Air Conditioning Research—Phase II Final Report

March 2017

Prepared for
Energy Trust of Oregon

CADMUS

This page left blank.

CADMUS

Prepared by:
Aquila Velonis
Shannon Donohue
Bradley Jones
Jane Colby

The Cadmus Group LLC

CADMUS

This page left blank.

Contents

Executive Summary

Project Description and Background

This report describes the findings and conclusions from Phase II of the Energy Trust of Oregon's (Energy Trust) reassessment of the cost-effectiveness potential for residential air conditioning incentive programs.

Historically, in residential settings, air conditioning (AC) has not proven cost-effective in Energy Trust territory. Recent developments, however, demonstrate that Energy Trust's funding electric utilities experience summer peaks—when air conditioners are more likely operating, thus increasing the value of AC savings.

Under Phase I of this study, Cadmus supported Energy Trust in determining whether market circumstances changed enough for some AC measures to become cost-effective. As part of the Phase I analysis, Cadmus included an assessment of costs and savings for AC measures. Cadmus relied on secondary data to conduct the preliminary measure review, based primarily on Regional Technical Forum (RTF) unit energy-savings workbooks. Various other sources supplemented this effort, including the following:

- Existing Residential Building Stock Assessment (RBSA) data
- U.S. Department of Energy's (DOE) Technical Support Documents (TSD) and ENERGY STAR®
- Data from previous Cadmus' AC work AC in other states, including cost -effectiveness analysis, potential assessments, program planning support, and evaluations

The Phase I report concluded that central and window AC measures still were not likely to be cost-effective throughout Energy Trust's territory, but they warranted further investigation. Phase I report results and conclusions were presented to the Conservation Advisory Committee (CAC) on February 8, 2017, and CAC members agreed that further investigation is warranted.

The Phase II study objective was to conduct a deeper analysis of incremental savings and costs of AC measures by focusing on historical weather data (over 14 distinct Oregon weather locations), Oregon-specific modeling inputs, and in-depth cost research to more closely evaluate the cost-effectiveness of relevant AC measures for Energy Trust's consideration. Since the last cost-effectiveness review in Phase I, Energy Trust's avoided costs have been updated, and electric avoided costs have fallen. Energy Trust, however, is working with key stakeholders to update avoided costs to include capacity benefits that reflect summer peaks for PGE and PacifiCorp, which will improve the cost-effectiveness of summer peaking measures such as AC.

One of Phase II's main purposes was to incorporate historical Oregon weather data rather than relying on typical meteorological year 2 (TMY2) and 3 (TMY3) data to determine the cooling load. This research examined the year-to-year variance in weather as well as potential trends. Energy Trust discussed this approach with a climate scientist, who recommended an ideal historical dataset would consist of

45 years (or at least a minimum of 30 years). To meet Phase II objectives, Cadmus summarized historical Oregon weather data and analyzed trends, estimated cooling load consumptions using building simulations, conducted contractor equipment cost research, and modeled AC cost-effectiveness.

As shown in Table 1, Cadmus began the Phase II analysis by defining the measure scenarios according to AC market segment.

Table 1. Analyzed Phase II Measure Scenarios

Segment*	Vintage	Equipment Type	Channel	Scenario
Single-Family	Existing Construction	Window Unit AC	Retail	Incremental Upgrade
		Central AC	Contractor	New Purchase
	New Construction—Code Built	Central AC	Contractor	New Purchase
	New Construction—ENERGY STAR	Central AC	Contractor	New Purchase
Mobile Homes	Existing Construction	Window Unit AC	Retail	Incremental Upgrade
		Central AC	Contractor	New Purchase

*As discussed with Energy Trust and the CAC, Cadmus excluded multifamily package terminal air conditioner (PTAC) modeling from this scope of work and assumed that scope will be covered by the Program Management Contractor (PMC) for the respective program. Furthermore, Energy Trust and Cadmus agreed to exclude window AC units from this scope because not enough is known about the building characteristics in multifamily settings to make defensible assumptions for modeling.

The historical weather data were used as an input to Simple Energy Enthalpy Model (SEEM),[1] which Cadmus used to estimate cooling energy usage for each weather station and year, addressing four home categories:

- Existing single-family homes
- New code-built single-family homes
- New ENERGY STAR single-family homes
- Existing manufactured homes

In addition, Cadmus conducted Energy Trust trade ally contractor interviews to determine equipment incremental costs and to benchmark results with other secondary cost data. Cadmus compiled the cost-effectiveness inputs to develop specified range savings and costs, helping inform Energy Trust at which point that AC systems become cost-effective.

The Phase II study was far more thorough than was the Phase I study; nevertheless, it faced some inherent limitations in conducting the research. Although incorporating historical weather data into building simulation models can provide some predictive estimates of cooling consumption, Cadmus did not calibrate the predictions to any actual metered cooling loads. In the absence of large-scale Northwest cooling load research, it relied on best practices (e.g., ASHRAE Fundamentals and Building America Research Benchmark Definition) and data within RBSA to revise the models for estimating

[1] SEEM is an energy simulation model developed by Ecotope for the Pacific Northwest

cooling consumption.[2] In addition, this study focused on traditional central ACs with efficiencies ranging from 13 to 18 Seasonal Energy Efficiency Ratios (SEER) and did not investigate higher-efficiency systems with variable capacity capabilities.[3] Across North America, there are few, if any programs that cost-effectively incent ACs with SEER's above 18. The SEEM Version 97 model does not have active features for modeling the performance of variable capacity central AC. We assumed that variable capacity systems would not be cost-effective due to high costs, but this may change over time, as the market changes.

High-Level Findings and Conclusions

This Phase II review of AC measures suggests that central AC scenarios are not cost-effective when using costs gathered from Energy Trust contractors, regardless of weather data, and using Energy Trust's 2018 avoided costs. However, this study reviewed different scenarios for incremental costs and found a significant amount of variation in incremental costs depending on the data source. When Cadmus screened for cost-effectiveness using the lowest costs from secondary data (a distributor cost study from another region), central AC measures were shown to be cost-effective in some home types and climate zones. Based on the findings in Phase II, increased avoided costs and lower incremental costs from Energy Trust contractors could result in cost-effective scenarios for central AC with SEER 15 and SEER 16 measures and might warrant Energy Trust's investment in AC program offerings for these two measures.

Cadmus found low savings for window ACs and, even with an increase in avoided costs, this measure is unlikely to be cost-effective, so an investment to promote this measure is unwarranted at this time. In addition, although not definitive, the weather data analysis indicated a slight trend of more cooling degree days (CDD) over the past 40 years. This study does not predict future weather patterns; it is intended only to provide a historical range of likely future cost-effectiveness scenarios (at least in the near term).

The remainder of this report describes Cadmus' analysis of the following components of Phase II of this research:

- Historical Oregon Weather Data
- Cooling Load Consumptions
- Cost Research
- Cost-Effectiveness
- Results

---

[2] 2011 RBSA did conduct a whole-house energy use metering study, including cooling load research, for a small sample of homes. It involved 12 central ACs and nine central heat pumps covering five regions throughout the Northwest. Cadmus did not rely on these whole-house energy-use metering study data; rather, it used data points collected through RBSA housing stock assessment for the use of SEEM modeling inputs. Northwest Energy Efficiency Alliance. Residential Building Stock Assessment: Metering Study, April 28, 2014. Online at: http://neea.org/resource-center/regional-data-resources

[3] Many SEER 18 central ACs do have two stage compressors; however, Cadmus assumed SEER 18 represents the upper end of performance curves for single-stage systems and can be extrapolated with reasonable accuracy.

Historical Weather Data

Cadmus gathered historical weather data from 14 Oregon weather stations. Energy Trust's extensive experience working with data from various Oregon weather stations helped in the selection of the stations for this study.[4] Energy Trust also discussed this analysis with a climate scientist, who recommended an ideal historical dataset consisting of 45 years (or a minimum of 30 years). Cadmus used these weather data as an input to SEEM to estimate cooling energy usage for each weather station and year for four home categories:

- Existing single-family homes
- New code-built single-family homes
- New ENERGY STAR single-family homes
- Existing manufactured homes

These weather stations are located throughout the state and represent residential sites throughout Energy Trust's territory. The SEEM energy model requires all weather data to be formatted into TMY2.[5] Therefore, Cadmus engaged White Box Technologies,[6] a commercial supplier of formatted weather data, to develop the initial weather dataset. White Box Technology gathered publicly available data and used established methods to build hourly weather datasets from meteorological observations archived in the Integrated Surface Hourly Database (ISD).[7] White Box then provided Cadmus with 697 TMY2-formatted weather files and raw data files. Each TMY2-formatted weather file represented one year at one weather station.

As shown in Table 2, 11 of the 14 weather stations contained 44 years of data, from 1973 through 2016. Three stations—North Bend, Roseburg, and Hillsboro—contained less than 44 years but more than 36 years of data. Three stations with only five years of data were rejected because of incomplete hourly data (see the Cleaning Weather Data section).[8]

---

4 Three of the 13 stations that Energy Trust selected had limited historical TMY weather data going back further than 30 years: Hermiston Municipal Airport (19 years), Ontario Municipal Airport (20 years), and La Grande (25 years). Hermiston was replaced with Pendleton, Ontario was replaced with Baker-Muni-AP, and La Grande was removed from the study because a suitable replacement was not available.

5 SEEM was developed to process TMY2-formatted weather data; it processes both TMY3 and TMY2 by reformatting TMY3 weather data into the TMY2 data format.TMY2 and TMY3 represent hourly values of solar radiation and meteorological data covering one "typical" year intended for computer simulations.

6 White Box Technologies processes weather data for use in building energy simulations. Accessed December 2017: http://weather.whiteboxtechnologies.com/home

7 National Oceanic and Atmospheric Administration, National Centers for Environmental Information. "Integrated Surface Database (ISD)." Accessed December 2017: https://www.ncdc.noaa.gov/isd

8 Station-Years rejected included: Redmond Roberts Field—1990 and 2010; Roseburg Reginal Airport(1980 and 1987), and Portland-Hillsboro 1981.

Table 2. Weather Stations

Station Number	Station Name	World Meteorological Organization (WMO) Station Number	Years Available	Included In Analysis	NWPCC Cooling Zone	Service Area Territory
1	Astoria Regional Airport	727910	44 (1973-2016)	All Available	1	Electric
2	Eugene Mahlon Sweet Airport	726930	44 (1973-2016)	All Available	1	Gas
3	Pendleton	726880	44 (1973-2016)	All Available	3	Both
4	Klamath Falls Int'l Airport	725895	44 (1973-2016)	All Available	2	Electric
5	Medford Rogue Valley Airport	725970	44 (1973-2016)	All Available	3	Electric
6	North Bend Regional Airport	726917	40 (1977-2016)	All Available	1	Both
7	Baker-Muni-AP	726886	44 (1973-2016)	All Available	1	Gas
8	Portland Int'l Airport	726980	44 (1973-2016)	All Available	2	Both
9	Redmond Roberts Field	726835 / 726920	44 (1973-2016)	42 (1973-1989, 1991-2009, 2011-2016)	1	Both
10	The Dalles Municipal Airport	726988	44 (1973-2016)	All Available	3	Gas
11	Salem McNary Field	726940	44 (1973-2016)	All Available	1	Both
12	Roseburg Regional Airport	726904	37 (1980-2016)	35 (1981-1986, 1988-2016)	2	Electric
13	Portland-Troutdale	726985	44 (1973-2016)	All Available	2	Both
14	Portland-Hillsboro	726986	36 (1981-2016)	35 (1982-2016)	1	Both

Cadmus mapped each weather station to a designated cooling zone, as defined by the Northwest Power and Conservation Council's Pacific Northwest cooling zones for the region.[9] As shown in Table 3, overlaying Energy Trust's residential customer service territory and the customer site (premise) count, Cadmus estimated the percentage of customers in each cooling zone: 90% of Energy Trust customers resided in cooling zones 1 and 2.

9 The Northwest Power Planning Council's heating and cooling zone maps are available online: Bonneville Power Administration. "Regional States Heating Climate Zone Assignments by County." March 16, 2011. https://www.bpa.gov/EE/Sectors/Residential/Documents/PNWHeatingandCoolingClimateZoneAssignmentsbyCounty.pdf

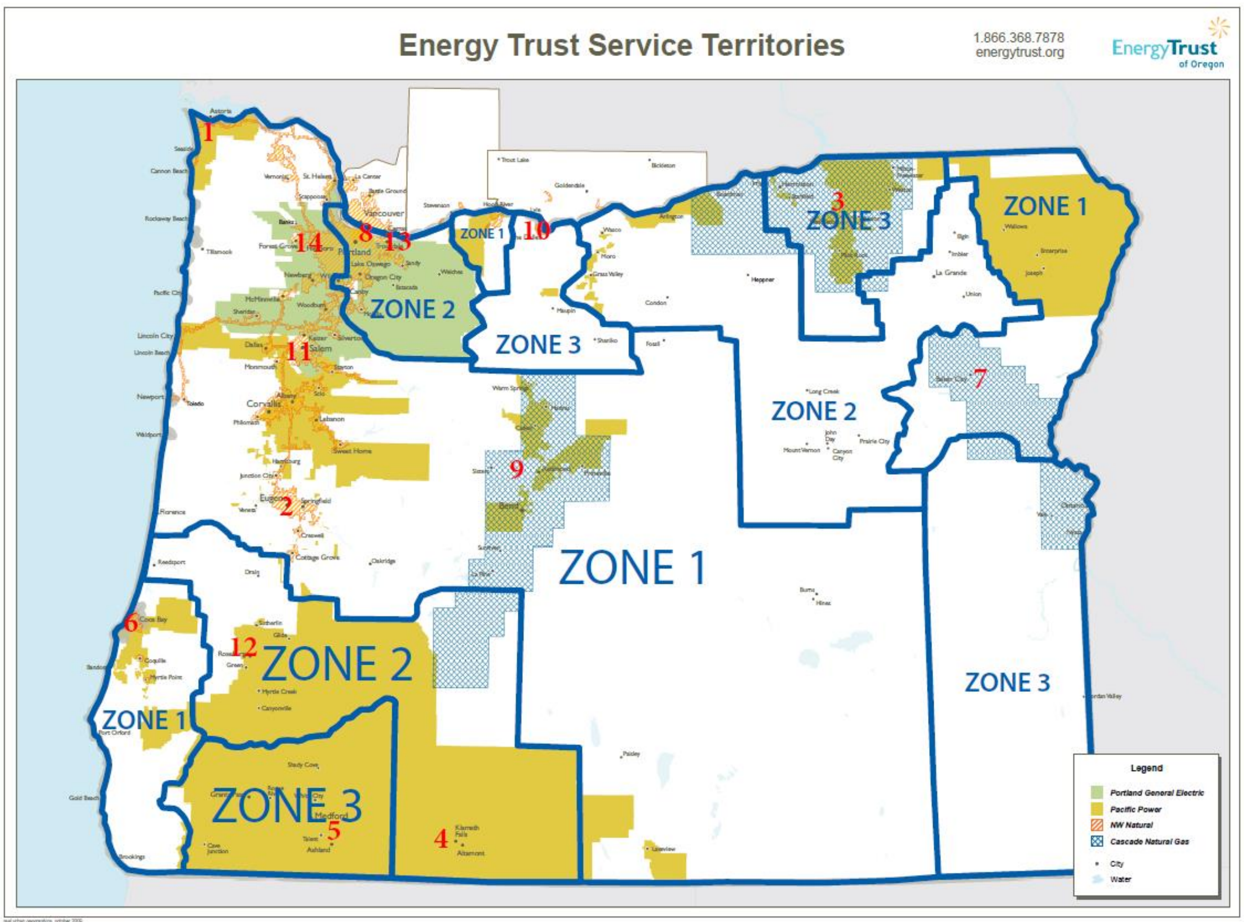
Table 3. Energy Trust Residential Site Count by Northwest Cooling Zone

PNW Cooling Zone*	Energy Trust Site Count	Percentage
Cooling Zone 1: < 300 CDD	401,887	31%
Cooling Zone 2: 300-600 CDD	752,460	59%
Cooling Zone 3: > 600 CDD	126,675	10%
Total	**1,281,022**	**100%**

*CDD (TMY3) represents cooling degree days for the Pacific Northwest.

As a large percentage of the state's population lives in Portland's metro area and divides between cooling zone 1 and zone 2, more stations in this area would benefit the analysis. Cadmus included three weather stations to characterize the Portland metro area: Portland-International Airport; Portland-Troutdale; and Portland-Hillsboro. Figure 1 shows Energy Trust's service territory with corresponding weather station numbers. Cadmus selected the remaining 11 stations to represent the variety of climates across Energy Trust's territory.

Figure 1. Energy Trust Service Territory with Weather Station Number by Cooling Zone



Source: Energy Trust of Oregon. 2009.

Cleaning Weather Data

Developing a formatted TMY2 weather file required some interpretation and estimations of raw ISD data. Though White Box provided most weather data parameters for every hour of every year,[10] some of these data have been estimated due to gaps in historical records. In processing all 697 weather files for quality assurance, Cadmus identified several notable issues with the provided data:

- **Modeled or interpolated nighttime conditions (approximately 95 files):** The dataset prior to the year 2000 often did not include nighttime data in the raw data, likely due to data collected manually during a typical workday. White Box used proprietary methods to fill in these data points using a mix of interpolation, modeling, and other methods.
- **Opaque sky cover data missing (N=409 files):** The SEEM model uses opaque sky cover data to estimate sky temperatures for radiative losses in the simulation. Opaque sky cover estimates the amount of the sky completely obscured by clouds. Not collected by any weather station after 1997, these data were available for eight weather stations prior to 1996.
- **Greater than 30 days of estimated data (N=15 files):** Several years of data contained more than consecutive 30 days of missing data.

Cadmus discussed these issues with the Energy Trust, White Box Technologies, and Ecotope,[11] and it developed the follow mitigation strategies.

- **Accept the modeled nighttime weather as reasonably representing actual conditions (all identified files):** Upon analyzing the nighttime temperature and wind data, it became apparent that these data represent typical nighttime conditions relatively well. The modeled nighttime conditions did follow expected cooling and warming trends.
- **Substitute opaque sky cover with total sky cover (N=409 files):** Cadmus consulted with Ecotope about substituting opaque sky cover with total sky cover because total sky cover was significantly more complete in the weather data. Ecotope agreed that the substitution should not cause significant problems as long as the substitution's impact remains known. Cadmus ran a test of the 188 station-years where opaque sky cover was a known value against the same weather where total sky cover was substituted. This resulted in a 1.5% average increase in cooling energy consumption upon substitution. Cadmus and the Energy Trust found this impact nominal and decided to substitute opaque sky cover with total sky cover in the remaining 409 weather files, applying a 1.5% correction factor to cooling energy consumption.

[10] SEEM models require the following parameters: dry bulb temperature, humidity, wind speed, opaque sky cover, and total sky cover.

[11] Ecotope developed SEEM for the Northwest Power Planning Council and Northwest Energy Efficiency Alliance (NEEA). They support and maintain the SEEM building simulation tool.

- **The analysis dropped long periods of estimated summer data (N=5 files):** Due to the study's cooling focus, Cadmus examined files with missing data in detail, seeking to determine if estimated data were in summer time and the data parameter proved critical. Cadmus decided to include nine identified files because only total sky cover was estimated for more than one month. Cadmus also retained one identified file because it missed dewpoint temperatures in November and December, which are not cooling months. The final analysis excluded the remaining five files.

The final weather dataset, after removing five weather files described above, used in the SEEM modeling analysis contained 26 million data points, with 90% of those data points from direct observation, 8% interpolated linearly and 2% interpolated using a non-linear approach.[12]

Summary of Historical Weather 1973 to 2016

Cooling degree days (CDD) provide an excellent indicator of summertime cooling needs. Cadmus calculated daily CDD base 65 by subtracting 65 degrees from the daily average temperature. If the average temperature was less than or equal to 65 degrees, then there were zero CDD. Cadmus then summed the daily CDD for each year to obtain the annual CDD.[13] Figure 2 shows the range, median, mean, and first and third quartile of the annual CDD across all available years of data for each weather station. The figure also includes a reference CDD base 65 calculated from TMY3 weather data.[14]

Astoria and North Bend—both coastal cities—had the lowest CDD. For example, in North Bend, five of the last 40 years recorded zero CDD, indicating average summertime daily temperature never exceeded 65 degrees. In contrast, Medford and The Dalles historically have had the warmest summers of sampled weather stations. For 12 of the 14 weather stations, the TMY3 weather data fell within the first and third quartile of the recent historical record. The Medford and Roseburg TMY3 datasets indicated CDD below the first quartile, though Roseburg's statistics notably have been based on a 35-year record rather than the 44 years available for most other stations.

