NW Natural®

2022-2023

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I. Executive Summary

In accordance with Washington Utilities and Transportation Commission's requirements, Northwest Natural, dba NW Natural ("NW Natural" or the "Company") presents this 2022-2023 Biennial Energy Efficiency Plan. This Plan outlines the Company's energy efficiency efforts and goals for its Washington service territory for the 2022-2023 program years.

2022-2023 EE Plan Summary		Biennial Therm Savings Goal	Biennial Budget
Incentive Program	Commercial Programs	351,447	$ 2,709,748
	Residential Programs	255,905	$ 3,182,266
Low Income	WA-LIEE	13,563	$ 302,163
Market Transformation	NEEA	TBD	$ 176,296
Regional Collaboration	RTF	N/A	$ 21,400
Pilot &Trial Programs	Pilot & Trial Programs	TBD	$ -
Evaluation	Evaluation	N/A	$ -
	EE Plan Total	620,915	$ 6,391,873
	CPA Savings Target	619,200	N/A

1.1 2022-2023 Goal Development

In accordance with RCW 80.28.380, NW Natural has established a two-year savings acquisition target that is based on a conservation potential assessment ("CPA") conducted by a third party. The CPA developed 30-year projections for technical potential, achievable technical potential, and achievable economic potential.

Using the achievable economic potential, NW Natural used the first two years of savings to determine the biennial savings goal. The CPA identified several savings opportunities that NW Natural does not currently have a way to offer. Among those are a residential behavioral program[1] and several industrial measures[2]. To address the industrial potential, NW Natural will work with stakeholders in 2022 to launch a new offering to serve this customer class. Since the development of a residential behavioral program may take a year or longer, the savings potential identified in the CPA for this measure was excluded from the CPA target. Instead, NW Natural plans to evaluate and set-up systems in 2022-23 to claim associated savings in the next biennium. This decision was presented and discussed with the Energy Efficiency Advisory Group.

In addition to the current forecasted savings from the incentive and low-income programs, the Company plans to achieve savings through the Northwest Energy Efficiency Alliance ("NEEA") and new pilot and trial programs. NEEA is anticipating having gas savings in 2022-23, but due to the volatile nature of the savings they have been excluded from the plan forecast.

[1] See Section 4.1.1 CPA Residential

[2] See Section 4.1.3 CPA Industrial

1.2 Cost Effectiveness

The Company continues to monitor its energy efficiency programs through cost effectiveness tests and levelized costs. In the upcoming 2022-23 program years, the introduction of new programs will drive up levelized costs from previous program years.

Anticipated Program Performance	2022	2023
Incentive Program UCT[3]	2.06	1.83
Incentive Program TRC[4]	1.73	1.56
Levelized Cost[5]	$0.89	$0.82

[3] See Section 2.5.1 Utility Cost Test

[4] See Section 2.5.2 Total Resource Cost Test

[5] See Section 2.5.4 Levelized Cost Metric

II. Background

NW Natural began offering its current energy efficiency programs to Washington customers on October 1, 2009. The Washington Utilities and Transportation Commission's ("WUTC's") Order No. 04 in the Company's 2008 rate case, docketed as UG-080546, directed the Company to create and begin offering a program.

Since the inception of the Company's energy efficiency programs, the programs have continued to develop and evolve under the direction and oversight of the Energy Efficiency Advisory Group ("EEAG") which is comprised of interested parties to the Company's 2008 rate case.

2.1 History

2.1.1 Program Implementation

The Company began using Energy Trust of Oregon ("Energy Trust") as the delivery arm for its Oregon energy efficiency incentive program in 2003. Since the Company's Washington service territory is contiguous with its Oregon territory, it made sense in 2009 to have Energy Trust extend the boundaries of the Oregon incentive program offerings into Washington.

As agreed to in UG-080546, Energy Trust implemented the Company's incentive program for one pilot year. During this time, the EEAG monitored the program's performance and assessed whether Energy Trust should be the ongoing incentive program implementer. On May 25, 2011, NW Natural made a compliance filing in UG-080546 wherein it stated the EEAG's opinion to allow Energy Trust to continue delivering the Company's energy efficiency incentive programs in Washington. On June 8, 2011, Public Counsel separately filed a letter supporting this decision.

2.1.2 Performance History

Historically, the Company's Washington service territory has had a large appetite for energy efficiency. In 2020, the impacts of COVID-19 shutdowns caused programs to lag resulting in savings that fell short of the annual goal. Despite the downturn in 2020, current 2021 uptake has been strong, and the Company is anticipating exceeding the planned savings goal.

Historical EE Incentive Program Therm Savings			
Program Year	Goal	Actual	Percent of Goal
2016	263,184	330,866	126%
2017	282,539	391,606	139%
2018	359,880	372,005	103%
2019	369,195	372,948	101%
2020	339,331	320,170	94%
2021	399,957	In Progress	N/A

2.1.3 Reporting and Cost Recovery Timeline

The WUTC's Order No. 06 in the Company's 2018 rate case, docketed as UG-181053, amended the reporting requirements and review timelines related to the program. Program funds are now forecasted and collected for the current program year in which the costs are incurred.

Order 06 also addressed the Company's cumulative deferral balance which will be amortized over a four-year period, November 1, 2019, through October 31, 2023.

Historically, the Company filed an annual conservation plan December 1 of each year that described anticipated conservation efforts for the upcoming calendar year. In 2019, House Bill 1257 was passed, which modified conservation planning for gas utilities, taking effect in 2022. The law requires a CPA to be conducted by an independent third party to establish a two-year savings acquisition target based on estimated savings from the CPA.

2.2 Oversight

The EEAG includes representatives from NW Natural, WUTC Staff, Public Counsel, Alliance of Western Energy Consumers ("AWEC") (formerly Northwest Industrial Gas Users), The Energy Project, and the NW Energy Coalition. The Company will consult with the EEAG prior to making any significant program changes and provides drafts of annual reports, conservation plans, and tariff adjustments to the EEAG for review.

2.3 Program Delivery

The Company's programs are currently delivered to customers through partnerships and contracts with third parties.

The Residential and Commercial incentive program is offered through Energy Trust. Energy Trust is an independent, nonprofit organization dedicated to helping utility customers save electric and gas energy. Energy Trust was formed in 2002 in response to Oregon legislation that restructured electric utilities[6] for multiple reasons, including allowing non-residential customers to purchase their electricity from providers other than the utility and reassigning the responsibility for demand side management from utility operations to Energy Trust.

The Washington Low Income program ("WA-LIEE") including outreach and delivery is provided through local community action agencies. The local community action agencies are Clark County Community Action Agency serving Clark County and Washington Gorge Action Programs and Community Action Council of Lewis, Mason and Thurston Counties serving Klickitat and Skamania Counties.

Regional collaborative efforts funded from multiple utilities include Market Transformation administered by NEEA and technical collaborative efforts through the Northwest Power & Conservation Council's Regional Technical Forum ("RTF").

2.4 Energy Efficiency Programs Offered

NW Natural supports energy efficiency through several different channels to promote widespread uptake and encourage market transformation in the region. The following subsections outline these various programs and offerings.

[6] Oregon's SB 1149, codified as ORS 757.612, mandated the creation of an independent entity capable of providing demand side management services to utility customers.

2.4.1 Incentive Program

Residential Program Description

Residential programs in southwest Washington acquire cost-effective gas savings by engaging with builders and homeowners. This program engages with builders to increase energy efficiency of newly constructed, single-family homes through incentives, education, trade ally and program support and quality assurance.

For existing single-family and small multifamily homeowners and landlords, incentives and services are available for the following energy saving efforts:

- Efficient space heating and controls
- Water heating
- Insulation
- Windows
- Water conservation and behavioral actions
- Education
- Trade ally support
- Financing with repayment through utility bills
- Market interventions

Specific measure offerings and details are listed in Appendix 1 and Appendix 2.

There are four tracks within the Residential Incentive Program: Standard Home Retrofit, Standard Multifamily, Mid-stream (distributor), and new homes.

2.4.1.1 Residential Standard Track (Existing Home Retrofit)

Residential customers with gas heated homes are offered incentives for cost-effective weatherization measures and certain efficient gas appliances. Customers are encouraged to work with trade allies to ensure they are being provided accurate energy efficiency information and access to the most efficient equipment and services. On-line home energy reviews are also available wherein an energy use estimation tool identifies incentives and qualifying insulation and weatherization measures that could be installed to improve the efficiency of customers' homes.

2.4.1.2 Residential Multifamily Track

Residential customers in multifamily buildings are offered a specialized subset of the Residential Standard Track incentives. Due to the usage profile of Multifamily buildings, there are unique measures within this sub sector. Condos, townhomes, duplexes, triplexes and fourplexes and stacked (2-4) units qualify for incentives for the approved measures. Multifamily properties that are served with commercial rate schedule gas service are served through the NWN WA Commercial Program.

2.4.1.3 Residential Mid-stream (Supply Chain) and Products Track

Mid-stream focuses efforts and incentives toward distributors to encourage them to stock and promote the sale of efficient equipment to contractors and residential customers. The Retail Products strategy focuses on retail engagement to promote efficient natural gas appliances and fixtures. Technologies that are included in the mid-stream efforts include gas fireplaces and gas tank water heaters.

2.4.1.4 New Homes Track

The New Homes track consists of three different offerings: EPS New Homes, Code Credits, and stand-alone measures. EPS New Homes is a whole-home, performance-based offering which encourages builders to construct homes to an energy efficiency standard that is at least 55% better than Washington building code. EPS is a trademarked named of an energy performance scoring tool that aims to highlight the benefits of energy-efficient newly built homes. The Company offers an energy performance score that rates the efficiency of a home and measures it against similar-sized homes built to 2018 Washington State Residential Energy Code (2018 WSEC-R). Qualifying new homes must also meet new construction Best Practice criteria established by the EPS New Construction (homes) Program. The compliance of all new homes is verified through an inspection process and homes are issued a score, called an EPS, upon completion.

The new homes track will also offer a new Code Credits pathway for 2022 and 2023 engagement. The Code Credits offering uses the 2018 WSEC-R energy credits structure (which went into effect February 2021) to award incentives to builders who earn more credits beyond what is required by code. This prescriptive offering provides incentives to builders based on implementation of practices as described in section R406 of the 2018 WSEC-R code. Compliance with this path is audited by independent, third-party verifiers, who provide a report of a home's code credit total to the efficiency Program. To qualify for program incentives, all builders must comply with the 95 AFUE furnace credit, and the 0.91 UEF water heater credit if using gas water heat. The Code Points engagement strategy will award standard incentives for every half point a home achieves greater than code. Since builders can meet credit requirements through a mix of measures, including solar, we will monitor and report on this occurrence.

2.4.1.5 Community Partner Funding

Community Partner Funding (CPF) is a pathway that provides increased incentive offers exclusively for community-based organizations to serve underserved populations living in single-family homes. This offering was introduced in 2021 and will be expanded over the biennium as more partnerships are developed in SW Washington.

Commercial Program Description

The Commercial Program provides natural gas energy-efficiency solutions for new and existing commercial buildings. Commercial customers of NW Natural in Washington can receive incentives for qualifying energy-efficient upgrades and retrofits. The program incentivizes select measures in existing and new commercial buildings, including office buildings, restaurants and other foodservice buildings, dormitory and assisted living facilities, greenhouses, and multifamily structures. Specific measure offerings and details are as listed in Appendix 1 and Appendix 2. The Washington Existing Buildings program consists of two tracks - custom and standard. The program will also be launching a new offering of Strategic Energy Management in 2022 that will not realize savings until 2023.

2.4.1.6 Commercial Custom Track

The Commercial Custom Track acquires gas savings through incentivizing energy efficient capital projects and operations and maintenance upgrades in complex and non-standard situation. The Program Management Contractor account managers and engineering firms identify and promote customer opportunities. The custom track also pursues opportunities in retro-commissioning, which features targeted incentives for operations and maintenance improvements such as controls or HVAC adjustments.

2.4.1.7 Commercial Standard Track

The Commercial Standard Track provides incentives for standard measures with predetermined (deemed) savings for buildings of all sizes and across all commercial market sectors. The program promotes measures through customer outreach and cultivation of trade ally contractors.

2.4.1.8 Commercial New Construction Tract

The Commercial Program provides standard, prescriptive measure offerings for new commercial buildings along with a custom modeled approach for some projects as appropriate. New construction has continued to be an important market segment for savings acquisition. Through this work the program has expanded its effort to work directly with development design teams to ensure efficiency is being considered with equipment selection and design elements. A custom approach will allow for smaller building features and elements to be considered in the overall efficiency plan for a newly built structure. The program team will work with new construction design teams to determine the best efficiency options as well as the best program approach to influence and capture all efficiency opportunities.

2.4.1.8 Commercial Strategic Energy Management ("SEM")

The Commercial Program will be launching a SEM offering in 2022 in collaboration with Clark Public Utility District (Clark PUD). SEM is an offering that provides tools and education to businesses and building managers to save energy through operation management that can be implemented into the future as well. SEM participants will learn how their business uses energy and identify where waste is happening. They will have the opportunity to share best practices with a cohort of peers, learn to increase employee engagement and monitor the progress of their energy savings work. In this collaboration, Energy Trust will be providing SEM gas services to a cohort of Clark PUD participants. The first year of the offering in 2022 will largely be focused on initial outreach to participants as well as providing analysis of gas savings opportunities. The savings acquisition will begin in late 2022 and will start being fully realized in 2023.

2.4.2 Low Income

Under NW Natural's low-income energy efficiency program, agencies administering the program provide free services and leverage other funding sources with WA-LIEE dollars to provide equipment repairs, upgrades, and whole-house weatherization services to qualifying customers.

Program details are available in the Company's Schedule I, "Washington Low Income Energy Efficiency Program (WA-LIEE)."

2.4.3 Market Transformation

The Company views the regional gas market transformation initiative led by NEEA as a necessary investment in the future of gas demand side management ("DSM") and as an enduring component of regional power planning. NEEA's primary work, as it pertains to gas energy efficiency, on behalf of the Pacific Northwest is focused on two strategic goals: 1) bring energy efficient emerging gas technologies to market, and 2) create the market conditions that will accelerate and sustain the market adoption of energy efficient emerging gas technologies. NEEA uses a stage-gate approach to manage its work. Below are the six phases that a technology would go through to fully achieve the two goals and result in a sustained market change that provides gas savings.

Prior to the market development phase, NEEA works on:

- Scanning for new technologies (shown in the graphic above as "scanning and concept identifications")
- Researching and assessing both the market and technology conditions and savings potential (through the concept opportunity assessment and market product assessment stages)
- Developing and testing the market intervention strategy for the technology and developing cost effectiveness models which produce long term cost effectiveness metrics and energy savings forecasts (both part of strategy testing and finalization)

The purpose of these phases is to develop additional efficiency measures and strategies over the long-term that will further the cost-effectiveness and reliability of savings and programs by acquiring savings at market scale. At each stage, the assessment of the potential for long-term cost-effective savings is refines. NEEA does not typically forecast savings associated with these earlier phases. These first four phases are where most of the activity has been in the early years of the NEEA gas collaborative. Significant savings begin in the fifth stage, Market Development.

2.4.4 Pilots & Trial Programs

The company offers pilots from time to time to test and evaluate new program or measure opportunities. Pilots should have defined objectives or purposes and will be limited in duration. The company may also pursue trial programs in an effort to take advantage of time sensitive opportunities, drive program uptake or to adaptively manage existing programs.

In 2022, the Company plans to work with the EEAG to develop a pilot for non-residential customers. The CPA identified a small potential for cost effective savings within the industrial sector. Since the Company does not have an established program serve these customers, this pilot will serve those customers and help inform future program decisions.

2.5 Cost Effectiveness Standards

Cost effectiveness is measured by comparing the benefits of an investment with the costs. It is an important metric used to show that energy efficiency is a responsible use of rate-payer funding.

2.5.1 UCT: Utility Cost Test

The Company utilizes the Utility Cost Test ("UCT") to evaluate the cost effectiveness of the incentive program. The UCT measures the present value of the energy savings in relation to the net costs incurred by the incentive program, including incentive costs and excluding any net costs incurred by the participant. The UCT measures utility benefits divided by utility costs where each is defined as follows:

Utility Benefits are:
The total system value of gas energy saved based on the Company's avoided costs. The Company's avoided costs include the following values:

- Gas Price Forecasts
- Supply and Distribution Capacity Infrastructure Costs
- Washington State Carbon Policy Adder (Social Cost of Carbon as directed by House B1257)
- Risk Reduction Value
- 10% Power Act Credit

Utility Costs are:

- Incentives paid to, or for the benefit of, the participant
- Administrative costs
- Evaluation, verification, and monitoring

2.5.2 TRC: Total Resource Cost Test

The Company will continue to monitor and report how the portfolio fares using the Total Resource Cost (TRC) Test. The TRC includes all quantifiable costs and benefits regardless of who accrues them. This includes participant and others' costs. The TRC Test is a calculation of total present value of total resource benefits divided by total resource costs when each is defined as follows:

Total Resource Benefits include:

- The total system value of gas energy saved based on the Company's avoided costs. The Company's avoided costs include the following values:
  - Gas Price Forecasts
  - Supply and Distribution Capacity infrastructure Costs
  - Washington State Carbon Policy Adder (Social Cost of Carbon as directed by House Bill (HB) 1257)
  - Risk Reduction Value
  - 10% Power Act Credit

- Non-energy benefits as quantified by a reasonable and practical method

Total Resource Costs are:
- Administrative costs
- Evaluation, verification, and monitoring
- The participant's remaining out-of-pocket costs for the installed cost of the measures after incentives and Federal tax credits

2.5.3 NSPM: National Standard Practice Manual

The Company may investigate the opportunities provided by the National Standard Practice Manual ("NSPM") methodology, such as the Resource Value Test (RVT), which is "intended to provide a comprehensive framework for assessing the cost-effectiveness of energy efficiency resources." Any change to the Cost Effectiveness test will be vetted through the EEAG process.

2.5.4 Levelized Cost Metric

The levelized cost is the present value of the total net cost of a measure over its economic life, converted to equal annual payments. The levelized cost calculation starts with the incremental capital cost of a given measure or package of measures. The total cost is amortized over an estimated measure lifetime using the after tax real discount rate established from the Company's most recent rate case. The annual net measure cost is then divided by the annual net energy savings (therms) from the measure application (again relative to a standard technology) to produce the levelized cost estimate in dollars per therm saved, as illustrated in the following formula.

$$Levelized\ Cost = \frac{Net\ Annual\ Cost(\$)}{Net\ Annual\ Savings}$$

The levelized cost of an energy efficiency measure is cost-effective if it is less than the average levelized costs of other supply-side options represented by the avoided costs. Avoided costs are presented and established in the Company's most current IRP or IRP update. Cost effectiveness is further refined for measures and the programs through the benefit-cost ratio (BCR) tests that use avoided costs as defined below.

2.5.5 Avoided Costs

Avoided costs were updated at the beginning of the 2020 calendar year for use in 2021 measure and program planning and these same values have carried into planning for 2021. The general methodology for calculating avoided costs is described in chapter four of the 2018 IRP and the values were updated in early 2020.[7]

Avoided cost values are based on assumptions including the natural gas price and risk reduction value associated with offsetting gas purchases on the spot market. Also included in these avoided costs are supply capacity costs based on peak-day coincident factors developed by NW Natural distribution capacity costs based on peak-hour coincident factors developed by NW

[7] https://www.nwnatural.com/about-us/rates-and-regulations/resource-planning.

Natural. Avoided costs also include values for the social cost of carbon as required by WA HB 1257 and posted on WUTC's website.[8]

The most recent avoided costs were used to retroactively review the cost-effectiveness of the 2020 program year. Moving forward, new avoided cost values will be calculated for 2023 measure planning. These updated values will also be used to retroactively to screen 2022 program results because these values will best represent the current value of 2022 savings to the Company.

The Company will adaptively manage and make improvements to the avoided cost calculation methodology as necessary. Continuing work on the avoided cost calculation further refines the true avoided cost for Washington customers by identifying how energy savings on peak help avoid or delay investment in capacity resources.

2.6 Program Evaluation, Monitoring and Verification

2.6.1 Impact Evaluations

Annual savings reported by the Company are based on the assumed gross savings for each measure. The assumed savings is consistent with the most current impact studies performed on the programs and measures. The Company or third parties perform impact studies used to validate the engineering assumptions used in setting biennial conservation targets. Impact evaluations of residential measures typically include analysis of a group of customers' energy usage data before and after a measure is installed (i.e., billing analysis). Non-residential measures receive a combination of engineering review of key algorithms and parameters, a document review of project files and specific building-level model inputs, and site visits to verify operational patterns and installation practices that affect savings estimates.

Savings from all measures are evaluated on a regular basis by the program implementer based on accepted practice, program activity, staff resources and evaluation priorities (unless sample sizes based on participation rates are not statistically significant). From the impact evaluation, a determination is made by the Company if evaluated savings are consistent with assumed savings. If they are not, the deemed savings values are "adjusted" by the program implementer to reflect the relevant evaluation findings. The adjustment of savings is accomplished through a combination of savings realization adjustment factors ("SRAF") and through updating the deemed savings values expressed in the measure approval documents ("MADs"). A link to the Impact Evaluation as well as a short summary of the results will be provided in the Annual report.

2.6.2 Process Evaluations

The Company or program delivery contractor may, as appropriate, contract with a third-party evaluation contractor to perform process evaluations on a subset or on all energy efficiency programs, WA-LIEE, pilots, and other efforts offered. The third-party evaluation contractor studies the programs and reports on the processes employed for each program with

[8] https://www.utc.wa.gov/regulated-industries/utilities/energy/conservation-and-renewable-energy-overview/clean-energy-transformation-act/social-cost-carbon

recommendations for improvement. A link to process evaluations, as well as short summaries of the results, will be provided in annual reports following the Process Evaluation Report's release.

