of 402.8 therms per year is 69% of the 582 therms per year modeled as the size-weighted average of a used gas furnace in the report. If

[38] Note that this excluded most homes in this size grouping as more homes this size have a basement as opposed to a crawl space

[39] When NW Natural began recording equipment information about new (conversion or new home) natural gas customers

this conservative percentage (relative to not overestimating gas usage) is applied to the assumed gas furnace usage across home-size, location and shell quality, it changes the annual energy costs for the natural gas systems as shown in Table 3 (updated figures are shown highlighted on the left whereas the figures from the draft report are shown on the right):[40]

Table 3: Updated Figures from Actual Customer Usage vs. Annual Energy Costs from Draft Results

HVAC System	Backup System	Annual Energy	LCC	HVAC System	Backup System	Annual Energy	LCC
New Gas + AC	Gas	$ 466	$ (10,799)	New Gas + AC	Gas	$ 632	$ (14,013)
Existing Gas + AC	Gas	$ 507	$ (9,425)	Existing Gas + AC	Gas	$ 692	$ (12,780)
ASHP9.2	New Gas	$ 580	$ (16,855)	ASHP9.2	New Gas	$ 581	$ (16,860)
ASHP9.2	Existing Gas	$ 582	$ (13,680)	ASHP9.2	Existing Gas	$ 583	$ (13,471)
ASHP9.2	Electric	$ 625	$ (14,209)	ASHP9.2	Electric	$ 625	$ (13,985)
VCHP	New Gas	$ 502	$ (24,952)	VCHP	New Gas	$ 502	$ (25,200)
VCHP	Existing Gas	$ 503	$ (21,796)	VCHP	Existing Gas	$ 503	$ (21,796)
VCHP	Electric	$ 520	$ (22,006)	VCHP	Electric	$ 520	$ (22,006)

The spreadsheets that contain the analysis that is included in the draft report with the suggested changes made by NW Natural are highlighted in yellow accompany this report.

Key concern #3: The "average" homeowner LCC is not being modeled for the heat pump systems

While it was NW Natural's understanding from the original scope of work that the "average" heat pump system would be included in the analysis[41] and page 2 of the draft report states "SBW's approach is to make a good estimate of the "average" homeowner LCC," the heat pumps systems analyzed in the draft report are not the systems the "average" homeowner installs. Based on the fact the market norm establishes the baseline for the cost effectiveness test, it stands to reason that the "average" homeowner installs a heat pump that is less efficient than the HSPF 9.2 system analyzed or Energy Trust would not have incentives for heat pumps HSPF 9.0 or higher (in fact an HSPF 8.5 heat pump is both the minimum code requirement and the baseline for heat pumps in Energy Trust's cost effectiveness tests and is therefore the system the "average" homeowner installs). However, while the baseline/market norm/average heat pump is not modeled in the analysis, the higher efficient heat pump systems that are modeler are compared against the natural gas furnace the "average" homeowner installs (95% AFUE) per the HVAC market update study from 2014 which sets the Energy Trust furnace baseline.

Furthermore, it is safe to presume the LCC of the heat pump that the "average"- or baseline-homeowner would install (HSPF 8.5) would have a LCC higher than that of the 9.2 HSPF system modeled or an Energy Trust incentive would not exist to incent homeowners to install higher efficiency heat pump units because the cost effectiveness criteria could not be satisfied. Additionally, the assumed annual energy costs for the heat pumps analyzed likely represents the minimum that can be expected for heat pump systems as the systems modeled are assumed to be operating under Energy Trust specifications for emergency heat temperature settings and thermostat setbacks, which is more efficient than the "average" homeowner experiences or Energy Trust would not offer heat pump optimization or heat pump lockout control incentives. To account for the actual energy consumption of "average" heat

[40] Note that this is the chart about annual energy costs that NW Natural believes should be included in the report per the comment on pages 11 and 12 of the draft report below as part of a new section 3.3

[41] Which included an HSPF 8.5 heat pump as one of the systems to be analyzed

pump homeowners it would require the electric utilities to complete a usage evaluation similar to what NW Natural did for customers that use gas furnaces detailed above.

While it is preferred that an 8.5 HSPF heat pump with weather normalized average actual annual usage from billing data to be modeled in this study, if it is deemed beyond the scope of this report to add the additional system, NW Natural recommends that at a minimum the following changes be considered:

1. A simple heating system equipment efficiency pie chart with two pies (one for gas furnace efficiencies and one for heat pump efficiencies) from the 2014 HVAC Market Update be included in section 2.2 of the report
2. The report note in the executive summary and section 2.2 that the “average” homeowner heat pump is less efficient than the systems modeled and would likely have a higher LCC than the systems modeled
3. The wording on page 2 of the report be modified to indicate that the “average” homeowner LCC is estimated for the gas furnace/air conditioner combination and the LCC of heat pump homeowners who accept Energy Trust incentives is modeled for the heat pump systems

NW Natural recognizes that managing a process with many stakeholders is a difficult and satisfying all parties is not possible, however, we believe the best way to address this is through transparency and the utilization of consistently applied assumptions. For example, NW Natural was surprised to see the HSPF 8.5 heat pump dropped from the analysis in the final scope of work after providing comments on the initial scope of work that included an HSPF 8.5 system. To ensure that stakeholders are not surprised by the final report, NW Natural recommends that the comments submitted on the draft be circulated to all parties and the decision- and its reasoning- on key points of contention be provided to stakeholders with the final report.