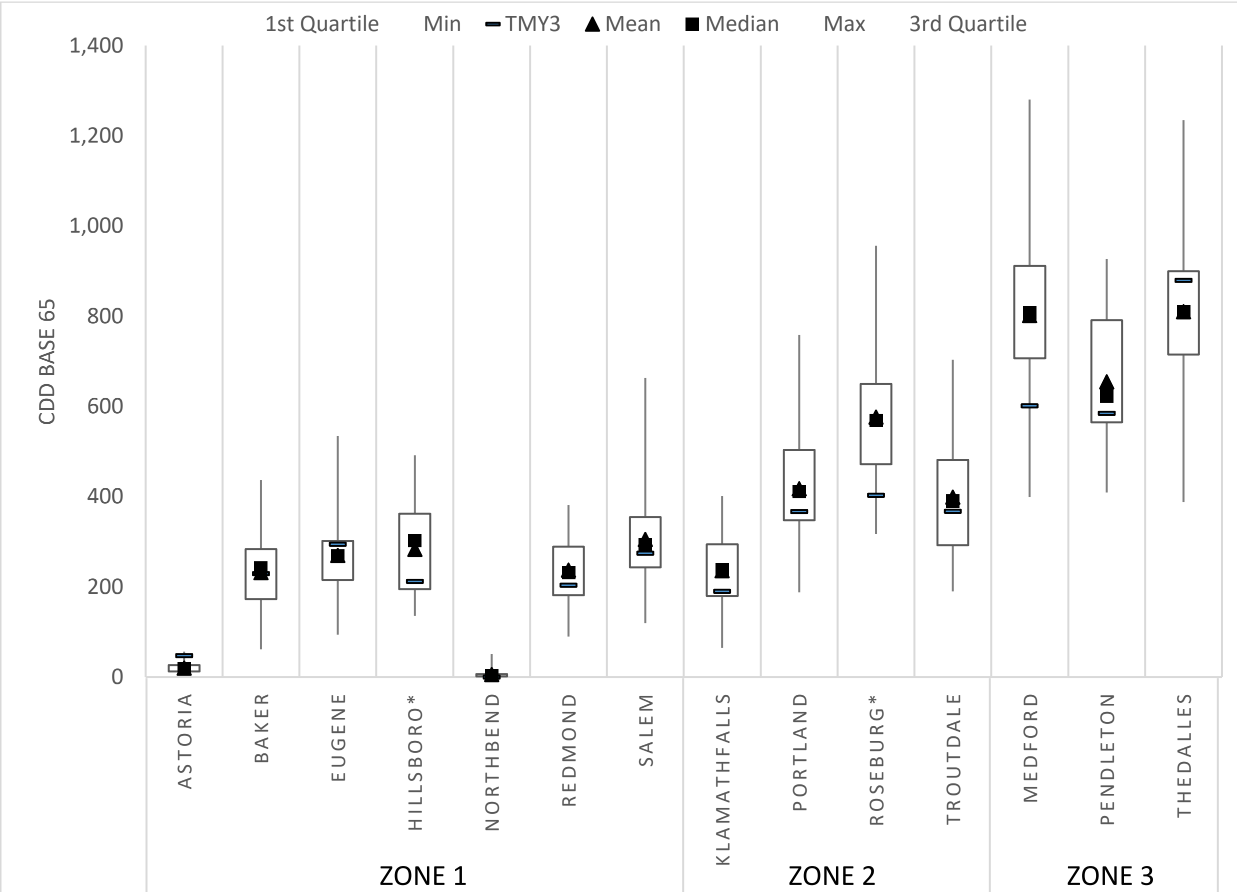
---

12 Method used by White Box to substitute missing data: Non-linearly interpolated using Fourier Series for daytime hours and sine curve approximation for nighttime hours, done only for dry-bulb temperatures.

13 CDD65 = Sum ((Average Daily Temperature(F) >65(F)) – 65(F))

14 TMY3 is the Typical Meteorological Year Version 3, designed to represent a typical year from the period 1961 to 2005.

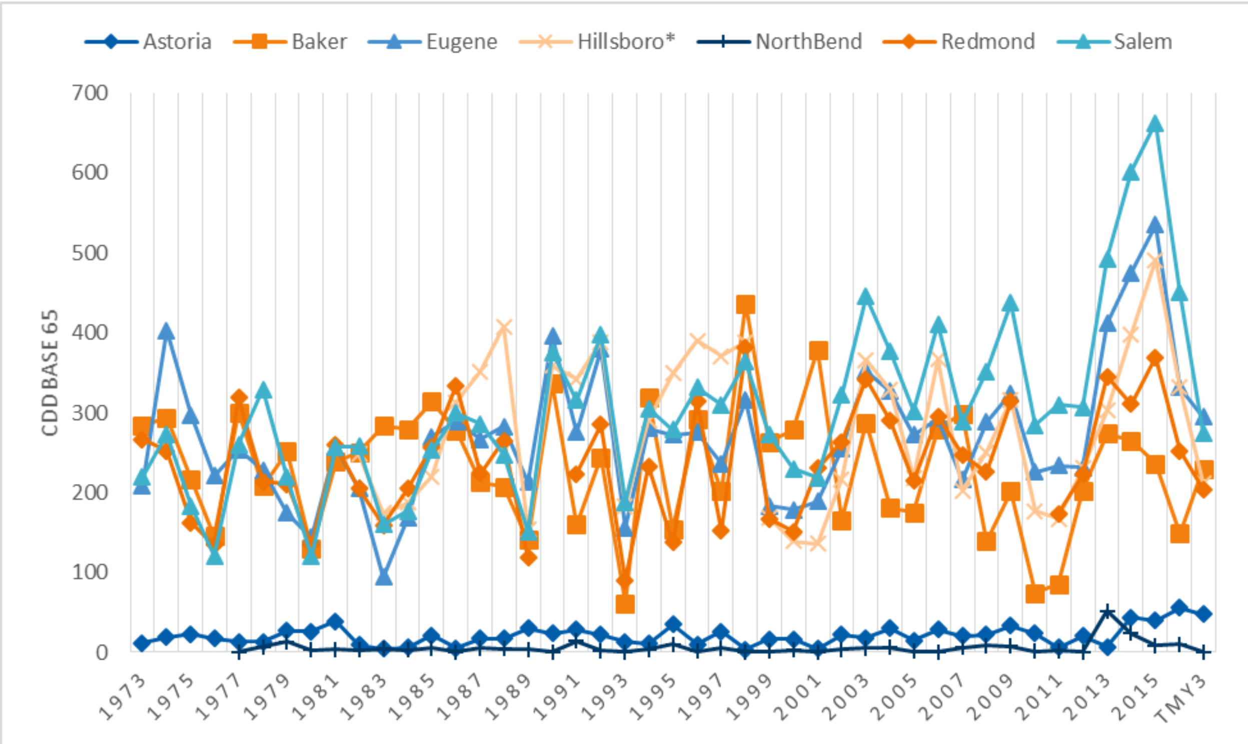
Figure 2. Cooling Degree Day Statistics



*Hillsboro and Roseburg only contained data back to 1982 and 1981, respectively.

As shown in Figure 3, similar CDD were observed among the remaining stations: Baker, Eugene, Hillsboro, and Redmond. Across much of Zone 1, 2015 historically had the warmest summer, though this effect concentrated primarily on the I-5 corridor. For example, the hottest year for Baker and Redmond, both east of the Cascades, was 1998.

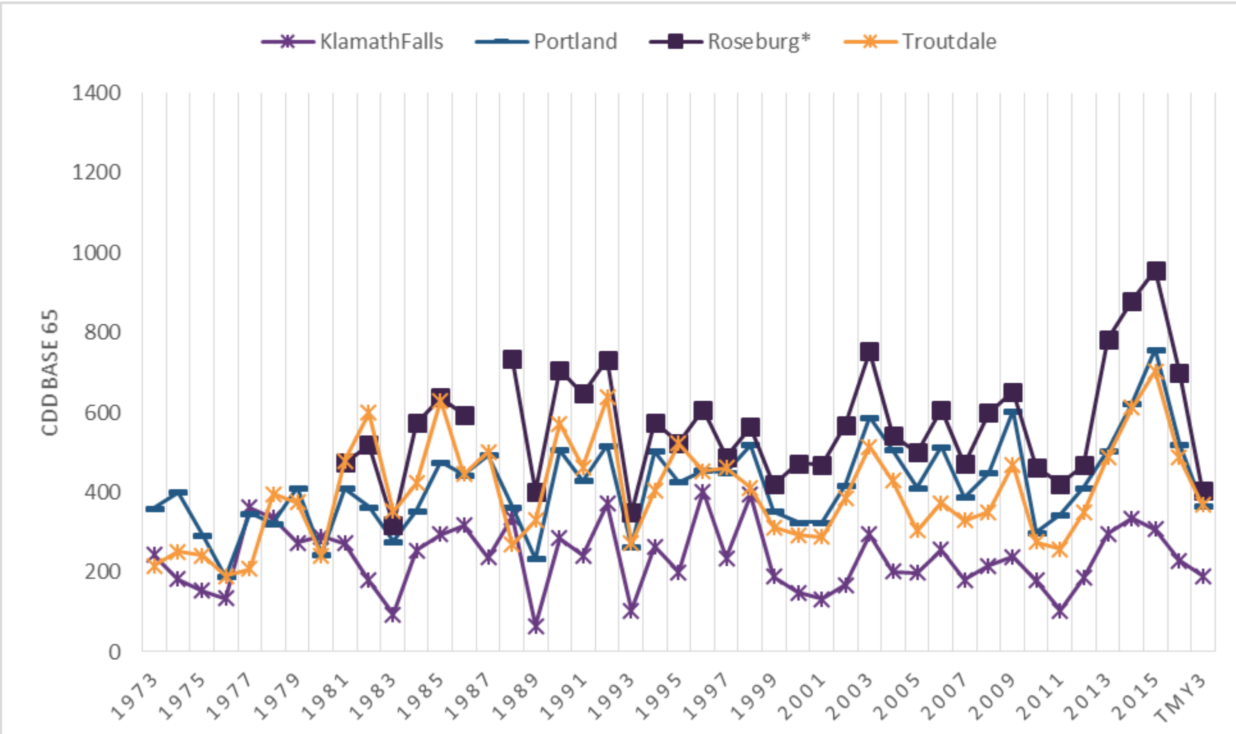
Figure 3. Zone 1 Historical Cooling Degree Days



*Hillsboro only contained data back to 1982.

Figure 4 shows zone 2 stations' historical CDD. Roseburg consistently had the highest CDD, while Klamath Falls had the lowest. As with zone 1 stations, those along the I-5 corridor had summers of highest CDD in 2015, while Klamath Falls, which is east of the Cascades, peaked in 1996.

Figure 4. Zone 2 Historical Cooling Degree Days



*Roseburg only contained data back to 1981.

Figure 5 shows zone 3 stations' historical CDD. Medford and The Dalles both showed similar historical trends, with peak CDD occurring in 2015, while Pendleton had its peak year in 1975.

Figure 5. Zone 3 Historical Cooling Degree Days

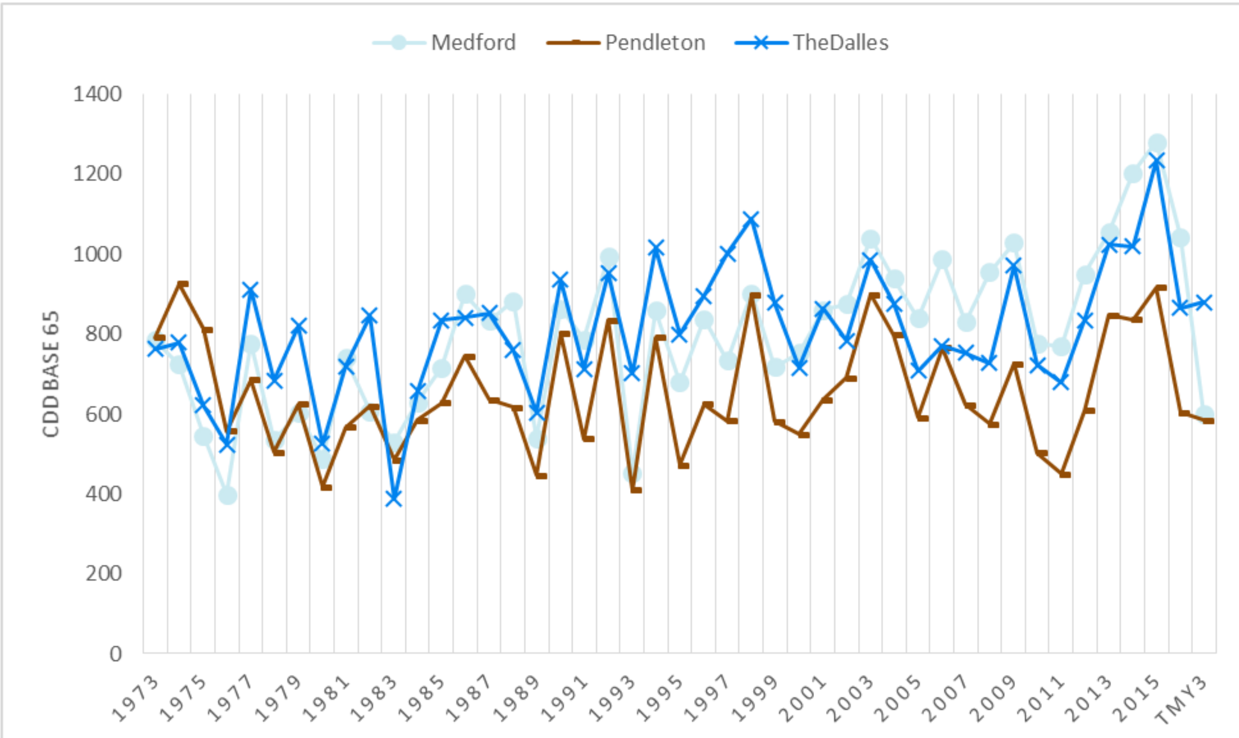


Table 4 shows the most extreme CDD base 65 years (cooling year) for each station in the sample. While eight stations had peak CDD base 65 in 2015, a similar trend did not become as apparent for minimum CDD base 65. Three stations had common minimum years across three years: 1976, 1983, and 1993 (shown in **bold** type).

From Table 4, Cadmus concluded that there is some commonality in years (post-2012) with extremely warm weather among weather stations (10 out of 14), but this is not 100% uniform. There is less uniformity for the years with the most moderate weather, therefore, some uncertainty for any effort to use these data to extrapolate future weather.

Table 4. High, Low, and Median CDD 65 years

Station	Year with Highest CDD (High)	Year with Median CDD (Med)	Year with Lowest CDD (Low)
Astoria	2016	2012	1998
Baker	1998	1981	**1993**
Eugene	**2015**	1985	**1983**
Hillsboro*	**2015**	2013	2001
Klamath Falls	1996	1987	1989
Medford	**2015**	1991	**1976**
North Bend	2013	1981	1986
Pendleton	1974	2007	**1993**
Portland	**2015**	2005	**1976**
Redmond	1998	2001	**1993**
Roseburg*	**2015**	2002	**1983**
Salem	**2015**	2007	1980
The Dalles	**2015**	1979	**1983**
Troutdale	**2015**	2002	**1976**

*Hillsboro and Roseburg only contained data back to 1982 and 1981, respectively.

Estimating Cooling Energy Consumption

To estimate cooling energy consumption, Cadmus developed Oregon-specific SEEM prototype models (single-family existing, single-family new construction code-compliant, single-family ENERGY STAR, and mobile home existing), processed with weather data developed as described above. Cadmus developed weighting strategies for each prototype model set to characterize a segment of the housing population. Finally, Cadmus population-weighted results for each category by weather stations to characterize cooling load by year in each weather zone and across the territory.

Table 5 shows the prototype categories, the number of prototypes, and the number of weather files. This analysis included a total of 10,656 SEEM simulations.

Table 5. Simulations Preformed

Home Type	Number of Prototypes	Number of Weather Files	Simulation Runs
Single-Family Existing	5	592	2,960
Single-Family New Construction Code Built	5	592	2,960
Single-Family New Construction ENERGY STAR Built	5	592	2,960
Mobile Home Existing	3	592	1,776
Total Simulations Run			**10,656**

Multiple Sources in Developing Prototype Models to Characterize Four Main Home Categories

Table 6 outlines Cadmus' source data by input category used in the SEEM prototypes.[15] The home sizes and geometry characteristics derived from the RTF Prototypes, used for nearly all SEEM modeling. The prototype envelope characteristics developed from the 2011 Residential Building Stock Assessment (RBSA) and a SEEM calibration run preformed for the RTF. Central AC systems were sized according to ASHRAE 0.4% design temperatures. Appendix A provides system sizes used in the analysis and other SEEM modeling inputs.

15 SEEM Standard information developed from calibration analysis. Many of the models' 77 inputs were fixed in the analysis to increase the model's repeatability and billing data's overall accuracy. While the calibration exercise focused on heating energy, Cadmus found many fixed variables appropriate to this analysis.

Table 6. SEEM Modeling Input Sources

Model Parameter	Single-Family Existing	Single-Family New Construction – Code Built	Single-Family New Construction – ENERGY STAR Built	Mobile Home Existing
Home Size & Geometry	RTF Prototype Standard Dimensions	RTF Prototype Standard Dimensions	RTF Prototype Standard Dimensions	RTF Prototype Standard Dimensions
Envelope Insulation & Sealing	Single-Family SEEM Runs[1]‡ & 2011 RBSA[2]	RTF ENERGY STAR HOMES SF-Oregon 2012[3, 4]	RTF ENERGY STAR HOMES SF-Oregon 2012[3,4]	Manufactured Homes SEEM Runs[5] & 2011 RBSA[6]
HVAC Equipment Sizes	ASHARE 0.4% Design Temperatures[7]	ASHARE 0.4% Design Temperatures[7]	ASHARE 0.4% Design Temperatures[7]	ASHARE 0.4% Design Temperatures[7]
Cooling Temperature Setpoints	2011 RBSA[2]	2011 RBSA[2]	2011 RBSA[2]	2011 RBSA[2]
Internal Moisture Gains	Building America Research Benchmark Definition[8]	Building America Research Benchmark Definition[8]	Building America Research Benchmark Definition[8]	Building America Research Benchmark Definition[8]

[1] RTF's SEEM modeling. Workbook name: SEEMruns_SingleFamilyExistingHVACandWeatherization_Feb2016.xlsm (SEEM v.97). Online at: https://rtf.nwcouncil.org/measure/air-source-heat-pump-upgrades-sf

[2]NEEA's 2011 Residential Building Stock Assessment: Single-Family Characteristics and Energy Use, September 18, 2012. Online at: http://neea.org/docs/reports/residential-building-stock-assessment-single-family-characteristics-and-energy-use.pdf

[3] RTF's measure assessment. Workbook name: ResNewSFEStarOR_V3_5.xlsm. Online at: https://rtf.nwcouncil.org/measure/energy-star-homes-sf-oregon-2012

[4]RTF's SEEM modeling. Workbook name: NewConstructionSingleFamilySEEM94Runs_OR_2_2 (SEEM v.94). Online at: https://rtf.nwcouncil.org/measure/energy-star-homes-sf-oregon-2012

[5]RTF's SEEM modeling. Workbook name: ManufacturedHomesWxSEEMWorkbookRuns05052015.xlsm Online at: https://rtf.nwcouncil.org/measure/commissioning-controls-sizing-mh

[6] Northwest Energy Efficiency Alliance. *Residential Building Stock Assessment: Manufactured Home Characteristics and Energy Use.* January 30, 2013. Online at: http://neea.org/docs/default-source/reports/residential-building-stock-assessment--manufactured-homes-characteristics-and-energy-use.pdf[7]ASHRAE Fundamentals 2009 & ACCA Manual S system selection procedures.

[8]Building America Research Benchmark Definition, NREL 2009 Online at: http://www.nrel.gov/docs/fy10osti/47246.pdf

High-Priority Inputs Specific to Cooling Due to RTF Focus on Heating

Cadmus identified that cooling setpoints and internal latent loads used in pervious RTF SEEM models could benefit from further research. Thermostat settings within RTF SEEM models for cooling historically have been based on engineering judgements. Cadmus researched the 2011 RBSA report to determine a mean cooling setpoint of 74.2F without a nighttime setback.[16] Cadmus also found RTF SEEM workbooks did not specify the internal latent load,[17] or they specified this as 0. Cadmus researched the Building

[16] Only 8% of surveyed customers reported using a nighttime setback during the cooling season.

[17] Internal latent load is the moisture introduced to the home from internal sources such as showers, cooking, dishwashing, people, plants and pets. This load does not significantly impact heating since moisture is desired during the heating season, it is a significant load for cooling as the moisture must be either exhausted or removed mechanically by the air conditioner.

America Benchmark Definition to develop an equation that estimated the latent load proportionally to a home's size and number of occupants (as estimated by the number of bedrooms). Table 7 shows the two inputs that the RTF used in the past and the updated inputs used in this analysis.

Table 7. SEEM Input Update

Updated Parameter	Past SEEM Inputs	Updated SEEM Input
Cooling Setpoint	78F day/ 78F night (Single-Family) 74F day/ 78F night (New Single-Family) 74F day/ 80F night (Manufactured Homes)	74.2F no setback (all homes)
Internal Latent Load	0 (lb/hr)	lb/hr =0.222+ 0.103 X N Bedrooms + 0.00001 X Conditioned Floor Area

All 10,656 Simulations Ran in SEEM V97

Cadmus chose SEEM 97 due to its 64 bit computability, which allowed many simulations to be conducted in a reasonable timeframe (i.e., six to eight hours). Cadmus then checked the SEEM output for erroneous data, failed simulations, or unreasonable results.

Weighted Prototypes Used to Develop Weighted Cooling Energy Consumption

Cadmus modeled all SEEM prototypes with a 13 SEER cooling system.[18] Cadmus applied the SEER adjustment in the equation below to the 13 SEER cooling energy consumption to calculate cooling energy usage for higher SEER systems:

$$Cooling\ kWh_{@\ X\ SEER} = Cooling\ kWh_{@\ 13\ SEER} \frac{X\ SEER}{13\ SEER}$$

The five single-family prototypes represented typical homes of various sizes and foundation types. Because this analysis focused on the potential for AC measures, Cadmus developed a weighting strategy to characterize existing single-family homes with duct systems from the 2011 RBSA. Cadmus then filtered the 2011 RBSA data to only include homes with duct systems for heating or cooling. The total square footage of these homes included representative survey weighting from the RBSA by five prototype categories for various building sizes and foundation types. The RTF standard information workbook was used to weight existing manufactured homes.[19] Cadmus used RTF weighting for new homes; these factors are outlined in the New Construction SEEM workbook.[20] Appendix B details the prototype weighting factors used for all models.

---

[18] For existing and new construction incremental upgrade applications, evaluations, planning, and cost-effectiveness analysis mostly commonly rely on the current federal standard baseline efficiency. The current federal standard minimum requirement for split-system central ACs is a SEER 13, per the Code of Federal Regulations in 10 CFR 430.32(c)(3).

[19] RTF Standard Information Workbook: RTFStandardInformationWorkbook_v2_6.xlsx

[20] New Construction SEEM runs: ResidentialSingleFamilySEEM92Runs_NewConstructionHPUpgrades_v2.xlsm

Weighted Results by Cooling Zone

Cadmus weighted the results for each modeled home by weather station for each cooling zone as well as statewide to develop the estimated cooling energy consumption of a home with 13 SEER central AC. Table 8, Table 9, and Table 10 detail the prototype-weighted cooling energy consumption of a 13 SEER central cooling system by station, weather zone, and statewide for each cooling year as determined above in Table 4. Table 8 details the year's high cooling energy consumption for each prototype; Table 9 details the median year cooling energy consumption for each prototype; and Table 10 details the year with low cooling energy consumption for each prototype. Appendix C: TMY and CDD Details provides additional information (e.g., modeled TMY3 cooling load consumption, CDD summary by location). Cooling zones (1, 2, and 3) and the statewide values presents the weighted cooling consumption by Energy Trust's residential customer service territory and the customer site (premise) counts, as provided in Table 3.