2.7 Process for Program Changes

The Company considers if incentive program year changes are needed when reviewing Unit Energy Savings ("UES") Measure List (Appendix 1) prior to filing the Plan. If the UES Measure List needs an offering added, changed, or removed, the Company will revise this Plan to make requested program modifications when it makes its tariff advice filing, to revise the performance metrics and budget that are also included in this Plan. This does not preclude the Company from filing to revise Schedule G or its EE Plan or Appendices at any time during the year.

Tariff advice filings revising or adding measures will include:

1) A measure-level BCR calculation as outlined in Section 2.5 "Cost Effectiveness".
2) For new measures, a summary of the vetting of a measure before it is introduced as a program offering.
3) New program proposed mid-cycle will include a program-specific plan addressing the possible need for program-specific metrics.
4) For pilots previously budgeted or with no additional budget impact, no filing will be required. The EEAG will be given the opportunity to review the offering before implementation if not previously outlined in the "Pilot Program" section. The Company will include summary notes in the appropriate report following the completion of any pilots.

Not all advice filings must include the Biennial EE Plan. The EE Plan will only be included when it is being revised.

The Company will work to resolve issues with EEAG members before filing. If the EEAG cannot agree and recommend approval of a filing, the Company may still choose to make the filing with the WUTC with the understanding that EEAG members may intervene in that public proceeding.

The Company will give the EEAG twenty days to review a draft filing.

2.8 Schedule for Program Planning

The Company will provide the EEAG with the following proposals for the next two program years, which will subsequently be filed with the WUTC in a new docket. The Company will file to this docket all the required reporting for the program years, except for program cost recovery through tariff Schedule 215, which is filed annually as part of the Purchased Gas Adjustment (PGA) filing. This annual filing included with the PGA will only cover the first program year and prior period true-up deferral balance, as specified in tariff Schedule G.

Budget

The Company provides in this plan a total estimated budget for the 2022-2023 program years. The budget presents expected expenditures by program and customer class. The budget component comprised of incentives and direct customer benefit shall be considered a soft cap and may be exceeded in order to acquire all available cost-effective savings or facilitate low-income projects. Notification should be made to the EEAG prior to exceeding incentive targets.

The budget forecast is based on the best information available at the time of filing. As the year progresses, budgeted dollars may be reallocated among the various programs and/or measures and/or new offerings that are submitted to the WUTC.

The Company may provide the necessary funding for program administration and delivery as appropriate, including reserves. The amounts dispersed in one year are the sum of all funds forecasted to be needed for the program year, adjusting for any unspent or uncommitted funds previously dispersed.

Performance Metrics

The Company proposes performance metrics that will address the following:

- Total program costs
- Projected therm savings consistent with most recent IRP
- Average levelized cost for measures
- Projected homes to be weatherized in the WA-LIEE program

The Company expects that UCT at the portfolio level should be greater than 1.0 and will report compliance to this in the Annual Report.

The Company will present the EEAG with the biennial budget and performance metrics before making a tariff filing with the WUTC to modify this plan so that it incorporates the projected costs and performance metrics accordingly. If performance varies greatly from the Biennial EE Plan, the Company will establish adjustments with the EEAG and file an update. Otherwise, this filing will be made biennially no later than November 1 for a January 1 effective date.

Quarterly

The Company will report on its program on a calendar year basis. Quarterly calls will be hosted by the Company to discuss progress towards its Biennial EE Plan goals.

Annual

An annual report will be due by the following June 1st after the end of the program year.

EEAG Review

The EEAG will meet either in person, virtually or by teleconference to review the annual report and will be invited to participate in quarterly calls.

2022 Program Year Schedule	
January 1st	Start of program year
March 22nd	1st Quarter check in with EEAG
May 24th	2nd Quarter check in with EEAG
June 1st	Annual report for previous program year is filed
August 16th	3rd Quarter check in with EEAG
October 18th	4th Quarter check in with EEAG
November 1st	File any EE Plan Updates
November 1st	Requested effective date of program cost filing
January 1st	Start of next program year

2023 Program Year Schedule	
January 1st	Start of program year
March	1st Quarter check in with EEAG
May	2nd Quarter check in with EEAG
June 1st	Annual report for previous program year is filed
August	3rd Quarter check in with EEAG
October	4th Quarter check in with EEAG
November 1st	File 2024-2025 Biennial EE Plan
November 1st	Requested effective date of program cost filing
January 1st	Start of next program year

2.9 Annual Reporting

The annual report will include the following:

1. The biennial conservation target
2. Planned and claimed gas savings
3. Budget compared to actual results by program
4. Cost-effectiveness calculations results as defined in Section 2.5 and outlined by program
5. Measure level participation (units installed and savings) under the incentive program
6. Reporting on achievement of metrics
7. Discussion of steps taken to adaptively manage conservation programs
8. A status report on NEEA market transformation efforts, spending, and activity
9. An overview of the Company's year-end review of program delivery expenses and transactions
10. All program evaluations completed in the preceding year
11. Pilot results/metrics
12. WA-LIEE program results including:
    - Total program year costs
    - Homes served
    - Estimated total therm savings
    - Average therms saved per home

2.10 Program Budget Guidelines

Forecasted program costs for the next calendar year will continue to be reviewed annually. If major variances from the budget are identified in 2022, updates to the Biennial EE Plan will be filed for the 2023 program year. Otherwise, the proposed forecasts for the 2024-2025 Biennial EE Plan will presented and filed in 2023 in accordance with WUTC staff conditions and EEAG guidance.

Each year, the Company will file its annual report by June 1 which will detail costs and acquisitions for the previous program year. This filing will trigger the EEAG's review of the energy efficiency programs. Any changes to the reporting timeline will be coordinated with the EEAG.

2.11 Cost Recovery

Incentive program, Market Transformation, Regional Technical Forum, Evaluation, Pilots, Evaluation, and all other Energy Efficiency expenses related to Schedule 215 are forecasted for the twelve-month period beginning each November 1st. Any differences between the forecast and actual dollars spent during the twelve months will be deferred and either credited or surcharged to customers based on over or under collection through rates. Schedule 230 costs will be deferred and later amortized for recovery from applicable customers on an equal percent of margin basis as established annually in the temporary rate adjustments. The Company will annually submit a stand-alone filing concurrent with its PGA filing, for cost recovery of its energy efficiency program forecast under Schedule 215 and historical expenses for the prior calendar year on Schedule 230.

III. 2022 – 2023 Energy Efficiency Plan

3.1 Current-Year Program Drivers

The Company's 2021 incentive program efforts have been extremely successful, largely due to efforts related to combating COVID setbacks and delays. Strategy for 2022 and 2023 will continue to capitalize on lessons learned during COVID and adjust program offerings for new energy legislation.

3.1.1 Residential

Overview

Energy Trust helps single-family and small multifamily homeowners served by NW Natural in Washington achieve gas energy savings by offering cash incentives for efficient space heating and controls, water heating, insulation, windows, water conservation, behavioral actions, education, trade ally support, financing with repayment through utility bills and market interventions. The program also influences new residential construction by engaging with builders to increase gas energy efficiency of newly constructed homes through incentives, education, trade and program ally support and quality assurance. As the Southwest Washington housing stock matures, and existing HVAC systems need replacement, gas furnaces are expected to continue as a large savings opportunity.

Residential Strategic Focus

- Expand participation
- Work effectively across the supply chain to support more targeted approaches to cost effective measure adoption
- Identify opportunities for program design changes, operational efficiencies in incentive processing, trade ally management, quality assurance, consolidated measure analysis and submissions processes across multiple sectors
- Continue to work with NW Natural to ensure alignment on goals of program delivery, outreach tactics and marketing strategies

2022 Residential Key Activities

- Expand the installed base of smart thermostats through instant coupon promotions, downstream incentives, and direct ship
- Work with residential weatherization market actors to promote incentives for insulation in single family, small multifamily, and rental markets
- Identify and engage with single-family housing rental property owners for installations of weatherization, DHW, and HVAC efficiency upgrades
- Promote and support do it yourself (DIY) participation through technical support, promotions, and marketing
- Continue to develop targeted marketing and communications strategies to drive leads to contractors
- Promote low-cost smart thermostats to low-to-moderate-income residents
- Find new distribution channels to reach non-participants by reintroducing Energy Saver Kits
- Continue to solicit Manufactured Home retailer participants for participation and new home submissions where homes are sold in NW Natural WA service territories

- Expand collaboration with community-based organizations (CBOs) to deliver capital measures to new customer segments through the Community Partner Funding (CPF) pathway
- Coordinate with NW Natural to research opportunities for the implementation of a behavioral program for single family homeowners
- Implement new offerings for residential home builders that allow for incremental and single measure incentives
  - One offering will leverage the 2018 WA energy code point structure
  - Stand-alone single measures will be offered for smart thermostats and efficient gas fireplaces
- Encourage cross program collaboration between the two program implementers in Washington and external stakeholders to support DEI and other shared strategies

Residential Activities—Ongoing

- Advance the viability, relevance, and performance of programs
- Utilize the five-year measure savings tool to continually inform 2-year forecast and support strategic planning
- Work with NW Natural to ensure compliance to Washington Utilities and Transportation Commission regulatory requirements
- Provide robust and accurate reporting
- Increase customer participation and awareness of energy efficiency and renewable energy benefits
- Increase savings from emerging savings opportunities such as smart thermostats through instant coupon and direct installation offers
- Continue to support the trade ally experience through customized in-person and on-line/virtual engagements
- Engage and participate in trade industry associations including Clark County HVAC Trade Association, Clark County Rental Association and Building Industry Association of Clark County
- Collaborate with Clark PUD on direct install of smart thermostats for low-income customers
- Continue to increase customer participation and awareness of multifamily incentive through trade ally and property management engagement
- Continue to coordinate with NW Natural to facilitate stakeholder and trade ally relationships that drive participation and awareness
- Across the supply chain, expand the use of customized program designs and promotional tactics for heating and water heating system replacements (i.e., lead generation marketing)
- Program to lead, and conduct EPS New Construction field quality assurance, including coordination with verifiers to maintain quality assurance and quality control procedures

2023 Expected Changes

- A residential RFP in 2022 for implementation in 2023 could mean a change in implementer which may influence savings acquisition strategies and tactics
- Savings, incentives, and project volume are currently forecasted to remain stable for the majority of Home Retrofit, Midstream and Multifamily measures

- Residential new construction savings acquisition may need to shift focus to upstream and distributor strategies to acquire small incremental savings on products sold to the entire new homes market

3.1.2 Commercial

Energy Trust provides standard and custom capital, operations and maintenance and retrocommissioning incentives for Washington State business customers on qualifying NW Natural commercial firm or interruptible rate schedules. These include upgrades and retrofits for existing buildings; energy-efficient equipment for new construction; energy-efficient equipment and retrofits at existing and new multifamily properties with two or more units; and measures for natural gas-heated production greenhouses.

The robust building market coupled with ongoing construction labor shortages continue to divert commercial customers' attention away from energy efficiency projects. Tariffs are increasing costs and have led to projects being rebid leading to delays. Many projects have also been delayed because of halts to construction due to COVID-19. At the same time, the passage of Washington school bond measures has led to significant retrofit and new construction activity expected to continue for the next few years. Working with design and construction teams has allowed the program to explore custom modeled savings approaches to ensure no savings opportunities are left behind. Washington HB 1444 and HB 1257 will begin to impact Energy Trust's ability to offer certain measures including commercial fryers, dishwashers, steam cookers, and showerheads beginning in 2022.

Commercial Savings Realization Adjustment Factors (SRAFs)

Starting with the 2019 EE Plan, Savings Realization Adjustment Factors or SRAFs have been applied to the commercial savings as a means of adjusting the deemed, gross (or working) savings to reflect the findings of recent program impact evaluations more accurately. SRAFs will again be applied to 2022-23 working savings to provide reportable savings. The commercial program will be applying the following SRAFs to the associated program track; Existing Buildings (standard/custom), 0.9090/0.7979; Existing Buildings Multifamily, 0.9090; New Buildings (standard and custom), 0.90; and Strategic Energy Management, 0.89. The application of SRAFs helps to ensure that savings are reported in alignment with what utilities should expect in terms of a reduction of load. This is meant to provide a conservative savings value to support IRP goals. This EE Plan represents savings goals in reportable savings in which the SRAFs have already been applied.

The program also updates engineering assumptions associated with measures as the Measure Approval Documents or MADs expire. Not all MADs are updated every year, so the application of SRAFs is meant to provide program savings adjustment that might be outside of the scheduled MAD update process. With this 'belt and suspenders' approach, the program is helping to ensure that savings are not over-reported.

The impact of the SRAFs and measure engineering updates is noteworthy. Between 2010 and 2018 the Washington efficiency programs reported gross, working savings. The commercial program has been experiencing a steady incline of customer participation and savings acquisition with 2017 Commercial goal at 156,525 and therms saved at 154,866, in 2018 Commercial goal at 160,000 therms and saved at 161,632. In 2019, the working savings goal

was 170,016 therms, however with the application of the SRAF is reduced to 147,481. In 2019, engineering assumptions on 19 commercial Measure Approval Documents were updated for 2020 delivery. Amongst these was a roughly 65% reduction in deemed savings for commercial boilers which has been a prominent measure for the WA portfolio.
For 2022-2023 Commercial working savings are forecasted at 433,955 therms. With the application of the SRAFs, the Reportable Savings is 351,447 therms.

Mega Project – Vancouver Innovation Center
Overall Commercial annual savings goals have increased since 2019 because of a large mega project being introduced into the project pipeline. The project is expected to bring in large amounts of savings over the next two years. Savings are expected to be realized in three phases, the first of which started in 2020. The project's third phase is expected to be completed in 2023.

Forecasted Commercial Project Pipeline
The Program has developed a pipeline of projects that is used for tracking and forecasting. Tracking information of the pipeline is updated monthly as details change; completion dates are shifted, projects complete, and new projects are identified. The pipeline consists of multiple school projects in the various SW WA school districts, Clark College, WSU campus buildings, libraries, county buildings, malls, and other commercial projects. Smaller capital measures such as restaurant equipment and steam traps are not typically included in the forecasted pipeline as they are typically identified just before completion. However, through outreach, many projects are identified as "prospects." Custom Studies are also indicators of future prospects and projects. Studies typically need to be completed and the building manager is asked to provide some level of commitment before a studied project is included in the forecasted pipeline. Some studies never materialize into projects.

Commercial Strategic Focus
Increase the flexibility and adaptability of Efficiency Programs
- Identifying custom measures that can be converted to prescriptive measures allowing for adaptability of frequently used measures
- Identify new opportunities to increase savings for 2022 and beyond
- Advance the viability, relevance, and performance of programs
- Organize trade ally outreach to effectively reach all prospective and eligible small business customers
- Perform market analysis to identify remaining market potential available to all tracks of the program
- Explore new approach to direct install that can support Existing Buildings in Washington
- Explore and utilize other market channels such as buy-down programs to more effectively deliver program elements such as restaurant equipment
- Increase customer participation and awareness of energy efficiency. Identify additional ways to serve minority and underserved markets such as rural communities and tribes
- Diversify program participation through increased outreach to small- to medium-sized businesses and trade allies
- Continue collaboration with like-minded organizations such as NEEA, Bonneville Power Administration ("BPA") and the Regional Technical Forum ("RTF") to identify opportunities for new measures, strategies, and delivery channels

- Increasing the portfolio of measures that are delivered midstream
- Work with outreach and trade ally staff to create more tailored pieces for specific offerings, customer segments and contractor trades
- Continue trade ally segmentation efforts, optimizing support depending on trade, program knowledge and participation and regional services
- Provide sales support to trade allies to help them build program incentives into their business models to further energy efficiency
- Build the technical knowledge of outreach staff on the value proposition of energy-efficient equipment choices
- Increase activity of delivery contractor’s market channel subject matter experts and trade ally coordinators to provide focused support for delivery contractor’s account managers working in Washington
- Form an outreach subgroup focused on small business market penetration to coordinate with trade allies to identify and serve appropriate target-market small businesses
- Utilize utility and project tracking data to improve forecasting methodologies to achieve higher confidence factors for savings and budget

2022 Commercial Key Activities

- Coordinate with Clark Public Utilities to launch a Strategic Energy Management offering which will be a new offering in the WA portfolio
- Conduct a program equity assessment and develop action plan to implement changes
- Expand collaboration with Clark Public Utilities on co-funded facility studies
- Identify new gas savings opportunities through market research, measure development and implementing bundled measures
- Work with Vancouver Housing Authority and other local agencies to reduce the energy burden of customers in low-income housing
- Help schools, universities and other customers build capacity for energy efficiency by increasing scholarships for operators to receive Building Operator Certification
- Expand regional involvement and cross-program collaboration in rural areas; support Clark County’s Green Business program activities; increase event sponsorships, training and outreach with local chambers and business organizations; and increase collaboration with the Washington Green Schools program
- Implement new marketing guidelines for NW Natural Washington delivery territory
- Work with the Vancouver Innovation Center project to ensure all savings opportunities are realized for existing custom, existing standard, and new buildings projects

2022 - 2023 Expected Changes

- Washington’s passage of WA HB 1444 “Concerning Appliance Efficiency Standards” which established efficiency standards for equipment such as foodservice and showerheads went into effect in 2021. As a result, some Energy Trust incentives will be discontinued in 2022 and 2023. Washington HB 1257 “Concerning Energy Efficiency” which establishes building performance standards that go into effect beginning 2026-2028, could drive shorter term participation in programs.
- Implement a new savings goal and budget process as defined through WUTC rulemaking which integrates a Conservation Potential Assessment that has been developed by a third

party (other than Energy Trust). The new Conservation Potential Assessment will influence savings goals for 2022 and 2023.

3.2 Incentive Program Metrics and Budget

3.2.1 Them Savings by Incentive Program

Incentive Program	Savings Pathway	2022 Therm Goal	2023 Therm Goal	2022-23 Therm Goal
Commercial	Existing Buildings - Standard	29,722	27,742	57,464
	Existing Buildings - Custom	124,155	76,000	200,155
	New Buildings - Standard	12,177	19,350	31,527
	New Buildings - Custom	0	2,693	2,693
	Strategic Energy Management	19,595	40,013	59,608
	Commercial Total	185,649	165,798	351,447
Residential	Existing Homes - Retrofit	106,599	105,495	212,094
	Mid-stream - Distributor	12,525	12,525	25,050
	New Home Construction	13,949	4,812	18,761
	Residential Total	133,073	122,832	255,905
	Total Savings	318,722	288,630	607,352

- Commercial Training Track included with Existing Buildings – Standard
- Residential Multifamily included with Existing Homes Retrofit

3.2.2 Expenses by Incentive Program

2022-23 Efficiency Program	Budgeted Expenditures	2022	2023	2022-23 Total
Commercial	Programs	$ 1,311,293	$ 1,249,802	$ 2,561,095
	Commercial Administration	$ 75,994	$ 72,659	$ 148,653
	Commercial Total	$ 1,387,287	$ 1,322,461	$ 2,709,748
Residential	Programs	$ 1,498,885	$ 1,495,834	$ 2,994,719
	Residential Administration	$ 95,581	$ 91,966	$ 187,547
	Residential Total	$ 1,594,466	$ 1,587,800	$ 3,182,266
	Total Expenditures	$ 2,981,753	$ 2,910,261	$ 5,892,014

- Expenditures include Incentives and Delivery
- Program expenditures not available or calculated by track

3.2.3 Incentives by Incentive Program

Incentive Budget By Program		2022	2023	2022-23 Total
Commercial Programs	Existing Buildings - Standard	$ 85,984	$ 80,476	$ 166,460
	Existing Buildings - Custom*	$ 476,500	$ 335,000	$ 811,500
	New Buildings - Standard	$ 36,204	$ 67,510	$ 103,714
	New Buildings - Custom*	$ 10,000	$ 18,467	$ 28,467
	Strategic Energy Management	$ 126,703	$ 155,092	$ 281,795
	Commercial Total	$ 735,391	$ 656,545	$ 1,391,936
Residential Programs	Existing Homes Retrofit	$ 591,218	$ 635,762	$ 1,226,980
	Mid-stream: Distributor	$ 49,900	$ 49,900	$ 99,800
	New Home Construction	$ 237,490	$ 171,625	$ 409,115
	Residential Total	$ 878,608	$ 857,287	$ 1,735,895
	Total Incentive	$ 1,613,999	$ 1,513,832	$ 3,127,831

* Commercial Custom Studies included in Custom Track

3.3 Low Income Metrics and Budget

The WA-LIEE program will strive to weatherize 25 homes in the 2022-2023 program years. Delays and reduced outreach due to COVID-19 have limited the number of low-income projects. The WA-LIEE 2022-2023 biennial goal has been adjusted to reflect the impacts of COVID-19. A breakout of costs and therm savings estimates are reflected below.

Targets below assume a change in Schedule I to incorporate previously temporary adjustments that were first implemented in 2018. After the change, the measure funding cap per home will be $10,000 with a $1,000 cap on heath/safety work. Furnace repairs, tune-ups and replacements will also become standard practice to serve eligible customers in a timely manner. Program providers may recover agency administrative costs up to 25% of project costs. The Company is allowed up to 5% for processing administration.

3.3.1 Low Income Performance Targets

WA-LIEE	2022 Goal	2023 Goal	Biennial Goal
Number of Homes Weatherized	10	15	25
Furnace Only	10	10	20
Therm Savings	5,425	8,138	13,563

3.3.2 Low Income Budget

WA-LIEE		Budget	
WA-LIEE	WA-LIEE Measures	$	185,219
	Health / Safety	$	25,000
	Furnace Only	$	20,000
	WA-LIEE Agency Administration (25%)	$	57,555
	WA-LIEE application processing admin (5% cap)	$	14,389
	WA-LIEE Total	**$**	**302,162**

3.3.3 Low Income Cost Effectiveness

The goal of the low-income program is primarily to address underserved markets and customers that do not have access to the energy efficiency incentive programs. For whole home efforts, WA-LIEE leverages funds provided by other state, federal and local agencies. Those leverage funds also utilize Savings to Investment Ratio (SIR) tests or approved measure lists.