<u>**Other Concerns and Questions:**</u>

Page ii: States that heat and cooling energy use was estimated with the SEEM simulation model, though this isn’t entirely accurate for the gas systems

Page 2: It may make sense to change the “energy costs” bullet to “heating and cooling energy costs” to make explicit that cooling costs are considered in the analysis

Page 3: It might make sense to include in the first paragraph that the SEEM model was developed for electricity usage of electric equipment and does not model natural gas usage

Page 3: What is the reasoning behind the assumption that the customer’s existing HVAC system is a gas furnace without AC?

Page 3: Per key concern #3, to give the reader a better idea of the equipment of the average customer, NW Natural recommends a pie chart that shows the efficiencies of furnaces (with the recommendation for furnaces 85% or lower, 85-89%, 90-94% and 95% or greater AFUE for gas furnaces and 8.5 to 8.9, 9.0-9.4, 9.5-11, and greater than 11 HSPF for ducted heat pumps) using data from the 2014 HVAC Market Study. Additionally, footnote 5 notes the share of heat pumps with HSPF’s greater than 9.5- does this exclude ductless heat pumps and why is there a range rather than a number?

Page 5: Section 2.3.3- It may be a good idea to point out here that salvage value is provided to systems that still have a useful life at the end of the study horizon

Page 7: Section 2.3.7- it may be a good idea to explain what the last sentence in this paragraph means and its implications to the casual reader with an example along the lines of “Therefore, a system that has half of its useful life remaining at the end of the study period will be credited with half of its original value in real terms.”

Page 8: The last sentence in section 2.3.8.1 states that “where a city represents more than one *gas* utility, the utility rate used is a simple average of the rates for the two utilities.” Should it say “electric utility” where it says “gas utility”? This would seem to make better sense as some cities have numerous electric providers, but no cities in Oregon have multiple gas utilities providing service.

Page 8: Table 3 shows a population weighting that seems to understate the “Portland” climate and overstate the “Medford” climate by excluding the populations of the mid-Willamette Valley that are rather populous and have both IOU and LDCs serving them. Grouping the populations of Multnomah, Washington, Clackamas, Marion, Linn, Yamhill, Benton, Polk and Clatsop counties in the Portland climate, the populations of Jackson, Douglas, Josephine, and Klamath counties in the Medford climate and Deschutes and Umatilla county in the Redmond climate gives the following population weighting:

Portland	78%
Medford	15%
Redmond	8%

Page 9: The first paragraph states “the low electric rate applies to usage under 1000 kWh per month; the high rate applies after that limit.” The annual energy costs of the heat pump systems are likely underestimated because the analysis assumes that all electric usage is for space heating and cooling so that only if the heating or cooling system used more than 1000 kWh for the month does the higher rate apply in the analysis. This underestimates the higher tiered rate usage associated with the HVAC system. NW Natural believes it is fair to assume that lighting, clothes washing and drying, water heating and other uses are considered to be necessities by customers so that the non-space heating or cooling electric load usage is far greater than the assumed 0 kWh per month. It would be a better approach to take the average electric usage of a home without electric space heating or cooling for each month and add the space heating and cooling usage for a given month to this and assign the tiered rates accordingly.

Page 9: Section 2.3.8.2- It may make sense to provide a small description of each of the 3 homes modeled including whether it (1) has any shared walls, (2) is one or two story, (3) has a basement, and (4) has the ducting within the heating envelope.

Page 11-12: It is NW Natural’s understanding that the primary component of the LCC that is of interest to the Commission is the energy costs of the different heating and cooling systems, while the draft report embeds this section in to the LCC rather than breaking it out like the initial costs and replacement and salvage costs sections (3.1 and 3.2 respectively). NW Natural recommends the energy cost section be made section 3.3 and it include both the assumed annual energy usage (both electric and natural gas usage) and the calculated annual energy costs of each system as this is a major component of the total LCC.

Pages 13-15: The analysis has three categories for each location, home prototype, and shell quality, though and Figures 4, 5, and 6 in the draft report show "highs" and "lows" of each. It may make more sense to add one more bar to each system and label each one. This will give the reader much more information at only a small cost in terms of complication in the graph.