Table 8. High CDD Cooling Energy Consumption – Base 13 SEER (kWh/home)

Station	Single-Family Existing	Single-Family New Construction – Code Built	Single-Family New Construction – ENERGY STAR Built	Mobile Home Existing
Astoria	522	293	335*	380
Baker	1,799	840	767	1,156
Eugene	2,487	1,236	1,145	1,538
Hillsboro	2,151	1,079	1,005	1,358
North Bend	449	244	314*	316
Redmond	2,172	1,023	930	1,369
Salem	2,410	1,229	1,131	1,510
Zone 1	**2,110**	**1,059**	**984**	**1,330**
Klamath Falls	2,043	977	900	1,304
Portland	2,332	1,232	1,154	1,481
Roseburg	3,203	1,630	1,485	1,967
Troutdale	2,441	1,272	1,191	1,536
Zone 2	**2,409**	**1,258**	**1,175**	**1,521**
Medford	4,033	1,975	1,782	2,466
Pendleton	3,141	1,536	1,398	1,937
The Dalles	4,027	1,980	1,797	2,438
Zone 3	**3,908**	**1,914**	**1,729**	**2,390**
Statewide	**2,432**	**1,237**	**1,148**	**1,526**

* Modeling ENERGY STAR or any well insulated building with a low balance point temperature, consequently require cooling more hours of the year due to internal loads rather than passively cooling because it's colder outside than inside.

Table 9. Median CDD Cooling Energy Consumption – Base 13 SEER (kWh/home)

Station	Single-Family Existing	Single-Family New Construction – Code Built	Single-Family New Construction – ENERGY STAR Built	Mobile Home Existing
Astoria	193	82	107*	151
Baker	1,335	619	574	887
Eugene	1,300	634	599	824
Hillsboro	1,289	666	640	841
North Bend	145	57	92*	122
Redmond	1,447	638	594	932
Salem	1,330	653	625	850
Zone 1	**1,224**	**604**	**579**	**792**
Klamath Falls	1,421	665	615	935
Portland	1,362	714	675	869
Roseburg	2,015	1,012	943	1,260
Troutdale	1,383	729	690	894
Zone 2	**1,414**	**736**	**694**	**906**
Medford	2,750	1,356	1,243	1,720
Pendleton	2,160	1,079	1,001	1,362
The Dalles	2,573	1,292	1,184	1,607
Zone 3	**2,657**	**1,314**	**1,206**	**1,662**
Statewide	**1,459**	**737**	**696**	**934**

* Modeling ENERGY STAR or any well insulated building with a low balance point temperature, consequently require cooling more hours of the year due to internal loads rather than passively cooling because it's colder outside than inside.

Table 10. Low CDD Cooling Energy Consumption – Base 13 SEER (kWh/home)

Station	Single-Family Existing	Single-Family New Construction – Code Built	Single-Family New Construction – ENERGY STAR Built	Mobile Home Existing
Astoria	95	32	36*	83
Baker	675	260	246	475
Eugene	712	343	349*	483
Hillsboro	837	425	408	565
North Bend	17	4	13*	20
Redmond	835	338	321	571
Salem	798	370	367	536
Zone 1	**746**	**354**	**345**	**505**
Klamath Falls	827	354	344	569
Portland	780	417	430*	528
Roseburg	1,252	703	686	820
Troutdale	516	271	274*	379

Station	Single-Family Existing	Single-Family New Construction – Code Built	Single-Family New Construction – ENERGY STAR Built	Mobile Home Existing
Zone 2	**731**	**387**	**394***	**503**
Medford	1,721	832	786	1,095
Pendleton	1,438	721	686	945
The Dalles	1,528	787	761	995
Zone 3	**1,669**	**813**	**770**	**1,068**
Statewide	**835**	**417**	**412**	**563**

* Modeling ENERGY STAR or any well insulated building with a low balance point temperature, consequently require cooling more hours of the year due to internal loads rather than passively cooling because it's colder outside than inside.

Benchmarking Central Air Conditioner Consumption

After modeling central AC consumptions, Cadmus compared the results to other regional data sources. In addition to benchmarking our modeling results, we also used these comparisons to identify applicable adjustments to the modelled consumptions as part of our sensitivity analysis (in Cost-Effectiveness Scenarios section). Generally speaking, regional cooling consumption data are pretty limited and even less available in Oregon. Although not an extensive review, Cadmus benchmarked the modeled results to these four regional data sources:

- **Energy Trust's Nest Thermostat Seasonal Savings Pilot Evaluation**[21] (Single-Family Existing)
  - 2016 study of single-family homes with Nest thermostats, conducted a fixed effects panel regression analysis of 572 homes with monthly billing data and 140 homes with interval data.
- **NEEA's RBSA Metering Study**[22] (Single-Family Existing and Mobile Home Existing)
  - 2011 RBSA whole-house energy use metering study including cooling load research for 12 central air conditioners and nine central heat pumps covering five regions throughout the Northwest.
- **Puget Sound Energy's Assessment of Potential with Conditional Demand Modeling**[23] (Single-Family Existing and Mobile Home Existing)

21 Apex Analytics November 22, 2017. Energy Trust of Oregon Nest Thermostat Seasonal Savings Pilot Evaluation. Online at: https://www.energytrust.org/wp-content/uploads/2017/12/Energy-Trust-of-Oregon-Nest-Seasonal-Savers-Pilot-Evaluation-FINAL-wSR.pdf

22 Ecotope Inc. April 28, 2014. Northwest Energy Efficiency Alliance Residential Building Stock Assessment: Metering Study. Online at: http://neea.org/resource-center/regional-data-resources

23 Cadmus Group, Inc. May 2013. Puget Sound Energy Comprehensive Assessment of Demand-Side Resource Potentials (2014–2033) Appendix D: Conditional Demand Modeling. Online at: https://pse.com/aboutpse/EnergySupply/Documents/IRP_2013_AppN.pdf

    - 2009 conditional demand analysis of over 4,300 homes with survey and billing data using Princeton ScoreKeeping models (PRISM) method to estimate end-use consumptions in the Puget Sound region.
- **NEEA's Residential New Home Codes Energy Use Savings Report**[24] (Single-Family New Construction Code Built and Single Family New Construction ENERGY STAR Home)
    - 2011 residential new construction study using SEEM modeling to estimate end-use consumption and savings of 2011 Oregon Residential Specialty Code (2011 ORSC) built and ENERGY STAR homes.

Single-Family Existing

Cadmus compared three of the benchmarking studies to the modeled results, as shown in Table 11. Initially, this comparison sought to validate the modeled energy results using real-world usage data from Northwest and Oregon households.

Table 11. Single Family Central Air Conditioner kWh Consumption Comparison

Station	Single-Family Existing SEER 13				Nest Pilot Single Family	PSE Conditional Demand Analysis Single-Family	RBSA Metering Single-Family NW Region
	Low	Med	High	TMY3	(Normalized TMY3)*	(Normalized TMY3)	(Normalized TMY3)
Astoria	95	193	522	247	310	178	N/A
Baker	675	1,335	1,799	1,355	N/A	853	N/A
Eugene	712	1,300	2,487	1,293	669	1,097	N/A
Hillsboro	837	1,289	2,151	1,098	N/A	790	N/A
North Bend	17	145	449	110	246	-	N/A
Redmond	835	1,447	2,172	1,248	664	759	N/A
Salem	798	1,330	2,410	1,323	731	1,021	N/A
Klamath Falls	827	1,421	2,043	1,352	692	707	N/A
Portland	780	1,362	2,332	1,204	787	1,365	N/A
Roseburg	1,252	2,015	3,203	1,421	829	1,500	N/A
Troutdale	516	1,383	2,441	1,292	N/A	1,368	N/A
Medford	1,721	2,750	4,033	2,073	1,070	2,236	N/A
Pendleton	1,438	2,160	3,141	1,888	N/A	2,175	N/A
The Dalles	1,528	2,573	4,027	2,560	1,449	3,271	N/A
Statewide**	835	1,459	2,432	1,283	N/A	N/A	820

*Nest study used TMY3 CDD base 62 than CDD base 65.
**Energy Trust data represents weighted consumptions specific to Energy Trust's territory.

Several key differences existed between this study and other benchmarking studies. The RBSA metering study represents the entire Northwest region and was based on 23 cooling consumption observations, making a direct comparison to Energy Trust territory difficult.

---

24 Ecotope Inc. August 22, 2012. Northwest Energy Efficiency Alliance 2011 Residential Codes Energy Use Savings. Online at: http://neea.org/docs/reports/2011-residential-codes-energy-use-savings.pdf?sfvrsn=18

Although the Nest Seasonal Savings pilot evaluation is within Energy Trust territory, the population groups are different. Seasonal Savings pilot participants all purchased and used Nest smart thermostats; consequently, this population of households is not expected to be representative of Oregon's standard population, probably resulting in differences in home sizes, vintages, envelopes, and other details. In addition, the Nest study had "limited amount of cooling and small cooling season response observed across the total Pilot population." This is partially because the cooling season of the Nest study took place in summer of 2016, which was a relatively cool summer. Therefore, Cadmus had difficulty drawing meaningful conclusions.

Conditional demand analysis conducted for Puget Sound Energy (PSE), although in the Washington, provides kWh per CDD values normalized to TMY3 weather. The PSE study estimated an average of 163 CDD for single-family homes. Since Puget Sound region is more coastal, a direct comparison is more meaningful to Oregon locations found in zone 1 and less meaningful in hotter areas such as zone 3.

As part of the sensitivity analysis (in Cost-Effectiveness Scenarios section), Cadmus used the PSE conditional demand analysis to estimate an average consumption adjustment factor between the two studies. The consumption adjustment factor was determined to be 67%, where the PSE conditional demand analysis was 33% less on average compared to the Energy Trust SEEM modeling used in this study.[25]

Mobile Home Existing

Two of the benchmarking studies were compared to these modeled results. The comparison included the PSE conditional demand analysis and RBSA metering study for mobile homes, as shown in Table 12.[26] The PSE study estimated an average of 160 CDD for mobile homes. As part of the sensitivity analysis (in the Cost-Effectiveness Scenarios section), Cadmus used the PSE conditional demand analysis to estimate an average consumption adjustment factor between the two studies and determined it was 44%.[27]

Table 12. Mobile Home Central Air Conditioner kWh Consumption Comparison

Station	Mobile Home Existing kWh Consumption CEER 11				PSE Conditional Demand Analysis Mobile Home	RBSA Mobile Home NW Region
	Low	Med	High	TMY3	(Normalized to TMY3)	(Normalized to TMY3)
Astoria	83	151	380	188	83	N/A
Baker	475	887	1,156	895	397	N/A
Eugene	483	824	1,538	835	510	N/A

25 This factor is based on PSE's conditional demand CDD per kWh results applied to Oregon locations with 0 to 326 CDD. This represent an assumed applicable range of ± 163 CDD (e.g., up to double the PSE results).

26 The comparison data includes cooling consumptions for manufactured homes. It is assumed to be a reasonable comparison to mobile homes.

27 This factor is based on PSE's conditional demand CDD per kWh results applied to Oregon locations with 0 to 320 CDD. This represent an assumed applicable range of ± 160 CDD (e.g., up to double the PSE results).

Station	Mobile Home Existing kWh Consumption CEER 11				PSE Conditional Demand Analysis Mobile Home	RBSA Mobile Home NW Region
	Low	Med	High	TMY3	(Normalized to TMY3)	(Normalized to TMY3)
Hillsboro	565	841	1,358	734	367	N/A
North Bend	20	122	316	107	-	N/A
Redmond	571	932	1,369	816	353	N/A
Salem	536	850	1,510	857	474	N/A
Klamath Falls	569	935	1,304	892	328	N/A
Portland	528	869	1,481	790	634	N/A
Roseburg	820	1,260	1,967	920	697	N/A
Troutdale	379	894	1,536	843	636	N/A
Medford	1,095	1,720	2,466	1,316	1,039	N/A
Pendleton	945	1,362	1,937	1,212	1,011	N/A
The Dalles	995	1,607	2,438	1,611	1,520	N/A
Statewide*	563	934	1,526	838	N/A	434

*Energy Trust data represents weighted consumptions specific to Energy Trust's territory.

Single-Family New Construction

The NEEA Residential New Home Codes Energy Use Savings Report was compared to these modeled results for single-family new construction code built and ENERGY STAR built homes. Both studies relied on SEEM modeling and had similar cooling consumption results, as shown in Table 13. As part of the sensitivity analysis (in the Cost-Effectiveness Scenarios section), Cadmus did not adjust the savings of the single-family new construction building types.

Table 13. Single Family New Construction Central Air Conditioner kWh Consumption Comparison

Weather Region*	Single-Family New Construction – Code Built kWh Consumption SEER 13				Single-Family New Construction – ENERGY STAR Built kWh Consumption SEER 13				NEEA Oregon Single Family New Construction Code Built (2011 ORSC)	NEEA Oregon Single Family New Construction ENERGY STAR Built
	Low	Med	High	TMY3	Low	Med	High	TMY3	TMY3	TMY3
Zone 1	354	604	1,059	536	345	579	984	511	440	405
Zone 2	387	736	1,258	645	394	694	1,175	618	853	795
Zone 3	813	1,314	1,914	1,035	770	1,206	1,729	961	1,394	1,307

*Energy Trust data represents weighted consumptions specific to Energy Trust's territory.

Window AC

As discussed during the CAC meeting on February 8, 2017, window AC consumption and usage patterns are difficult to estimate without metering window ACs. As an alternative solution, Cadmus first gathered secondary data on window AC loads in other regions and adjusted these to the climate in Energy Trust's territory. Cadmus found two reports with large-scale, *in situ* window AC metering:[28]

- California Public Utilities Commission Energy Division: 102 Residential Metered Room Air Conditioners[29]
- Northeast Energy Efficiency Partnerships' New England Evaluation and State Program Working Group: 93 Residential Metered Room Air Conditioners[30]

Table 14 summarizes full-hour hours (FLH) from these two studies and calculated a conversion factor of FLH to CDD. Based on an average of the two studies, the conversion factor of FLH to CDD resulted in roughly one-third (0.32). Therefore, for every cooling degree day results in 0.32 full load hours of window conditioner operation.

**Table 14. Secondary Window Air Conditioning Study Data—
Conversion Factor of Full Load Hours to Cooling Degree Days**

Study	Location	Cooling FLH	CDD at 65	Conversion Factor (FLH to CDD)
(1) CPUC—2009*	CA Zone 6	225	742	0.30
	CA Zone 7	273	865	0.32
	CA Zone 8	370	1072	0.35
	CA Zone 9	522	1456	0.36
	CA Zone 10	631	1620	0.39
(1) CPUC—2009—Average				**0.34**
(2) NEEP—2008**	Albany, NY	184	544	0.34
	Boston, MA	175	777	0.23
	Burlington, VT	141	489	0.29

[28] Cadmus found two other studies. The first study represented only 13 residential sites with portable ACs and was not easily transferable to Oregon weather. The second study metered 55 units found 500 full-load hours for high and medium living density homes (~50% ratio of FLH to CDD). The study reported that room ACs ran significantly longer in the more densely populated areas than in the less densely populated; this did not make for a good comparison.

Study 1: Lawrence Berkeley National Laboratory. *Using Field-Metered Data to Quantify Annual Energy Use of Portable Air Conditioners.* December 2014. Online at: https://www.osti.gov/scitech/servlets/purl/1166989.

Study 2: Energy & Resource Solutions (ERS). "Impact Evaluation of Con Edison Residential Room Air Conditioner Program for Con Edison." October 10, 2013. Online at: http://neep.org/sites/default/files/resources/EEPS_CY1_Residential_Room_AC_Impact_Evaluation_Report.pdf

[29] Cadmus. *Residential Retrofit High-Impact Measure Evaluation Report.* February 8, 2010. Online at: http://www.calmac.org/publications/FinalResidentialRetroEvaluationReport_11.pdf

[30] RLW. *Final Report: Coincidence Factor Study Residential Room Air Conditioners.* June 23, 2008. Online at: http://www.puc.state.nh.us/electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/124_SPWG%20Room%20%20AC%20Evaluation%20FINALReport%20June%2023%20ver7.pdf

	Caribou, ME	42	191	0.22
	Concord NH	149	442	0.34
	Hartford, CT	253	759	0.33
	Portland, ME	102	347	0.29
	Providence, RI	204	714	0.29
	Worcester, MA	134	371	0.36
(2) NEEP—2008—Average				**0.30**
Average CPUC and NEEP - Conversion Factor				**0.32**

*Final Report Table 153. ENERGY STAR Room AC Modeled Annual Energy Usage (kWh) and Annual Hours of Use; California Climate Zones—CDD average across cities. Online at: http://www.pge.com/includes/docs/pdfs/about/edusafety/training/pec/toolbox/arch/climate/california_climate_zones_01-16.pdf

**Table i-2: Summary of CF and FLEH by Weather File using Average Load Zone Data. Used TMY2 FLH and TMY2 CDD@65 for each reference city.

Using this conversion factor to approximate FLH within the Oregon territory, Cadmus applied the factor to the low, median and high CDD base 65 found in the Oregon weather data. With this approach, it was not possible to vary window AC consumption by building type. Table 15 shows the resulting window AC cooling load derived using this approach.

Table 15. Window AC Cooling Load Consumption – Base 10.9 CEER(kWh/unit)

Station	Low	Median	High
Astoria	1	6	16
Baker	18	71	128
Eugene	28	79	157
Hillsboro	40	89	144
North_Bend	0	1	15
Redmond	26	68	112
Salem	35	86	195
Zone 1	**32**	**77**	**147**
Klamath_Falls	19	70	118
Portland	55	121	223
Roseburg	93	167	281
Troutdale	56	115	207
Zone 2	**56**	**119**	**216**
Medford	117	237	376
Pendleton	120	183	272
The_Dalles	114	238	363
Zone 3	**117**	**230**	**361**
Statewide	**52**	**112**	**201**

Efficiency Options

In Phase II, Cadmus analyzed four efficiency options greater than the established standard for central ACs as well as one efficiency option for window ACs. For both AC types, Cadmus identified efficiency levels based on a review of ENERGY STAR qualifications, ENERGY STAR Most Efficient minimum criteria, and Consortium for Energy Efficiency (CEE) specifications. These sources and efficiency levels represented common rebate qualifications in energy efficiency programs. Table 16 and Table 17 list efficiency levels for central ACs and window ACs.

Table 16. Central Air Conditioner Efficiency Levels

Level	Central Air Conditioner Equipment
Baseline	Federal Standard—SEER 13*
1	ENERGY STAR/CEE Tier 1 Central Air Conditioner—SEER 15/EER 12.5
2	CEE Tier 2 Central Air Conditioner—SEER 16/EER 13
3	High Efficiency Central Air Conditioner—SEER 17/EER 13
4	ENERGY STAR 2016 Most Efficient/CEE Tier 3 Central Air Conditioner—SEER 18/EER 13

*Code of Federal Regulations found in 10 CFR 430.32(c)(3).

Table 17. Window Air Conditioner Efficiency Level*

Level	Window Air Conditioner Equipment (8,000 Btu/h to 10,999 Btu/h)
Baseline	Federal Standard—CEER 10.9
1	ENERGY STAR—CEER 12

*Window AC efficiencies represent units with louvered sides and without reverse cycles—the most common configuration. As of June 1, 2014, the window AC federal standard minimum requirement for a typical-sized unit (8,000 Btu/h to 13,999 Btu/h) had a CEER of 10.9 (per Code of Federal Regulations found in 10 CFR 430.32(b)). ENERGY STAR's specification for window AC took effect on October 26, 2015. The current product list does not contain higher efficiency levels (i.e., 12.1 CEER is the highest for this size). Therefore, Cadmus chose only one efficiency for window ACs.

Conduct Cost Research

Contractor Survey of Local HVAC Contractors

To gather contractors' insights on demand for central AC equipment within Oregon and to assess the incremental costs of installing efficient central AC relative to the SEER baseline of 13, Cadmus conducted a survey of local HVAC contractors installing central AC systems. Appendix E: Energy Trust of Oregon Residential
Central Air Conditioning Cost Survey provides the full survey instrument used.

As part of assessing incremental costs from contractors, Cadmus included questions to determine the sales distribution of equipment efficiencies. The survey questionnaire sought to achieve the following research objectives:

- Determine baseline equipment costs for the standard (SEER 13)
- Estimate cost differences between equipment sizes in tons (i.e., two-, three-, and four-ton systems)
- Assess incremental equipment costs for each efficiency option (SEER 14, 15, 16, 17, 18, 19+)
- Establish an understanding of labor costs for replacing existing equipment with new equipment
- Establish an understanding of labor costs for installing new equipment in new construction
- Determine if additional labor is required for installing efficient equipment compared to standard equipment
- Identify any differences in labor costs between building applications (e.g., single-family, multifamily, mobile homes)

For this study, Cadmus sought to complete 20 surveys. Energy Trust provided Cadmus with a list of 27 HVAC contractors to contact, and Energy Trust staff emailed each contractor to inform them that Cadmus would contact them directly as part of the survey effort. Cadmus then emailed the contractors, providing a description of the survey effort along with a copy of the survey.

This email included two options for completing the survey: by either inserting responses into the survey document and emailing it to Cadmus or arranging a time to complete the survey during a phone call with Cadmus staff. Cadmus offered a $250 incentive, in the form of a gift certificate, for each completed survey to compensate for the time required to gather the required cost data.

For contractors not responding to the initial emails, Cadmus followed with up to five phone calls and up to three emails to remind contractors of the survey effort, offer to answer any questions they had about the survey, and encourage them to complete the survey.

Cadmus completed surveys with four contractors.[31] Of 27 contractors contacted, two were ineligible as they installed only heat pumps. Twelve other contractors declined to take the survey, most commonly citing that they were too busy or did not track the data required for the survey. The nine remaining contractors either did not respond to emails and voicemails or informed Cadmus that they would review the survey and attempt to complete it. Four completed the survey, Energy Trust staff followed up with these remaining contractors to encourage their participation, and Cadmus followed up with another round of calls, but no additional surveys were completed.

After aggregating the data across the four survey participants, Cadmus found that the contractors installed a combined total of 676 central ACs in 2016, ranging from 2-ton to 4-ton systems. Table 18 provides a summary of the survey respondents central AC installation characteristics. Of the four contractors, the preferred energy-efficient central AC option was SEER 16 (80% of all high-efficiency systems).