3.4 Gas Market Transformation Metrics and Budget

The Company will continue its participation with NEEA. The NEEA budget is on track and in line with the 5-year business plan spanning 2020-2024. Actual expenditures are based on invoiced total arising from the actual progress of NEEA during the year.

NEEA Budget		2022		2023		Biennial Budget
NEEA	$	88,148	$	88,148	$	176,296

3.5 Pilots & Trial Programs Metrics and Budgets

The Company plans to investigate and initiate opportunities to further strengthen the suite of offerings through pilot projects and temporary or test programs. These programs and offerings are often referred to as “Pilots” but some may be temporary program structures or supporting efforts to enhance and drive existing offerings. The Company’s EEAG will be briefed as progress is made and budgets are provided in Section 3.5.1 to outline expected expenditures.

3.5.1 Enhanced Energy Services

The CPA conducted for the Biennial EE Plan identified cost-effective potential from Sales customers in the industrial sector. Since NW Natural’s Washington EE programs have not historically served this sector, the Company plans to set up a new offering to address these customers. NW Natural will work with its advisory group to identify program activities, assessments, and energy efficiency opportunities that may be included in this pilot offering. Given the uncertainties in this offering the budget is to be determined. Cost recovery for this offering was not included in the forecast and will use a different recovery mechanism.

Enhanced Energy Services	2022	2023	Biennial
Budget	TBD	TBD	TBD

3.5.2 Gas Heat Pump Water Heaters

For the last couple of years, the Company has been collaborating with NEEA, the North American Gas Heat Pump Collaborative, and various manufactures to promote commercialization of gas heat pump technology. Gas heat pump water heaters have the potential to be twice as efficient as baseline products, providing high long-term savings for our gas customers.

To increase demand and bring down cost barriers, the Company plans to promote this technology starting in 2023. Work in 2022 will continue collaboration with stakeholders and refine saving analysis and any potential incentives.

3.6 Northwest Power and Conservation Council – Regional Technical Forum (RTF)

The Company has agreed to support the work of the Regional Technical Forum's 2020-2024 Business Plan. The work of the RTF will assist the Company in developing and acquiring cost-effective conservation through research and evaluation of conservation investments.

3.6.1 RTF Budget

RTF	2022	2023	Biennial Budget
RTF – NWN WA Funding	$10,600	$10,800	$21,400

3.7 Conservation Potential Assessment

The acquisition targets of this Biennial Plan were established through a conservation potential assessment (CPA) conducted by Applied Energy Group (AEG). As a requirement of RCW 80.28, gas utilities must set an acquisition target every two years. The conservation potential assessment ("CPA") will be updated every two years to ensure targets are based on the most current and reliable data.

During 2023, the Company will work with an independent third party to update the CPA. Costs for the CPA will be recovered through general rates.

3.8 Loans and On-the-bill Repayment Services

The Company will continue to provide access to a low-interest, unsecured financing offer to residential homeowners who heat their homes with natural gas. The program lender will originate loans granted for the purposes of purchasing and installing conservation and energy efficiency measures incented by the existing homes program, and the Company will provide billing and remittance services to the program lender by placing the loan repayment fee on the participating customers' monthly gas bill. Customers who obtain a loan with on-the-bill repayment services will receive a loan repayment charge itemized as "Energy Upgrade Loan" on their monthly bill for natural gas service. This will be reflected for the term of the loan or until the loan has been paid off, transferred, or otherwise discharged or removed from the bill in accordance with the terms and conditions of the Company's service agreement. The Company will lead and manage the coordination of activities between the program lender, the program management contractor, and the Company. More information can be found in Appendix 3.

3.9 Evaluation Activities and Budget

In 2010 the Company hired Navigant for a two-part study on the Company's Washington Energy Efficiency program. The first part was a benchmark study to evaluate how the pilot program compared to other programs in Washington and the second part was an evaluation of how the Company should proceed with turning the pilot into a full-fledged program. The Company has no plans for Program level outside evaluation work in 2022 or 2023.

IV. Development Considerations

Targets for the biennial incentive program targets were set based on the 2021 Conservation Potential Assessment[9] ("CPA") provided by Applied Energy Group ("AEG"). The CPA developed independent and credible estimates of energy efficiency potential for NW Natural's Washington service territory using measure assumptions consistent with 2021 Power Plan supply curves, Regional Technical Forum ("RTF") measure workbooks, and information from Northwest Energy Efficiency Alliance's ("NEEA's") market research initiatives. AEG customized its LoadMAP end-use planning tool with data specific to NW Natural's Washington territory to develop an estimate of achievable cost-effective energy efficiency potential between 2022 and 2051.

Transportation customers were excluded from consideration in the CPA as they have not previously been included in the energy efficiency program tariffs. Additional data and clarification on the appropriate avoided costs, how these customers use natural gas, and their view on energy savings would be required to assess the cost-effective potential for transportation customers. Since transportation customers were excluded from the CPA, WUTC staff has stipulated that energy audits be offered as a way to serve these customers and help assess the cost-effective potential of this sector.

[9] https://www.utc.wa.gov/casedocket/2021/210773/docsets

4.1 Conservation Potential Assessment

Summary of Energy Efficiency Potential (mTherms)							
Scenario	**2022**	**2023**	**2024**	**2026**	**2031**	**2040**	**2050**
Baseline Load Projection (mTherms)	80,831	82,581	84,282	87,530	95,229	109,312	125,747
Cumulative Savings (mTherms)							
TRC Achievable Economic Potential	354	725	1,036	1,827	4,390	9,345	11,392
UCT Achievable Economic Potential	477	992	1,470	2,671	6,523	13,936	16,818
Achievable Technical Potential	874	1,799	2,702	4,808	10,350	19,102	22,321
Technical Potential	2,033	4,189	6,160	10,491	20,957	35,383	42,373
Cumulative Savings (% of Baseline)							
TRC Achievable Economic Potential	0.4%	0.9%	1.2%	2.1%	4.6%	8.5%	9.1%
UCT Achievable Economic Potential	0.6%	1.2%	1.7%	3.1%	6.8%	12.7%	13.4%
Achievable Technical Potential	1.1%	2.2%	3.2%	5.5%	10.9%	17.5%	17.8%
Technical Potential	2.5%	5.1%	7.3%	12.0%	22.0%	32.4%	33.7%

Cumulative TRC Achievable Economic Potential by Sector (mTherms)							
Sector	**2022**	**2023**	**2024**	**2026**	**2031**	**2040**	**2050**
Residential	182	369	478	837	2,250	5,380	6,612
Commercial	155	323	509	908	1,979	3,713	4,526
Industrial	16	33	49	82	162	253	254
Total	**354**	**725**	**1,036**	**1,827**	**4,390**	**9,345**	**11,392**

4.1.1 CPA Residential

In 2022 and 2023, the achievable economic potential for the residential sector is 183 and 187 mTherms respectively. The identified savings potential for the two program years represents 0.7% of the residential baseline projection. Behavioral programs, which are not currently part of the Company's portfolio show up in these first two years with a large amount of savings potential.

Residential Top Measures in 2022 and 2023 (mTherms)			
Rank	Measure	Cumulative Savings (mTherms)	% of Total Savings
1	Furnace - AFUE 98%	129.4	35.0%
2	Behavioral Programs - HER-style customer awareness program	105.8	28.7%
3	ENERGY STAR - Connected Thermostat - Interactive/learning thermostat (i.e., NEST)	78.9	21.4%
4	ENERGY STAR Clothes Washers - ENERGY STAR unit	24.9	6.7%
5	Insulation - Ceiling, Installation - R-49 (Retro only)	6.0	1.6%
6	Water Heater - Low Flow Showerhead - 1.5 GPM showerhead	5.3	1.4%
7	Boiler - AFUE 95%	4.0	1.1%
8	Water Heater - Pipe Insulation - Insulated 5' of pipe between unit and conditioned space	3.1	0.9%
9	Ducting - Repair and Sealing - 50% reduction in duct leakage	2.6	0.7%
10	Insulation - Wall Cavity, Installation - R-11	2.0	0.5%
11	Water Heater - Temperature Setback - Setback to 120° F	1.9	0.5%
12	Insulation - Ducting - duct thermal losses reduced 50%	1.6	0.4%
13	Water Heater - Faucet Aerator - 1.5 GPM aerator	1.5	0.4%
14	Gas Boiler - Pipe Insulation - Pipe insulated throughout home	1.0	0.3%
15	Insulation - Basement Sidewall - R-15	0.8	0.2%
16	Insulation - Slab Foundation - R-11 (NC Only)	0.2	0.0%
17	Thermostatic Radiator Valves - Thermostatic Restriction Valve	0.1	0.0%
18	Insulation - Ceiling, Upgrade - R-49	0.1	0.0%
19	Water Heater - Drainwater Heat Recovery - Drain equipped with heat recovery system	0.0	0.0%
20	Building Shell - Whole-Home Aerosol Sealing - 20% reduction in ACH50	0.0	0.0%
	Total	**369.3**	**100.0%**

4.1.2 CPA Commercial

In 2022 and 2023, the achievable economic potential for the commercial sector is 155 and 168 mTherms respectively. The identified savings potential for these two years represents 1.4% of the commercial baseline projection. Space heating measure make up a majority of the potential in the next two program years.

Commercial Top Measures in 2022 and 2023 (mTherms)			
Rank	Measure	Cumulative Savings (mTherms)	% of Total Savings
1	Water Heater - TE 96% Condensing	11	3.4%
2	Boiler - AFUE 97%	58	18.0%
3	Insulation - Roof/Ceiling - R-38	94	29.0%
4	Broiler - Infrared Burners	6	1.9%
5	Insulation - Wall Cavity - R-21	28	8.8%
6	Furnace - AFUE 96%	2	0.6%
7	Range - High Efficiency	3	0.8%
8	HVAC - Demand Controlled Ventilation - DCV enabled	3	1.0%
9	Gas Boiler - Insulate Hot Water Lines - Insulated water lines	15	4.7%
10	ENERGY STAR Connected Thermostat - Wi-Fi/interactive thermostat installed	32	10.1%
11	Double Rack Oven - FTSC Qualified (>50% Cooking Efficiency)	2	0.5%
12	Hydronic Heating Radiator Replacement -	9	2.7%
13	Building Automation System - Automation system installed and programmed	1	0.2%
14	Kitchen Hood - DCV/MUA - vent hood	5	1.6%
15	Water Heater - Efficient Dishwasher - ESTAR unit	1	0.2%
16	Gas Boiler - Insulate Steam Lines/Condensate Tank - Lines and condensate tank insulated	6	1.8%
17	Space Heating - Heat Recovery Ventilator - HRV installed	5	1.6%
18	Gas Boiler - Hot Water Reset - Reset control installed	4	1.4%
19	Unit Heater - Infrared Radiant	0	0.1%
20	Gas Boiler - Burner Control Optimization - Optimized burner controls	1	0.2%
	Subtotal	**286**	**88.7%**
	Total Savings in Year	**323**	**100.0%**

4.1.3 CPA Industrial

In 2022 and 2023, the achievable economic potential for the industrial sector is 16 and 17 mTherms respectively. The identified savings potential for these two years represents 0.7% of the projected industrial baseline. While large, custom process optimization and control measures are present in the potential these are not applicable to all applications. For this reason, the long term potential for industrial is a lower percentage of the overall baseline compared to the residential and commercial sectors.

Industrial Top Measures in 2022 and 2023 (mTherms)

Rank	Measure	Cumulative Savings (mTherms)	% of Total Savings
1	Strategic Energy Management - Energy management system installed and programmed	10	31.7%
2	Gas Boiler - Insulate Hot Water Lines - Insulated water lines	5	14.4%
3	Building Automation System - Automation system installed and programmed	0	0.6%
4	Gas Boiler - Stack Economizer - Economizer installed	4	12.6%
5	Gas Boiler - Hot Water Reset - Reset control installed	2	4.9%
6	Insulation - Roof/Ceiling - R-38	3	8.6%
7	Gas Boiler - Burner Control Optimization - Optimized burner controls	0	0.5%
8	Gas Boiler - Insulate Steam Lines/Condensate Tank - Lines and Condensate Tank insulated	1	3.4%
9	Process - Insulate Heated Process Fluids - Insulated process fluid lines	2	6.5%
10	Boiler - AFUE 97%	1	2.5%
	Subtotal	**28**	**85.9%**
	Total Savings in Year	**33**	**100.0%**

V. Appendices

Appendix 1: On-the-bill Repayment

Residential Loans and On-The-Bill Repayment Services: Description of On-the-Bill Repayment Services

The Company assists in marketing a low-interest financing offer to residential homeowners who heat their homes with gas heat. The program lender will originate loans granted for the purposes of installing conservation and energy efficiency measures incented by the existing homes program, and the Company will provide billing and remittance services to the program lender by placing the loan repayment fee on the customers' monthly gas bill. Customers who obtain a loan with On-the-Bill Repayment Services will receive a loan repayment charge separately itemized as "Energy Upgrade Loan" on their monthly bill for natural gas service. This will be reflected for the term of the loan or until the loan has been paid off, transferred, or otherwise discharged or removed from the bill in accordance with the terms and conditions of the Company's service agreement.

Program Lender

Craft3, a non-profit community development financial institution ("CDFI") lender, will act as the program lender under the terms and conditions of a service agreement with Energy Trust. Craft3 received a grant from the State of Washington's Clean Energy Revolving Loan Fund[10] for the purpose of providing financing to Washington residents for installing energy efficiency measures. The intent of this offering is to facilitate the acquisition of cost-effective natural gas savings while extending the benefit of the State of Washington's Clean Energy Revolving Loan Fund to natural gas ratepayers in Southwest Washington.

Loan

The loan offerings through Craft3 that will qualify for On-the-Bill Repayment Services must fit the following parameters:

- Loans must be granted to residential homeowners who use natural gas as their primary heating fuel
- Loan amounts must be used to install conservation and energy efficient measures incented under NW Natural's existing homes program
- Loan Amount:
    - Loan amounts must be no less than $2,500 and no more than $15,000.
- Term of loan:
    - Loans up to $7,500 to have a max term of 7 years,
    - Loans between $7,500-$15,000 up to 15 years.
- The program has a fixed interest rate at 4.99%. Contingent on market conditions, Craft3 may at a later date revise the interest rate offer for future customers, not to exceed 5.49%. Under all circumstances rates will be fixed and consistent for any qualifying customer
- Loans will be unsecured
- No penalty for early repayment

[10] https://www.commerce.wa.gov/growing-the-economy/energy/clean-energy-fund/energy-revolving-loan-fund/

- Craft3 may assess a financing fee of $100 for loans between $2,500-$7,500, $200 for loans between $7,500-$15,000
    - Fees may be financed as an addition to the loan balance
- At least 51% of the loan must be for costs that are directly attributable to the commissioning and installation of the qualifying measure(s), costs incurred to comply with applicable building code, mechanical code, or other pertinent regulations, or costs incurred to meet any technical specifications established by the Energy Trust. Whereas 49% of the loan may be allocated toward non-qualifying energy measures such as cooling

Terms and Conditions

1. The Company will directly bill Energy Trust or Craft3 for ongoing administrative costs, including costs associated with loan setup, loan termination and other incremental activities related to accounting and processing of bill payments.
2. The business relationship and the services exchanged between Energy Trust and the Company shall be in accordance with an executed Service Agreement. The Energy Trust will act as the program manager of this offering.
3. The provision of On-the-Bill Repayment Services will in no way conflict with the Company's compliance to WAC 480-90, Washington Administrative Code (WAC).
4. A Customer's decision to enter into a loan agreement with Craft3 will not affect his/her ability to establish credit with the Company; it will have no impact on the amount that a Customer may be required to pay on deposit for Natural Gas utility service; and it will have no effect on a Customer's ability to receive reliable natural gas service. The Company will communicate this in writing to customers who participate in this loan program.
5. By entering into a loan agreement with Craft3, the customer will be responsible to remit the monthly loan repayment amount to NW Natural with his/her monthly bill payment for natural gas services.
6. NW Natural is not a party to the loan agreements and has no financial interest in these loans.
7. Monthly payments received from customers participating in this program will be allocated to the customers' account in accordance with Rule 4 of this the Company's Tariff.
8. The Company will not disconnect gas service to a customer for non-payment of loan repayment charges.
9. NW Natural is solely a billing agent for Craft3. Participating Customers must acknowledge that the Company shall be held harmless for any liability resulting from contractors' actions with regard to installation of energy efficiency measures resulting from this program.
10. NW Natural has no responsibility to collect charges, penalties, or fees beyond the remitting to Craft3 the loan repayment collections the Company receives from Customers in accordance with the services described herein.
11. Craft3 is responsible to tell the Company how much to bill per month for each loan and how many months each customer should be billed. The Company is not responsible for any information provided by Craft3.
12. The Company will not a) accept loan payoffs, b) issue refunds on loan payments, c) offer payment arrangements on loan amounts due, or d) allow energy assistance to be applied to loan balances.
13. Craft3 must obtain a signed consent form from participating Customers that states that the Customer agrees to allow the Company to provide Craft3 with Customer-specific bill payment information.

14. Craft3 must obtain signed documentation from the Customer that certifies that the Customer has been made aware of the Company's limited role in the loan repayment process.
15. Craft3 must provide the Company with a toll-free customer service phone number to which the Company will refer Customers who have questions or concerns about their loan. The Company is not responsible for Customer questions and disputes related to the loan or the Customer's perceived or real experience related to any portion of the loan or energy efficiency measures.
16. The Company will provide Customers with an overview of the loan product. Specific terms and conditions of the loan will be provided by Craft3.
17. A Customer with a loan open at the time he/she sells his/her home may either pay the loan off at the time of the sale; or if the new homeowner is willing to assume the loan and is able to pass the Craft3's credit requirements, the new homeowner may assume the remaining balance of the loan.
18. If a Customer with a loan refinances his/her mortgage, Craft3 will work with the Customer. A fee may be assessed if Craft3 subordinates its lien to the new mortgage lender.

Appendix 2: UES Measure Lists

Commercial Measure Description	Incremental (TRC) Cost per Quantity	Savings (Therms) per Quantity	Annual NEBs	UCT BCR	TRC BCR	MAD #
Multifamily - Condensing Tank WH	$3.39	0.723	$0.00	1.50	1.33	21
All Commercial - Condensing Tank WH	$3.35	1.395	$0.00	2.89	2.59	21
Steam Trap - Multifamily Space Heating- Operating Pressure ≤5 psig	$427.83	116.68	$0.00	5.19	1.21	40
Steam Trap - Commercial Space Heating - Operating Pressure < 30 psig	$477.46	331.79	$0.00	16.13	3.38	42
Steam Trap - Commercial Space Heating - Operating Pressure ≥ 30 psig and ≤ 50 psig	$500.96	679.8	$0.00	33.05	6.60	42
Steam Trap - Dry Cleaners (no test report required) - Operating Pressure ≥ 75 psig and ≤ 125 psig	$329.92	211.14	$0.00	4.94	1.50	42
Steam Trap - Commercial Space Heating (High Use) - Operating Pressure < 30 psig	$477.46	654.86	$0.00	31.84	6.67	42
Steam Trap - Commercial Space Heating (High Use) - Operating Pressure ≥ 30 psig and ≤ 50 psig	$500.96	1377.23	$0.00	66.97	13.37	42
Multifamily Buildings - Thermostatic Radiator Valve	$215.00	42	$0.00	4.47	2.08	45
High-Rise Apartment - CTWH ≥200 kBtu/h	$1.52	0.13	$0.00	1.03	0.68	72
All Commercial - CTWH ≥200 kBtu/h	$1.51	0.18	$0.00	1.42	0.94	72
Rack Oven – Gas - Double	$1,860.27	218.44	$0.00	0.80	0.80	101
ES v2.2 Convection Oven - Gas - Full-size	$995.88	92.67	$0.00	1.99	0.63	101
ES v2.2 Combination Oven - Gas	$3,063.53	296.48	$0.00	2.68	0.66	101
Steam Cookers - Gas	$1.00	555.32	$238.28	1.88	5797.95	101
Conveyor Broilers with belt width < 20”	$2,523.03	1,145.29	$550.09	3.88	4.94	101

Conveyor Broilers with belt width 20” - 26”	$3,145.87	1,932.84	$493.03	5.24	5.50	101
Conveyor Broilers with belt width > 26”	$3,658.65	3,161.26	$1,836.00	7.14	10.14	101
MF WA Clothes Washer - Gas DHW	$65	5.53	$20.64	0.46	3.45	152
MF WA Laundry Center Washer/Dryer - Gas DHW	$88	5.46	$24.56	0.28	2.65	152
Restaurant - CTWH 199 kBtu/h	$201	44.28	$0.00	2.12	1.74	212
Motel - CTWH 199 kBtu/h	$201	16.70	$0.00	0.80	0.66	212
Coin-op Laundry - CTWH 199 kBtu/h	$201	103.93	$0.00	4.98	4.10	212
Gym/Fitness Center- CTWH 199 kBtu/h	$201	21.71	$0.00	1.04	0.86	212
Schools- CTWH 199 kBtu/h	$201	14.99	$0.00	0.72	0.59	212
Furnace >=95% AFUE in existing commercial buildings	$8.44	0.82	$0.07	1.91	1.51	270
Furnace >=95% AFUE in new commercial buildings	$8.44	0.51	$0.06	1.19	0.96	270
Gas Fryers	$1,290.00	431	$0.00	1.55	1.50	272
Gas Fryers	$1,290.00	431	$0.00	1.55	1.50	272

Residential Measure Description	Incremental Cost per Quantity	Savings (Therms) per Quantity	Other NEB (Annual $)	UCT BCR	TRC BCR	MAD #
Community Partner Funded Gas Furnace 90%+, Gas-only	$1607	91.81	$2.16	2.30	0.81	23
Gas Furnace- Rentals 90%+ AFUE WA	$1607	91.81	$2.16	2.30	0.81	23
Gas Furnace SW WA 95%+ AFUE	$1607	91.81	$2.16	2.30	0.81	23
Community Partner Funded Gas Furnace 90%+, Gas-only	$1607	91.81	$2.16	2.30	0.81	23
Gas Furnace- Rentals 90%+ AFUE WA	$1607	91.81	$2.16	2.30	0.81	23
Gas Furnace SW WA 95%+ AFUE	$1607	91.81	$2.16	2.30	0.81	23
Build Your Own Kit, 1.5 gpm Showerhead Gas	$13	3.9	$7.74	20.70	11.65	27
Build Your Own Kit, 1.5 gpm Shower wand Gas	$22	12.1	$23.92	12.69	7.82	27