Thank you the high quality work that has been completed on this report and the opportunity to provide comments. We look forward to seeing the final report.

C. Stakeholder Comments on Final Report

NW Natural Comments-

NW Natural is appreciative of the work that has been completed on this report and is thankful to Energy Trust of Oregon for providing detailed explanations on what changes were- and were not- made to the final report in response to comments received on the draft report in September. NW Natural understands the amount of work a study like this entails and the number of sources that need to be tapped and assumptions that need to be made to complete the analysis. Furthermore, we recognize satisfying all parties is not possible. From the explanations provided it is clear Energy Trust thoughtfully considered all comments and appreciates that stakeholders were heard. The Company is also appreciative of Energy Trust and OPUC Staff for including in the final report the comments received on the draft report and the final report in an appendix to the final report. NW Natural believes the transparency is beneficial to all parties. NW Natural is satisfied with the responses to its comments from the Energy Trust on the draft report with the exception of one issue.

<u>Resolution to NW Natural's concern that assumed natural gas furnace usage is significantly overestimated in the analysis</u>

NW Natural would like to respond to Energy Trust's response to our comment on the analysis behind the draft (and consequently to the identical analysis in the final report) about the assumed energy usage of a natural gas furnace being a significant overestimation compared to an empirical analysis.

While Energy Trust did not refute NW Natural's analysis showing that the assumed gas furnace usage is overestimated, it stated:

> *In consulting with SBW it was determined to be an expensive addition to project scope and would also add significant time to the project to either calibrate the SEEM model to actual NWN billing data or simply to utilize NWN billing data. Additionally, Energy Trust and SBW would need to do something similar with the electric utilities and the other gas utilities given that SEEM does not use any utility's specific data but rather has been calibrated around an aggregation of RBSA data and data from the region's utilities. When presenting both options to OPUC Staff as possible additions to SBW's analysis OPUC Staff was against both options because of the cost and time impacts would more than likely not result in any deeper clarity to the analysis and that the opportunity to challenge the data used by SEEM was during the project's scope development. We point out that SEEM was agreed to by all stakeholders as the model that would be used for determining energy usage, for both electricity and natural gas, when the work plan was developed at the beginning of the project.*

NW Natural understands comprehensive billing analysis and a review of it would delay the project and would result in additional expenditures, and further recognizes this may not make sense for this study. However, if the assumed usage of the furnace were to be reduced 30%, which is what empirical billing data analysis of natural gas furnace usage for the Portland weather area indicates is appropriate, this would change the results drastically. Therefore, the Company disagrees that making accurate assumptions about HVAC system usage in an LCC study of HVAC life-cycle costs (of which energy costs are a critically important component) would "more than likely not result in any deeper clarity to the analysis." Since energy costs are equal to energy usage times energy price, a 30% reduction in assumed energy usage of one type of system to better match reality results in a substantial change to relative LCCs.

NW Natural is also sympathetic to the concern that the opportunity to challenge the data used by SEEM was during a review of the draft scope of work (SOW) (in which NW Natural was involved). However, the Company would like to point out that without knowing exactly what assumptions would be made and calculations would be done by the consultant from a review of the draft SOW and completing the work described by the draft SOW itself, it was impossible for NW Natural to know the method employed would lead to a significant overestimation of natural gas furnace usage. The draft SOW sent out for review by the parties in this docket did not include this detail, and even if it had, it is unreasonable to assume the Company should do the work itself to provide comments on the SOW document.

NW Natural erred in assuming that the work described at a high level in the draft SOW would reasonably represent natural gas furnace usage. That being said, it is not uncommon in quantitative analysis to find that initial results seem implausible and review assumptions and calculations in response to these initial findings so that the final results are more accurate. The first step in the process that NW Natural could have realistically been aware the method employed by the consultant resulted in a substantial usage overestimate for the gas furnace is in a review of the spreadsheets supporting the draft report. NW Natural registered its concern after its initial review of the analysis- in a review of the draft report.

Moreover, when NW Natural voiced concern that calculating gas usage based on a conversion from an electric model overestimated gas usage by roughly 30%, Energy Trust acknowledged that "SEEM has not been calibrated to actual natural gas usage in the same way that it has been calibrated to actual electric usage." Additionally, PGE, Energy Trust and SBW all seem to recognize that SEEM has its limitations even for modeling some electric systems (even without the additional step of a conversion calculation to another fuel source). In response to PGE's comment that SEEM may not be able to accurately model usage of variable speed heat pumps (VSHPs) Energy Trust pointed out that "SBW(,) agreed to insert a note in the report indicating that SEEM's ability to model Variable Speed Heat Pumps usage is limited to only a few efficiency levels of equipment….(and) will include report language noting that the SEEM model was unable to exactly estimate the usage for the specific level of VSHP efficiency that was found in the Energy Trust program and instead used a different level of heat pump efficiency that the model *was* able to handle."