Table 18. Summary of Survey Participant Central AC Characteristics

Survey Participant Characteristics				
Installed efficiency levels	**SEER 13-13.99**	**SEER 14-15.99**	**SEER 16-16.99**	**SEER 17+**
Percent	45%	6%	44%	6%
Installed equipment sizes	**2 Ton**	**3 Ton**	**4 Ton**	
Percent	49%	38%	12%	
Percent of survey sample installations	**Contractor 1**	**Contractor 2**	**Contractor 3**	**Contractor 4**
Percent	4%	8%	19%	69%

Table note: Totals may not sum to 100% due to rounding.

Due to the limited and varying responses received, Cadmus summarized the results into three efficiency categories for each AC replacement scenario (no material costs were provided for SEER 14 to 14.99 and SEER 18 to 18.99):

- Baseline case of SEER 13 to 13.99
- SEER 15 to 16.99
- SEER 17 to 19+

Table 19 summarizes average costs for central AC material, labor, and incremental costs by tonnage and efficiency category for existing homes (without combining it with a furnace replacement).

[31] One of the four surveys contained inconsistent material cost data. Repeated attempted were made to clarify the values, but they could not be confirmed. Hence, material cost data from this contractor were not used. All other data and responses were used from the contactor.

Table 19. Average Costs for Central Air Conditioner in an Existing Home (Not Combined with Furnace Replacement Costs)

Efficiency Level	Two-Ton			Three-Ton			Four-Ton		
	Material Costs	Labor Costs	Incremental Cost	Material Costs	Labor Costs	Incremental Cost	Material Costs	Labor Costs	Incremental Cost
SEER 13-13.99	$2,402	$1,060	$0	$2,595	$1,060	$0	$2,937	$1,085	$0
SEER 15-16.99	$2,841	$1,070	$449	$3,076	$1,070	$491	$3,516	$1,095	$590
SEER 17-19+	$4,330	$1,120	$1,988	$4,720	$1,120	$2,185	$5,333	$1,187	$2,498

All responding trade allies indicated that installing central ACs concurrently with a furnace replacement does lower overall costs. The survey found minimal reduction material and labor costs for SEER 15 to 16.99 and no reduction for SEER 17 to 19+. Incremental costs when there was no concurrent furnace replacement were similar to existing homes without furnace replacements, as shown in Table 20.

Table 20. Average Costs for Central Air Conditioner in an Existing Home (Combined with Furnace Replacement Costs)

Efficiency Level	Two-Ton			Three-Ton			Four-Ton		
	Material Costs	Labor Costs	Incremental Cost	Material Costs	Labor Costs	Incremental Cost	Material Costs	Labor Costs	Incremental Cost
SEER 13-13.99	$2,387	$1,057	$0	$2,580	$1,057	$0	$2,922	$1,309	$0
SEER 15-16.99	$2,826	$1,067	$449	$3,061	$1,067	$491	$3,501	$1,323	$593
SEER 17-19+	$4,333	$1,175	$2,064	$4,723	$1,175	$2,261	$5,335	$1,663	$2,767

Three of the four trade allies indicted that central ACs installed in new construction homes cost less than existing homes. As shown in Table 21, costs were found to be lower, especially for high efficiencies.

Table 21. Average Costs for Central Air Conditioner Included in New Home Construction

Efficiency Level	Two-Ton			Three-Ton			Four-Ton		
	Material Costs	Labor Costs	Incremental Cost	Materia l Costs	Labor Costs	Incremental Cost	Material Costs	Labor Costs	Incremental Cost
SEER 13-13.99	$2,077	$795	$0	$2,370	$795	$0	$2,712	$820	$0
SEER 15-16.99	$2,516	$805	$449	$2,851	$805	$491	$3,288	$830	$587
SEER 17-19+	$3,868	$825	$1,821	$4,405	$825	$2,066	$5,015	$892	$1,676

Cadmus also examined differences between tonnages. The contractor data indicated that costs declined per ton as the size of the system increased. The average cost variances between the different scenarios (existing home not combined with furnace, existing home combined with furnace, and new construction) had a fairly tight range. Considering the low response rate and to avoid giving a false sense of precision from its small sample, Cadmus used the average incremental cost per ton across the three scenarios, as shown in Table 22. Incremental costs for SEER 15 to 16.99 stayed relatively similar across all categories as the higher-efficiency tier varied.

Table 22. Average Costs Summary for Central Air Conditioner Installation per Ton

Installation Scenario	Efficiency Level	Per Ton (Two-Ton)	Per Ton (Three-Ton)	Per Ton (Four-Ton)
Average Incremental Cost	SEER 15-16.99	$225	$164	$147
	SEER 17-19+	$979	$723	$637

Secondary Cost Research

In addition to the primary research, Cadmus collected incremental costs from other secondary sources to compare to Energy Trust's trade ally survey. Cadmus compiled data from five secondary sources:

- DOE's Residential Central Air Conditioners and Heat Pumps TSD (DOE 2016 TSD). December 2016. Table 8.2.33.[32] National costs based on manufacturer selling price data for central ACs at different input capacities (from the engineering analysis), multiplied by wholesaler markups and contractor markups plus sales tax.
- The Northeast Energy Efficiency Partnerships (NEEP) "Incremental Cost Study" (NEEP 2013).[33] For this study, 15 contractors in the Northeast were interviewed in 2011.
- The Electric and Gas Program Administrators of Massachusetts report (MA 2015) *Cool Smart Incremental Cost Study: Final Report.* July 2015.[34] This study used a teardown and cost model of six indoor air handler units and six outdoor units.
- Illinois Statewide Technical Reference Manual for Energy Efficiency Version 6.0. February 8, 2017 (IL TRM-2017).[35] Based on incremental cost results from Cadmus' *HVAC Program: Incremental Cost Analysis Update.* December 19, 2016. Based on two hedonic pricing analyses to estimate the effects of differing efficiency levels from two distributors and one online wholesale website.
- The California Public Utilities Commission report. (CPUC 2014): *2010–2012 Ex Ante Measure Cost Study Final Report*. [36] May 27, 2014. For air conditioners, this study collected distributor cost data and then developed hedonic price models.

---

32 U.S. Department of Energy. *Technical Support Document: Energy Efficiency Program for Consumer Products: Residential Central Air Conditioners and Heat Pumps.* December 2016. Online at: https://www.regulations.gov/document?D=EERE-2014-BT-STD-0048-0098

33 Navigant. *Northeast Energy Efficiency Partnerships (NEEP) Incremental Cost Study* (air conditioner data collected in 2011). Incremental Cost Study Phase Two Published: January 2013. Online at: http://www.neep.org/incremental-cost-study-phase-4-report

34 Cadmus, et al. *Cool Smart Incremental Cost Study: Final Report*. July 2015. Prepared for Electric and Gas Program Administrators of Massachusetts.

35 IL-TRM Version 6.0. February 8, 2017. Available online: http://www.ilsag.info/il_trm_version_6.html

36 Itron. *2010–2012 WO017 Ex Ante Measure Cost Study Final Report*. California Public Utilities Commission. May 2014. Online at: http://www.calmac.org/publications/2010-2012_WO017_Ex_Ante_Measure_Cost_Study_-_Final_Report.pdf

Each study relied on different methods to determine incremental costs. The CPUC and Illinois TRM looked at distributor costs. The DOE relied on manufacturer prices. The Massachusetts study used a teardown approach, examining only efficiency improvements costs. NEEP surveyed contractors similar to the Energy Trust survey. Consequently, these varying methods provided a large range of possible incremental costs, as shown in Table 23, Table 24, and Table 25. Energy Trust survey results were within the range of costs found in the other studies, though near the highest end.

The NEEP study, which also relied on contractors, presented the highest costs. Contractor surveys may be biased in that contractor pricing includes installation and markup that may be based on what they feel the market will bear rather than the incremental cost of more efficient equipment. Further, higher efficiency units are also likely to have other "high end" features, such as noise dampers that are not related to efficiency. The two studies that attempted to compensate for this were the hedonic studies in Illinois and California. For this study, Cadmus evaluated a range of incremental costs when assessing cost-effectiveness and evaluated two incremental cost scenarios for the cost-effective analysis: the Energy Trust survey (high scenario)[37] and the Illinois TRM (low scenario).

Table 23. Two-Ton Average Incremental Cost Comparison

Source	Two-Ton System				
	SEER 14	SEER 15	SEER 16	SEER 17	SEER 18
DOE 2016 TSD	$49	$109	$217	$917	$1,043
NEEP 2013*	$901	$1,382	$2,585		
MA 2015	$13	$147	$325	$993	$1,725
IL TRM 2017	$0	$108	$221	$620	$620
CPUC 2014	$184	$369	$553	$737	$921
Energy Trust—Contractor Survey	N/A	$449		$1,958	

*Estimated 14 SEER based on 14.5 SEER and SEER 16-18 based on data representing 16+ SEER.

Table 24. Three-Ton Average Incremental Cost Comparison

Source	Three-Ton System				
	SEER 14	SEER 15	SEER 16	SEER 17	SEER 18
DOE 2016 TSD	$67	$199	$280	$1,053	$1,161
NEEP 2013*	$930	$1,412	$2,615		
MA 2015	$13	$147	$325	$993	$1,725
IL TRM 2017	$0	$108	$221	$620	$620
CPUC 2014	$276	$553	$829	$1,106	$1,382
Energy Trust—Contractor Survey	N/A	$491		$2,170	

*Estimated 14 SEER based on 14.5 SEER and SEER 16-18 based on data representing 16+ SEER.

37 As building types and locations varied in system size, Cadmus used power functions to approximate incremental costs per discrete tonnage values. This varied the power functions by existing and new construction applications. An average of existing homes with and without combined furnace replacement was taken as the incremental costs were very similar.

Table 25. Four-Ton Average Incremental Cost Comparison

Source	Four-Ton System				
	SEER 14	SEER 15	SEER 16	SEER 17	SEER 18
DOE 2016 TSD*	$90	$334	$444	$955	$1,182
NEEP 2013**	$960	$1,441	$2,644		
MA 2015	$13	$147	$325	$993	$1,725
IL TRM 2017	$0	$108	$221	$620	$620
CPUC 2014	$369	$737	$1,106	$1,474	$1,843
Energy Trust—Contractor Survey	N/A	$590		$2,547	

*Estimated 4-ton system, based on the average of 3- and 5-ton systems.

**Estimated 14 SEER based on 14.5 SEER and SEER 16-18 based on data representing 16+ SEER.

Window AC Cost Research

As part of the Phase I research, Cadmus compiled 34 online product retail prices,[38] with 16 meeting the federal standard and 18 meeting the ENERGY STAR specification. The study also gathered price data by capacity:

- 10 prices for 8,000 Btu/h units
- 11 prices for 10,000 Btu/h units
- 13 prices for 12,000 Btu/h units

This resulted in an incremental cost of $38.60 per window AC. In comparison, ENERGY STAR assumed a $50.00 incremental cost (though this information was from 2008). Consequently, Cadmus relied on current retail price data. Cadmus did not conduct further Phase II research for window AC as the Energy Trust and Cadmus agreed that the existing 32 data points collected in Phase I were sufficient for this study.

38 In November 2016, Cadmus conducted retailer product research from Home Depot, Sears, Lowes, Wal-Mart, Best Buy, AJ Madison, and BrandSmartUSA.com.

Cost-Effectiveness Modeling

Using these three main inputs (i.e., savings, incremental, and effective useful life), Cadmus populated Energy Trust's cost-effectiveness calculator (2018 v1.0) with different AC configurations, savings, and incremental costs to determine the measures' cost-effectiveness using the Total Resource Cost (TRC) test.[39] To be considered passing, the TRC test benefit-cost ratio (BCR) must be 1.0 or higher.

Effective Useful Life

To evaluate cost-effectiveness, effective useful life of the equipment also must be incorporated. In Phase I, Cadmus' benchmarking of the effective useful life for central ACs revealed lifetimes ranging from 14 years to 24 years, as follows:

- DEER 2014 (15 years)
- DOE's TSD (24 years)
- NEEP Measure Life Report (18 years)
- RTF Heat Pumps (15 years)
- ENERGY STAR (14 years)

For window ACs, Cadmus' benchmarking of the effective useful life ranged from nine years to 12 years, with the common value of nine years, as follows:

- DEER 2014 (9 years)
- NEEP Measure Life Report (12 years)
- NREL's National Residential Efficiency Measures Database (12 years)
- Association of Home Appliance Manufactures (9 years)
- ENERGY STAR (9 years)

Cost-Effectiveness Scenarios

Cadmus evaluated various scenarios of different inputs (savings, incremental costs, lifetimes, and avoided costs) to determine the feasible range of cost-effectiveness results for central and window ACs. Including the base scenario, five central AC scenarios and three window AC scenarios were developed, as shown in Table 26. These scenarios mainly focused on the upper bound (e.g., increasing the TRC) of the cost-effectiveness inputs, except for the alternative saving scenario where the savings are adjusted lower than the base scenario. The purpose of this is to provide the plausible range of results to help inform planning staff.

---

39 Cadmus compared Phase I results, which used Energy Trust's 2017 cost-effectiveness calculator, with the new 2018 cost-effectiveness calculator. Between 2017 and 2018, the changes in avoided costs and other assumptions within the tool resulted in a 51% decline in cost-effectiveness. While the discount rate changed slightly, the reduction in avoided cost served as the primary driver.

Table 26. Cost-Effectiveness Scenarios

Scenario	Savings	Incremental Cost	Lifetime	Avoided Cost
Central Air Conditioner				
Base Scenario	SEEM Modeling	Energy Trust Survey	15	Energy Trust 2018 v1.0
Low-cost Scenario	SEEM Modeling	IL TRM Cost Data	15	Energy Trust 2018 v1.0
Alternative Saving Scenario	Benchmark Savings	Energy Trust Survey	15	Energy Trust 2018 v1.0
Lifetime Scenario	SEEM Modeling	Energy Trust Survey	24	Energy Trust 2018 v1.0
Avoided Cost Scenario	SEEM Modeling	Energy Trust Survey	15	Energy Trust 2018 v1.A
Window Air Conditioner				
Base Scenario	Benchmark Savings	Cost Research	10	Energy Trust 2018 v1.0
Lifetime Scenario	Benchmark Savings	Cost Research	12	Energy Trust 2018 v1.0
Avoided Cost Scenario	Benchmark Savings	Cost Research	10	Energy Trust 2018 v1.A

Central Air Conditioner

For the central AC scenarios, the results were provided for each building type across all weather stations: low, median, and high weather ranges (CDD); cooling zones; and Energy Trust territory-wide average by efficiency level. For each of the five central AC scenarios, 864 configurations were analyzed.

Base scenario. Of 864 building, efficiency, and location configurations analyzed using Energy Trust trade ally cost data for this scenario, no iterations proved cost-effective. Considering the relatively high incremental costs compared to other cost sources, it is unsurprising to see low cost-effectiveness results.

Low-cost scenario. Using the Illinois TRM incremental cost for central air conditioners, 130 configurations out of 864 configurations were cost-effective. Single-family existing SEER 15 and SEER 16 had the most cost-effective iterations across cooling zones.

Alternative saving scenario. Using the benchmarking cooling consumption data from the PSE conditional demand analysis, an adjustment consumption factor was applied to the single-family existing and mobile home SEEM model consumptions.[40] No iterations proved cost-effective since there were lower savings compared to the base scenario. This provided a lower bound of cost-effectiveness results.

Lifetime scenario. To determine the upper bound of the effective useful life of a central AC, the measure life was adjusted from 15 years to 24 years based on DOE's TSD. Seven configurations out of 864 were found cost-effective.

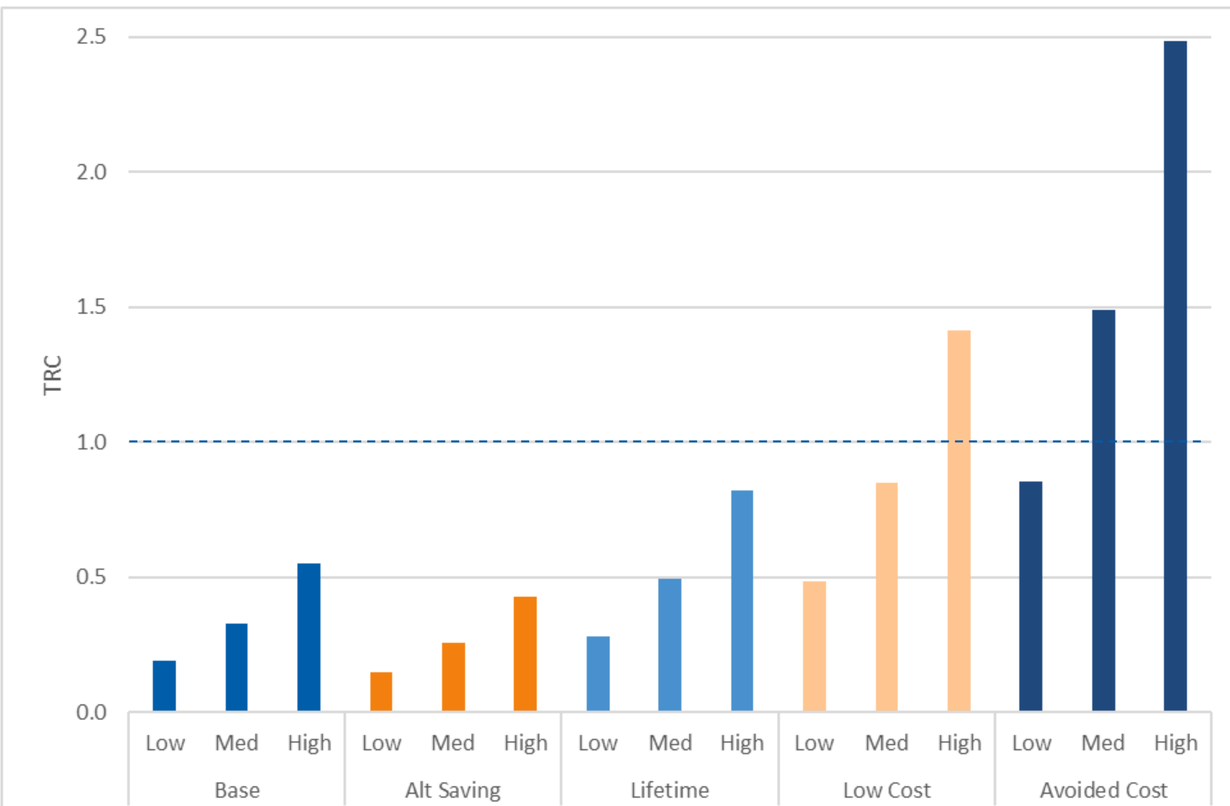
Avoided cost scenario. Energy Trust adjusted the cost-effectiveness calculator (2018 v1.0) with updated avoided costs that provided additional summer capacity benefits. Energy Trust developed these new

40 To fully account for the reduction in cooling consumption, the adjustment consumption factor was also applied to the equipment capacities impacting the equipment costs.

avoided costs as a hypothetical scenario (upper bound) to include the value of capacity costs for summer peaking loads. Of the 864 configurations, 248 configurations were cost-effective including most single-family existing SEER 16 locations and weather ranges (low, med, and high). All configuration cost-effectiveness results can be found in section Appendix D: Detailed Cost-Effectiveness Inputs and Results.

To provide context of how each scenario relates, Figure 6 provides the magnitude of all the scenarios compared to the base assessment within Energy Trust territory (state-wide average). The state-wide results represents the weighted average of Energy Trust residential sites by county that were allocated to the nearest weather station used in this study. For this comparison, single-family existing SEER 16 statewide TRC results were used. The hypothetical scenario of the avoided costs with higher capacity costs provided the largest impact to the cost-effectiveness results. While combination of multiple scenarios were not in the scope of this project, it appears likely that even the lower alternative savings scenario combined with the higher avoided cost scenario would be cost-effective for various configurations. The dashed line in the figure represents the Energy Trust's cost effectiveness threshold of 1.0 TRC.

Figure 6. Central Air Conditioner Single Family Existing SEER 16 Average Statewide Scenarios



Window Air Conditioner

For window AC, the results were provided for all weather stations of low, median, and high weather ranges; cooling zones; and the Energy Trust territory-wide average by efficiency level. As noted earlier, this analysis assumed one high-efficiency level and did not account for differences in window AC consumptions within each building type. Because of this, Cadmus analyzed 54 location configurations for cost-effectiveness of each scenario (base, lifetime, and avoided cost).

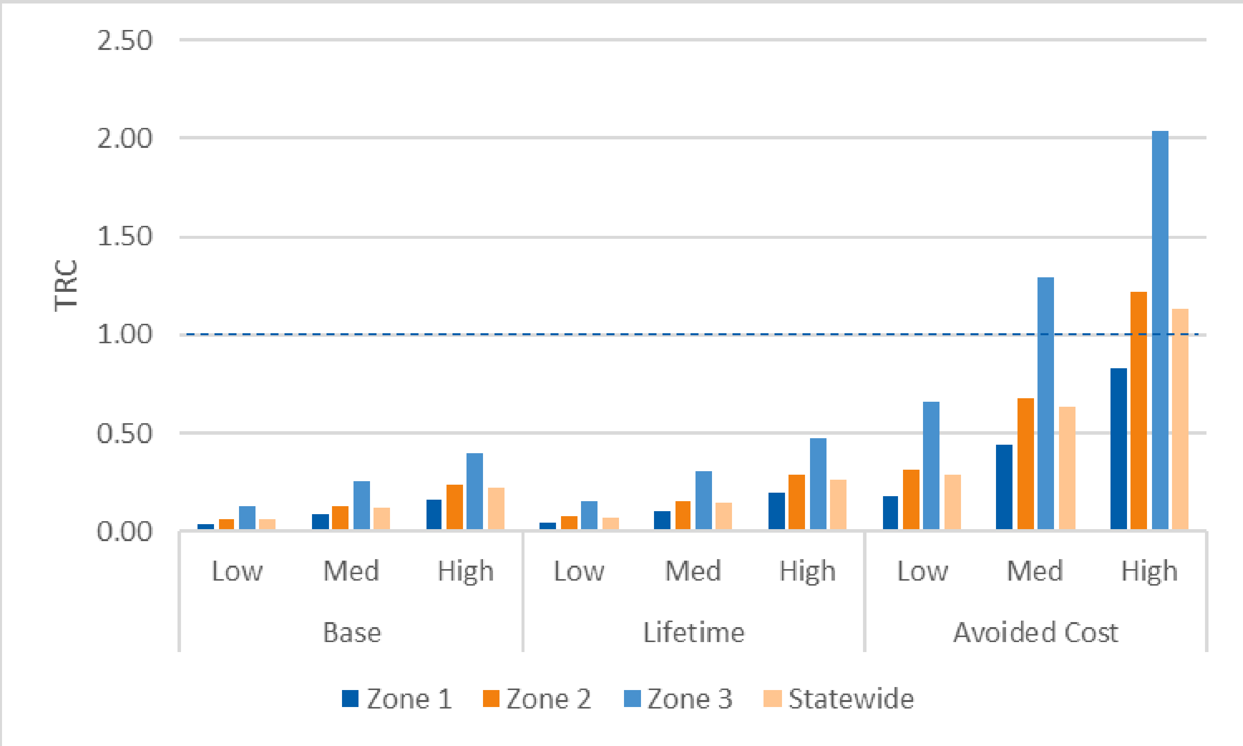
Base Scenario. Of 54 location configurations—analyzed using retail incremental cost research results and secondary research of FLH/CDD adjustment factor for cooling consumption—no iterations proved cost-effective. Even with the relatively low incremental costs, the low savings from the window AC contributed to the low cost-effectiveness results.