Build Your Own Kit, Low Flow Thermostatic Shower Valve	$5	4.4	$8.58	3.21	12.44	27
Community Partner Funded Windows - GAS Only - U .28-.30	$1	0.13	$0.01	1.72	4.24	28
Windows - GAS - U .28 - .30 Gas only	$1	0.13	$0.01	2.86	7.96	28
Windows - GAS - U .28 - .30 Gas only	$1	0.13	$0.01	2.86	7.96	28
Windows - GAS- U .25-.27 Gas only	$2	0.27	$0.02	2.60	7.37	28
Windows - GAS- U .25-.27 Gas only	$2	0.27	$0.02	2.60	7.37	28
Windows - GAS - U <=.24 Gas only	$3	0.46	$0.03	2.96	7.15	28
Windows - GAS - U <=.24 Gas only	$3	0.46	$0.03	2.96	7.15	28
Gas Hearth 75+ FE w/ ele ignition	$	60.51	$0.00	5.60	139,982.86	29
Gas Hearth 75+ FE w/ ele ignition	$	60.51	$0.00	5.60	139,982.86	29
Gas Hearth 70-74 FE w/ ele ignition	$	48.54	$0.00	7.49	112,291.66	29
Gas Hearth 70-74 FE w/ ele ignition	$	48.54	$0.00	7.49	112,291.66	29
Gas hearth-Electronic Ignition $25, retailer/distributor incent	$105	7.41	$0.00	11.00	4.18	29
Gas hearth-Electronic Ignition $30, retailer/distributor incent	$105	7.41	$0.00	9.17	3.51	29
Attic Insulation/SQFT, Gas Heat	$1	0.07	$0.03	N/A	N/A	58
Community Partner Funded Attic Insulation, Gas Heat, Zone 1 GO	$1	0.07	$0.03	2.14	36.85	58
Attic Insulation/SQFT, Gas Heat	$1	0.07	$0.03	3.60	26.62	58
Community Partner Funded Attic Insulation, Gas Heat, Zone 1 GO	$1	0.07	$0.03	1.98	57.54	58
Community Partner Funded Wall Insulation, Gas Heat, Zone 1 GO	$3	0.05	$0.03	0.96	0.29	58
Wall Insulation/SQFT, Gas Heat	$3	0.05	$0.03	0.96	(9.82)	58

Wall Insulation/SQFT, Gas Heat	$3	0.05	$0.03	0.10	1.51	58
Community Partner Funded Floor Insulation, Gas Heat, Zone 1 GO	$2	0.04	$0.00	0.74	7.97	58
Floor Insulation/SQFT, Gas Heat	$2	0.04	$0.00	2.06	0.85	58
Floor Insulation/SQFT, Gas Heat	$2	0.04	$0.00	2.06	0.85	58
Midstream Gas Tank WH, Energy Star, Distributor	$	15.05	$0.52	3.48	34,816.43	102
Energy Star Mfg Home Customer Incentive	$	0	$0.00	-	N/A	109
Neem+ Mfg Home Customer Incentive	$	0	$0.00	-	N/A	109
Energy Star Mfg Home SPIF, Gas Zone 1	$3097	105.91	$1.99	5.08	0.49	109
Neem+ Mfg Home SPIF, Gas Zone 1	$5063	123.77	$17.98	0.59	0.04	109
CustomEPSVerf-GAS	$		$0.00	-	N/A	145
EPS: New Single Family, Gas - Path 1 GHGW	$699	22.98	$2.41	0.90	1.32	145
EPS: New Single Family, Gas - Path 1 GHEW	$588	16.86	$1.69	0.77	1.15	145
EPS: New Single Family, Gas - Path 2 GHGW	$1271	35.93	$4.14	0.90	1.08	145
EPS: New Single Family, Gas - Path 2 GHEW	$713	29.98	$4.37	0.89	1.68	145
EPS: New Single Family, Gas - Path 3 GHGW	$2177	53.01	$5.29	1.05	0.94	145
EPS: New Single Family, Gas - Path 3 GHEW	$1472	42.33	$4.02	0.95	1.18	145
EPS: New Single Family, Gas - Path 4 GHGW	$2463	66.41	$7.96	1.15	1.04	145
EPS: New Single Family, Gas - Path 4 GHEW	$2197	52.8	$4.52	N/A	N/A	145
Smart Thermostat Contractor Installed - Gas Only Territory	$170	39.7	$4.17	15.31	9.01	153
Smart Thermostat - Gas Only Territory	$170	39.7	$4.17	19.13	9.00	153
Smart Thermostat Instant Coupon - Gas Only Territory	$170	39.7	$4.17	19.13	9.00	153
Smart Thermostat Contractor Installed - Gas Only Territory	$170	39.7	$4.17	15.31	9.00	153
Smart Thermostat - Gas Only Territory	$170	39.7	$4.17	5.03	2.40	153

Smart Thermostat Instant Coupon - Gas Only Territory	$170	39.7	$4.17	-	-	153
Gas Tankless Water Heater	$450	76	$0.00	7.33	6.61	197
Gas Tankless Water Heater	$1838	76	$0.00	7.33	1.59	197
Gas Tankless Water Heater w gas line upgrade	$1650	60.69	-$1.84	5.85	1.42	197
Resideo Winter Thermostat Optimization Winter gFAF WA	$8	15.5	$3.87	-	-	217
Resideo Annual Thermostat Optimization gFAF + AC Gas Only	$12	15.23	$6.25	48.94	81.01	217
Resideo Annual Thermostat Optimization gFAF Gas Only	$12	15.23	$3.81	47.11	54.01	217
Resideo Annual Thermostat Optimization Control Group GO	$12	0	$0.00	-	0.58	217
Resideo Winter Thermostat Optimization Winter Control Group GO	$8	0	$0.00	-	-	217
Community Partner DI SmartStat - Gas Only Territory	$595	41.37	$3.60	0.59	0.11	222
Community Partner DI SmartStat - Gas Only Territory	$482	33.87	$2.30	-	-	222
Direct Ship Smart Thermostat Gas Only	$249	39.7	$1.80	6.35	6.07	250
Direct Ship Smart Thermostat Gas Only	$249	39.7	$1.80	6.43	6.21	250
CPF DI R0-R11 Ceiling Insulation- Gas Heat GOT	$4	0.09	$0.01	-	-	252
CPF DI R0-R11 Ceiling Insulation- Gas Heat GOT	$4	0.09	$0.01	0.55	9.07	252
CPF DI R12-R18 Ceiling Insulation- Gas Heat GOT	$3	0.06	$0.01	0.47	8.31	252
CPF DI R12-R18 Ceiling Insulation- Gas Heat GOT	$3	0.06	$0.01	0.47	6.58	252
WA Code Credits: Half Credit Above Code	$1104	34.28	$0.00	0.60	0.43	267
WA Code Credits: Efficient Fireplace	$1	18.3	$0.00	1.26	259.15	267
WA Code Credits: Smart Thermostat	$125	14.1	$0.78	2.09	2.09	267
WA New Homes Smart thermostat	$125	14.1	$0.78	N/A	N/A	274

Appendix 3: Measure Approval Documents

Measure Approval Document for Commercial Condensing Tank Water Heaters

Valid Dates
January 1, 2022 – December 31, 2024

End Use or Description
High efficiency, condensing, storage-type water heater installed in a commercial setting.

Applicability
Based on the referenced analysis and associated cost-effectiveness screening, the measures described below are approved for use in the following programs:

- Existing Buildings
- Existing Multifamily
- New Buildings
- Production Efficiency

Within these programs, the measure is applicable to the following cases:

- New
- Replacement

Purpose of Re-Evaluating Measure
During this update, the baseline conditions incremental costs, measure life, savings analysis method, and the hot water demand per market segment are updated.

Cost Effectiveness
Cost effectiveness is demonstrated for Oregon in Table 1 and Washington in Table 2. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2022-v1.0. In Oregon the electric avoided cost year is 2022 and the gas avoided cost year is 2022. In Washington the gas avoided cost year is 2020. The values in these tables are per kBtu/h.

Table 1 Cost Effectiveness Calculator Oregon, per kbtuh

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Office - Condensing Tank WH	15	0	0.490	$3.30	$0.00	$3.30	1.1	1.1	0%	100%
2	Schools- Condensing Tank WH	15	0	0.648	$3.36	$0.00	$3.36	1.5	1.5	0%	100%
4	Hotel - Condensing Tank WH	15	0	3.239	$3.38	$0.00	$3.38	7.4	7.4	0%	100%
5	Restaurant - Condensing Tank WH	15	0	0.803	$3.29	$0.00	$3.29	1.9	1.9	0%	100%
6	Multifamily - Condensing Tank WH	15	0	0.723	$3.39	$0.00	$3.39	1.6	1.6	0%	100%
8	Coin-op Laundry - Condensing Tank WH	15	0	0.884	$3.41	$0.00	$3.41	2.0	2.0	0%	100%
9	All Commercial - Condensing Tank WH	15	0	1.395	$3.35	$0.00	$3.35	3.2	3.2	0%	100%

Table 2 Cost Effectiveness Calculator Washington, per kbtuh

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Office - Condensing Tank WH	15	0.490	$3.30	$0.00	$3.30	1.7	1.7	0%	100%
2	Schools- Condensing Tank WH	15	0.648	$3.36	$0.00	$3.36	2.2	2.2	0%	100%
3	Healthcare - Condensing Tank WH	15	0.333	$3.35	$0.00	$3.35	1.1	1.1	0%	100%
4	Hotel - Condensing Tank WH	15	3.239	$3.38	$0.00	$3.38	10.9	10.9	0%	100%
5	Restaurant - Condensing Tank WH	15	0.803	$3.29	$0.00	$3.29	2.8	2.8	0%	100%
6	Multifamily - Condensing Tank WH	15	0.723	$3.39	$0.00	$3.39	2.4	2.4	0%	100%
7	Gym/Fitness Center - Condensing Tank WH	15	0.397	$3.40	$0.00	$3.40	1.3	1.3	0%	100%
8	Coin-op Laundry - Condensing Tank WH	15	0.884	$3.41	$0.00	$3.41	2.9	2.9	0%	100%
9	All Commercial - Condensing Tank WH	15	1.395	$3.35	$0.00	$3.35	4.7	4.7	0%	100%

Requirements

- Condensing, storage-type water heaters
- Tank volume ≥10gal (additional storage-only tanks may be present)
- Water heater input capacity of greater than 75 kBtu/h
- Must have a minimum 94.0% thermal efficiency (or recovery efficiency) rating

For commercial building projects (not multifamily):

- Programs may choose the “All Commercial” option (CEC row 9) which is a weighted average of savings and costs **or** the building-specific options (Office, Schools, Healthcare, Hotel, Restaurant, Coin-op Laundry).
  - Gym/Fitness Centers and Healthcare are cost-effective for Oregon, but these building types could be served utilizing the All Commercial option and is included in the All Commercial weighted average.
- Programs may not use All Commercial for some projects and specific building types for other projects as that would not conform to the weighted average scheme.
- If programs choose to use the All Commercial savings option, installation in additional building types is approved.
  - For example, in previous years the All Commercial option has been used to serve building types Car wash, Recreation (casino), and Jail/Reformatory/Penitentiary
- If programs choose to apply the measure by specific building type (not use all commercial), the measure for each building type can be made to areas of multi-use sites for hot water systems that provide dedicated service to that area and additional building type requirements listed in Table 3.
  - For example, a university building with a cafeteria that has a dedicated hot water system could use the Restaurant building type. However, it may be advisable, at a program’s discretion, to require additional review or a custom or special measure for these cases.

Table 3 Requirements by Building Type

Building Type	Requirements
Office	Must be > 5,500 sq ft
Commercial Gym	Must have shower facilities
Multifamily	Must have a shared central DHW system

Baseline

This measure uses a Full Market Baseline. The full market baseline includes a mix of non-condensing and condensing tank water heaters.

The baseline equipment is a commercial tank water heater with an 86% thermal efficiency for commercial-grade water heaters and 86% recovery efficiency for residential-grade water heaters.

Recovery efficiency is equivalent to thermal efficiency for commercial water heaters. Per the Code of Federal Regulations, Part 430, Subpart B, *recovery efficiency* for residential water heaters is defined as "the ratio of energy delivered to the water to the energy content of the fuel consumed by the water heater". This is analogous to thermal efficiency for commercial water heaters.

The Full Market baseline was determined based on the analysis of tank water heater product list and efficiency through the AHRI database.

The analysis approach and findings are described below:

- AHRI database findings
  - Commercial storage water heaters and residential storage waters with input capacity greater than 75 kBtuh product data from the AHRI Directory database was analyzed. The dataset includes a total of 609 active models.
  - The water heater type (condensing versus non-condensing) within the AHRI dataset was determined by establishing a minimum thermal efficiency of 86% for condensing water heaters.
    - Of the 609 active models, 278 models (46%) were determined to be condensing while the remaining 331 (54%) were determined to be non-condensing.
  - Once the water heater type was identified, the average thermal efficiency for both condensing and non-condensing water heaters was determined.
  - It was found that the average thermal efficiency of non-condensing water heaters is 79% and that of condensing water heaters is 95%.

Based on the analysis of the data from the above sources, it was established that the Full market baseline is a mix of condensing and non-condensing water heaters.

Measure Analysis

Savings were modeled using a spreadsheet-based calculation approach. Inputs from several sources such as ASHRAE prototype models, DOE National Building Stock, and AHRI were analyzed. Savings were analyzed for the following building types:

- Office (Medium and Large)
- Schools (primary and secondary)
- Healthcare (outpatient and hospitals)
- Hotels (small and large)
- Restaurants (full and quick service)
- Multifamily Apartments
- Gyms
- Coin-op laundry facilities
- All commercial (weighted average of all building types aside from multifamily)

WHAM Energy Consumption Equation for Water Heaters

The savings analysis method is the Water Heater Adjustment Model, (WHAM)[1] to align with RTF[2] gas water heater measure methodology. The total consumption in British Thermal Units (BTU) for each market segment is calculated using that market segment's estimated daily hot water demand (in gallons), estimated temperature rise, the specific heat capacity of water, water heater efficiency, and the average density of water using this equation:

$$Q_{in} = \frac{vol \times den \times C_p \times (T_{tank} - T_{in})}{TE} \times \left(1 - \frac{UA \times (T_{tank} - T_{amb})}{P_{on}}\right) + 24 \times UA \times (T_{tank} - T_{amb})$$

Where:

Q_{in} = total water heater energy consumption
Vol = daily draw volume, gal/day
den = density of water, lb/gal
C_p = specific heat of water, Btu/lb-°F
T_{tank} = set point of tank thermostat, °F
T_{in} = inlet water temperature, °F
TE = thermal efficiency, %
UA = standby heat loss coefficient, Btu/h-°F
T_{amb} = ambient air temperature, °F
P_{on} = rated input power, Btu/h

This WHAM equation is used for RTF residential water heater measures and is designed for residential water heaters, so an adjustment was needed in order to use the equation for commercial water heaters. The UA input referenced is calculated using the water heater rated energy factor which is only available for residential-grade water heaters. For this analysis, "$UA \times (T_{tank} - T_{amb})$" is replaced with AHRI Certified Rating *Standby Loss* (Btuh/h). AHRI Standby Loss value is available for commercial-grade water heaters. Method for calculating an equivalent standby loss value for residential-grade water heaters is described below.

Used the UA calculation from the RTF presentation:

$$UA = \frac{(\frac{1}{EF} - \frac{1}{RE})}{(T_{tank} - T_{amb}) \times (\frac{24}{Q_{out}} - \frac{1}{(RE \times P_{on})})}$$

[1] WHAM: A Simplified Energy Consumption Equation for Water Heaters
[2] RTF gas water heater measure methodology presentation: https://nwcouncil.app.box.com/v/20210414GasWaterHeaterPres

where:

UA = standby heat loss coefficient, Btu/h-°F
EF = energy factor
RE = recovery efficiency, %
T_{tank} = set point of tank thermostat, °F
T_{amb} = ambient air temperature, °F
Q_{out} = heat content of water drawn from the water heater, Btu/h
P_{on} = rated input power, Btu/h

Calculated UA is multiplied by (T_{tank}-T_{amb}) to convert to Standby Loss comparable to commercial-grade water heater rated value.

Consumption for the baseline and proposed measure case water heaters is calculated using the base and measure case thermal efficiency values. The savings is the difference between the calculated base and measure case consumption. Savings are converted from annual BTU to therm per input kBtu/h.

Hot Water Demand per market segment or sub-sector

The hot water demand for various market segments that was determined from multiple sources are detailed in the table below:

Table 4: Hot Water Demand per Market Segment

Market Segment	Sub-sector	Annual Hot Water Demand (Gal)	Source
Office	Medium Office	35,803	Annual hot water demand from ASHRAE Prototype Building Models, Table 2.2 and model summary.[3] (aligns with MAD 212 and 72)
	Large Office	301,179	
Healthcare	Outpatient Health Care	63,248	
	Hospital	501,605	
Hotel	Small Hotel	340,540	
	Large Hotel	4,953,120	
Restaurant	Quick-service	102,417	
	Full-service	218,058	
Multifamily	-	631,308	
Schools	Primary School	71,060	
	Secondary School	1,685,043	
Gym	-	411,897	Calculated using peak demand (gallon per hour) from Table 11 and demand ratio profile from Appendix B (secondary school showers) in the U.S. Department of Energy Commercial Reference Building Models of the National Building Stock.[4]
Coin-op Laundry	-	1,252,402	Calculated using several sources for washer count for large and small facilities, loads washed per day, average water gallon per load, and percent hot water per load. Used EPS Water Use of Commercial Coin- or coin-operated washer or multi-load washer (gallons/year) equation[5]

Heat Load Input Assumptions

In addition to the annual hot water consumption, the heat load calculations are based on density of water, specific heat capacity of water, and the temperature rise which is calculated as the difference between the inlet and outlet temperatures of the water heater.

Water heater inlet temperatures were calculated by using the heating zone ground water temperature from RTF's Standard Information Workbook v4.2 and taking a weighted average inlet temperature based on the previously installed project locations of this measure in the Existing and New Building program between 2019-2021. Water heating outlet setpoint temperatures are adopted from the RTF's commercial heat pump water heater measure.

The physical constants for water (density and specific heat capacity) were found using the Properties of water values from 2010 DOE TSD. The table below shows the assumptions for these inputs:

Table 5: Heat Load Inputs

Input	Value
Water Heater Inlet Temperature (°F)	58.146
Water Heater Outlet Temperature (°F)	1407
Temperature Rise (°F)	81.86
Density of Water (lb/gal)	8.298
Specific Heat Capacity, Water (btu/ lb x °F)	1.000743

Thermal efficiency

Baseline case:

Using the baseline efficiency described in the baseline section above, the weighted average thermal efficiency for the full market baseline (mix of condensing and non-condensing water heaters) was determined. The table below summarizes the AHRI data findings and the weighted average thermal efficiency:

Table 6: Baseline Case - Weighted Average Thermal Efficiency

Value	Condensing	Non-Condensing
Percent AHRI Data (%)	46%	54%
Average AHRI Thermal Efficiency (%)	95%	79%
Weighted Average Thermal Efficiency (%)	86%	

3 PNNL and DOE. 2014. "Enhancements to ASHRAE Standard 90.1 Prototype Building Models.": https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-23269.pdf https://www.energycodes.gov/prototype-building-models
4 NREL. 2011. "U.S. Department of Energy Commercial Reference Building Models of the National Building Stock." http://www.nrel.gov/docs/fy11osti/46861.pdf
5 EPA *WaterSense at Work Best Practices for Commercial and Industrial Facilities,* Equation 3-9. Water Use of Commercial Coin- or coin-operated washer or multi-load washer (gallons/year): https://www.allianceforwaterefficiency.org/sites/www.allianceforwaterefficiency.org/files/assets/ws-commercial-water-sense-at-work-ci.pdf
6 Regional Technical Forum. 2020. "RTFStandardInformationWorkbook_v4_2.xlsx." https://rtf.nwcouncil.org/standard-information-workbook
7 Regional Technical Forum. 2020. "ComHPWH_v1_3.xlsm." , GPD Guide tab, Rows 45-65, Column O. https://nwcouncil.app.box.com/v/CommercialHPWHv1-3
8 Properties of water (values from 2010 DOE TSD)

Proposed case:
Minimum efficiency of 94% selected to align with the Energy Star criteria[9] for commercial Gas-fired water heaters minimum thermal efficiency requirement.

Sub-sector Weighting Methodology
To establish savings across the market segment the weightage associated with the sub-sectors of Office, Schools, Healthcare, Restaurants, and Hotels was estimated. Sub-sector weightage shown in Table 7.

The number (counts) of schools in Oregon was found using the Oregon Department of Education data[10]. In this dataset, Schools were categorized into Primary Schools, Secondary Schools, and some were not well classified. The counts of primary and secondary schools were used to estimate the weightage (%) of each sub-sector under the Schools market segment.

Counts of different healthcare facilities and restaurants were found using US Bureau of Labor Statistics[11]. The counts of outpatient care centers and hospitals were used to estimate the weightage (%) of each sub-sector under the Healthcare market segment. Counts of quick and full-service restaurants were used to estimate the weightage (%) of each sub-sector under the Restaurant market segment. North American Industry Classification System (NAICS) codes for the following were assigned to measure building types:

- "Outpatient Care Centers" assigned as Outpatient Health Care
- "Hospitals" assigned as Hospitals
- "Cafeterias, grill buffets, and buffets" and "Limited-service restaurants" assigned as Quick Service Restaurants
- "Full-service restaurants" assigned as Full-Service Restaurants.

Counts of different hotels were found using US Census of Service Industries[12]. Census data for hotels with less than 25 guests was assigned as Small Hotel and census data for hotels with 25 guests or more was assigned as Large Hotel. The counts of Small and Large Hotels were used to estimate the weightage (%) of each sub-sector under the Hotel market segment.

Counts of different office buildings were found using Commercial Building Stock Assessment[13] (CBSA) data. CBSA data for offices with more than 5,500 square feet and less than 150,000 square feet were assigned as Medium Office. CBSA data for offices with 150,000 square feet and more was assigned as Large Office[14]. The counts of medium and large offices were used to estimate the weightage (%) of each sub-sector under the Office market segment.

Table 7: Weightage of sub-sectors under Office, Schools, Healthcare, Hotel, and Restaurant market segments

Market Segment	Sub-sector	Weighting
Office	Medium Office	69%
	Large Office	31%
Schools	Primary School	79%
	Secondary School	21%
Healthcare	Outpatient Health Care	84%
	Hospitals	16%
Hotel	Small Hotel	48%
	Large Hotel	52%
Restaurant	Quick Service	43%
	Full Service	57%

The savings for each sub-sector were weighted and calculated accordingly.

All Commercial Weighting Methodology
A weighted average was determined to cover all commercial building types based on project data for this measure in the Existing and New Building programs from 2016-2021. The weightings are shown in Table 8 below.

Table 8: Weightage averaging across all commercial building types

Market Segment	Weighting
Office	4%
Schools (K-12 School, College/University)	37%
Healthcare	6%
Hotel (Lodging/Hotel/Motel)	28%
Restaurant (Food service)	22%
Coin-op Laundry	2%
Gym	1%

Savings
Savings are summarized in Table 9.

Table 9: Summary of gas savings in therms per market segment

9 https://www.energystar.gov/products/water_heaters/commercial_water_heaters/key_product_criteria
10 Oregon Department of Education : https://www.oregon.gov/ode/reports-and-data/students/Pages/Student-Enrollment-Reports.aspx
11 US Bureau of Labor Statistics – Quarterly Census of Employment and Wages. 2019 Dataset: https://www.bls.gov/cew/downloadable-data-files.htm
12 Census of Service Industries: Subject Series, Hotels, Motels, and Other Lodging Places: https://www.census.gov/library/publications/1996/econ/sc92-s-3.html
13 https://neea.org/data/commercial-building-stock-assessments
14 Large office SF range pulled from DOE *481 Prototypical Commercial Buildings for 20 Urban Market Areas* report which references the same data used for the DOE prototype models: https://escholarship.org/content/qt1g90f5gj/qt1g90f5gj_noSplash_3463aaed8c0d372d9e4d93875ee8c04f.pdf

Market Segment	Sub-sector	Total annual supply hot water (SHW) end use (gal/yr)	WHAM Savings, (therm/input kBtu/h)	Weighting per sub-sector	All Commercial weighting per sub-sector	Weighted Savings per Market Segment (therm/input kBtu/h)
Office	Medium Office	35,803	0.39	69%	4%	0.49
	Large Office	301,179	0.71	31%		
Schools	Primary School	71,060	0.31	79%	37%	0.65
	Secondary School	1,685,043	1.89	21%		
Healthcare	Outpatient Health Care	63,248	0.29	84%	6%	0.33
	Hospital	501,605	0.58	16%		
Hotel	Small Hotel	340,540	0.80	48%	28%	3.24
	Large Hotel	4,953,120	5.49	52%		
Restaurant	Quick Service Restaurant	102,417	0.82	43%	22%	0.80
	Full-Service Restaurant	218,058	0.79	57%		
Multifamily	-	631,308	0.72	N/A	N/A	0.72
Commercial Gym	-	411,897	0.40	N/A	1%	0.40
Coin-op Laundry	-	1,252,402	0.88	N/A	2%	0.88
All Commercial	-					1.39

Measure Life
Measure life is 15 years based on the DEER database. Reference EUL ID "WtrHt-Com" for commercial storage water heaters in the DEER database.

Load Profile
The gas load profile for this measure is DHW.

Cost
Equipment costs
A dataset of 94 tank water heaters from various online retailers collected in May of 2021 was used to determine the equipment costs of various efficiencies. The water heaters were categorized into different efficiency categories including:
- Non-condensing (≤86% TE)
- Standard efficiency condensing (>0.86%-<94% TE)
- High efficiency condensing (≥94% TE)

Each of the units were allocated under one of the above categories and the normalized cost per kBtuh was calculated per category and for the 'all condensing' category.

The costs for the non-condensing units and average of all condensing units (both standard efficiency condensing and high efficiency condensing) was selected to establish the full market baseline costs. The costs for high efficiency condensing units are used for the proposed measure case costs.

Labor and Ancillary Costs
Labor and ancillary material costs will align with previous MAD version 21.2. The costs were adopted from a California Codes and Standards Enhancement (CASE) report for high efficiency water heaters[15].

The costs used in this analysis only include costs that are incremental between the non-condensing and condensing water heaters. For non-condensing water heaters this includes costs of steel venting materials which are required for the hotter exhaust gases. For condensing water heaters this includes costs of PVC venting materials, a drain connection, neutralizer filter and a small condensate pump.

Table 10: Labor and Ancillary Costs: Non-Condensing Water Heater

Item	Cost
Metal Venting (Type-B Steel)	$482

Table 11: Labor and Ancillary Costs: Condensing Water Heater

Item	Cost
Venting System (PVC)	$204
Drain Connection	$113
Neutralizer Filter	$86
Condensate Pump	$40
Total	**$443**

Incremental Cost
The incremental cost per kBtuh per market sector was calculated by adding up the equipment, labor and ancillary costs per category. Final incremental costs are shown in Table 12.

Table 12: Final incremental costs

15 California Utilities Statewide Codes and Standards Team. 2011. "High-efficiency Water Heater Ready", Figure 8. http://title24stakeholders.com/wp-content/uploads/2017/10/2013_CASE-Report_High-efficiency-Water-Heater-Ready.pdf

Building Type	Capacity (kBtuh)	Non-Condensing Total ($/kBtuh)	All Condensing Total ($/kBtuh)	Condensing - HE Total ($/kBtuh)	Weighted Average Baseline Cost ($/kBtuh)	Efficient Case Cost ($/kBtuh)	Incremental Cost ($/kBtuh)
Office (weighted average)	163	$39.15	$44.89	$45.07	$41.77	$45.07	$3.30
Schools (weighted average)	286	$37.88	$43.72	$43.90	$40.54	$43.90	$3.36
Healthcare (weighted average)	265	$38.01	$43.84	$44.02	$40.67	$44.02	$3.35
Hotel (weighted average)	456	$37.25	$43.14	$43.32	$39.94	$43.32	$3.38
Restaurant (weighted average)	157	$39.26	$44.99	$45.17	$41.87	$45.17	$3.29
High-Rise Apartment	600	$37.00	$42.90	$43.09	$39.69	$43.09	$3.39
Gym	727	$36.85	$42.78	$42.96	$39.56	$42.96	$3.40
Coin-op Laundry	958	$36.69	$42.63	$42.81	$39.40	$42.81	$3.41
All Commercial	-	-	-	-	-	-	$3.35

Non-Energy Benefits

There are no non-energy benefits estimated for this measure.

Incentive Structure

The maximum incentives listed in Table 1 and Table 2 are for reference only and are not suggested incentives. Incentives will be structured per kBtu/h capacity and will not exceed the maximum incentives.

Follow-Up

The full market baseline is a mix of condensing and non-condensing tank water heaters. This was established based on water heater AHRI data. The market share of condensing versus non-condensing units should be analyzed during the next update using regional sales data as opposed to AHRI data for a more accurate market share of condensing and non-condensing tank water heaters.

Similarly, baseline efficiency is a weighted average of the thermal efficiency of condensing and non-condensing tank water heaters and their market share. The AHRI database and market share should both be researched to assess if the baseline efficiency needs to be updated.

The hot water demand per market segment and the costs (equipment, labor, and ancillary) should be validated in future updates. If the ASHRAE 90.1 prototype models continue to be used as the source for hot water demand data, the next update should determine demand using models as opposed to html output tables since the hot water use data is not complete for some building types.

Basic assumptions and methodology should be aligned between the gas commercial and multifamily water heating measures.

Supporting Documents

The cost-effective screening for these measures is number 21.3.2. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Commercial and Industrial\Commercial Water Heating\condensing tank water heat

21_3_2_OR_WA_CEC_2022_v_1_Com_Cc

MAD21_SavingsAnalysis_2021-07-21.xlsx

Version History and Related Measures

Energy Trust has been offering Commercial Condensing Tank Water Heaters measure for many years. These predate our measure approval documentation process and record retention requirements. Table 13 may be incomplete, particularly for measures approved prior to 2013.

Table 13 Version History

Date	Version	Reason for revision
12/23/2003	87.x	Approve various commercial gas measures including condensing tank water heaters.
3/14/2012	x.x	Approve various multifamily gas water heaters including condensing tank water heaters.
9/19/2014	21.1	Update savings. Base measure on building type. Merge multifamily and commercial approvals into single document.
7/13/2018	21.2	Update savings and costs, Add additional building types.
10/6/2021	21.3	Update baseline conditions, incremental costs, measure life, savings analysis method, and the hot water demand per market segment.

Table 14 Related Measures

Measures	MAD ID
Commercial and Multifamily Condensing Tankless Water Heaters and Boilers >200 kBtu/h	72
Commercial Condensing Tankless Water Heaters <200 kBtu/h	212
Multifamily Condensing Tankless Water Heaters <200 kBtu/h	196

Approved & Reviewed by

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Planning Engineer

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Energy Trust of Oregon

Measure Approval Document for Commercial and Multifamily Steam Trap Replacement

Valid Dates
1/1/2022 – 12/31/2024

End Use or Description
Steam traps are mechanical components of central steam systems in space heating and process applications. A steam trap's main function is to release the condensate that is built up in steam pipelines but allow the steam from the pipeline to escape. When steam traps fail open, they release not only condensate but also release steam from the steam system, resulting in energy and water loss. The steam system then compensates for energy loss by generating more steam leading to excessive water use and natural gas consumption by the boiler. The purpose of this measure is to replace failed steam traps, which can result in natural gas savings.

Applicability
Based on the referenced analysis and associated cost-effectiveness screening, the measures described below are approved for use in the following programs:
- Existing Buildings
- Existing Multifamily

Within these programs, applicability to the following building types are expected:
- Healthcare facilities
- Correctional facilities
- Dry cleaners / laundry facilities
- K-12 schools
- College campuses
- Office buildings
- Hotels / lodging
- Multifamily buildings (low-rise, mid-rise, and high-rise)
- Dorms
- Assisted living

Within these programs, the measure is applicable to the following cases:
- Retrofit

Purpose of Re-Evaluating Measure
This update includes the following changes:
- Updated the savings calculations methodology Grashof's method.
- Updated the measure costs
- Combined the MADs for Multifamily (MAD 40) and Commercial (MAD 42) steam traps into a single document.
- Changed the measure analysis and incentive structure from steam trap capacities ($ per lb/hr) to per steam trap ($ per steam trap).
- Removed steam trap repairs from measure eligibility.

Cost Effectiveness
Cost effectiveness is demonstrated for Oregon in Table 1 and Washington in Table 16. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2022-v1.0. In Oregon the electric avoided cost year is 2022 and the gas avoided cost year is 2022. In Washington the gas avoided cost year is 2020.

Table 15 Cost Effectiveness Calculator Oregon

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Ele	% Gas
56	Steam Trap - Multifamily Space Heating- Operating Pressure ≤5 psig	6	0	116.68	$427.83	0	$427.83	1.4	1.4	0%	100%
57	Steam Trap - Commercial Space Heating - Operating Pressure < 30 psig	6	0	331.79	$477.46	0	$477.46	3.4	3.4	0%	100%
58	Steam Trap - Commercial Space Heating - Operating Pressure ≥ 30 psig and ≤ 50 psig	6	0	697.80	$500.96	0	$500.96	6.8	6.8	0%	100%
59	Steam Trap - Dry Cleaners - Operating Pressure ≥ 75 psig and ≤ 125 psig	6	0	211.14	$329.92	0	$329.92	1.9	1.9	0%	100%
60	Steam Trap - Commercial Space Heating (High Use) - Operating Pressure < 30 psig	6	0	654.86	$477.46	0	$477.46	6.7	6.7	0%	100%
61	Steam Trap - Commercial Space Heating (High Use) - Operating Pressure ≥ 30 psig and ≤ 50 psig	6	0	1,377.23	$500.96	0	$500.96	13.4	13.4	0%	100%

Table 16 Cost Effectiveness Calculator Washington

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
56	Steam Trap - Multifamily Space Heating- Operating Pressure ≤5 psig	6	116.68	$427.83	0	$427.83	2.2	2.2	0%	100%
57	Steam Trap - Commercial Space Heating - Operating Pressure < 30 psig	6	331.79	$477.46	0	$477.46	6.1	6.1	0%	100%
58	Steam Trap - Commercial Space Heating - Operating Pressure ≥ 30 psig and ≤ 50 psig	6	697.80	$500.96	0	$500.96	12.3	12.3	0%	100%
59	Steam Trap - Dry Cleaners (no test report required) - Operating Pressure ≥ 75 psig and ≤ 125 psig	6	211.14	$329.92	0	$329.92	2.9	2.9	0%	100%
60	Steam Trap - Commercial Space Heating (High Use) - Operating Pressure < 30 psig	6	654.86	$477.46	0	$477.46	12.1	12.1	0%	100%
61	Steam Trap - Commercial Space Heating (High Use) - Operating Pressure ≥ 30 psig and ≤ 50 psig	6	1,377.23	$500.96	0	$500.96	24.2	24.2	0%	100%

Requirements

- Must replace existing steam trap.
- Steam trap must be installed in a commercial or multifamily building utilizing natural gas fired steam boiler fueled by a participating gas utility.
  For all commercial and multifamily facilities except dry cleaners, all steam traps in the system must be tested for failure status (failed open, failed closed or working) prior to replacement and only existing steam traps that have failed in open position are eligible to participate.
  For dry cleaners, all steam traps (operating or failed) are eligible to participate. In addition, a dry-cleaning facility must provide details of last steam trap replacement including date of replacement and if the steam traps being replaced have been replaced earlier with incentives from Energy Trust of Oregon.
- Washington participation is limited to multifamily and commercial properties that qualify for services through the Existing Buildings program on a commercial gas rate.

Details

Steam traps are components of central steam systems, used primarily for space heating, but also for process uses such as in dry cleaning facilities. Failed open traps release steam from the pressurized steam system either into open atmosphere or into a condensate recovery system (which is more typical), resulting in water and energy loss. The steam system then compensates for energy/water loss by generating more steam leading to excessive water use and natural gas consumption by the boiler. This measure aims to replace steam traps that have failed in the open position.

Baseline

This measure uses an Existing Condition Baseline.

Baseline equipment for multifamily and commercial space heating applications is steam traps in the failed open position.

Baseline equipment in dry cleaners is a mix of failed and not failed steam traps. The reason for considering a mix of failed and not failed steam traps as baseline in dry cleaning facilities is that although all steam traps in a dry-cleaning facility may not have failed, it is a common practice to replace all steam traps at dry cleaning facilities, irrespective of whether they have failed or not[16,17,18]. There are a few reasons for this practice (a) It is common practice to install inverted bucket (mechanical type) steam traps at dry cleaning facilities and they are relatively cheaper than other types of steam traps (b) The cost of testing steam traps is as much as or higher than simply replacing all inverted bucket steam traps (c) Compared to industrial steam systems, commercial steam systems such as dry cleaning facilities receive less maintenance and thus there is a higher likelihood that most commercial steam traps at a dry cleaning facility could need replacement.

Measure Analysis

Energy savings from replacing failed open steam traps is estimated using Grashof's method. Grashof's method was found to be a more conservative approach of estimating energy savings compared to the previous methodology used, which was Masoneilan's formula.

The loss of steam in lb/hr is estimated by Grashof's method[19] by the following equation:

$$Steam\ Loss\ (lb/hr) = 60\ \times \frac{\pi d^2}{4} \times P^{0.97} \times CD\ \times LF$$

Where,

- 60 is Grashof's constant
- d is the diameter of the orifice
- P is the pressure in the steam line at trap
- CD is the Coefficient of Discharge, which is a factor to account for the fact a steam trap's orifice is not perfectly circular, thus actual steam loss will be reduced. A generally accepted value to be used for this factor is between 0.70-0.72 which was found using secondary research [20].
- LF is Leak Factor, it is included in the equation to account for partially obstructed orifices and non-ideal steam flow. When steam traps fail in the open position, they may be found to have failed open as any of the following modes: (a) Partially Leak (b) Fully Leak (c) Partial blow through (d) Full blow through, where Partial Leak mode allows only 20-25% of Full blow through mode which leaks maximum possible steam under certain pressure and orifice size. Non-ideal steam flow can arise because when condensate also leaks along with steam, it reduces the area available for steam to leak, reducing the steam loss compared to theoretical/ideal flow and one of the factors determining this is the trap capacity. Since predicting the type of failed open status for steam trap is not possible without a steam trap audit and there is significant uncertainty with estimating non-ideal steam flow, an estimated value for this factor has to be used with prescriptive approach and the factor can be assigned an average value of anywhere between 0% and 100%. From literature survey, the following approaches for estimating Leak Factor were found:

16 Dry Cleaning Steam Trap Assessment, Energy Trust of Oregon, June 2009, https://www.energytrust.org/wp-content/uploads/2016/11/090625_Dry_Cleaning_Report0.pdf
17 Massachusetts 2013 Prescriptive Gas Impact Evaluation- Steam Trap Evaluation Phase 1, June 2015, https://ma-eeac.org/wp-content/uploads/MA-2013-Prescriptive-Gas-Impact-Evaluation-Steam-Trap-Evaluation-Phase-1.pdf
18 Steam Traps Workpaper for PY 2006-08, SoCal Gas Company, https://www.sdge.com/sites/default/files/SteamTrap%2520Workpaper%2520%252811Dec06%2529_0.doc
19 Massachusetts Steam Trap Evaluation Phase 2, March 2017, https://ma-eeac.org/wp-content/uploads/Steam-Trap-Evaluation-Phase-II.pdf
20 Inspect and Repair Steam Traps, U.S DoE Advanced Manufacturing Office, https://www.energy.gov/sites/prod/files/2014/05/f16/steam1_traps.pdf

- A Massachusetts Steam Trap Evaluation Study determined LF by collecting steam trap data of different commercial facilities and their billed natural gas usage and then empirically derived the value for it using parameter calibration analysis. Estimated range for LF was determined to be between 26.4% to 54.9%. However, the weighted average LF in this analysis was 36.9%, rounded to 37% for this analysis.
- A DOE study included a rough estimation, assuming a trap has failed with an orifice size equivalent to one-half of its fully opened condition was made, thus assigning LF a value of 50%.

The LF of 37% from the MA Steam Trap Evaluation was selected because it was estimated using actual data from steam systems in commercial facilities as opposed to the DOE LF of 50%, which was assumed due to lack of data.

$$Energy\ Saved\ per\ trap\ (Therms) = \frac{No.of\ traps\ \times Steam\ Loss\ \times Hours\ steam\ trap\ is\ under\ pressure \times Enthalpy\ of\ Vap. \times CR}{Boiler\ efficiency\ \times 10^5}$$

Where,

- Boiler efficiency is assumed to be 80% based on the 'Oregon Commercial and Industrial Boilers Market Characterization' Study by Cadeo in December 2020[22] (see Fig 10 of the report).
- Number of hours steam trap is under pressure:
  - Commercial Facilities:2,219 hours/year. This was estimated using a linear relationship between the heating degree days (HDD) and heating EFLH for commercial facilities from the 2021 Illinois Statewide Technical Reference Manual for Energy Efficiency (version 9.0)[23]. Then the weighted average (by population) HDD for all climate zones in Oregon (per the Table 14-4 of the Technical Guidelines document) and the linear relationship derived above were used to estimate heating EFLH for commercial. For commercial properties operating 24x7, see 'Commercial Facilities (High Use)' below.
  - Multifamily buildings: 2,090 hours/year, which is the weighted average of operating hours for low rise and high-rise multifamily buildings. This was estimated using a linear relationship between the heating degree days (HDD) and heating EFLH for multifamily buildings from the New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs (version 8)24. the weighted average (by population) HDD for all climate zones in Oregon (per the Table 14-4 of the Technical Guidelines document) and the linear relationship derived above were used to estimate heating EFLH for low-rise multifamily buildings in Oregon. For high-rise buildings, EFLH for commercial facilities was utilized. Then, a weighted average for low-rise and high-rise multifamily buildings was calculated using data available on number of high-rise and low-rise buildings in Oregon using data from Residential Building Stock Assessment (RBSA).
  - Dry Cleaners: 2,425 hours/year: This estimate is sourced from a Workpaper from 2006 by the Southern California Gas Company.
  - Commercial Facilities (High Use): 4,380 hours/year. This is applicable to facilities which are occupied continuously, for example, hospitals. The estimate for 4380 hours/year is based on field experience that in large facilities occupied 24x7, the steam system for space heating runs at least for 6 months, which spans from mid-October to mid-April. Hospitals, correctional facilities/prisons, transit (train/bus) stations and college campuses with central boiler plant should be considered under this category.
- Enthalpy of Vaporization values (Btu/lb) for each pressure range were taken from steam tables and are shown in Table 17.

Table 17 Enthalpy of Vaporization for steam at different pressure values

Enthalpy of Vap. (Btu/lb)	
psig	Btu/lb
0.5	968
1.5	968
5	961
15	945
30	929
50	912
75	895
100	881
125	868

- CR is Condensate Recovery Factor: When a steam trap fails in open position, some part of lost steam becomes condensate, which is essentially hot water that has been chemically treated to be fit for use in boilers. There are two scenarios to what happens to this lost steam and condensate:
  - No condensate recovery in place: In this scenario, it is assumed that all the steam lost from a failed trap is lost to a drain and neither the condensate water nor the energy is recovered from it. This is not typical.
  - Condensate recovery is in place: This is a typical scenario in steam systems, and it is assumed that most steam systems in Oregon have this in place. In this scenario, when a failed steam trap discharges into the condensate recovery system, some of that lost steam is converted to condensate and that condensate is sent back to the boiler, thereby 'saving' some of the energy that was in the lost steam.
  - If CR factor is assigned a value of 1, it indicates that there is no condensate recovery and all the energy in discharged steam is lost. However, this analysis assumes that condensate recovery is typical in steam systems and based on New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs (version 8), it is assumed to be 0.45.