Lifetime Scenario. To determine the upper bound of the effective useful life of a window AC, the measure life was adjusted from 10 years to 12 years based on National Renewable Energy Laboratory's National Residential Efficiency Measures Database and other sources. The two-year increase in measure life did not result in any configurations to be cost-effective.

Avoided Cost Scenario. Energy Trust adjusted the cost-effectiveness calculator (2018 v1.0) with updated avoided costs that provided additional summer capacity benefits. Energy Trust developed these new avoided costs as a hypothetical scenario (upper bound) to include the value of capacity costs for summer peaking loads. Of the 54 configurations, 14 configurations were cost-effective primarily in cooling zones 2 and 3.

Figure 7 provides the presented magnitude of the three widow AC scenarios. For this comparison, Oregon cooling zones 1, 2, and 3 and the statewide TRC results were used. The base scenario relatively low energy savings yielded low TCR results. The method for determining FLH using secondary data resulted in lower estimated savings than in Phase I—an expected result as Phase I applied only a ratio adjustment of central system tonnage to window AC tonnage while keeping the FLH the same. The Phase II method tries to account for operational differences between a thermostatically controlled central system and a manually operated window unit. However, when accounting for the hypothetical scenario of the avoided costs, window ACs were cost-effective in cooling zones 2 and 3 weather regions for a few weather ranges (med and high). The dashed line in the figure represents the Energy Trust's cost effectiveness threshold of 1.0 TRC.

Figure 7. Window Air Conditioner CEER 12 Cooling Zone and Statewide Scenarios



Appendix D: Detailed Cost-Effectiveness Inputs and Results provides additional cost-effectiveness details.

Conclusions and Findings

This Phase II review of AC measures suggests that AC scenarios are not cost-effective using contractor costs regardless of weather data unless there are significant changes in avoided costs (capacity costs). In addition, significant changes in incremental cost (e.g., low-cost scenario) resulted in some central AC measures being cost-effective. While not definitive, the weather data indicates a slight increase in CDD over the past 40 years. This study is not predicting future weather patterns; instead the intent is to provide a historical range of likely future cost-effectiveness scenarios (at least in the near term). Under certain conditions, the Phase II cost-effectiveness results could warrant an Energy Trust investment or possible introduction of AC program offerings.

Based on the sensitivity analysis, Cadmus drew the following inferences:

- Determining the type of incremental cost data (i.e., contractor vs. distributor and reported vs. hedonic) can greatly affect cost-effectiveness results. Contractor prices appear to include additional markups and/or equipment features in addition to energy efficiency improvements.
- Location and weather trends indicate a large range in cost-effectiveness (two to three times) between the low and high range in weather.
- For most scenarios, high-efficiency equipment (SEER 17 and above) does not prove cost-effective for most scenarios, mainly due to higher incremental costs.
- Valuing the avoided capacity benefits from AC had a substantial impact to the overall cost-effectiveness. As a result, central ACs statewide were cost-effective regardless of cooling zone for the median weather range.

Central Air Conditioners

Central AC equipment upgrade iterations for all weather stations did not prove cost-effective using the cost data from contractors surveyed for this study. With liberal incremental cost assumptions or by increasing the value of avoided capacity for central ACs, however, the results revealed that these measures were cost-effective for existing single-family homes with SEER 15 and 16 across most weather locations and weather years. Existing single-family homes represent the majority of Energy Trust residential customers. Under these scenarios, it would be feasible to administer a regional prescriptive rebate program offering for SEER 15 and possibly SEER 16 equipment. At this time, higher-efficiency systems (i.e., SEER 17 and above) are not likely to be cost-effective and do not warrant Energy Trust offering incentives for these higher-efficiency tiers.

Window Air Conditioners

Cadmus assessed the impacts using secondary sources to align with previous evaluations (in New York [ERS 2013], New England [RLW Analytics 2008], and California [Cadmus 2010]) that indicated lower FLH than central systems (e.g., compared to ENERGY STAR FLH). For these reasons, the results for window AC equipment upgrade iterations do not operate cost-effectively in any location. However, when increasing the value of avoided capacity, several locations (primarily cooling zone 3) were found to be cost-effective. As noted, uncertainties remain regarding FLH for window ACs in Oregon and the Northwest. Validating these assumptions would require additional research, which may not be practical given current Energy Trust priorities. Furthermore, the Northwest Energy Efficiency Alliance, which offers a Retail Product Portfolio, is currently developing a midstream window AC buydown of $10 for the region.

Appendix A: SEEM Modeling Inputs

AC Measure Scan
Model Information.x

Appendix B: SEEM Model Weighting

Table 27. Prototype weighting

Prototype Name	Prototype Category	Prototype Size	Prototype Weight*
SF_Exist_1344c	Single-Family Existing	1344	31%
SF_Exist_1344s	Single-Family Existing	1344	5%
SF_Exist_2200c	Single-Family Existing	2200	27%
SF_Exist_2200s	Single-Family Existing	2200	5%
SF_Exist_2688b	Single-Family Existing	2688	32%
SF_NEWCODE_1344c	Single-Family New Code Built	1344	21%
SF_NEWCODE_1344s	Single-Family New Code Built	1344	4%
SF_NEWCODE_2200c	Single-Family New Code Built	2200	34%
SF_NEWCODE_2200s	Single-Family New Code Built	2200	6%
SF_NEWCODE_2688b	Single-Family New Code Built	2688	35%
SF_NEWESTAR_1344c	Single-Family New ESTAR Built	1344	21%
SF_NEWESTAR_1344s	Single-Family New ESTAR Built	1344	4%
SF_NEWESTAR_2200c	Single-Family New ESTAR Built	2200	34%
SF_NEWESTAR_2200s	Single-Family New ESTAR Built	2200	6%
SF_NEWESTAR_2688b	Single-Family New ESTAR Built	2688	35%
MH_Exist_924	Mobile Home Existing	924	80%
MH_Exist_1568	Mobile Home Existing	1568	16%
MH_Exist_2352	Mobile Home Existing	2352	4%

* May not sum to 100% due to rounding.

Table 28. Zone and Statewide Weighting

Station	Zone	Population Weight	Zone Weight*	Statewide Weight*
Astoria	1	32,041	6%	3%
Baker	1	8,805	2%	1%
Eugene	1	35,192	6%	3%
Hillsboro	1	222,699	39%	17%
North Bend	1	18,266	3%	1%
Redmond	1	62,536	11%	5%
Salem	1	192,351	34%	15%
Zone 1 Subtotal	***1***	***571,890***	***100%***	***45%***
Klamath Falls	2	28,908	5%	2%
Portland	2	329,900	57%	26%
Roseburg	2	37,697	7%	3%
Troutdale	2	179,003	31%	14%
Zone 2 Subtotal	***2***	***575,508***	***100%***	***45%***
Medford	3	106,396	80%	8%
Pendleton	3	18,627	14%	1%
The Dalles	3	8,602	6%	1%
Zone 3 Subtotal	***3***	***133,625***	***100%***	***10%***

*May not sum to 100% due to rounding.

Appendix C: TMY and CDD Details

Table 29. Central Air Conditioner Cooling Energy Consumption TMY3 – SEER 13 (kWh/home)

Station	Single-Family Existing	Single-Family New Construction – Code Built	Single-Family New Construction – ENERGY STAR Built	Mobile Home Existing
Astoria	247	109	127	188
Baker	1,355	623	580	895
Eugene	1,293	607	567	835
Hillsboro	1,098	523	498	734
North Bend	110	39	74	107
Redmond	1,248	553	511	816
Salem	1,323	648	617	857
Zone 1 Weight	**1,127**	**536**	**511**	**742**
Klamath Falls	1,352	634	590	892
Portland	1,204	627	604	790
Roseburg	1,421	728	692	920
Troutdale	1,292	663	633	843
Zone 2 Weight	**1,253**	**645**	**618**	**820**
Medford	2,073	1,028	956	1,316
Pendleton	1,888	952	886	1,212
The Dalles	2,560	1,302	1,192	1,611
Zone 3 Weight	**2,078**	**1,035**	**961**	**1,321**
Statewide Weight	**1,283**	**637**	**606**	**838**

Table 30. Cooling Degree Day Range (Low, Median, High, TMY3)

Station	Low CDD	Median CDD	High CDD	TMY3
Astoria	4	19	56	48
Baker	61	241	437	229
Eugene	94	268	535	295
Hillsboro	136	303	492	212
North Bend	0	3	51	0
Redmond	90	232	382	204
Salem	119	294	663	275
Zone 1	**110**	**264**	**500**	**N/A**
Klamath Falls	65	238	401	190
Portland	188	411	758	367
Roseburg	318	569	957	403
Troutdale	190	390	704	368
Zone 2	**191**	**406**	**736**	**N/A**
Medford	399	808	1,280	601
Pendleton	409	623	927	585
The Dalles	387	810	1,235	879
Zone 3	**399**	**783**	**1,228**	**N/A**
Statewide	**176**	**382**	**682**	**N/A**

Appendix D: Detailed Cost-Effectiveness Inputs and Results

Table 31. Cost-Effectiveness Scenarios

Scenario	Savings	Incremental Cost	Lifetime	Avoided Cost
Central Air Conditioner				
Base Scenario	SEEM Modeling	Energy Trust Survey	15	Energy Trust 2018 v1.0
Low-cost Scenario	SEEM Modeling	IL TRM Cost Data	15	Energy Trust 2018 v1.0
Alternative Saving Scenario	Benchmark Savings	Energy Trust Survey	15	Energy Trust 2018 v1.0
Lifetime Scenario	SEEM Modeling	Energy Trust Survey	24	Energy Trust 2018 v1.0
Avoided Cost Scenario	SEEM Modeling	Energy Trust Survey	15	Energy Trust 2018 v1.A
Window Air Conditioner				
Base Scenario	Benchmark Savings	Cost Research	10	Energy Trust 2018 v1.0
Lifetime Scenario	Benchmark Savings	Cost Research	12	Energy Trust 2018 v1.0
Avoided Cost Scenario	Benchmark Savings	Cost Research	10	Energy Trust 2018 v1.A

Central Air Conditioning Inputs

Table 32. Existing Single-Family—Savings (Base, Low-cost, Lifetime, and Avoided Cost Scenarios)

Weather Station / Region	Savings (kWh)											
	SEER 15			SEER 16			SEER 17			SEER 18		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Astoria	13	26	70	18	36	98	22	45	123	26	53	145
Baker	90	178	240	127	250	337	159	314	423	188	371	500
Eugene	95	173	332	134	244	466	168	306	585	198	361	691
Hillsboro	112	172	287	157	242	403	197	303	506	233	358	598
North Bend	2	19	60	3	27	84	4	34	106	5	40	125
Redmond	111	193	290	157	271	407	196	340	511	232	402	603
Salem	106	177	321	150	249	452	188	313	567	222	369	669
Klamath Falls	110	189	272	155	266	383	195	334	481	230	395	567
Portland	104	182	311	146	255	437	183	320	549	217	378	648
Roseburg	167	269	427	235	378	601	294	474	754	348	560	890
Troutdale	69	184	325	97	259	458	122	325	574	143	384	678
Medford	229	367	538	323	516	756	405	647	949	478	764	1,120
Pendleton	192	288	419	270	405	589	338	508	739	399	600	873
The Dalles	204	343	537	286	482	755	359	605	948	424	715	1,119
Zone 1	99	163	281	140	229	396	175	288	497	207	340	586
Zone 2	97	189	321	137	265	452	172	333	567	203	393	669
Zone 3	223	354	521	313	498	733	393	625	920	464	738	1,086
Statewide	**111**	**194**	**324**	**157**	**273**	**456**	**197**	**343**	**572**	**232**	**405**	**675**

Table 33. New Construction Code Built Single-Family—Savings (Base, Low-cost, Lifetime, and Avoided Cost Scenarios)

Weather Station / Region	Savings (kWh)											
	SEER 15			SEER 16			SEER 17			SEER 18		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Astoria	4	11	39	6	15	55	7	19	69	9	23	81
Baker	35	82	112	49	116	157	61	146	198	72	172	233
Eugene	46	85	165	64	119	232	81	149	291	95	176	343
Hillsboro	57	89	144	80	125	202	100	157	254	118	185	300
North Bend	1	8	33	1	11	46	1	13	57	1	16	68
Redmond	45	85	136	63	120	192	80	150	241	94	177	284
Salem	49	87	164	69	122	230	87	154	289	103	181	341
Klamath Falls	47	89	130	66	125	183	83	157	230	98	185	271
Portland	56	95	164	78	134	231	98	168	290	116	198	342
Roseburg	94	135	217	132	190	306	165	238	383	195	281	453
Troutdale	36	97	170	51	137	239	64	172	299	75	203	353
Medford	111	181	263	156	254	370	196	319	465	231	377	549
Pendleton	96	144	205	135	202	288	170	254	361	200	300	427
The Dalles	105	172	264	148	242	371	185	304	466	219	359	550
Zone 1	47	81	141	66	113	198	83	142	249	98	168	294
Zone 2	52	98	168	73	138	236	91	173	296	108	204	349
Zone 3	108	175	255	153	246	359	191	309	450	226	365	532
Statewide	**56**	**98**	**165**	**78**	**138**	**232**	**98**	**173**	**291**	**116**	**205**	**344**

Table 34. New Construction ENERGY STAR Built Single-Family—Savings (Base, Low-cost, Lifetime, and Avoided Cost Scenarios)

Weather Station / Region	Savings (kWh)											
	SEER 15			SEER 16			SEER 17			SEER 18		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Astoria	5	14	45	7	20	63	8	25	79	10	30	93
Baker	33	76	102	46	108	144	58	135	181	68	159	213
Eugene	46	80	153	65	112	215	82	141	269	97	166	318
Hillsboro	54	85	134	77	120	188	96	151	236	113	178	279
North Bend	2	12	42	2	17	59	3	22	74	4	26	87
Redmond	43	79	124	60	111	174	76	140	219	89	165	258
Salem	49	83	151	69	117	212	86	147	266	102	174	314
Klamath Falls	46	82	120	65	115	169	81	145	212	96	171	250
Portland	57	90	154	81	127	216	101	159	272	119	187	321
Roseburg	92	126	198	129	177	279	161	222	349	191	262	413
Troutdale	37	92	159	51	129	223	64	162	280	76	192	331
Medford	105	166	238	147	233	334	185	293	419	218	345	495
Pendleton	91	133	186	129	188	262	161	235	329	191	278	388
The Dalles	102	158	240	143	222	337	179	279	423	211	329	499
Zone 1	46	77	131	65	109	185	81	136	232	96	161	273
Zone 2	53	93	157	74	130	220	93	163	276	109	193	326
Zone 3	103	161	231	144	226	324	181	284	407	214	335	480
Statewide	**55**	**93**	**153**	**77**	**131**	**215**	**97**	**164**	**270**	**114**	**193**	**319**

Table 35. Mobile Home Existing—Savings (Base, Low-cost, Lifetime, and Avoided Cost Scenarios)

Weather Station / Region	Savings (kWh)											
	SEER 15			SEER 16			SEER 17			SEER 18		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Astoria	11	20	51	16	28	71	20	35	89	23	42	105
Baker	63	118	154	89	166	217	112	209	272	132	246	321
Eugene	64	110	205	91	155	288	114	194	362	134	229	427
Hillsboro	75	112	181	106	158	255	133	198	319	157	234	377
North Bend	3	16	42	4	23	59	5	29	74	6	34	88
Redmond	76	124	183	107	175	257	134	219	322	159	259	380
Salem	71	113	201	100	159	283	126	200	355	149	236	419
Klamath Falls	76	125	174	107	175	244	134	220	307	158	260	362
Portland	70	116	197	99	163	278	124	205	348	147	242	411
Roseburg	109	168	262	154	236	369	193	296	463	228	350	547
Troutdale	51	119	205	71	168	288	89	210	362	105	248	427
Medford	146	229	329	205	322	462	258	405	580	304	478	685
Pendleton	126	182	258	177	255	363	222	321	456	263	378	538
The Dalles	133	214	325	187	301	457	234	378	574	276	446	677
Zone 1	67	106	177	95	149	249	119	186	313	140	220	369
Zone 2	67	121	203	94	170	285	118	213	358	140	252	422
Zone 3	142	222	319	200	312	448	251	391	562	297	462	664
Statewide	**75**	**125**	**204**	**106**	**175**	**286**	**132**	**220**	**359**	**156**	**259**	**424**

Table 36. Existing Single-Family—Savings (Alternative Savings Scenario)

Weather Station / Region	Savings (kWh)											
	SEER 15			SEER 16			SEER 17			SEER 18		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Astoria	8	17	46	12	24	65	15	30	82	18	36	97
Baker	60	119	160	84	167	225	106	209	282	125	247	333
Eugene	63	115	221	89	162	311	112	204	390	132	241	460
Hillsboro	74	115	191	105	161	269	131	202	337	155	239	398
North Bend	1	13	40	2	18	56	3	23	70	3	27	83
Redmond	74	128	193	104	181	271	131	227	340	154	268	402
Salem	71	118	214	100	166	301	125	208	378	148	246	446
Klamath Falls	73	126	181	103	177	255	130	223	320	153	263	378
Portland	69	121	207	97	170	291	122	213	366	144	252	432
Roseburg	111	179	284	156	252	400	196	316	502	232	373	593
Troutdale	46	123	217	64	173	305	81	217	383	96	256	452
Medford	153	244	358	215	343	504	270	431	632	318	509	746
Pendleton	128	192	279	180	270	392	225	339	492	266	400	581
The Dalles	136	228	358	191	321	503	239	403	631	283	476	745
Zone 1	66	109	187	93	153	264	117	192	331	138	226	390
Zone 2	65	126	214	91	177	301	115	222	377	135	262	446
Zone 3	148	236	347	208	332	488	262	416	612	309	491	723
Statewide	**74**	**130**	**216**	**104**	**182**	**304**	**131**	**229**	**381**	**155**	**270**	**450**

Table 37. New Construction Code Built Single-Family—Savings (Alternative Savings Scenario)

Weather Station / Region	Savings (kWh)											
	SEER 15			SEER 16			SEER 17			SEER 18		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Astoria	4	11	39	6	15	55	7	19	69	9	23	81
Baker	35	82	112	49	116	157	61	146	198	72	172	233
Eugene	46	85	165	64	119	232	81	149	291	95	176	343
Hillsboro	57	89	144	80	125	202	100	157	254	118	185	300
North Bend	1	8	33	1	11	46	1	13	57	1	16	68
Redmond	45	85	136	63	120	192	80	150	241	94	177	284
Salem	49	87	164	69	122	230	87	154	289	103	181	341
Klamath Falls	47	89	130	66	125	183	83	157	230	98	185	271
Portland	56	95	164	78	134	231	98	168	290	116	198	342
Roseburg	94	135	217	132	190	306	165	238	383	195	281	453
Troutdale	36	97	170	51	137	239	64	172	299	75	203	353
Medford	111	181	263	156	254	370	196	319	465	231	377	549
Pendleton	96	144	205	135	202	288	170	254	361	200	300	427
The Dalles	105	172	264	148	242	371	185	304	466	219	359	550
Zone 1	47	81	141	66	113	198	83	142	249	98	168	294
Zone 2	52	98	168	73	138	236	91	173	296	108	204	349
Zone 3	108	175	255	153	246	359	191	309	450	226	365	532
Statewide	**56**	**98**	**165**	**78**	**138**	**232**	**98**	**173**	**291**	**116**	**205**	**344**

Table 38. New Construction ENERGY STAR Built Single-Family—Savings (Alternative Savings Scenario)

Weather Station / Region	Savings (kWh)											
	SEER 15			SEER 16			SEER 17			SEER 18		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Astoria	5	14	45	7	20	63	8	25	79	10	30	93
Baker	33	76	102	46	108	144	58	135	181	68	159	213
Eugene	46	80	153	65	112	215	82	141	269	97	166	318
Hillsboro	54	85	134	77	120	188	96	151	236	113	178	279
North Bend	2	12	42	2	17	59	3	22	74	4	26	87
Redmond	43	79	124	60	111	174	76	140	219	89	165	258
Salem	49	83	151	69	117	212	86	147	266	102	174	314
Klamath Falls	46	82	120	65	115	169	81	145	212	96	171	250
Portland	57	90	154	81	127	216	101	159	272	119	187	321
Roseburg	92	126	198	129	177	279	161	222	349	191	262	413
Troutdale	37	92	159	51	129	223	64	162	280	76	192	331
Medford	105	166	238	147	233	334	185	293	419	218	345	495
Pendleton	91	133	186	129	188	262	161	235	329	191	278	388
The Dalles	102	158	240	143	222	337	179	279	423	211	329	499
Zone 1	46	77	131	65	109	185	81	136	232	96	161	273
Zone 2	53	93	157	74	130	220	93	163	276	109	193	326
Zone 3	103	161	231	144	226	324	181	284	407	214	335	480
Statewide	**55**	**93**	**153**	**77**	**131**	**215**	**97**	**164**	**270**	**114**	**193**	**319**

Table 39. Mobile Home Existing—Savings (Alternative Savings Scenario)