Savings

Energy savings were calculated for individual cases as shown in Table 18. Table 19 shows simple averages (no weighting included) calculated from results in Table 18 for each case defined by facility type and pressure range:

Table 18 Energy savings calculated for each individual case evaluated

21 Federal Technology Alert- Steam Trap Performance Assessment, https://invenoeng.com/wp-content/uploads/2017/08/Steam-Trap-Performance-Assessment.pdf
22 EnergyTrust_CIGasBoilerMarketResearch-Memo_FINAL.pdf
23 2021 Illinois Statewide Technical Reference Manual for Energy Efficiency (version 9.0), Sep 2020, https://ilsag.s3.amazonaws.com/IL-TRM_Effective_010121_v9.0_Vol_2_C_and_I_09252020_Final.pdf
24 New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs, Version 8, July 2020, https://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/72c23decff52920a85257f1100671bdd/$FILE/NYS%20TRM%20V8.pdf

Facility Type	Operating Pressure (Psig)	Orifice Size (inch)	Estimated Energy Savings (Therms)
Multifamily	0.5	1/8	30.40
		7/32	93.10
		5/16	189.99
	1.5	1/8	32.34
		7/32	99.03
		5/16	202.11
	5	1/8	39.09
		7/32	119.72
		5/16	244.33
Commercial	5	1/8	40.53
		7/32	124.11
		5/16	253.29
		1/2	648.43
	15	1/8	60.35
		7/32	184.83
		5/16	377.19
		1/2	965.62
	30	1/8	88.21
		7/32	270.13
		5/16	551.28
		1/2	1,411.28
	50	1/8	123.95
		7/32	379.60
		5/16	774.70
		1/2	1,983.22
Dry Cleaning	75	1/8	49.27
		7/32	150.89
		5/16	307.94
	100	1/8	61.56
		7/32	188.53
		5/16	384.76
	125	1/8	73.44
		7/32	224.90
		5/16	458.99
Commercial (High Use)	5	1/8	79.99
		7/32	244.96
		5/16	499.92
		1/2	1,279.80
	15	1/8	119.11
		7/32	364.79
		5/16	744.46
		1/2	1,905.83
	30	1/8	174.09
		7/32	533.15
		5/16	1,088.06
		1/2	2,785.43
	50	1/8	244.64
		7/32	749.21
		5/16	1,529.01
		1/2	3,914.26

Table 19 Energy savings averaged by facility type and operating pressure (using results from Table 18)

Facility Type	Operating Pressure Range (Psig)	Average Energy Savings (Therms)
Multifamily	≤ 5 psig	116.68
Commercial	< 30 psig	331.79
Commercial	≥ 30 psig and ≤ 50 psig	697.80
Dry Cleaning	> 75 psig and ≤ 125 psig	211.14
Commercial (High Use)	< 30 psig	654.86
Commercial (High Use)	≥ 30 psig and ≤ 50 psig	1,377.23

Comparison to RTF or other programs

The Production Efficiency program has an offering for replacement of all steam traps, whether failed or operating correctly as approved in MAD 200, assuming a 16.3% failure rate. Savings and costs vary for industrial steam trap replacement in some cases due to differences in orifice sizes and higher hours of use.

Measure Life

The measure life is 6 years based on a 2007 study by ICF. This measure life was also confirmed from other technical resources including the New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs (version 8), the 2021 Illinois Statewide Technical Reference Manual for Energy Efficiency (version 9.0) and the Massachusetts Steam Trap Evaluation Phase 2 report.

Load Profile

The gas load profiles are as follows:

- ‘Res Heating’ for multifamily buildings
- ‘Com Heating’ for commercial facilities
- ‘Flat’ for dry cleaning facilities

Cost

Steam Trap costs vary with orifice size, design pressure and type of facility. Cost estimates were obtained from research data shared by Energy Trust. Costs range between $103 - $291 per steam trap for commercial and multifamily applications and generally increase with increase in design pressure and orifice size. For dry cleaning application, the typical steam trap installed is an inverted bucket type trap and they are generally lower in cost, with costs around $100 each. Table 20 summarizes the steam trap cost data obtained from steam trap vendors and Southern California Gas Workpaper 2007.

Table 20 Steam Traps Cost Data

Hourly Install Fee:		$150.00	**per trap**		**Labor Hours:**	1.5	**hrs per trap**
Orifice	**Δ P**	**SCG 2007 Workpaper**	**Proctor Sales**	**Trade Allies**	**Armstrong**	**McKinstry**	**Pyramid Heating**
1/8"	2 or 15	$100.56	$130.00	$70.00	-	-	-
1/8"	50 or 100	$100.56	$173.00	$70.00	-	-	-
5/16"	2 or 15	$107.09	$302.00	-	-	-	-
5/16"	50 or 100	$118.76	$465.00	-	-	-	-
1/2"	3.5	-	-	-	$151.50	$375.00	-
1/2"	15	-	-	-			-
1/2"	125	-	-	$70.00	-	-	-
3/4"	2	-	-	-	-	-	-
3/4"	50	-	-	-	$151.50	$300.00	-
3/4"	100	-	-	-		$608.00	-
1"	2	-	-	-	-	-	-
1"	50	-	-	-	$326.00	$850.00	-
1"	100	-	-	-	-	$850.00	-
1" inv. Bucket	30	-	-	-	-	-	$668.00
1" inv. Bucket	250	-	-	-	-	-	$1,067.00

The energy savings calculations consider four orifice sizes - 1/8”, 7/32”, 5/16” and 1/2" and steam system pressure ranging between 0.5 psig and 125 psig. Cost data in Table 20 was used to estimate steam trap costs. In cases where an exact match for cost was not available for a specific orifice size or pressure, an average of costs for orifice size or pressure above and below the missing orifice size/pressure range was used. This approach is explained with examples below:

- Example scenarios where exact match was used:
    a. Orifice size 1/8” and pressure <15 psig- $100.56
    b. Orifice size 5/16” and pressure <15 psig- $107.09
    c. Orifice size 1/8” and pressure ≥ 50 psig- $173.00
- Example scenarios where average of different cost sources across different orifice sizes was used:
    a. Since orifice size 7/32” was not directly available in data, averages of orifice size larger than 7/32” (which is 5/16”) and orifice size smaller than 7/32” (which is 1/8”) were calculated and then those costs were averaged between different vendor sources, for example, SCG and Proctor Sales. This approach was applied for orifice size 7/32” and pressure ≥ 50 psig.
    b. For orifice size 7/32” and pressure < 50 psig, the higher costs from 5/16” orifice size were selected to ensure the cost is not underestimated.
- Example scenarios where average within same orifice size category was used:
    a. Orifice size 5/16” and pressure 50 psig- Average of $118.76 (SCG) and $465.00 (Proctor Sales)
    b. Orifice size 1/2" and pressures ≥ 15 psig and < 50 psig- Average of $151.50 (Armstrong) and $375.00 (McKinstry)

Non-Energy Benefits

Replacing failed open steam traps will result in water savings if the steam system is setup to release condensate in an open drain. If there is an existing condensate recovery system in place (which is typical and assumed in the analysis), there will be negligible or no water savings because the steam lost condenses to water and that water goes back to the boiler via the condensate return system. This analysis assumed that condensate recovery systems are typical in most facilities and thus no water savings were estimated.

Incentive Structure

The maximum incentives listed in Table 1 and Table 16 are for reference only and are not suggested incentives. Incentives will be structured per replaced steam trap. Also, total incentive cost will not exceed project cost.

Follow-Up

Next update could consider the following:

- Aligning the savings methodology between the Existing Buildings and Production Efficiency steam traps MADs could be considered.
- Collecting the following information: (a) orifice size of steam traps being replaced and (b) operating pressure of steam traps being replaced
- If the program participation for steam traps measure increases substantially, Energy Trust could consider further research, in the form of a CRP or field test for TRVs and steam traps together to measure actual energy savings from installing TRVs and steam traps in our climate and building stock.

Supporting Documents

The cost-effective screening for these measures is number 42.3.2. It is attached and can be found along with supporting documentation at:

42.3.2 OR-WA-CE Calculator_2022_v_1

2021 Steam Traps savings calculator.xl

Version History and Related Measures

Energy Trust has been offering steam trap measures for many years. These predate our measure approval documentation process and record retention requirements. Table 13 may be incomplete, particularly for measures approved prior to 2013.

Table 21 Version History

Date	Version	Reason for revision
12/03/07	42.X	Approve steam trap replacements in dry cleaners and laundries.
05/17/10	42.X	Revise dry cleaner steam trap offering, direct install/testing by program staff.
12/02/10	42.X	Combined schools and dry cleaners into same document. Schools savings based on pilot results. Revised dry cleaner offering to allow both direct install and standard program approach.
09/18/13	40.x	Introduce MF steam traps
04/09/14	42.1	Removed direct install options and testing incentives from school and dry cleaning applications.
04/18/14	40.1	Reduced multifamily operation hours to 6 months x 12 hours
06/28/18	40.2	Added Washington Multifamily
07/19/18	42.2	Commercial savings methods revised. Update units to per capacity from per trap. Add building types. Changed dry cleaner savings to replace all.
9/10/21	42.3	Combined commercial and multifamily applications into one MAD. MAD 40 will be retired. Updated energy savings methodology and costs, changed units to per trap.

Table 22 Related Measures

Measures	MAD ID
Multifamily Thermostatic Radiator valves	45
Industrial Steam Traps	200

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Measure Approval Document for Thermostatic Radiator Valves

Valid Dates
1/1/2022 – 12/31/2024

End Use or Description
Thermostatic Radiator Valves (TRV) installed on radiators reduce heating load on the central boiler and avoid overheating in buildings with central steam or hydronic heating.

Applicability
Based on the referenced analysis and associated cost-effectiveness screening, the measures described below are approved for use in the following programs:

- Existing Multifamily Buildings

Within these programs, the measure is applicable to the following cases:

- Retrofit

Purpose of Re-Evaluating Measure
Updates include change in energy savings methodology and resulting change in energy savings.

Cost Effectiveness
Cost effectiveness is demonstrated for Oregon in Table 1 and Washington in Table 2. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2022-v1.0. In Oregon, the electric avoided cost year is 2022 and the gas avoided cost year is 2022. In Washington the gas avoided cost year is 2020. The values in these tables are per TRV installed.

Table 23 Cost Effectiveness Calculator Oregon, per valve

#	Measure	Measure Life (years)	Savings (kWh)	Savings (Therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Multifamily Buildings - Thermostatic Radiator Valve	15	0	41.48	215.00	0	215.00	2.5	2.5	0%	100%

Table 24 Cost Effectiveness Calculator Washington, per valve

#	Measure	Measure Life (years)	Savings (Therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Multifamily Buildings - Thermostatic Radiator Valve	15	42.01	215.00	0	215.00	3.5	3.5	0%	100%

Requirements
- Existing multifamily buildings with central steam or hot water boiler and radiators for space heating which do not already have TRVs installed on the radiators.
- Thermostatic valves or other zonal controls are considered baseline in new construction space heating systems, so this measure is not applicable to new construction multifamily buildings.

Details
Space heating systems in multifamily buildings often comprise a central steam or hot water boiler and pipes that transfer the steam or hot water to radiators installed in rooms/spaces. The boilers are generally controlled by a single thermostat and when the boiler operates, steam or hot water is supplied to all radiators, irrespective of the space heating requirements of a specific space. This often leads to over-heated spaces, causes residents to open windows, or run fans thereby increasing infiltration and unnecessary use of energy.

Thermostatic radiator valves (TRVs) offer a solution to this issue. They are self-operating valves installed on a radiator and provide temperature control by allowing steam to bypass a radiator based on a temperature set point. This avoids overheating of a space and reduces undesired consumption of steam in the radiator.

Baseline
This measure uses an Existing Condition Baseline.

The baseline is existing condition which is a steam/hot water radiator without a TRV installed.

Measure Analysis and Savings
Since the last savings methodology update in 2018, no studies/pilot programs were conducted in Oregon which evaluated energy savings from installing TRVs.

This savings analysis update uses findings from a detailed study performed by NYSERDA (New York State Energy Research & Development Authority) in 1995, which measured energy savings from installing TRVs on radiators in multifamily buildings in New York City[25]. The study measured baseline central steam boiler fuel usage and then measured boiler fuel usage and change in temperature in zones with radiators after installation of TRVs. The entire project including measurement & verification of energy savings spanned three years. The TRV study conducted by NYSERDA has also been cited by multiple other sources[26,27] which have attempted to investigate energy savings and benefits of installing TRVs.

[25] Thermostatic Radiator Valve (TRV) Demonstration Project, NYSERDA, September 1995, https://www.osti.gov/servlets/purl/119941
[26] Thermostatic Radiator Valve Evaluation, Jan 2015, NREL / U.S. DoE, https://www.nrel.gov/docs/fy15osti/63388.pdf
[27] Case study: Thermostatic radiator steam traps and thermostatic steam trap replacements, Environmental Defense Fund & Urban Green Council, https://www.edf.org/sites/default/files/10076_EDF_BottomBarrel_AppB.pdf

To utilize the savings results from the study for this savings analysis update, the measured energy savings from installing TRVs from the NYSERDA study were normalized for heating degree days (HDD) using average HDD for New York City[28] and this resulted in 0.008524 Therms savings/HDD per TRV installed.

Then, energy savings from installing TRVs in Oregon was calculated using the following expression:

$$Energy\ savings\ (Therms\ per\ TRV) = \frac{0.008524\ Therms}{HDD.TRV} \times Avg.HDD\ for\ Oregon$$

Average HDD for Oregon was calculated with a weighted average HDD approach using data from Table 14-4 (Table 25 below) in Energy Trust's 2021 Technical Guidelines for Energy Efficiency Measures. The weighted average HDD for Oregon considering all climate zones mentioned in the technical guidelines was calculated to be 4,867.

Table 25 Climate zones, Average HDDs and population weightings

Table 14-4 Climate zone population weightings

Climate Zone	HZ Average HDD_{65}	CZ Average CDD_{65}	Energy Trust Population Weighting
HZ1_CZ1	4,928	214	44.9%
HZ1_CZ2	4,424	396	40.3%
HZ1_CZ3	4,620	737	6.0%
HZ2_CZ1	6,665	184	6.8%
HZ2_CZ2	6,291	425	0.5%
HZ2_CZ3	6,002	851	0.5%
HZ3_CZ1	7,921	98	1.0%

Using the above equation, average energy savings from installing TRVs in Oregon is 41.48 Therms per TRV.

Energy savings from installing TRVs in area served by utilities in Washington, which is Southwestern part of Washington state was calculated using the same expression as above but with HDD for climate zone HZ1_CZ1 (4,928 HDD) because Southwest Washington territory is HZ1_CZ1. The calculated energy savings using this approach is 42.07 Therms per TRV for Washington.

Measure Life
The measure life is 15 years. This remains unchanged from last update and was also confirmed from a study by NREL.

Load Profile
The measure used 'Res Heating' profile for existing multifamily buildings.

Cost
The cost for the measure is sourced from the existing multifamily program (BEM) data between 2018 and 2020 and it is $215 per TRV (includes installation cost).

Non-Energy Benefits
Non-energy benefits include increased comfort for residents, however at this time increased comfort is a non-quantifiable parameter.

Incentive Structure
The maximum incentives listed in Table 1 and Table 2 are for reference only and are not suggested incentives. Incentives will be structured per TRV installed and should not exceed project cost.

Follow-Up
If the program participation for the TRV measure increases so that its savings contribute to 5% or more of overall natural gas savings, Energy Trust could consider performing a Measurement & Verification (M&V) study for TRVs and steam traps together to verify savings for these measures. Such an M&V study could be valuable for future MAD updates as it could provide accurate energy savings for both measures and eliminate reliance on custom studies performed without correct M&V protocols or drawing from savings results from other programs/states.

Supporting Documents
The cost-effective screening for these measures is number 45.3.2. It is attached and can be found along with supporting documentation at: \\etoo.org\home\Groups\Planning\Measure Development\Commercial and Industrial\Commercial HVAC\thermostatic radiator valves

45.3.2 OR-WA-CE Calculator_2022 v1.(

Version History and Related Measures
Table 13

Table 26 Version History

Date	Version	Reason for revision
3/4/2014	45.1	Introduced measure
5/18/2018	45.2	Added Washington. Updated cost effectiveness
9/10/2021	45.3	Updated energy savings methodology

Table 27 Related Measures

[28] New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs ver. 8, July 2020, pg. page 635/1040, https://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/72c23decff52920a85257f1100671bdd/$FILE/NYS%20TRM%20V8.pdf

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Measure Approval Document for Commercial Condensing Tankless Water Heaters ≥ 200 kBtu/h

Valid Dates
January 1, 2022 – December 31, 2024

End Use or Description
High efficiency, condensing, tankless water heater or water supply boiler, sized ≥ 200 kBtu/h, installed in a commercial or multifamily building.

Applicability
Based on the referenced analysis and associated cost-effectiveness screening, the measures described below are approved for use in the following programs:
- Existing Buildings
- Existing Multifamily (Washington Only)
- New Buildings
- Production Efficiency

Within these programs, the measure is applicable to the following cases:
- New
- Replacement

Purpose of Re-Evaluating Measure
During this update, the baseline conditions, minimum thermal efficiency, incremental costs, measure life, savings analysis method, and the hot water demand per market segment are updated for the reasons listed below:
- The baseline conditions are updated to move to a full market baseline from a code baseline.
- The minimum efficiency requirement updated to 94%.
- The hot water demand per market segment is updated
- The measure life is updated.
- The savings analysis method is updated.

Multifamily applications in Oregon are no longer approved.

Cost Effectiveness
Cost effectiveness is demonstrated for Oregon in Table 1 and Washington in Table 2. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2022-v1.0. In Oregon the electric avoided cost year is 2022 and the gas avoided cost year is 2022. In Washington the gas avoided cost year is 2020. The values in these tables are per kBtu/h input capacity.

Table 28 Cost Effectiveness Calculator Oregon, per kBtu/h

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Large Office - CTWH ≥200 kBtu/h	20	0	0.18	$1.50	$0.00	$1.50	1.2	1.2	0%	100%
2	Schools- CTWH ≥200 kBtu/h	20	0	0.16	$1.50	$0.00	$1.50	1.1	1.1	0%	100%
4	Hotel - CTWH ≥200 kBtu/h	20	0	0.47	$1.52	$0.00	$1.52	3.1	3.1	0%	100%
7	Gym/Fitness Center - CTWH >200 kBtu/h	20	0	0.25	$1.51	$0.00	$1.51	1.6	1.6	0%	100%
8	Coin-op Laundry - CTWH >200 kBtu/h	20	0	0.58	$1.50	$0.00	$1.50	3.8	3.8	0%	100%
9	All Commercial - CTWH ≥200 kBtu/h	20	0	0.18	$1.51	$0.00	$1.51	1.2	1.2	0%	100%

Table 29 Cost Effectiveness Calculator Washington, per kBtu/h

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Large Office - CTWH ≥200 kBtu/h	20	0.18	1.50	$0.00	$1.50	1.7	1.7	0%	100%
2	Schools- CTWH ≥200 kBtu/h	20	0.16	1.50	$0.00	$1.50	1.5	1.5	0%	100%
3	Healthcare - CTWH ≥200 kBtu/h	20	0.06	1.51	$0.00	$0.85	1.0	0.6	0%	100%
4	Hotel - CTWH ≥200 kBtu/h	20	0.47	1.52	$0.00	$1.52	4.5	4.5	0%	100%
5	Restaurant - CTWH ≥200 kBtu/h	20	0.04	1.52	$0.00	$0.64	1.0	0.4	0%	100%
6	Multifamily - CTWH ≥200 kBtu/h	20	0.13	1.52	$0.00	$1.52	1.3	1.3	0%	100%
7	Gym/Fitness Center - CTWH >200 kBtu/h	20	0.25	1.51	$0.00	$1.51	2.4	2.4	0%	100%
8	Coin-op Laundry - CTWH >200 kBtu/h	20	0.58	1.50	$0.00	$1.50	5.5	5.5	0%	100%
9	All Commercial - CTWH ≥200 kBtu/h	20	0.18	1.51	$0.00	$1.51	1.7	1.7	0%	100%

Requirements
For tankless commercial gas water heaters and hot water supply boilers:
- Condensing, tankless-type water heaters and hot water supply boilers used to supply domestic hot water
  - Installed equipment must not provide building space heating
- Integral tank volume <10 gal
- Must have a minimum 94.0% thermal efficiency rating
- Must have a minimum capacity of 200 kBtu/h

For commercial building projects (not multifamily):
- Programs may choose the "All Commercial" option in row 9 of the CEC which is a weighted average of savings and costs **or** the building-specific options (Large Office, Schools, Healthcare, Hotel, Restaurant, Coin-op Laundry, Gym/fitness Center).
  - Healthcare and Restaurant options are not cost-effective for Oregon, but these building types could be served utilizing the All Commercial option and are included in the all commercial weighted average.

- Programs may not use All Commercial for some projects and specific building types for other projects, as that would not conform to the weighted average scheme.
- If programs choose to use the All Commercial savings option, installation in additional building types is approved.
  - For example, in previous years the All Commercial option has been used to serve building types: Car wash, Recreation (casino), and Jail/Reformatory/Penitentiary
- If programs choose to apply the measure by specific building type (not use all commercial), the measure for each building type can be made to areas of multi-use sites for hot water systems that provide dedicated service to that area and additional building type requirements listed in Table 3.
  - For example, a university building with a cafeteria that has a dedicated hot water system could use the Restaurant building type. However, it may be advisable, at a program's discretion, to require additional review or a custom or special measure for these cases.

Table 30 Requirements by Building Type

Building Type	Requirements
Office	Must be > 5,500 sq ft
Commercial Gym	Must have shower facilities
Multifamily	Must have a shared central DHW system

Baseline

This measure uses a Full Market Baseline. The full market baseline includes a mix of non-condensing and condensing tankless water heaters.

The baseline equipment is a commercial tankless water heater or hot water supply boiler with an 89% thermal efficiency rating.

The full market baseline was determined based on the analysis of tankless water heater product list and efficiency through the AHRI database.

The analysis approach and findings are described below:

- AHRI database findings
  - Commercial instantaneous water heaters and hot water supply boilers with input capacity greater than 200 kBtu/h product data from the AHRI Directory database was analyzed. The dataset included a total of 1,533 active models.
  - The water heater type (condensing versus non-condensing) within the AHRI dataset was determined by establishing a minimum thermal efficiency of 87% for condensing tankless water heaters.
    - Of the 1,533 active models, 844 models (55%) were determined to be condensing while the remaining 689 (45%) were determined to be non-condensing.
  - Once the water heater type was identified, the average thermal efficiency for both condensing and non-condensing tankless water heaters was determined.
  - It was found that the average thermal efficiency of non-condensing tankless water heaters is 83% and that of condensing tankless water heaters is 94%.

Based on the analysis of the data from the above sources, it was established that the Full market baseline is a mix of condensing and non-condensing water heaters.

Measure Analysis

Savings were modeled using a spreadsheet-based calculation approach. Inputs from several sources such as ASHRAE prototype models, DOE National Building Stock, and AHRI were analyzed. Savings were analyzed for the following building types:

- Large Office
- Schools (primary and secondary)
- Healthcare (outpatient and hospitals)
- Hotels (small and large)
- Full-service restaurants
- Multifamily
- Gyms
- Coin-op laundry facilities
- All commercial (weighted average of all building types aside from multifamily)

Savings are based on annual hot water demand for various market segments and the thermal efficiencies of the baseline and efficient case conditions. Savings are normalized based on the equipment capacity. Where necessary, savings are weighted by percentage of each sub-sector for that market segment. Savings are calculated using the Water Heater Analysis Model, (WHAM)[29] to align with RTF[30] gas water heater measure methodology

WHAM Energy Consumption Equation for Water Heaters

The total consumption in British Thermal Units (BTU) for each market segment is calculated using that market segment's estimated daily hot water demand (in gallons), estimated temperature rise, the specific heat capacity of water, water heater efficiency, and the average density of water using this equation:

$$Q_{in} = \frac{vol \times den \times C_p \times (T_{tank} - T_{in})}{TE \times (1 + PA_{iwh})}$$

Where:

Q_{in} = total water heater energy consumption
Vol = daily draw volume, gal/day
Den = density of water, lb/gal
C_p = specific heat of water, Btu/lb-°F
T_{tank} = set point of tank thermostat, °F
T_{in} = inlet water temperature, °F
TE = thermal efficiency, %
PA_{iwh} = performance adjustment factor

[29] WHAM: A Simplified Energy Consumption Equation for Water Heaters
[30] RTF gas water heater measure methodology presentation: https://nwcouncil.app.box.com/v/20210414GasWaterHeaterPres

The total heat output required by the water heaters for each building in BTU is converted to therms. The energy input for the baseline case and proposed measure case water heaters is calculated using the base and measure case thermal efficiency values. The savings is the difference between the calculated base and measure case consumption.

Converting tank to tankless capacity

An additional step was necessary to convert the assumed Energy Plus models' storage-type DHW system capacities to a capacity appropriate to tankless systems. The conversion method used for the below equation from MAD 72.2 is presented in Chapter 7, section 7.7, *Sizing to Maximum Load* of the in the US Department of Energy document, *Technical Support Document (TSD): Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment*[31]. Conversion factors assumed demand periods, and additional detail for this conversion are presented in Appendix 7B of the TSD and summarized below.

$$Q_{in,adjust} = (Adj_{tankless} \times y \times dT \times Vol \times Tank_u \div GD_{hr} + Adj_{tankless} \times Q_{in}) \times C_p \times 1kBtu/h \div 1000Btu/h$$

Where:

$Q_{in,adjust}$ =	Adjusted tankless capacity, kBtu/h
$Adj_{tankless}$ =	Tankless adjustment factor, developed from the modified Hunter's curve to adjust the sizing methodology for water heaters with storage to suit water heaters without storage, shown in Table 31
y =	Specific weight of water, 8.29lb/gal
dT =	Assumed change in inlet temperature from the equipment's set-point, 81.86°F
Vol =	Volume of water in the tank in gallons, shown in Table 31
$Tank_u$ =	Tank utilization the fraction of hot water in the tank that is usable before the dilution by cold water lowers the temperature below an acceptable level, assumed 70%
GD_{hr} =	Demand period for building type in hours, shown in Table 31
Q_{in} =	Input capacity of the equipment, Btu/h, shown in Table 31
C_p =	Specific heat of water, 1.0 Btu/lb/°F

Table 4 summarizes the assumptions used to determine the tankless capacity necessary to serve the model buildings as well as the results.

Table 31 Modeled Tank Properties, Assumptions and Tankless Capacities for Each Building Type

DOE Prototype or Other Building Type	Modeled WH total volume (gal)	Modeled WH total capacity (kBtu/h)	Demand Period (hr)	Tankless adjustment factor	Required tankless capacity (kBtu/h)
Large Office	300	300	1	1.58	699
Primary School	206	220	1	1.58	466
Secondary School	606	665	1	1.58	1398
Outpatient Health Care	200	200	1	1.58	466
Hospital	900	900	1	3.49	3089
Small Hotel	500	500	2	3.49	1296
Large Hotel	900	900	2	3.49	2591
Full-Service Restaurant	206	227	1	6.98	2059
High-Rise Apartment	600	600	1	2.25	1991
Commercial Gym	NA	694	N/A		694
Coin Laundry	NA	914	N/A		914

In the case of the two non-DOE prototype buildings analyzed, Commercial Gym and Coin Laundry, capacities for these buildings represent tankless systems, so the capacities were not altered as for the Energy Plus building types. Information regarding typical square footage and typical number of units (clothes washers, sinks, gyms) was determined from multiple internet resources.

Hot Water Demand per market segment or sub-sector

The hot water demand for various market segments that was determined from multiple sources are detailed in the Table 32.

Table 32: Hot Water Demand per Market Segment

Market Segment	Sub-sector	Annual Hot Water Demand (Gal)	Source
Large Office	-	301,179	Annual hot water demand from ASHRAE Prototype Building Models, Table 2.2 and model summary.32 (aligns with MAD 212 and 21)
Healthcare	Outpatient Health Care	63,248	
	Hospital	501,605	
Hotel	Small Hotel	340,540	
	Large Hotel	4,953,120	
Full-service Restaurant	-	218,058	
High-rise Apartments	Multifamily	631,308	
Schools	Primary School	71,060	
	Secondary School	1,685,043	

[31] US Department of Energy, Navigant Consulting, Inc. and Pacific Northwest National Laboratory. April 18, 2016, Technical Support Document (TSD): Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Water Heating Equipment. Docket ID: EERE-2014-BT-STD-0042: https://downloads.regulations.gov/EERE-2014-BT-STD-0042-0016/attachment_1.pdf,

[32] PNNL and DOE. 2014. "Enhancements to ASHRAE Standard 90.1 Prototype Building Models." https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-23269.pdf https://www.energycodes.gov/prototype-building-models

Coin-op Laundry	-	1,252,402	Calculated using several sources for washer count for large and small facilities, loads washed per day, average water gallon per load, and percent hot water per load. Used EPA Water Use of Commercial Coin- or coin-operated washer or multi-load washer (gallons/year) equation33
Gym	-	411,897	Calculated using peak demand (gallon per hour) from Table 11 and demand ratio profile from Appendix B (secondary school showers) in the U.S. Department of Energy Commercial Reference Building Models of the National Building Stock.34

Heat Load Input Assumptions

In addition to the annual hot water consumption, the heat load calculations are based on density of water, specific heat capacity of water, and the temperature rise which is calculated as the difference between the inlet and outlet temperatures of the water heater.

Water heater inlet temperatures were calculated by using the heating zone ground water temperature from RTF's Standard Information Workbook v4.2 and taking a weighted average inlet temperature based on the previously installed project locations of this measure in the Existing and New Building program between 2018-2020. Water heating outlet setpoint temperatures are adopted from the RTF's commercial heat pump water heater measure.

The physical constants for water (density and specific heat capacity) were found using the Properties of water values from 2010 DOE TSD. Table 33 shows the assumptions for these inputs:

Table 33: Heat Load Inputs

Input	Value
Water Heater Inlet Temperature (°F)	58.1435
Water Heater Outlet Temperature (°F)	14036
Temperature Rise (°F)	81.86
Density of Water (lb/gal)	8.29
Specific Heat Capacity, Water (btu/ lb x °F)	1.000743

Thermal efficiency

Baseline case:

Using the baseline efficiency described in the baseline section above, the weighted average thermal efficiency for the full market baseline (mix of condensing and non-condensing water heaters) was determined. Table 34 summarizes the AHRI data findings and the weighted average thermal efficiency:

Table 34: Baseline Case - Weighted Average Thermal Efficiency

Value	Condensing	Non-Condensing
Percent AHRI Data (%)	55%	45%
Average AHRI Thermal Efficiency (%)	94%	83%
Weighted Average Thermal Efficiency (%)	89%	

Proposed case:

Minimum efficiency of 94% selected to align with the RTF Commercial Condensing Gas Boiler measure case efficiency and the average thermal efficiency for condensing tankless water heaters from AHRI database.

Sub-sector Weighting Methodology

To establish, savings across the market segment the weightage associated with the sub-sectors of Schools, Healthcare and Hotels was estimated.

The number (counts) of schools in Oregon were found using the Oregon Department of Education data37. In this dataset, Schools were categorized into Primary Schools, Secondary Schools, and some were not well classified. The counts of primary and secondary schools were used to estimate the weightage (%) of each sub-sector under the Schools market segment, shown in Table 35.

Similarly, counts of different healthcare facilities were found using US Bureau of Labor Statistics38. NAICS code for "Outpatient Care Centers" was assigned as Outpatient Health Care and NAICS code for "Hospitals" were assigned as Hospitals. The counts of Outpatient Care Centers and Hospitals were used to estimate the weightage (%) of each sub-sector under the Healthcare market segment, shown in Table 35.

Counts of different hotels was found using US Census of Service Industries39. Census data for hotels with less than 25 guests was assigned as Small Hotel and census data for hotels with 25 guests or more was assigned as Large Hotel. The counts of Small and Large Hotels were used to estimate the weightage (%) of each sub-sector under the Hotel market segment, shown in Table 35.

Table 35: Weightage of sub-sectors under Schools, Healthcare and Hotel market segments

Market Segment	Sub-sector	Weighting
Schools	Primary School	79%
	Secondary School	21%
Healthcare	Outpatient Health Care	84%
	Hospitals	16%
Hotel	Small Hotel	48%
	Large Hotel	52%

The savings for each sub-sector were weighted and calculated accordingly.

33 EPA *WaterSense at Work Best Practices for Commercial and Industrial Facilities,* Equation 3-9. Water Use of Commercial Coin- or coin-operated washer or multi-load washer (gallons/year): https://www.allianceforwaterefficiency.org/sites/www.allianceforwaterefficiency.org/files/assets/ws-commercial-water-sense-at-work-ci.pdf
34 NREL. 2011. "U.S. Department of Energy Commercial Reference Building Models of the National Building Stock." http://www.nrel.gov/docs/fy11osti/46861.pdf
35 Regional Technical Forum. 2020. "RTFStandardInformationWorkbook_v4_2.xlsx." https://rtf.nwcouncil.org/standard-information-workbook
36 Regional Technical Forum. 2020. "ComHPWH_v1_3.xlsm." , GPD Guide tab, Rows 45-65, Column O. https://nwcouncil.app.box.com/v/CommercialHPWHv1-3
37 Oregon Department of Education (https://www.oregon.gov/ode/reports-and-data/students/Pages/Student-Enrollment-Reports.aspx)
38 US Bureau of Labor Statistics – Quarterly Census of Employment and Wages (2019 Dataset: https://www.bls.gov/cew/downloadable-data-files.htm)
39 Census of Service Industries: Subject Series, Hotels, Motels, and Other Lodging Places: https://www.census.gov/library/publications/1996/econ/sc92-s-3.html

All Commercial Weighting Methodology

A weighted average was determined to cover all commercial building types based on project data from both Existing Building and New Buildings from 2016-2020. The data for MAD 72 was minimal, so data from MAD 212 (condensing tankless < 200 kBtuh) was included for more accurate weighting between market types. The weightings are shown in Table 36. Multifamily is not included in the weighted average because of its large market share.

Table 36: Weightage averaging across all commercial building types

Market Segment	Weighting
Large Office (Office)	5.41%
Schools (K-12 School, College/University)	21.62%
Healthcare	5.41%
Hotel (Lodging/Hotel/Motel)	16.22%
Restaurant (Food service)	24.32%
Coin-op Laundry	8.11%
Gym	18.92%

Savings

Table 37 summarizes savings results.

Table 37: Summary of gas savings in therms per market segment

Market Segment	Sub-sector	Total annual SHW end use (gal/yr)	WHAM Savings, therm/input kBtu/h	Weighting per sub-sector	All Commercial weighting per sub-sector	Weighted Savings per Market Segment (therm/input kBtu/h)
Large Office	Large Office	301,179	0.18	-	5%	0.18
Schools	Primary School	71,060	0.06	79%	22%	0.16
	Secondary School	1,685,043	0.51	21%		
Healthcare	Outpatient Health Care	63,248	0.06	84%	5%	0.06
	Hospital	501,605	0.07	16%		
Hotel	Small Hotel	340,540	0.11	48%	16%	0.47
	Large Hotel	4,953,120	0.81	52%		
Restaurant	Full-Service Restaurant	218,058	0.04	-	24%	0.04
High-Rise Apartment	Multifamily	631,308	0.13	-	-	0.13
Commercial Gym	Commercial Gym	411,897	0.25	-	19%	0.25
Coin-op Laundry	Coin-op Laundry	1,252,402	0.58	-	8%	0.58
All Commercial	All Commercial					0.18

Measure Life

Measure life is 20 years based on the DEER database. Reference EUL ID “WtrHt-Instant-Com” for Commercial Instantaneous Water Heater in the DEER database

Load Profile

The gas load profile for this measure is DHW.

Cost

Equipment costs

A dataset of 24 tankless water heaters from various online retailers collected in May of 2021 was used to determine the equipment costs of various efficiencies. The water heaters were categorized into different efficiency categories including:

- Non-condensing (≤86% TE)
- Standard efficiency condensing (>0.86%-<94% TE)
- High efficiency condensing (≥94% TE)

Each of the units were allocated under one of the above categories and the normalized cost per kBtuh was calculated per category and for the ‘all condensing’ category.

The costs for the non-condensing units and average of all condensing units was selected to establish the full market baseline costs. The costs for high efficiency condensing units are used for the proposed measure case costs.

Labor and Ancillary Costs

Labor and ancillary material costs will align with MAD 212. The costs were adopted from a California Codes and Standards Enhancement (CASE) report for high efficiency water heaters[40].

The costs used in this analysis only include costs that are incremental between the non-condensing and condensing water heaters. For non-condensing water heaters this includes costs of steel venting materials which are required for the hotter exhaust gases. For condensing water heaters this includes costs of PVC venting materials, a drain connection, neutralizer filter and a small condensate pump.

Table 38: Labor and Ancillary Costs: Non-Condensing Tankless Water Heater

Item	Cost
Metal Venting (Type-B Steel)	$482

Table 39: Labor and Ancillary Costs: Condensing Tankless Water Heater

40 California Utilities Statewide Codes and Standards Team. 2011. “High-efficiency Water Heater Ready”, Figure 8. http://title24stakeholders.com/wp-content/uploads/2017/10/2013_CASE-Report_High-efficiency-Water-Heater-Ready.pdf

Item	Cost
Venting System (PVC)	$204
Drain Connection	$113
Neutralizer Filter	$86
Condensate Pump	$40
Total	**$443**

Incremental Cost

The incremental cost per kBtuh per market sector was calculated by adding up the equipment, labor and ancillary costs per category

Table 40:Final incremental costs

Market Segment	Capacity (kBtuh)	Non-Condensing Total ($/kBtuh)	All Condensing Total ($/kBtuh)	Condensing - HE Total ($/kBtuh)	Weighted Average Baseline Cost ($/kBtuh)	Efficient Case Cost ($/kBtuh)	Incremental Cost ($/kBtuh)
Large Office	699	$17.52	$20.91	$20.89	$19.39	$20.89	$1.50
Schools (weighted average)	665	$17.56	$20.94	$20.92	$19.42	$20.92	$1.50
Healthcare (weighted average)	892	$17.37	$20.77	$20.75	$19.24	$20.75	$1.51
Hotel (weighted average)	1969	$17.08	$20.50	$20.48	$18.96	$20.48	$1.52
Full-Service Restaurant	2059	$17.07	$20.49	$20.47	$18.95	$20.47	$1.52
High-Rise Apartment	1,991	$17.08	$20.50	$20.48	$18.96	$20.48	$1.52
Coin-op Laundry	914	$17.36	$20.76	$20.74	$19.23	$20.74	$1.51
Gym	694	$17.53	$20.91	$20.90	$19.39	$20.90	$1.50
All Commercial	-	-	-	-	-	-	$1.51

Non-Energy Benefits

There are no non-energy benefits estimated for this measure

Incentive Structure

The maximum incentives listed in Table 1 and Table 2 are for reference only and are not suggested incentives. Incentives will be structured per kBtu/h capacity.

Follow-Up

The full market baseline is a mix of condensing and non-condensing tankless water heaters. This was established based on water heater AHRI data, which indicated that the market share of condensing tankless water heaters is higher than non-condensing water heaters. The market share of condensing versus non-condensing units should be analyzed during the next update using sales data as opposed to AHRI data for a more accurate market share of condensing and non-condensing tankless water heaters.

Similarly, baseline efficiency is a weighted average of the thermal efficiency of condensing and non-condensing tankless water heaters and their market share. The AHRI database and market share should both be researched to assess if the baseline efficiency needs to be updated.

The hot water demand per market segment and the costs (equipment, labor, and ancillary) should be validated in future updates. If the ASHRAE 90.1 prototype models continue to be used as the source for hot water demand data, the next update should determine demand using models as opposed to html output tables since the hot water use data is not complete for some building types.

Basic assumptions and methodology should be aligned between the three gas commercial water heating measures.

Supporting Documents

The cost-effective screening for these measures is number 72.3.2. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Commercial and Industrial\Commercial Water Heating\gas tankless water heat\Commercial and MF greater than 200

72_3_2_OR_WA_CEC_2022_v_1_Large_C

MAD72.3_SavingsAnalysis_2021-07-11.x

Version History and Related Measures

Energy Trust has been offering the commercial condensing tankless water heater measure for many years. These predate our measure approval documentation process and record retention requirements. Table 13 may be incomplete, particularly for measures approved prior to 2013.

Table 41 Version History

Date	Version	Reason for revision
2004	86.x	Approve various gas commercial measures including water service boilers
4/6/2011	72.1	Introduce commercial tankless for commercial and multifamily. Requirement is 94% efficient.
7/31/2018	72.2	Update savings based on modeled buildings. Add building types. Change efficiency requirement to 92%.
10/6/2021	72.3	Update baseline type, savings analysis method and most other measure properties. Change efficiency requirement to 94%

Table 42 Related Measures

Measures	MAD ID
Commercial and Multifamily Condensing Tankless < 199 kBtu/h	212
Commercial and Multifamily Condensing Tank Water Heaters	21
Multifamily ≤199 kBtu Condensing Tankless WH	196
New Homes Tankless	178
Residential Tankless Oregon	259
Residential Tankless Washington	197

Approved & Reviewed by

Kenji Spielman
Planning Engineer

Disclaimer

Measure Approval Document for Commercial Foodservice Cooking Measures

Valid Dates
January 1, 2022 to December 31, 2024

End Use or Description
Electric and gas food service cooking equipment.

Applicability
Based on the referenced analysis and associated cost-effectiveness screening, the measures described below are approved for use in the following programs:

- Existing Buildings, including multifamily
- New Buildings, including multifamily
- Production Efficiency

Within these programs, applicability to the following building types or market segments are expected but not limited to:

- Full and quick service restaurants, including those in mixed use buildings such as hotels or casinos.
- Cafeterias, including those in, penitentiaries, hospitals, and schools
- Grocery stores

Within these programs, the measure is applicable to the following cases:

- New
- Replacement

Purpose of Re-Evaluating Measure
This update adjusts the baseline of most equipment to a full market baseline as Energy Trust's net/gross policy has changed since the last revision. The following cooking equipment measures' baselines were impacted by Oregon appliance standard changes which are effective in 2022:

- Gas and electric fryers - moved to MAD 272 and only available through mid-2022.
- Steam Cookers - efficiency requirements changed

The following measures are no longer cost effective and no longer approved in Oregon:

- Hot Food holding cabinets – full or double size
- Rack ovens
- Griddles
- Gas convection ovens
- Gas combination ovens

The following measures are no longer approved in Washington.

- Griddles

Automated Conveyor Broilers measure have been added to this document. The size bins for this measure have changed.

Cost Effectiveness
Cost effectiveness is demonstrated for Oregon in Table 1 and Washington in Table 2. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2022-v1.0. In Oregon the electric avoided cost year is 2022 and the gas avoided cost year is 2022. In Washington the gas avoided cost year is 2020. The values in these tables are per cooking appliance.