Weather Station / Region	Savings (kWh)											
	SEER 15			SEER 16			SEER 17			SEER 18		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Astoria	5	9	23	7	13	33	9	16	41	11	19	49
Baker	29	55	71	41	77	100	52	97	126	61	114	148
Eugene	30	51	95	42	71	133	53	90	167	62	106	197
Hillsboro	35	52	84	49	73	118	61	92	148	73	108	174
North Bend	1	8	19	2	11	27	2	13	34	3	16	41
Redmond	35	57	84	50	81	119	62	101	149	73	120	176
Salem	33	52	93	46	74	131	58	93	164	69	109	194
Klamath Falls	35	58	80	49	81	113	62	102	142	73	120	167
Portland	33	54	91	46	75	128	57	95	161	68	112	190
Roseburg	51	78	121	71	109	171	89	137	214	105	162	253
Troutdale	23	55	95	33	77	133	41	97	167	49	115	197
Medford	68	106	152	95	149	214	119	187	268	141	221	317
Pendleton	58	84	119	82	118	168	103	148	211	121	175	249
The Dalles	61	99	150	86	139	211	108	175	265	128	206	313
Zone 1	31	49	82	44	69	115	55	86	145	65	102	171
Zone 2	31	56	94	44	79	132	55	99	165	65	116	195
Zone 3	66	102	147	93	144	207	116	181	260	137	214	307
Statewide	**35**	**58**	**94**	**49**	**81**	**132**	**61**	**102**	**166**	**72**	**120**	**196**

Table 40. Existing Single-Family—TRC Benefit Cost Ratio—Base

Weather Station / Region	TRC Benefit Cost Ratio											
	SEER 15			SEER 16			SEER 17			SEER 18		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Astoria	0.02	0.03	0.09	0.02	0.04	0.12	0.01	0.01	0.03	0.01	0.02	0.04
Baker	0.11	0.22	0.29	0.16	0.31	0.41	0.04	0.09	0.12	0.05	0.10	0.14
Eugene	0.12	0.21	0.41	0.16	0.30	0.57	0.05	0.09	0.17	0.06	0.10	0.20
Hillsboro	0.14	0.21	0.35	0.19	0.30	0.50	0.06	0.09	0.14	0.07	0.10	0.17
North Bend	0.00	0.02	0.07	0.00	0.03	0.10	0.00	0.01	0.03	0.00	0.01	0.04
Redmond	0.14	0.24	0.36	0.19	0.33	0.50	0.06	0.10	0.14	0.07	0.11	0.17
Salem	0.13	0.22	0.40	0.18	0.31	0.56	0.05	0.09	0.16	0.06	0.10	0.19
Klamath Falls	0.13	0.23	0.33	0.19	0.32	0.46	0.05	0.09	0.13	0.06	0.11	0.16
Portland	0.13	0.22	0.38	0.18	0.31	0.53	0.05	0.09	0.15	0.06	0.11	0.18
Roseburg	0.20	0.32	0.52	0.28	0.46	0.73	0.08	0.13	0.21	0.10	0.16	0.25
Troutdale	0.08	0.22	0.39	0.12	0.31	0.55	0.03	0.09	0.16	0.04	0.11	0.19
Medford	0.26	0.41	0.60	0.36	0.58	0.84	0.10	0.17	0.24	0.12	0.20	0.29
Pendleton	0.21	0.32	0.47	0.30	0.45	0.66	0.09	0.13	0.19	0.10	0.15	0.22
The Dalles	0.23	0.38	0.60	0.32	0.54	0.84	0.09	0.16	0.24	0.11	0.18	0.29
Zone 1	0.12	0.20	0.35	0.17	0.28	0.49	0.05	0.08	0.14	0.06	0.10	0.17
Zone 2	0.12	0.23	0.39	0.17	0.32	0.55	0.05	0.09	0.16	0.06	0.11	0.19
Zone 3	0.25	0.40	0.58	0.35	0.56	0.82	0.10	0.16	0.24	0.12	0.19	0.28
Statewide	**0.13**	**0.23**	**0.39**	**0.19**	**0.33**	**0.55**	**0.05**	**0.10**	**0.16**	**0.06**	**0.11**	**0.19**

Table 41. New Construction Code Built Single-Family—TRC Benefit Cost Ratio—Base

Weather Station / Region	TRC Benefit Cost Ratio											
	SEER 15			SEER 16			SEER 17			SEER 18		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Astoria	0.01	0.02	0.07	0.01	0.03	0.09	0.00	0.01	0.03	0.00	0.01	0.03
Baker	0.06	0.14	0.19	0.08	0.20	0.27	0.02	0.06	0.08	0.03	0.07	0.09
Eugene	0.08	0.15	0.28	0.11	0.20	0.40	0.03	0.06	0.11	0.04	0.07	0.13
Hillsboro	0.10	0.15	0.25	0.14	0.21	0.35	0.04	0.06	0.10	0.05	0.07	0.12
North Bend	0.00	0.01	0.06	0.00	0.02	0.08	0.00	0.01	0.02	0.00	0.01	0.03
Redmond	0.08	0.15	0.23	0.11	0.21	0.33	0.03	0.06	0.09	0.04	0.07	0.11
Salem	0.08	0.15	0.28	0.12	0.21	0.40	0.03	0.06	0.11	0.04	0.07	0.13
Klamath Falls	0.08	0.15	0.22	0.11	0.21	0.31	0.03	0.06	0.09	0.04	0.07	0.11
Portland	0.10	0.16	0.28	0.13	0.23	0.40	0.04	0.07	0.11	0.05	0.08	0.13
Roseburg	0.16	0.23	0.37	0.23	0.33	0.52	0.06	0.09	0.15	0.08	0.11	0.18
Troutdale	0.06	0.17	0.29	0.09	0.23	0.41	0.02	0.07	0.12	0.03	0.08	0.14
Medford	0.18	0.29	0.42	0.25	0.41	0.59	0.07	0.12	0.17	0.08	0.14	0.20
Pendleton	0.15	0.23	0.33	0.22	0.32	0.46	0.06	0.09	0.13	0.07	0.11	0.16
The Dalles	0.17	0.27	0.42	0.24	0.39	0.59	0.07	0.11	0.17	0.08	0.13	0.20
Zone 1	0.08	0.14	0.24	0.11	0.19	0.34	0.03	0.06	0.10	0.04	0.07	0.11
Zone 2	0.09	0.17	0.29	0.12	0.24	0.40	0.04	0.07	0.12	0.04	0.08	0.14
Zone 3	0.17	0.28	0.41	0.24	0.39	0.57	0.07	0.11	0.16	0.08	0.13	0.19
Statewide	**0.09**	**0.17**	**0.28**	**0.13**	**0.24**	**0.39**	**0.04**	**0.07**	**0.11**	**0.04**	**0.08**	**0.13**

Table 42. New Construction ENERGY STAR Built Single-Family—TRC Benefit Cost Ratio—Base

Weather Station / Region	TRC Benefit Cost Ratio											
	SEER 15			SEER 16			SEER 17			SEER 18		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Astoria	0.01	0.03	0.08	0.01	0.04	0.12	0.00	0.01	0.03	0.00	0.01	0.04
Baker	0.06	0.14	0.19	0.09	0.20	0.27	0.02	0.06	0.08	0.03	0.07	0.09
Eugene	0.09	0.15	0.29	0.12	0.21	0.41	0.04	0.06	0.12	0.04	0.07	0.14
Hillsboro	0.10	0.16	0.25	0.14	0.23	0.36	0.04	0.06	0.10	0.05	0.08	0.12
North Bend	0.00	0.02	0.08	0.00	0.03	0.11	0.00	0.01	0.03	0.00	0.01	0.04
Redmond	0.08	0.15	0.23	0.11	0.21	0.33	0.03	0.06	0.09	0.04	0.07	0.11
Salem	0.09	0.16	0.28	0.13	0.22	0.40	0.04	0.06	0.11	0.04	0.07	0.13
Klamath Falls	0.09	0.15	0.23	0.12	0.22	0.32	0.03	0.06	0.09	0.04	0.07	0.11
Portland	0.11	0.17	0.29	0.15	0.24	0.41	0.04	0.07	0.12	0.05	0.08	0.14
Roseburg	0.17	0.24	0.37	0.24	0.33	0.53	0.07	0.10	0.15	0.08	0.11	0.18
Troutdale	0.07	0.17	0.30	0.10	0.24	0.42	0.03	0.07	0.12	0.03	0.08	0.14
Medford	0.17	0.28	0.39	0.24	0.39	0.56	0.07	0.11	0.16	0.08	0.13	0.19
Pendleton	0.15	0.22	0.31	0.21	0.31	0.44	0.06	0.09	0.12	0.07	0.11	0.15
The Dalles	0.17	0.26	0.40	0.24	0.37	0.56	0.07	0.11	0.16	0.08	0.12	0.19
Zone 1	0.09	0.15	0.25	0.12	0.21	0.35	0.03	0.06	0.10	0.04	0.07	0.12
Zone 2	0.10	0.17	0.30	0.14	0.25	0.42	0.04	0.07	0.12	0.05	0.08	0.14
Zone 3	0.17	0.27	0.38	0.24	0.38	0.54	0.07	0.11	0.15	0.08	0.13	0.18
Statewide	**0.10**	**0.17**	**0.28**	**0.14**	**0.24**	**0.40**	**0.04**	**0.07**	**0.11**	**0.05**	**0.08**	**0.13**

Table 43. Mobile Home Existing—TRC Benefit Cost Ratio—Base

Weather Station / Region	TRC Benefit Cost Ratio											
	SEER 15			SEER 16			SEER 17			SEER 18		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Astoria	0.02	0.03	0.08	0.02	0.04	0.11	0.01	0.01	0.03	0.01	0.01	0.04
Baker	0.10	0.18	0.23	0.14	0.25	0.33	0.04	0.07	0.09	0.05	0.09	0.11
Eugene	0.10	0.17	0.31	0.14	0.23	0.44	0.04	0.07	0.13	0.05	0.08	0.15
Hillsboro	0.11	0.17	0.28	0.16	0.24	0.39	0.05	0.07	0.11	0.05	0.08	0.13
North Bend	0.00	0.02	0.06	0.01	0.03	0.09	0.00	0.01	0.03	0.00	0.01	0.03
Redmond	0.12	0.19	0.28	0.16	0.27	0.39	0.05	0.08	0.11	0.06	0.09	0.13
Salem	0.11	0.17	0.31	0.15	0.24	0.43	0.04	0.07	0.12	0.05	0.08	0.15
Klamath Falls	0.12	0.19	0.26	0.16	0.27	0.37	0.05	0.08	0.11	0.05	0.09	0.13
Portland	0.11	0.18	0.30	0.15	0.25	0.42	0.04	0.07	0.12	0.05	0.08	0.14
Roseburg	0.17	0.26	0.40	0.23	0.36	0.56	0.07	0.10	0.16	0.08	0.12	0.19
Troutdale	0.08	0.18	0.31	0.11	0.25	0.44	0.03	0.07	0.13	0.04	0.09	0.15
Medford	0.20	0.32	0.46	0.29	0.45	0.65	0.08	0.13	0.19	0.10	0.15	0.22
Pendleton	0.18	0.25	0.36	0.25	0.36	0.51	0.07	0.10	0.15	0.08	0.12	0.17
The Dalles	0.19	0.30	0.46	0.26	0.42	0.64	0.08	0.12	0.18	0.09	0.14	0.22
Zone 1	0.10	0.16	0.27	0.14	0.23	0.38	0.04	0.06	0.11	0.05	0.08	0.13
Zone 2	0.10	0.18	0.31	0.14	0.26	0.43	0.04	0.07	0.12	0.05	0.09	0.15
Zone 3	0.20	0.31	0.45	0.28	0.44	0.63	0.08	0.13	0.18	0.10	0.15	0.21
Statewide	**0.11**	**0.19**	**0.31**	**0.16**	**0.26**	**0.43**	**0.05**	**0.08**	**0.12**	**0.05**	**0.09**	**0.15**

Central Air Conditioning Results – Low-cost Scenario

Table 44. Existing Single-Family—TRC Benefit Cost Ratio—Low-cost

Weather Station / Region	TRC Benefit Cost Ratio											
	SEER 15			SEER 16			SEER 17			SEER 18		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Astoria	0.08	0.16	0.44	0.06	0.11	0.30	0.02	0.05	0.14	0.03	0.06	0.16
Baker	0.57	1.13	1.52	0.39	0.78	1.05	0.18	0.35	0.47	0.21	0.41	0.55
Eugene	0.60	1.10	2.10	0.41	0.76	1.45	0.19	0.34	0.65	0.22	0.40	0.76
Hillsboro	0.71	1.09	1.82	0.49	0.75	1.25	0.22	0.34	0.56	0.26	0.40	0.66
North Bend	0.01	0.12	0.38	0.01	0.08	0.26	0.00	0.04	0.12	0.01	0.04	0.14
Redmond	0.71	1.22	1.84	0.49	0.84	1.26	0.22	0.38	0.56	0.26	0.44	0.67
Salem	0.67	1.13	2.04	0.46	0.77	1.40	0.21	0.35	0.63	0.24	0.41	0.74
Klamath Falls	0.70	1.20	1.73	0.48	0.83	1.19	0.21	0.37	0.53	0.25	0.44	0.63
Portland	0.66	1.15	1.97	0.45	0.79	1.36	0.20	0.35	0.61	0.24	0.42	0.72
Roseburg	1.06	1.70	2.71	0.73	1.17	1.86	0.33	0.52	0.83	0.38	0.62	0.98
Troutdale	0.44	1.17	2.06	0.30	0.80	1.42	0.13	0.36	0.63	0.16	0.42	0.75
Medford	1.46	2.33	3.41	1.00	1.60	2.34	0.45	0.72	1.05	0.53	0.84	1.24
Pendleton	1.22	1.83	2.66	0.84	1.26	1.83	0.37	0.56	0.82	0.44	0.66	0.96
The Dalles	1.29	2.18	3.41	0.89	1.50	2.34	0.40	0.67	1.05	0.47	0.79	1.24
Zone 1	0.63	1.04	1.79	0.43	0.71	1.23	0.19	0.32	0.55	0.23	0.38	0.65
Zone 2	0.62	1.20	2.04	0.42	0.82	1.40	0.19	0.37	0.63	0.22	0.43	0.74
Zone 3	1.41	2.25	3.31	0.97	1.54	2.27	0.43	0.69	1.02	0.51	0.82	1.20
Statewide	**0.71**	**1.23**	**2.06**	**0.49**	**0.85**	**1.41**	**0.22**	**0.38**	**0.63**	**0.26**	**0.45**	**0.75**

Table 45. New Construction Code Built Single-Family—TRC Benefit Cost Ratio—Low-cost

Weather Station / Region	TRC Benefit Cost Ratio											
	SEER 15			SEER 16			SEER 17			SEER 18		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Astoria	0.03	0.07	0.25	0.02	0.05	0.17	0.01	0.02	0.08	0.01	0.03	0.09
Baker	0.22	0.52	0.71	0.15	0.36	0.49	0.07	0.16	0.22	0.08	0.19	0.26
Eugene	0.29	0.54	1.05	0.20	0.37	0.72	0.09	0.16	0.32	0.11	0.19	0.38
Hillsboro	0.36	0.56	0.91	0.25	0.39	0.63	0.11	0.17	0.28	0.13	0.20	0.33
North Bend	0.00	0.05	0.21	0.00	0.03	0.14	0.00	0.01	0.06	0.00	0.02	0.08
Redmond	0.29	0.54	0.87	0.20	0.37	0.59	0.09	0.17	0.27	0.10	0.20	0.31
Salem	0.31	0.55	1.04	0.21	0.38	0.71	0.10	0.17	0.32	0.11	0.20	0.38
Klamath Falls	0.30	0.56	0.83	0.21	0.39	0.57	0.09	0.17	0.25	0.11	0.20	0.30
Portland	0.35	0.60	1.04	0.24	0.41	0.72	0.11	0.19	0.32	0.13	0.22	0.38
Roseburg	0.59	0.86	1.38	0.41	0.59	0.95	0.18	0.26	0.42	0.22	0.31	0.50
Troutdale	0.23	0.62	1.08	0.16	0.42	0.74	0.07	0.19	0.33	0.08	0.22	0.39
Medford	0.70	1.15	1.67	0.48	0.79	1.15	0.22	0.35	0.51	0.26	0.42	0.61
Pendleton	0.61	0.91	1.30	0.42	0.63	0.89	0.19	0.28	0.40	0.22	0.33	0.47
The Dalles	0.67	1.09	1.67	0.46	0.75	1.15	0.20	0.34	0.51	0.24	0.40	0.61
Zone 1	0.30	0.51	0.90	0.21	0.35	0.62	0.09	0.16	0.28	0.11	0.19	0.32
Zone 2	0.33	0.62	1.06	0.23	0.43	0.73	0.10	0.19	0.33	0.12	0.23	0.39
Zone 3	0.69	1.11	1.62	0.47	0.76	1.11	0.21	0.34	0.50	0.25	0.40	0.59
Statewide	**0.35**	**0.62**	**1.05**	**0.24**	**0.43**	**0.72**	**0.11**	**0.19**	**0.32**	**0.13**	**0.23**	**0.38**

Table 46. New Construction ENERGY STAR Built Single-Family—TRC Benefit Cost Ratio—Low-cost

Weather Station / Region	TRC Benefit Cost Ratio											
	SEER 15			SEER 16			SEER 17			SEER 18		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Astoria	0.03	0.09	0.28	0.02	0.06	0.19	0.01	0.03	0.09	0.01	0.03	0.10
Baker	0.21	0.49	0.65	0.14	0.33	0.45	0.06	0.15	0.20	0.08	0.18	0.24
Eugene	0.30	0.51	0.97	0.20	0.35	0.67	0.09	0.16	0.30	0.11	0.18	0.35
Hillsboro	0.35	0.54	0.85	0.24	0.37	0.58	0.11	0.17	0.26	0.13	0.20	0.31
North Bend	0.01	0.08	0.27	0.01	0.05	0.18	0.00	0.02	0.08	0.00	0.03	0.10
Redmond	0.27	0.50	0.79	0.19	0.35	0.54	0.08	0.15	0.24	0.10	0.18	0.29
Salem	0.31	0.53	0.96	0.21	0.36	0.66	0.10	0.16	0.29	0.11	0.19	0.35
Klamath Falls	0.29	0.52	0.76	0.20	0.36	0.52	0.09	0.16	0.23	0.11	0.19	0.28
Portland	0.36	0.57	0.98	0.25	0.39	0.67	0.11	0.18	0.30	0.13	0.21	0.35
Roseburg	0.58	0.80	1.26	0.40	0.55	0.86	0.18	0.25	0.39	0.21	0.29	0.46
Troutdale	0.23	0.58	1.01	0.16	0.40	0.69	0.07	0.18	0.31	0.08	0.21	0.37
Medford	0.66	1.05	1.51	0.46	0.72	1.04	0.20	0.32	0.46	0.24	0.38	0.55
Pendleton	0.58	0.85	1.18	0.40	0.58	0.81	0.18	0.26	0.36	0.21	0.31	0.43
The Dalles	0.64	1.00	1.52	0.44	0.69	1.04	0.20	0.31	0.47	0.23	0.36	0.55
Zone 1	0.29	0.49	0.83	0.20	0.34	0.57	0.09	0.15	0.26	0.11	0.18	0.30
Zone 2	0.33	0.59	0.99	0.23	0.40	0.68	0.10	0.18	0.31	0.12	0.21	0.36
Zone 3	0.65	1.02	1.46	0.45	0.70	1.01	0.20	0.31	0.45	0.24	0.37	0.53
Statewide	**0.35**	**0.59**	**0.97**	**0.24**	**0.40**	**0.67**	**0.11**	**0.18**	**0.30**	**0.13**	**0.21**	**0.35**

Table 47. Mobile Home Existing—TRC Benefit Cost Ratio—Low-cost

Weather Station / Region	TRC Benefit Cost Ratio											
	SEER 15			SEER 16			SEER 17			SEER 18		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Astoria	0.07	0.13	0.32	0.05	0.09	0.22	0.02	0.04	0.10	0.03	0.05	0.12
Baker	0.40	0.75	0.98	0.28	0.52	0.67	0.12	0.23	0.30	0.15	0.27	0.35
Eugene	0.41	0.70	1.30	0.28	0.48	0.89	0.13	0.21	0.40	0.15	0.25	0.47
Hillsboro	0.48	0.71	1.15	0.33	0.49	0.79	0.15	0.22	0.35	0.17	0.26	0.42
North Bend	0.02	0.10	0.27	0.01	0.07	0.18	0.01	0.03	0.08	0.01	0.04	0.10
Redmond	0.48	0.79	1.16	0.33	0.54	0.80	0.15	0.24	0.36	0.18	0.29	0.42
Salem	0.45	0.72	1.28	0.31	0.49	0.88	0.14	0.22	0.39	0.16	0.26	0.46
Klamath Falls	0.48	0.79	1.10	0.33	0.54	0.76	0.15	0.24	0.34	0.17	0.29	0.40
Portland	0.45	0.74	1.25	0.31	0.51	0.86	0.14	0.23	0.39	0.16	0.27	0.45
Roseburg	0.69	1.07	1.66	0.48	0.73	1.14	0.21	0.33	0.51	0.25	0.39	0.60
Troutdale	0.32	0.76	1.30	0.22	0.52	0.89	0.10	0.23	0.40	0.12	0.27	0.47
Medford	0.93	1.45	2.09	0.64	1.00	1.43	0.28	0.45	0.64	0.34	0.53	0.76
Pendleton	0.80	1.15	1.64	0.55	0.79	1.13	0.25	0.35	0.50	0.29	0.42	0.59
The Dalles	0.84	1.36	2.06	0.58	0.93	1.42	0.26	0.42	0.63	0.31	0.49	0.75
Zone 1	0.43	0.67	1.13	0.29	0.46	0.77	0.13	0.21	0.35	0.16	0.24	0.41
Zone 2	0.43	0.77	1.29	0.29	0.53	0.88	0.13	0.24	0.40	0.15	0.28	0.47
Zone 3	0.90	1.41	2.02	0.62	0.97	1.39	0.28	0.43	0.62	0.33	0.51	0.73
Statewide	**0.48**	**0.79**	**1.29**	**0.33**	**0.54**	**0.89**	**0.15**	**0.24**	**0.40**	**0.17**	**0.29**	**0.47**

Table 48. Existing Single-Family—TRC Benefit Cost Ratio—Alternative Savings

Weather Station / Region	TRC Benefit Cost Ratio											
	SEER 15			SEER 16			SEER 17			SEER 18		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Astoria	0.01	0.02	0.07	0.02	0.03	0.09	0.00	0.01	0.03	0.01	0.01	0.03
Baker	0.09	0.17	0.23	0.12	0.24	0.32	0.03	0.07	0.09	0.04	0.08	0.11
Eugene	0.09	0.17	0.32	0.13	0.23	0.45	0.04	0.07	0.13	0.04	0.08	0.15
Hillsboro	0.11	0.16	0.27	0.15	0.23	0.39	0.04	0.07	0.11	0.05	0.08	0.13
North Bend	0.00	0.02	0.06	0.00	0.03	0.08	0.00	0.01	0.02	0.00	0.01	0.03
Redmond	0.11	0.18	0.28	0.15	0.26	0.39	0.04	0.07	0.11	0.05	0.09	0.13
Salem	0.10	0.17	0.31	0.14	0.24	0.43	0.04	0.07	0.12	0.05	0.08	0.15
Klamath Falls	0.10	0.18	0.26	0.15	0.25	0.36	0.04	0.07	0.10	0.05	0.08	0.12
Portland	0.10	0.17	0.29	0.14	0.24	0.41	0.04	0.07	0.12	0.05	0.08	0.14
Roseburg	0.16	0.25	0.40	0.22	0.36	0.56	0.06	0.10	0.16	0.07	0.12	0.19
Troutdale	0.06	0.17	0.31	0.09	0.24	0.43	0.03	0.07	0.12	0.03	0.08	0.15
Medford	0.20	0.32	0.47	0.28	0.45	0.66	0.08	0.13	0.19	0.10	0.15	0.22
Pendleton	0.17	0.25	0.36	0.23	0.35	0.51	0.07	0.10	0.15	0.08	0.12	0.17
The Dalles	0.18	0.30	0.47	0.25	0.42	0.66	0.07	0.12	0.19	0.08	0.14	0.22
Zone 1	0.10	0.16	0.27	0.13	0.22	0.38	0.04	0.06	0.11	0.05	0.07	0.13
Zone 2	0.09	0.18	0.30	0.13	0.25	0.42	0.04	0.07	0.12	0.04	0.08	0.14
Zone 3	0.19	0.31	0.45	0.27	0.43	0.64	0.08	0.12	0.18	0.09	0.15	0.22
Statewide	**0.10**	**0.18**	**0.30**	**0.15**	**0.26**	**0.43**	**0.04**	**0.07**	**0.12**	**0.05**	**0.09**	**0.15**

Table 49. New Construction Code Built Single-Family—TRC Benefit Cost Ratio—Alternative Savings

Weather Station / Region	TRC Benefit Cost Ratio											
	SEER 15			SEER 16			SEER 17			SEER 18		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Astoria	0.01	0.02	0.07	0.01	0.03	0.09	0.00	0.01	0.03	0.00	0.01	0.03
Baker	0.06	0.14	0.19	0.08	0.20	0.27	0.02	0.06	0.08	0.03	0.07	0.09
Eugene	0.08	0.15	0.28	0.11	0.20	0.40	0.03	0.06	0.11	0.04	0.07	0.13
Hillsboro	0.10	0.15	0.25	0.14	0.21	0.35	0.04	0.06	0.10	0.05	0.07	0.12
North Bend	0.00	0.01	0.06	0.00	0.02	0.08	0.00	0.01	0.02	0.00	0.01	0.03
Redmond	0.08	0.15	0.23	0.11	0.21	0.33	0.03	0.06	0.09	0.04	0.07	0.11
Salem	0.08	0.15	0.28	0.12	0.21	0.40	0.03	0.06	0.11	0.04	0.07	0.13
Klamath Falls	0.08	0.15	0.22	0.11	0.21	0.31	0.03	0.06	0.09	0.04	0.07	0.11
Portland	0.10	0.16	0.28	0.13	0.23	0.40	0.04	0.07	0.11	0.05	0.08	0.13
Roseburg	0.16	0.23	0.37	0.23	0.33	0.52	0.06	0.09	0.15	0.08	0.11	0.18
Troutdale	0.06	0.17	0.29	0.09	0.23	0.41	0.02	0.07	0.12	0.03	0.08	0.14
Medford	0.18	0.29	0.42	0.25	0.41	0.59	0.07	0.12	0.17	0.08	0.14	0.20
Pendleton	0.15	0.23	0.33	0.22	0.32	0.46	0.06	0.09	0.13	0.07	0.11	0.16
The Dalles	0.17	0.27	0.42	0.24	0.39	0.59	0.07	0.11	0.17	0.08	0.13	0.20
Zone 1	0.08	0.14	0.24	0.11	0.19	0.34	0.03	0.06	0.10	0.04	0.07	0.11
Zone 2	0.09	0.17	0.29	0.12	0.24	0.40	0.04	0.07	0.12	0.04	0.08	0.14
Zone 3	0.17	0.28	0.41	0.24	0.39	0.57	0.07	0.11	0.16	0.08	0.13	0.19
Statewide	**0.09**	**0.17**	**0.28**	**0.13**	**0.24**	**0.39**	**0.04**	**0.07**	**0.11**	**0.04**	**0.08**	**0.13**

Table 50. New Construction ENERGY STAR Built Single-Family—TRC Benefit Cost Ratio—Alternative Savings

Weather Station / Region	TRC Benefit Cost Ratio											
	SEER 15			SEER 16			SEER 17			SEER 18		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Astoria	0.01	0.03	0.08	0.01	0.04	0.12	0.00	0.01	0.03	0.00	0.01	0.04
Baker	0.06	0.14	0.19	0.09	0.20	0.27	0.02	0.06	0.08	0.03	0.07	0.09
Eugene	0.09	0.15	0.29	0.12	0.21	0.41	0.04	0.06	0.12	0.04	0.07	0.14
Hillsboro	0.10	0.16	0.25	0.14	0.23	0.36	0.04	0.06	0.10	0.05	0.08	0.12
North Bend	0.00	0.02	0.08	0.00	0.03	0.11	0.00	0.01	0.03	0.00	0.01	0.04
Redmond	0.08	0.15	0.23	0.11	0.21	0.33	0.03	0.06	0.09	0.04	0.07	0.11
Salem	0.09	0.16	0.28	0.13	0.22	0.40	0.04	0.06	0.11	0.04	0.07	0.13
Klamath Falls	0.09	0.15	0.23	0.12	0.22	0.32	0.03	0.06	0.09	0.04	0.07	0.11
Portland	0.11	0.17	0.29	0.15	0.24	0.41	0.04	0.07	0.12	0.05	0.08	0.14
Roseburg	0.17	0.24	0.37	0.24	0.33	0.53	0.07	0.10	0.15	0.08	0.11	0.18
Troutdale	0.07	0.17	0.30	0.10	0.24	0.42	0.03	0.07	0.12	0.03	0.08	0.14
Medford	0.17	0.28	0.39	0.24	0.39	0.56	0.07	0.11	0.16	0.08	0.13	0.19
Pendleton	0.15	0.22	0.31	0.21	0.31	0.44	0.06	0.09	0.12	0.07	0.11	0.15
The Dalles	0.17	0.26	0.40	0.24	0.37	0.56	0.07	0.11	0.16	0.08	0.12	0.19
Zone 1	0.09	0.15	0.25	0.12	0.21	0.35	0.03	0.06	0.10	0.04	0.07	0.12
Zone 2	0.10	0.17	0.30	0.14	0.25	0.42	0.04	0.07	0.12	0.05	0.08	0.14
Zone 3	0.17	0.27	0.38	0.24	0.38	0.54	0.07	0.11	0.15	0.08	0.13	0.18
Statewide	**0.10**	**0.17**	**0.28**	**0.14**	**0.24**	**0.40**	**0.04**	**0.07**	**0.11**	**0.05**	**0.08**	**0.13**

Table 51. Mobile Home Existing—TRC Benefit Cost Ratio—Alternative Savings

Weather Station / Region	TRC Benefit Cost Ratio											
	SEER 15			SEER 16			SEER 17			SEER 18		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Astoria	0.01	0.02	0.05	0.01	0.03	0.07	0.00	0.01	0.02	0.00	0.01	0.02
Baker	0.06	0.11	0.15	0.08	0.16	0.20	0.02	0.04	0.06	0.03	0.05	0.07
Eugene	0.06	0.10	0.19	0.09	0.15	0.27	0.02	0.04	0.08	0.03	0.05	0.09
Hillsboro	0.07	0.11	0.17	0.10	0.15	0.24	0.03	0.04	0.07	0.03	0.05	0.08
North Bend	0.00	0.02	0.04	0.00	0.02	0.06	0.00	0.01	0.02	0.00	0.01	0.02
Redmond	0.07	0.12	0.17	0.10	0.16	0.24	0.03	0.05	0.07	0.03	0.06	0.08
Salem	0.07	0.11	0.19	0.09	0.15	0.27	0.03	0.04	0.08	0.03	0.05	0.09
Klamath Falls	0.07	0.12	0.16	0.10	0.17	0.23	0.03	0.05	0.07	0.03	0.06	0.08
Portland	0.07	0.11	0.19	0.09	0.15	0.26	0.03	0.04	0.07	0.03	0.05	0.09
Roseburg	0.10	0.16	0.25	0.15	0.22	0.35	0.04	0.06	0.10	0.05	0.07	0.12
Troutdale	0.05	0.11	0.19	0.07	0.16	0.27	0.02	0.04	0.08	0.02	0.05	0.09
Medford	0.13	0.20	0.29	0.18	0.28	0.40	0.05	0.08	0.11	0.06	0.09	0.14
Pendleton	0.11	0.16	0.22	0.15	0.22	0.32	0.04	0.06	0.09	0.05	0.07	0.11
The Dalles	0.12	0.19	0.28	0.16	0.26	0.40	0.05	0.07	0.11	0.05	0.09	0.13
Zone 1	0.06	0.10	0.17	0.09	0.14	0.24	0.03	0.04	0.07	0.03	0.05	0.08
Zone 2	0.06	0.11	0.19	0.09	0.16	0.27	0.03	0.05	0.08	0.03	0.05	0.09
Zone 3	0.12	0.19	0.28	0.17	0.27	0.39	0.05	0.08	0.11	0.06	0.09	0.13
Statewide	**0.07**	**0.12**	**0.19**	**0.10**	**0.16**	**0.27**	**0.03**	**0.05**	**0.08**	**0.03**	**0.05**	**0.09**

Central Air Conditioning Results – Lifetime Scenario

Table 52. Existing Single-Family—TRC Benefit Cost Ratio—Lifetime

Weather Station / Region	TRC Benefit Cost Ratio											
	SEER 15			SEER 16			SEER 17			SEER 18		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Astoria	0.02	0.05	0.13	0.03	0.07	0.18	0.01	0.02	0.05	0.01	0.02	0.06
Baker	0.17	0.33	0.44	0.23	0.46	0.62	0.07	0.13	0.18	0.08	0.16	0.21
Eugene	0.17	0.32	0.61	0.25	0.45	0.86	0.07	0.13	0.25	0.08	0.15	0.29
Hillsboro	0.20	0.32	0.53	0.29	0.44	0.74	0.08	0.13	0.21	0.10	0.15	0.25
North Bend	0.00	0.04	0.11	0.01	0.05	0.15	0.00	0.01	0.04	0.00	0.02	0.05
Redmond	0.20	0.35	0.53	0.29	0.50	0.75	0.08	0.14	0.22	0.10	0.17	0.25
Salem	0.20	0.33	0.59	0.27	0.46	0.83	0.08	0.13	0.24	0.09	0.16	0.28
Klamath Falls	0.20	0.34	0.49	0.28	0.48	0.69	0.08	0.14	0.20	0.10	0.16	0.24
Portland	0.19	0.33	0.56	0.26	0.46	0.79	0.08	0.13	0.23	0.09	0.16	0.27
Roseburg	0.30	0.48	0.77	0.42	0.68	1.08	0.12	0.20	0.31	0.14	0.23	0.37
Troutdale	0.12	0.33	0.59	0.17	0.47	0.83	0.05	0.14	0.24	0.06	0.16	0.28
Medford	0.38	0.61	0.90	0.54	0.86	1.26	0.16	0.25	0.36	0.18	0.29	0.43
Pendleton	0.32	0.48	0.70	0.45	0.67	0.98	0.13	0.20	0.28	0.15	0.23	0.34
The Dalles	0.34	0.57	0.89	0.48	0.80	1.26	0.14	0.23	0.36	0.16	0.27	0.43
Zone 1	0.18	0.30	0.52	0.26	0.42	0.73	0.07	0.12	0.21	0.09	0.14	0.25
Zone 2	0.18	0.34	0.58	0.25	0.48	0.81	0.07	0.14	0.24	0.08	0.16	0.28
Zone 3	0.37	0.59	0.87	0.52	0.83	1.22	0.15	0.24	0.35	0.18	0.28	0.42
Statewide	**0.20**	**0.35**	**0.58**	**0.28**	**0.49**	**0.82**	**0.08**	**0.14**	**0.24**	**0.10**	**0.17**	**0.28**

Table 53. New Construction Code Built Single-Family—TRC Benefit Cost Ratio—Lifetime

Weather Station / Region	TRC Benefit Cost Ratio											
	SEER 15			SEER 16			SEER 17			SEER 18		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Astoria	0.01	0.03	0.10	0.02	0.04	0.14	0.00	0.01	0.04	0.01	0.01	0.05
Baker	0.09	0.21	0.29	0.12	0.30	0.40	0.04	0.08	0.12	0.04	0.10	0.14
Eugene	0.12	0.22	0.42	0.16	0.30	0.59	0.05	0.09	0.17	0.06	0.10	0.20
Hillsboro	0.15	0.23	0.37	0.20	0.32	0.52	0.06	0.09	0.15	0.07	0.11	0.17
North Bend	0.00	0.02	0.08	0.00	0.03	0.12	0.00	0.01	0.03	0.00	0.01	0.04
Redmond	0.12	0.22	0.35	0.16	0.31	0.49	0.05	0.09	0.14	0.05	0.10	0.17
Salem	0.13	0.22	0.42	0.18	0.31	0.59	0.05	0.09	0.17	0.06	0.11	0.20
Klamath Falls	0.12	0.23	0.33	0.17	0.32	0.47	0.05	0.09	0.13	0.06	0.11	0.16
Portland	0.14	0.24	0.42	0.20	0.34	0.59	0.06	0.10	0.17	0.07	0.12	0.20
Roseburg	0.24	0.35	0.56	0.34	0.49	0.78	0.10	0.14	0.22	0.11	0.16	0.26
Troutdale	0.09	0.25	0.43	0.13	0.35	0.61	0.04	0.10	0.17	0.04	0.12	0.21
Medford	0.26	0.43	0.63	0.37	0.61	0.88	0.11	0.17	0.25	0.13	0.20	0.30
Pendleton	0.23	0.34	0.49	0.32	0.48	0.69	0.09	0.14	0.20	0.11	0.16	0.23
The Dalles	0.25	0.41	0.63	0.35	0.58	0.88	0.10	0.17	0.25	0.12	0.20	0.30
Zone 1	0.12	0.21	0.36	0.17	0.29	0.51	0.05	0.08	0.15	0.06	0.10	0.17
Zone 2	0.13	0.25	0.43	0.19	0.35	0.60	0.05	0.10	0.17	0.06	0.12	0.20
Zone 3	0.26	0.42	0.61	0.36	0.59	0.85	0.10	0.17	0.24	0.12	0.20	0.29
Statewide	**0.14**	**0.25**	**0.42**	**0.20**	**0.35**	**0.59**	**0.06**	**0.10**	**0.17**	**0.07**	**0.12**	**0.20**

Table 54. New Construction ENERGY STAR Built Single-Family—TRC Benefit Cost Ratio—Lifetime

Weather Station / Region	TRC Benefit Cost Ratio											
	SEER 15			SEER 16			SEER 17			SEER 18		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Astoria	0.01	0.04	0.13	0.02	0.06	0.18	0.01	0.02	0.05	0.01	0.02	0.06
Baker	0.09	0.22	0.29	0.13	0.30	0.41	0.04	0.09	0.12	0.04	0.10	0.14
Eugene	0.13	0.23	0.43	0.18	0.32	0.61	0.05	0.09	0.17	0.06	0.11	0.20
Hillsboro	0.15	0.24	0.38	0.22	0.34	0.53	0.06	0.10	0.15	0.07	0.11	0.18
North Bend	0.00	0.03	0.12	0.01	0.05	0.17	0.00	0.01	0.05	0.00	0.02	0.06
Redmond	0.12	0.22	0.35	0.17	0.31	0.49	0.05	0.09	0.14	0.06	0.11	0.17
Salem	0.14	0.24	0.43	0.19	0.33	0.60	0.06	0.09	0.17	0.07	0.11	0.20
Klamath Falls	0.13	0.23	0.34	0.18	0.33	0.48	0.05	0.09	0.14	0.06	0.11	0.16
Portland	0.16	0.25	0.43	0.23	0.36	0.61	0.06	0.10	0.17	0.08	0.12	0.21
Roseburg	0.26	0.35	0.56	0.36	0.50	0.79	0.10	0.14	0.22	0.12	0.17	0.26
Troutdale	0.10	0.26	0.45	0.14	0.37	0.63	0.04	0.10	0.18	0.05	0.12	0.21
Medford	0.26	0.41	0.59	0.37	0.58	0.83	0.10	0.17	0.24	0.12	0.20	0.28
Pendleton	0.23	0.33	0.46	0.32	0.47	0.65	0.09	0.13	0.19	0.11	0.16	0.22
The Dalles	0.25	0.39	0.59	0.35	0.55	0.84	0.10	0.16	0.24	0.12	0.19	0.28
Zone 1	0.13	0.22	0.37	0.18	0.31	0.52	0.05	0.09	0.15	0.06	0.10	0.18
Zone 2	0.15	0.26	0.44	0.21	0.37	0.62	0.06	0.10	0.18	0.07	0.12	0.21
Zone 3	0.25	0.40	0.57	0.36	0.56	0.80	0.10	0.16	0.23	0.12	0.19	0.27
Statewide	**0.15**	**0.26**	**0.42**	**0.21**	**0.36**	**0.60**	**0.06**	**0.10**	**0.17**	**0.07**	**0.12**	**0.20**

Table 55. Mobile Home Existing—TRC Benefit Cost Ratio—Lifetime

Weather Station / Region	TRC Benefit Cost Ratio											
	SEER 15			SEER 16			SEER 17			SEER 18		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Astoria	0.03	0.05	0.11	0.04	0.06	0.16	0.01	0.02	0.05	0.01	0.02	0.05
Baker	0.14	0.27	0.35	0.20	0.38	0.49	0.06	0.11	0.14	0.07	0.13	0.17
Eugene	0.15	0.25	0.47	0.21	0.35	0.65	0.06	0.10	0.19	0.07	0.12	0.22
Hillsboro	0.17	0.25	0.41	0.24	0.36	0.58	0.07	0.10	0.17	0.08	0.12	0.20
North Bend	0.01	0.04	0.10	0.01	0.05	0.13	0.00	0.01	0.04	0.00	0.02	0.05
Redmond	0.17	0.28	0.41	0.24	0.40	0.58	0.07	0.11	0.17	0.08	0.13	0.20
Salem	0.16	0.26	0.46	0.23	0.36	0.64	0.07	0.10	0.18	0.08	0.12	0.22
Klamath Falls	0.17	0.28	0.39	0.24	0.40	0.55	0.07	0.11	0.16	0.08	0.13	0.19
Portland	0.16	0.26	0.45	0.22	0.37	0.63	0.06	0.11	0.18	0.08	0.13	0.21
Roseburg	0.25	0.38	0.60	0.35	0.54	0.84	0.10	0.15	0.24	0.12	0.18	0.28
Troutdale	0.11	0.27	0.46	0.16	0.38	0.65	0.05	0.11	0.19	0.05	0.13	0.22
Medford	0.31	0.48	0.69	0.43	0.67	0.97	0.12	0.19	0.28	0.15	0.23	0.33
Pendleton	0.26	0.38	0.54	0.37	0.53	0.76	0.11	0.15	0.22	0.13	0.18	0.26
The Dalles	0.28	0.45	0.68	0.39	0.63	0.96	0.11	0.18	0.28	0.13	0.21	0.32
Zone 1	0.15	0.24	0.40	0.21	0.34	0.57	0.06	0.10	0.16	0.07	0.11	0.19
Zone 2	0.15	0.27	0.46	0.21	0.39	0.65	0.06	0.11	0.19	0.07	0.13	0.22
Zone 3	0.30	0.46	0.67	0.42	0.65	0.94	0.12	0.19	0.27	0.14	0.22	0.32
Statewide	**0.17**	**0.28**	**0.46**	**0.24**	**0.39**	**0.64**	**0.07**	**0.11**	**0.18**	**0.08**	**0.13**	**0.22**

Central Air Conditioning Results – Avoided Cost Scenario

Table 56. Existing Single-Family—TRC Benefit Cost Ratio—Avoided Cost

Weather Station / Region	TRC Benefit Cost Ratio											
	SEER 15			SEER 16			SEER 17			SEER 18		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Astoria	0.07	0.14	0.39	0.10	0.20	0.54	0.03	0.06	0.16	0.03	0.07	0.19
Baker	0.50	0.99	1.33	0.70	1.39	1.88	0.20	0.40	0.54	0.24	0.47	0.64
Eugene	0.53	0.96	1.84	0.74	1.36	2.59	0.21	0.39	0.75	0.25	0.46	0.88
Hillsboro	0.62	0.96	1.60	0.87	1.34	2.24	0.25	0.39	0.65	0.30	0.46	0.76
North Bend	0.01	0.11	0.33	0.02	0.15	0.47	0.01	0.04	0.14	0.01	0.05	0.16
Redmond	0.62	1.07	1.61	0.87	1.51	2.26	0.25	0.44	0.65	0.30	0.51	0.77
Salem	0.59	0.99	1.79	0.83	1.39	2.51	0.24	0.40	0.72	0.28	0.47	0.86
Klamath Falls	0.60	1.04	1.49	0.85	1.46	2.09	0.24	0.42	0.60	0.29	0.50	0.71
Portland	0.57	0.99	1.70	0.80	1.40	2.39	0.23	0.40	0.69	0.27	0.48	0.81
Roseburg	0.91	1.47	2.33	1.28	2.06	3.28	0.37	0.60	0.95	0.44	0.70	1.12
Troutdale	0.38	1.01	1.78	0.53	1.42	2.50	0.15	0.41	0.72	0.18	0.48	0.85
Medford	1.16	1.85	2.71	1.63	2.60	3.81	0.47	0.75	1.10	0.56	0.89	1.30
Pendleton	0.97	1.45	2.11	1.36	2.04	2.97	0.39	0.59	0.86	0.46	0.70	1.01
The Dalles	1.03	1.73	2.71	1.44	2.43	3.81	0.42	0.70	1.10	0.49	0.83	1.30
Zone 1	0.55	0.91	1.56	0.78	1.28	2.20	0.22	0.37	0.63	0.26	0.43	0.75
Zone 2	0.53	1.03	1.75	0.75	1.45	2.47	0.22	0.42	0.71	0.26	0.49	0.84
Zone 3	1.12	1.79	2.63	1.58	2.51	3.70	0.46	0.73	1.07	0.54	0.86	1.26
Statewide	**0.61**	**1.06**	**1.77**	**0.85**	**1.49**	**2.49**	**0.25**	**0.43**	**0.72**	**0.29**	**0.51**	**0.85**

Table 57. New Construction Code Built Single-Family—TRC Benefit Cost Ratio—Avoided Cost

Weather Station / Region	TRC Benefit Cost Ratio											
	SEER 15			SEER 16			SEER 17			SEER 18		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Astoria	0.03	0.09	0.30	0.05	0.12	0.43	0.01	0.03	0.12	0.02	0.04	0.14
Baker	0.27	0.64	0.87	0.38	0.90	1.22	0.11	0.26	0.35	0.13	0.30	0.41
Eugene	0.35	0.66	1.28	0.50	0.92	1.80	0.14	0.26	0.51	0.17	0.31	0.61
Hillsboro	0.44	0.69	1.12	0.62	0.97	1.57	0.18	0.28	0.45	0.21	0.33	0.53
North Bend	0.00	0.06	0.25	0.01	0.08	0.36	0.00	0.02	0.10	0.00	0.03	0.12
Redmond	0.35	0.66	1.06	0.49	0.93	1.49	0.14	0.27	0.43	0.17	0.31	0.50
Salem	0.38	0.68	1.27	0.54	0.95	1.79	0.15	0.27	0.51	0.18	0.32	0.60
Klamath Falls	0.37	0.69	1.01	0.52	0.97	1.42	0.15	0.28	0.41	0.17	0.33	0.48
Portland	0.43	0.74	1.27	0.61	1.04	1.79	0.17	0.30	0.51	0.20	0.35	0.60
Roseburg	0.73	1.05	1.69	1.02	1.47	2.37	0.29	0.42	0.68	0.34	0.50	0.80
Troutdale	0.28	0.75	1.32	0.39	1.06	1.85	0.11	0.30	0.53	0.13	0.36	0.62
Medford	0.80	1.30	1.90	1.13	1.83	2.67	0.32	0.53	0.77	0.38	0.62	0.90
Pendleton	0.69	1.04	1.48	0.98	1.46	2.08	0.28	0.42	0.59	0.33	0.49	0.70
The Dalles	0.76	1.24	1.90	1.07	1.75	2.68	0.31	0.50	0.77	0.36	0.59	0.91
Zone 1	0.37	0.62	1.10	0.51	0.88	1.54	0.15	0.25	0.44	0.17	0.30	0.52
Zone 2	0.40	0.76	1.30	0.56	1.07	1.83	0.16	0.31	0.52	0.19	0.36	0.62
Zone 3	0.78	1.26	1.84	1.10	1.78	2.59	0.32	0.51	0.74	0.37	0.60	0.88
Statewide	**0.43**	**0.76**	**1.27**	**0.60**	**1.06**	**1.79**	**0.17**	**0.30**	**0.51**	**0.20**	**0.36**	**0.60**

Table 58. New Construction ENERGY STAR Built Single-Family—TRC Benefit Cost Ratio—Avoided Cost

Weather Station / Region	TRC Benefit Cost Ratio											
	SEER 15			SEER 16			SEER 17			SEER 18		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Astoria	0.04	0.12	0.38	0.06	0.17	0.54	0.02	0.05	0.15	0.02	0.06	0.18
Baker	0.28	0.65	0.87	0.39	0.92	1.23	0.11	0.26	0.35	0.13	0.31	0.41
Eugene	0.40	0.68	1.30	0.56	0.96	1.83	0.16	0.27	0.52	0.19	0.32	0.62
Hillsboro	0.47	0.73	1.14	0.65	1.02	1.61	0.19	0.29	0.46	0.22	0.34	0.54
North Bend	0.01	0.10	0.36	0.02	0.15	0.50	0.01	0.04	0.14	0.01	0.05	0.17
Redmond	0.37	0.68	1.06	0.51	0.95	1.49	0.15	0.27	0.42	0.17	0.32	0.50
Salem	0.42	0.71	1.29	0.59	1.00	1.81	0.17	0.29	0.52	0.20	0.34	0.61
Klamath Falls	0.39	0.70	1.03	0.55	0.98	1.44	0.16	0.28	0.41	0.19	0.33	0.49
Portland	0.49	0.77	1.31	0.69	1.08	1.85	0.20	0.31	0.53	0.23	0.36	0.62
Roseburg	0.78	1.07	1.69	1.10	1.51	2.38	0.31	0.43	0.68	0.37	0.51	0.80
Troutdale	0.31	0.79	1.36	0.44	1.11	1.91	0.13	0.32	0.54	0.15	0.37	0.64
Medford	0.79	1.25	1.78	1.11	1.75	2.51	0.32	0.50	0.72	0.37	0.59	0.85
Pendleton	0.69	1.00	1.40	0.97	1.41	1.97	0.28	0.40	0.56	0.33	0.48	0.67
The Dalles	0.76	1.19	1.80	1.07	1.67	2.53	0.31	0.48	0.72	0.36	0.56	0.85
Zone 1	0.39	0.66	1.12	0.55	0.93	1.58	0.16	0.26	0.45	0.19	0.31	0.53
Zone 2	0.45	0.79	1.34	0.63	1.11	1.88	0.18	0.32	0.54	0.21	0.37	0.63
Zone 3	0.77	1.21	1.73	1.09	1.70	2.44	0.31	0.49	0.70	0.37	0.57	0.82
Statewide	**0.46**	**0.78**	**1.29**	**0.65**	**1.10**	**1.81**	**0.19**	**0.31**	**0.52**	**0.22**	**0.37**	**0.61**

Table 59. Mobile Home Existing—TRC Benefit Cost Ratio—Avoided Cost

Weather Station / Region	TRC Benefit Cost Ratio											
	SEER 15			SEER 16			SEER 17			SEER 18		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Astoria	0.08	0.14	0.35	0.11	0.19	0.49	0.03	0.06	0.14	0.04	0.07	0.17
Baker	0.44	0.81	1.06	0.61	1.14	1.49	0.18	0.33	0.43	0.21	0.39	0.50
Eugene	0.44	0.76	1.41	0.62	1.06	1.98	0.18	0.30	0.57	0.21	0.36	0.67
Hillsboro	0.52	0.77	1.24	0.73	1.08	1.75	0.21	0.31	0.50	0.25	0.37	0.59
North Bend	0.02	0.11	0.29	0.03	0.16	0.41	0.01	0.05	0.12	0.01	0.05	0.14
Redmond	0.52	0.85	1.26	0.74	1.20	1.76	0.21	0.34	0.51	0.25	0.41	0.60
Salem	0.49	0.78	1.38	0.69	1.10	1.95	0.20	0.31	0.56	0.23	0.37	0.66
Klamath Falls	0.52	0.86	1.19	0.73	1.21	1.68	0.21	0.35	0.48	0.25	0.41	0.57
Portland	0.48	0.80	1.36	0.68	1.12	1.91	0.20	0.32	0.55	0.23	0.38	0.65
Roseburg	0.75	1.15	1.80	1.06	1.62	2.54	0.30	0.47	0.73	0.36	0.55	0.86
Troutdale	0.35	0.82	1.41	0.49	1.15	1.98	0.14	0.33	0.57	0.17	0.39	0.67
Medford	0.93	1.45	2.08	1.30	2.04	2.93	0.37	0.59	0.84	0.44	0.69	0.99
Pendleton	0.80	1.15	1.64	1.12	1.62	2.30	0.32	0.47	0.66	0.38	0.55	0.78
The Dalles	0.84	1.36	2.06	1.18	1.91	2.90	0.34	0.55	0.83	0.40	0.65	0.98
Zone 1	0.46	0.73	1.22	0.65	1.02	1.71	0.19	0.29	0.49	0.22	0.35	0.58
Zone 2	0.46	0.83	1.39	0.65	1.17	1.96	0.19	0.33	0.56	0.22	0.40	0.66
Zone 3	0.90	1.41	2.02	1.27	1.98	2.84	0.36	0.57	0.82	0.43	0.67	0.96
Statewide	**0.51**	**0.85**	**1.39**	**0.72**	**1.19**	**1.95**	**0.21**	**0.34**	**0.56**	**0.24**	**0.40**	**0.66**

Window Air Conditioning Inputs and Results

Table 60. Savings and TRC Benefit Cost Ratio Regardless of Building Type (Base, Lifetime, and Avoided Cost Scenarios)

Weather Station / Region	Savings (kWh)			TRC Benefit Cost Ratio - Scenarios								
	CEER 12			Base			Lifetime			Avoided Cost		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Astoria	0	1	2	0.00	0.01	0.02	0.00	0.01	0.02	0.01	0.03	0.09
Baker	2	7	12	0.02	0.08	0.14	0.02	0.09	0.17	0.10	0.40	0.72
Eugene	3	7	14	0.03	0.09	0.17	0.04	0.10	0.21	0.16	0.44	0.89
Hillsboro	4	8	13	0.04	0.10	0.16	0.05	0.12	0.19	0.23	0.50	0.81
North Bend	0	0	1	0.00	0.00	0.02	0.00	0.00	0.02	0.00	0.01	0.09
Redmond	2	6	10	0.03	0.08	0.12	0.03	0.09	0.15	0.15	0.38	0.63
Salem	3	8	18	0.04	0.10	0.22	0.05	0.11	0.26	0.20	0.49	1.10
Klamath Falls	2	6	11	0.02	0.08	0.13	0.03	0.09	0.16	0.11	0.39	0.67
Portland	5	11	20	0.06	0.13	0.25	0.07	0.16	0.30	0.31	0.68	1.26
Roseburg	9	15	26	0.10	0.19	0.31	0.12	0.22	0.37	0.53	0.94	1.59
Troutdale	5	11	19	0.06	0.13	0.23	0.07	0.15	0.27	0.31	0.65	1.17
Medford	11	22	34	0.13	0.26	0.42	0.16	0.31	0.50	0.66	1.34	2.12
Pendleton	11	17	25	0.13	0.20	0.30	0.16	0.24	0.36	0.68	1.03	1.54
The Dalles	10	22	33	0.13	0.26	0.40	0.15	0.32	0.48	0.64	1.34	2.05
Zone 1	3	7	13	0.04	0.09	0.16	0.04	0.10	0.19	0.18	0.44	0.83
Zone 2	5	11	20	0.06	0.13	0.24	0.07	0.16	0.29	0.32	0.67	1.22
Zone 3	11	21	33	0.13	0.25	0.40	0.16	0.30	0.48	0.66	1.30	2.04
Statewide	**5**	**10**	**18**	**0.06**	**0.12**	**0.22**	**0.07**	**0.15**	**0.27**	**0.29**	**0.63**	**1.13**

Appendix E: Energy Trust of Oregon Residential Central Air Conditioning Cost Survey

Hello, thank you for helping Energy Trust of Oregon with this study of residential air conditioning system costs. Your input will help Energy Trust of Oregon to continue to offer effective energy-efficiency programs in the coming years. The information collected within this form is confidential and will not be shared. We will only report costs in aggregate across all participants of the survey and individual trade ally names will not be referenced. We appreciate the time and care you will take with your answers to our questions below and will provide you with a $250 pre-paid VISA gift card within 2 weeks as a token of our appreciation for your participation.

A few notes and instructions before you begin:

- If you would prefer to complete this survey over the phone, you can call or email Bradley Jones at (207-536-3104 or bradley.jones@cadmusgroup.com) to set up a time for the survey call.
- If you provide your answers in the document below, please enter your answers in red as your font color.
- Please make every attempt to provide accurate answers instead of providing "ballpark" estimates for your responses. The accuracy of data provided by contractors is crucial to this study.
- If you are confused by any questions or unsure of your response, you can call or email Bradley Jones at (207-536-3104 or bradley.jones@cadmusgroup.com) for clarification.

We recommend reviewing the entire survey before you respond to any of the questions. There are six sections in the survey:

1. Installation History – 2016 installations by size and efficiency level
2. AC Installation Cost in an Existing Home NOT Combined with a Furnace Replacement
3. AC Installation Cost in an Existing Home Combined with a Furnace Replacement
4. AC Installation Cost in a New Home
5. Additional Questions – (3 questions)
6. Contact Information – needed to receive your gift card.

A. Installation History

A1. Please fill in the table below regarding how many central air conditioning systems you installed in the past 12 months with the specified efficiency ratings. Enter a “0” if you did not install any and if you do not know please enter “not known”.

Total Number of Air Conditioning Systems Installed in 2016

#	Systems Installed in 2016	SEER 13-13.99	SEER 14-14.99	SEER 15-15.99	SEER 16-16.99	SEER 17-17.99	SEER 18-18.99	SEER 19+
A1.1	Number of Two-Ton Systems (#)							
A1.2	Number of Three-Ton Systems (#)							
A1.3	Number of Four-Ton Systems (#)							

B. AC Installation Cost in an Existing Home NOT Combined with a Furnace Replacement

B1. Please take the time to fill in the tables below with accurate cost data. If you do not install air conditioners in a certain size/efficiency range, then please enter “n/a” in the corresponding areas of the table. For the cost estimates, please assume that you are replacing an air conditioning system only (**not combined with a furnace replacement**) for an **existing single-family home** (question D1 will ask about new construction homes). Please provide the stand-alone costs for this application - Do not include the cost of relocating any ducts in the home.

- Please note that we are asking you to provide cost data for materials and labor separately. If you are unable to provide these costs separately, then please include the combined total cost in the rows provided under “total cost” in the table below. [Note: Only answer this question if you were unable to include material and labor costs separately in table below] In the costs that you provided below, approximately what percentage is related to labor? (please clarify if this percentage is different for different size/efficiency systems)

Two-Ton Central Air Conditioners per Unit Cost – Existing Home

#	2-Ton	SEER 13-13.99	SEER 14-14.99	SEER 15-15.99	SEER 16-16.99	SEER 17-17.99	SEER 18-18.99	SEER 19+
B1.1	Material Cost ($)							
B1.2	Labor Cost ($)							
If only total costs are known enter data below:								
B1.3	Total (Material and Labor) Cost ($)							
B1.4	Estimated labor percentage of total cost (%)							

Three-Ton Central Air Conditioners per Unit Cost – Existing Home

#	3-Ton	SEER 13-13.99	SEER 14-14.99	SEER 15-15.99	SEER 16-16.99	SEER 17-17.99	SEER 18-18.99	SEER 19+
B1.5	Material Cost ($)							
B1.6	Labor Cost ($)							
If only total costs are known enter data below:								
B1.7	Total (Material and Labor) Cost ($)							
B1.8	Estimated labor percentage of total cost (%)							

Four-Ton Central Air Conditioners per Unit Cost – Existing Home

#	4-Ton	SEER 13-13.99	SEER 14-14.99	SEER 15-15.99	SEER 16-16.99	SEER 17-17.99	SEER 18-18.99	SEER 19+
B1.9	Material Cost ($)							
B1.10	Labor Cost ($)							
If only total costs are known enter data below:								
B1.11	Total (Material and Labor) Cost ($)							
B1.12	Estimated labor percentage of total cost (%)							

C. AC Installation Cost in an Existing Home Combined with a Furnace Replacement

C1. Are there any cost savings if a homeowner replaces an air conditioning system and a furnace at the same time? (please enter “Yes” or “No” below)

C2. If you answer “Yes,” please enter cost data below. If you answer “No”, please skip to the next section D1.

Please take the time to fill in the tables below with accurate cost data. If you do not install air conditioners in a certain size/efficiency range, then please enter “n/a” in the corresponding areas of the table. For the cost estimates, please assume that you are replacing an air conditioning system at the same time as installing a new furnace for an **existing single-family home.** Please provide the AC stand-alone costs for this application - <u>Do not include</u> the furnace cost or the cost of relocating any ducts in the home.

- Please note that we are asking you to provide cost data for materials and labor separately. If you are unable to provide these costs separately, then please include the combined total cost in the rows provided under “total cost” in the table below. [Note: Only answer this question if you were unable to include material and labor costs separately in table below] In the costs that you provided below, approximately what percentage is related to labor? (please clarify if this percentage is different for different size/efficiency systems)

Two-Ton Central Air Conditioners per Unit Cost – Existing Home
(combin**e with furnace replacement)**

#	2-Ton	SEER 13-13.99	SEER 14-14.99	SEER 15-15.99	SEER 16-16.99	SEER 17-17.99	SEER 18-18.99	SEER 19+
C2.1	Material Cost ($)							
C2.2	Labor Cost ($)							
If only total costs are known enter data below:								
C2.3	Total (Material and Labor) Cost ($)							
C2.4	Estimated labor percentage of total cost (%)							

Three-Ton Central Air Conditioners per Unit Cost – Existing Home
(combine **with furnace replacement)**

#	3-Ton	SEER 13-13.99	SEER 14-14.99	SEER 15-15.99	SEER 16-16.99	SEER 17-17.99	SEER 18-18.99	SEER 19+
C2.5	Material Cost ($)							
C2.6	Labor Cost ($)							
If only total costs are known enter data below:								
C2.7	Total (Material and Labor) Cost ($)							
C2.8	Estimated labor percentage of total cost (%)							

Four-Ton Central Air Conditioners per Unit Cost – Existing Home (combine with furnace replacement**)**

#	4-Ton	SEER 13-13.99	SEER 14-14.99	SEER 15-15.99	SEER 16-16.99	SEER 17-17.99	SEER 18-18.99	SEER 19+
C2.9	Material Cost ($)							
C2.10	Labor Cost ($)							
If only total costs are known enter data below:								
C2.11	Total (Material and Labor) Cost ($)							
C2.12	Estimated labor percentage of total cost (%)							

D. AC Installation Cost in a New Home

D1. Do the labor and/or material costs differ for installing a central air conditioning system in a new construction home versus an existing home? (not including costs of relocating or installation of ducts). (please enter "Yes" or "No" below)

If you answer "Yes," please enter cost data below. If you answer "No", please skip to the next section E1.

D2. Please fill in the tables below with accurate cost data. If you do not install air conditioners in a certain size/efficiency range, then please enter "n/a" in the corresponding areas of the table. For the cost estimates, please assume that you are replacing an air conditioning system for a new construction single-family home. Please provide the stand-alone costs for this application - Do not include the cost of duct installation in the home.

- Please note that we are asking you to provide cost data for materials and labor separately. If you are unable to provide these costs separately, then please include the combined total cost in the rows provided under "total cost" in the table below. [Note: Only answer this question if you were unable to include material and labor costs separately in table below] In the costs that you provided below, approximately what percentage is related to labor? (please clarify if this percentage is different for different size/efficiency systems)

Two-Ton Central Air Conditioners per Unit Cost – New Construction

#	2-Ton	SEER 13-13.99	SEER 14-14.99	SEER 15-15.99	SEER 16-16.99	SEER 17-17.99	SEER 18-18.99	SEER 19+
D2.1	Material Cost ($)							
D2.2	Labor Cost ($)							
If only total costs are known enter data below:								
D2.3	Total (Material and Labor) Cost ($)							
D2.4	Estimated labor percentage of total cost (%)							

Three-Ton Central Air Conditioners per Unit Cost – New Construction

#	3-Ton	SEER 13-13.99	SEER 14-14.99	SEER 15-15.99	SEER 16-16.99	SEER 17-17.99	SEER 18-18.99	SEER 19+
D2.5	Material Cost ($)							
D2.6	Labor Cost ($)							
If only total costs are known enter data below:								
D2.7	Total (Material and Labor) Cost ($)							
D2.8	Estimated labor percentage of total cost (%)							

Four-Ton Central Air Conditioners per Unit Cost – New Construction

#	4-Ton	SEER 13-13.99	SEER 14-14.99	SEER 15-15.99	SEER 16-16.99	SEER 17-17.99	SEER 18-18.99	SEER 19+
D2.9	Material Cost ($)							
D2.10	Labor Cost ($)							
If only total costs are known enter data below:								
D2.11	Total (Material and Labor) Cost ($)							
D2.12	Estimated labor percentage of total cost (%)							

E. Additional Questions

E1. Is there any additional labor cost for installing high efficiency air conditioning systems compared to installing standard efficiency air conditioning systems? (Please select an answer from the four options below by either highlighting your selected answer, or entering “X” next to your selection below)

1) Yes, higher efficiency costs more in labor
2) Yes, standard efficiency costs more in labor
3) No, both cost the same in labor
4) Don’t know

If you answered “Yes,”(options 1 or 2 above) please also include a brief explanation why the labor costs are higher below:

E2. Beside equipment size, are there any cost differences for installing air conditioning systems in a single-family home compared to multifamily apartment or mobile home? Identify all that apply.

1) All building types cost the same to install
2) Multifamily cost more to install than in single-family
3) Multifamily cost less to install than in single-family
4) Mobile homes cost more to install than in single-family
5) Mobile homes cost less to install than in single-family

If costs do vary by building type, please provide a brief explanation with your answer below.

Multifamily differences including a proximate percentage difference in cost compared to single-family:

Mobile home differences including a proximate percentage difference in cost compared to single-family:

E3. Are there operational and maintenance differences between efficiency levels? If “Yes”, please provide a brief explanation:

F. Contact Information

F1. To confirm the best address and contact information to receive the $250 gift card, please fill out the following:

Name __________________________________

Company __________________________________

Address __________________________________

State/Zip __________________________________

Thank you again for your participation. If you have any questions regarding this survey or gift card, you can call or email Bradley Jones at (207-536-3104 or bradley.jones@cadmusgroup.com).

THANK YOU!