Table 43 Cost Effectiveness Calculator Oregon, per unit

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Hot food holding cabinet - Half size	12	736.04	0.00	$498.74	$0.00	$498.74	1.1	1.1	100%	0%
11	ES v3.0 Convection Oven - Electric - Half-size	12	912.22	0.00	$359.75	$0.00	$359.75	1.8	1.8	100%	0%
12	ES v3.0 Convection Oven - Electric - Full-size	12	989.16	0.00	$703.11	$0.00	$703.11	1.0	1.0	100%	0%
15	ES v2.2 Convection Oven - Electric- Half-size	12	912.22	0.00	$359.75	$0.00	$359.75	1.8	1.8	100%	0%
16	ES v2.2 Convection Oven - Electric - Full-size	12	968.37	0.00	$640.81	$0.00	$640.81	1.1	1.1	100%	0%
19	ES v3.0 Combination Oven - Electric 3-4 pan Capacity	12	973.78	0.00	$1.00	$0.00	$735.00	1.0	701.2	100%	0%
20	ES v3.0 Combination Oven - Electric 5-40 pan Capacity	12	3,303.27	0.00	$1.00	$0.00	$2,000.00	1.2	2378.7	100%	0%
23	ES v2.2 Combination Oven - Electric	12	4,597.75	0.00	$1.00	$0.00	$2,000.00	1.7	3310.9	100%	0%
29	Steam Cookers - Electric	12	13,612.88	0.00	$1.00	$74.83	$3,400.00	2.9	10485.2	100%	0%
30	Steam Cookers - Gas	12	0.00	555.32	$1.00	$238.28	$3,400.00	1.0	5404.8	0%	100%
32	Conveyor Broilers with belt width < 20”	12	7,143.84	1,145.29	$2,523.03	$0	$2,523.03	4.7	4.7	44%	56%
33	Conveyor Broilers with belt width 20” - 26”	12	6,403.32	1,932.84	$3,145.87	$0	$3,145.87	5.0	5.0	29%	71%
34	Conveyor Broilers with belt width > 26”	12	23,849.10	3,161.26	$3,658.65	$0	$3,658.65	9.7	9.7	48%	52%
35	Conveyor Broilers with belt width < 20” - Electric Only Territory	12	7,143.84	0.00	$2,523.03	$903	$2,523.03	2.0	5.3	100%	0%
36	Conveyor Broilers with belt width 20” - 26” - Electric Only Territory	12	6,403.32	0.00	$3,145.87	$1,524	$3,145.87	1.5	5.9	100%	0%
37	Conveyor Broilers with belt width > 26” - Electric Only Territory	12	23,849.10	0.00	$3,658.65	$2,493	$3,658.65	4.7	10.9	100%	0%
38	Conveyor Broilers with belt width < 20” - Gas Only Territory	12	0.00	1,145.29	$2,523.03	$556	$2,523.03	2.6	4.7	0%	100%
39	Conveyor Broilers with belt width 20” - 26” - Gas Only Territory	12	0.00	1,932.84	$3,145.87	$498	$3,145.87	3.6	5.0	0%	100%
40	Conveyor Broilers with belt width > 26” - Gas Only Territory	12	0.00	3,161.26	$3,658.65	$1,856	$3,658.65	5.0	9.7	0%	100%

Table 44 Cost Effectiveness Calculator Washington, per unit

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Rack Oven - Gas - Single	12	129.99	$2,944.49	$0.00	$1,602.11	1.0	0.5	0%	100%
2	Rack Oven – Gas - Double	12	218.44	$1,860.27	$0.00	$1,860.27	1.4	1.4	0%	100%
5	ES v3.0 Convection Oven - Gas - Full-size	12	62.15	$745.83	$0.00	$745.83	1.0	1.0	0%	100%
6	ES v2.2 Convection Oven - Gas - Full-size	12	92.67	$995.88	$0.00	$995.88	1.1	1.1	0%	100%
8	ES v3.0 Combination Oven – Gas	12	207.91	$3,063.53	$0.00	$2,562.46	1.0	0.3	0%	100%
9	ES v2.2 Combination Oven - Gas	12	296.48	$3,063.53	$0.00	$3,063.53	1.2	1.2	0%	100%
13	Steam Cookers - Gas	12	555.32	$1.00	$238.28	$3,400.00	2.0	8,990.0	0%	100%
15	Conveyor Broilers with belt width < 20”	12	1,145.29	$2,523.03	$550.09	$2,523.03	5.6	7.6	0%	100%
16	Conveyor Broilers with belt width 20” - 26”	12	1,932.84	$3,145.87	$493.03	$3,145.87	7.6	9.0	0%	100%
17	Conveyor Broilers with belt width > 26”	12	3,161.26	$3,658.65	$1,836	$3,658.65	10.6	15.2	0%	100%

Additional cooking equipment types were analyzed but are not included in these tables because they are not cost effective and not approved. Further information can be found in the supporting documents.

Requirements

- ENERGY STAR Products must appear on the most current ENERGY STAR Certified list under the Commercial Food Service Equipment program.
- ENERGY STAR specifications are expected to change for some measures while these offerings are approved. DOE has indicated that version with changes for rack, convection, and combination ovens. Version 3.0 will likely go into effect in late 2022 or early 2023 until which version 2.2 will be in effect. For the Program implementation, version 2.2 will be in effect until January 1, 2023 or until 3 months after version 3.0 is launched.

Equipment-specific requirements

- All products must meet the criteria shown in Table 45.
- Convection ovens must be capable of accommodating standard full-size sheet pans measuring 18 x 26 x 1 inch to be considered as full size, half-size sheet pans measuring 18 x 13 x 1-inch to be considered half size.
- Single Rack ovens must be capable of accommodating one removable single rack of standard sheet pans measuring 18 x 26 x 1 inch.
- Double rack ovens must be capable of accommodating two removable single racks of standard sheet pans measuring 18 x 26 x 1-inch, or one removable double width rack.
- Hot Food Holding Cabinets must have interior volume less than 13 cubic feet to be considered half-size
- Broilers must be installed under a Type I Hood
- Broilers fueled by an alternate fuel such as propane may be considered and booked under the electric only territory measure.

Table 45 Required Efficiency levels

Equipment	Required Efficiency levels
Hot Food Holding Cabinets	ENERGY STAR version 2.0[41]
Convection Ovens	ENERGY STAR version 2.2[42] until ENERGY STAR version 3.0[43] is in effect
Combination Ovens	ENERGY STAR version 2.2 until ENERGY STAR version 3.0 is in effect
Rack Ovens	ENERGY STAR version 2.2 until ENERGY STAR version 3.0 is in effect (Both version requirements are the same)
Electric Steam Cookers	Cooking energy efficiency >= 62% & Idle Rate (W) <= 300W
Gas Steam Cookers	Cooking energy efficiency >= 43% & Idle Rate (Btu/hr) <= 2770 BTU/hr
Automated Conveyor Broilers	Must be an automatic conveyor broiler with a catalyst and have one of the following burner features: • an input rate less than 80 kBtu/h or • dual stage or modulating gas valve with a capability of throttling the input rate below 80 kBtu/h.

Baseline
This measure uses full market baseline.

Ovens and Holding Cabinets Baseline
An ENERGY STAR study on market penetration titled ‘ENERGY STAR Unit Shipment and Market Penetration Report Calendar Year 2019 Summary’[44] was used to obtain the penetration rate (%) of ENERGY STAR products in the market and this rate is used to allocate market share of ENERGY STAR vs non-ENERGY STAR equipment. This methodology is followed by RTF as well. Table 46 summarizes the ENERGY STAR baseline type, efficient case required, and ENERGY STAR market penetration rates used for each equipment.

Table 46 ENERGY STAR Market penetration rates

Equipment	2019 ENERGY STAR market penetration rate
Hot Food Holding Cabinets	13%
Convection Ovens	51%
Combination Ovens	51%
Rack Ovens	51%

We assume that the market penetration will not change when ENERGY STAR versions are updated.

Steam Cookers Baseline
Per House Bill 2062[45] Commercial Steam Cookers manufactured on or after January 1, 2022, must meet the qualification criteria, testing requirements and other requirements for ENERGY STAR version 1.2. This code requirement will change the penetration rate of ENERGY STAR equipment in the market to effectively 100% of new equipment, changing the market baseline to be equivalent to code.

Broilers Baseline
There are no federal guidelines or ENERGY STAR ratings for broilers. The baseline equipment is a conveyor broiler, meeting specifications described in the Workpaper SWFS017-02 (Automated Conveyor Broiler, Commercial), available on the California electronic Technical Reference Manual (eTRM).[46] Given the small number of broiler projects (15) participating in Energy Trust programs from 2019 to 2020, it is assumed that the efficient equipment has little to no market share. The baseline broiler is assumed to be an automatic conveyor broiler capable of maintaining a temperature above 600°F with a tested idle rate greater than:
- 40kBtu/h for a belt narrower than 20"
- 60kBtu/h for a belt between 20 and 26"
- 70kBtu/h for a belt wider than 26"

Baseline equipment performance specifications in the SWFS017-02 workpaper are based upon lab tests applying American Society for Testing and Materials (ASTM) procedures for conveyor broilers (ASTM F2239-10), generated by Fischer and Nickel[47] as part of PG&E’s Emerging Technologies Program. Some of these values were verified and supplemented by field test data collected by SCG & PG&E.

Measure Analysis
The savings calculations for all equipment except broilers were performed using ENERGY STAR’s Commercial Kitchen Equipment Savings Calculator available on the ENERGY STAR website. The calculator provides the total energy consumption for non-ENERGY STAR and ENERGY STAR equipment. Savings are the difference in consumption between the baseline consumption and efficient equipment. For most equipment types, the total energy use is a sum of the:
- Cooking energy (function of cooking energy efficiency, pounds of food cooked per day)
- Preheat energy (function of preheat energy, number of preheats per day and preheat time)
- Idle energy (function of idle energy rate, equipment idle time, production capacity, operating hours, pounds of food cooked per day).

Assumptions for the hours of operation and quantity of food cooked with each approved equipment type are shown in Table 47. Most of these assumptions are based on RTF research. Operating hours for broilers are based on Southern California Edison’s field research of quick service restaurants that serve all three meals - breakfast, lunch, and dinner (estimated to have larger conveyor size > 20”) and the ones that do not serve breakfast (assumed to have small conveyor size <20”). The hours of restaurants that serve all three meals is higher than the hours of operation used for other food service equipment which assumes 10-14 hours of operations for different equipment types.

Table 47 Cooking equipment usage assumptions.

41 https://www.energystar.gov/ia/partners/product_specs/program_reqs/Commercial_HFHC_Program_Requirements_2.0.pdf
42 https://www.energystar.gov/sites/default/files/Commercial%20Ovens%20Final%20Version%202.2%20Specification.pdf
43 https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%203.0%20Commercial%20Ovens%20Draft%201%20 Specification.pdf
44 https://www.energystar.gov/sites/default/files/asset/document/2019%20Unit%20Shipment%20Data%20Summary%20Report.pdf
45 https://olis.oregonlegislature.gov/liz/2021R1/Downloads/MeasureDocument/HB2062/Introduced
46 “Automatric Conveyor Broiler, Commercial.” https://www.caetrm.com/measure/SWFS017/02/
47 Fisher-Nickel, Inc. 2017. “Energy Efficient Underfired Broilers, ET ProjectNumber: ET16PGE1941.” Prepared on behalf of Pacific Gas & Electric. March 24, 2017.

Equipment	Daily hours of Operation (hours)	Annual Days of Operation (days)	Food Cooked per day (lbs)
Hot food holding cabinets	14	343	NA
Rack Ovens single size	11	291	600
Rack Ovens double size	11	291	1200
Convection Ovens full size	10	270	122
Convection Ovens half size	10	270	61
Combination Ovens	11	297	283
Steam Cookers	13	308	144
Conveyor Broilers with belt width < 20"	12	363	75
Conveyor Broilers with belt width 20" - 26"	18	363	150
Conveyor Broilers with belt width > 26"	18	363	110

The average energy efficiency, production capacity, pre-heat energy and idle energy rate for each approved and federally regulated equipment type are shown in Table 48 through Table 58. For each variable, values are shown for standard non-ENERGY STAR rated equipment, qualifying ENERGY STAR equipment as well as the full market baseline. These are generally the default values per the ENERGY STAR's Commercial Kitchen Equipment Savings Calculator or based on analysis using data from ENERGY STAR Qualified Products List (QPL). Full market baseline is the weighted average of standard and efficient equipment based on the market penetration shown in Table 46.

Hot Food Holding Cabinets

There is only a hot food holding cabinet ENERGY STAR specification for electrically-heated cabinets. This equipment comes in three sizes, but only the half size is approved as the others are not cost effective. Hot food holding cabinets, unlike other food service cooking equipment are for storage so cooking efficiency, production capacity and preheat energy are not applicable to this technology. Idle energy rate is shown in Table 48.

Table 48 Hot Food Holding Cabinets ENERGY STAR v2.0 – Electric –Efficiency Values

Hot Food Holding Cabinets ENERGY STAR v2.0 - Electric	Non-ES			ES v2.0			Market Baseline		
	Half	Full	Double	Half	Full	Double	Half	Full	Double
Average Idle Energy Rate (W)	327.9	518.9	601.4	145.4	286.3	402.8	304.2	488.7	575.6

Rack Ovens

Rack ovens are only ENERGY STAR rated for gas. This equipment comes in single and double sizes. Neither size is approved in Oregon as they are not cost effective. In Washington, single and double sized rack ovens are approved. Rack oven efficiency metrics are shown in Table 49. The ENERGY STAR rating change from version 2.2 to version 3.0 does not impact efficiency of this equipment.

Table 49 Rack Ovens ENERGY STAR v2.2 and v3.0 – Gas –Efficiency Values

Rack Ovens ENERGY STAR v2.2 and 3.0 - Gas	ES		Non-ES		Market Baseline	
	Single	Double	Double	Single	Single	Double
Average Energy Efficiency (%)	51	58	52	44	48	55
Average Production Capacity (lb/hr)	139	289	273	144	142	281
Average Preheat Energy (Btu)	42,522	71,598	87,705	49,343	45,864	79,491
Average Idle Energy Rate (Btu/hr)	20,680	22,786	35,608	27,120	23,835	29,069

Convection Ovens

The ENERGY STAR rating for convection ovens is expected to change from 2.2 to 3.0 in late 2022 or early 2023. Table 50 and Table 52 show efficiency metrics for ENERGY STAR version 2.2 and Table 51Table 52**Error! Reference source not found.** and Table 53 show metrics for ENERGY STAR version 3.0.

Electric Convection ovens are rated in half and full sizes.

Table 50 Convection Ovens ENERGY STAR v2.2 – Electric – Efficiency Values

Convection Ovens ENERGY STAR v2.2 - Electric	ES v2.2		Non-ES		Market Baseline	
	Half-size	Full-size	Half-size	Full-size	Half-size	Full-size
Average Energy Efficiency (%)	75	78	64	71	70	74
Average Production Capacity (lb/hr)	42	96	45	88	43	92
Average Preheat Energy (Wh)	N/A	1,416	885	1,563	885	1,488
Average Idle Energy Rate (W)	807	1,283	1,510	1,988	1,152	1,629

Table 51 Convection Ovens ENERGY STAR v3.0 – Electric –Efficiency Values

Convection Ovens ENERGY STAR v3.0 - Electric	ES v3.0		Non-ES		Market Baseline	
	Half-size	Full-size	Half Size	Full Size	Half-size	Full-size
Average Energy Efficiency (%)	75	80	64	75	70	78
Average Production Capacity (lb/hr)	42	75	45	102	43	88
Average Preheat Energy (Wh)	N/A	806	885	1,567	885	1,179
Average Idle Energy Rate (W)	807	917	1,510	1,584	1,152	1,244

Gas convection ovens are only rated in full sizes. Gas convection ovens are not approved or cost effective in Oregon. They are approved in Washington.

Table 52 Full size Convection Ovens ENERGY STAR v2.2 – Gas – Efficiency Values

Convection Ovens ENERGY STAR v2.2 - Gas	ES v2.2	Non-ES	Market Baseline
Average Energy Efficiency (%)	51	41	46
Average Production Capacity (lb/hr)	95	85	90
Average Preheat Energy (Btu)	10,277	13,096	11,658
Average Idle Energy Rate (Btu/hr)	9,497	16,425	12,892

Table 53 Full Size Convection Ovens ENERGY STAR v3.0 – Gas –Efficiency Values

Convection Ovens ENERGY STAR v3.0 - Gas	ES v3.0	Non-ES	Market baseline
Average Energy Efficiency (%)	53	47	50
Average Production Capacity (lb/hr)	93	93	93
Average Preheat Energy (Btu)	10,385	11,162	10,766
Average Idle Energy Rate (Btu/hr)	7,680	12,239	9,914

Combination Ovens

The ENERGY STAR rating for combination ovens is expected to change from 2.2 to 3.0 in late 2022 or early 2023. Table 54 and Table 56 show efficiency metrics for ENERGY STAR version 2.2 while Table 55 and Table 57 show metrics for ENERGY STAR version 3.0. ENERGY STAR v3.0 requirements for electric combination ovens includes a sizing parameter based on pan capacity, which is not included in the 2.2 specification and does not apply to gas equipment. Therefore, electric combination oven measures based on v3.0 have an additional measure identifier for pan capacity.

Combination ovens are capable of functioning as either convection ovens or steamers. Based on RTF data, the analysis assumes cooking time is split evenly between the two modes. ENERGY STAR does not specify water use for combination ovens as it does steamers, so no water savings are quantified for this equipment.

Table 54 Combination Ovens ENERGY STAR v2.2 – Electric – Efficiency Values

Combination Ovens ENERGY STAR v2.2 - Electric	ES v2.2		Non-ES		Market Baseline	
Mode	Conv.	Steam	Conv.	Steam	Conv.	Steam
Average Energy Efficiency (%)	80	64	70	48	75	56
Average Production Capacity (lb/hr)	143	205	103	147	123	176
Average Preheat Energy (Wh)	1,877	1,437	3,015	1,850	2,434	1,639
Average Idle Energy Rate (W)	1,398	1,764	2,233	6,854	1,807	4,258

Table 55 Combination Ovens ENERGY STAR v3.0 – Electric – Efficiency Values

Combination Ovens ENERGY STAR v3.0 - Electric	ES v3.0				Non-ES				Market Baseline			
	3-4 pan		5-40 pan		3-4 pan		5-40 pan		3-4 pan		5-40 pan	
Mode	Conv.	Steam	Conv.	Steam	Conv.	Steam	Conv.	Steam	Conv.	Steam	Conv.	Steam
Average Energy Efficiency (%)	76	61	81	65	64	46	72	52	70	54	77	59
Average Production Capacity (lb/hr)	37	59	178	251	31	44	105	151	34	51	142	202
Average Preheat Energy (Wh)	311		1,362		767		2,479		534		1,910	
Average Idle Energy Rate (W)	574	1,080	1,596	2,056	751	2,098	2,074	5,844	661	1,579	1,830	3,912

Gas combination ovens are not approved or cost effective in Oregon. They are only approved in Washington.

Table 56 Combination Ovens ENERGY STAR v2.2 – Gas – Efficiency Values

Combination Ovens ENERGY STAR v2.2 - Gas	ES v2.2		Non-ES		Market Baseline	
Mode	Conv.	Steam	Conv.	Steam	Conv.	Steam
Average Energy Efficiency (%)	60	50	44	30	52	40
Average Production Capacity (lb/hr)	184	273	112	159	149	217
Average Preheat Energy (Btu)	8,508		9,164		8,829	
Average Idle Energy Rate (Btu/hr)	5,866	7,174	12,944	35,017	9,334	20,817

Table 57 Combination Ovens ENERGY STAR v3.0 – Gas – Efficiency Values

Combination Ovens ENERGY STAR v3.0 - Gas	ES v3.0		Non-ES		Market Baseline	
Mode	Conv.	Steam	Conv.	Steam	Conv.	Steam
Average Energy Efficiency (%)	61	52	50	37	55	45
Average Production Capacity (lb/hr)	162	262	152	211	157	237
Average Preheat Energy (Btu)	7,804		8,194		7,995	7,995
Average Idle Energy Rate (Btu/hr)	4,853	6,311	10,646	24,749	7,691	15,346

Steam Cookers

State appliance standards in Oregon and Washington will require all new steam cookers to meet ENERGY STAR v1.2. So, the market baseline is equivalent to ENERGY STAR. The program researched available products and developed a specification at the 50th percentile above ENERGY STAR. The efficient equipment properties are sources from that research. The idle rates and cooking efficiencies used in analysis match the participation requirements.

In addition to energy savings, highly efficient steam cookers use less water. Table 58 shows efficiency metrics for both gas and electric steam cookers, including water use.

Table 58 Steam Cookers– Electric and Gas –Efficiency Values

Steam Cookers - Electric and Gas	Efficient - 50 Percentile		Market Baseline - ES v1.2	
	Ele	Gas	Ele	Gas
Average Energy Efficiency (%)	62%	62%	50%	38%
Production Capacity (lb)	110	110	125.6	92.0
Preheat Energy (Btu/hr)	1,745	1,745	1,750	9,617
Idle Energy Rate (Btu/hr)	300	300	800.	12,500
Water Use (Gallons / hr)	1.5	1.5	2.6	4.8

Broilers

Conveyor broilers typically use gas heat, though they save both gas and electricity in idle mode. There is no ENERGY STAR rating or federal minimum efficiency for this equipment. Conveyor broilers are available in multiple sizes, designated by the width of the conveyor belt.

The industry standard method ASTM F2239-10 was used to test the performance of conveyor broilers. The test method evaluates the energy consumption and cooking performance of conveyor broilers through characterizing the broiler preheat, idle and cooking in terms of gas and electric energy consumption. The laboratory test results are used as inputs for Equation 1, and they are summarized in Table 59. Lab test results show that the electricity energy usage is mostly driven by idle energy. Therefore, cooking and pre-heat energy are negligible in the assessment of the annual electricity consumption.

Equation 1 – Daily Energy Consumption for Conveyor Broilers

$$E_{daily} = \frac{W}{PC} \times \left(q_{gas,h} + q_{elec,h}\right) + \left(q_{gas,i} + q_{elec,i}\right) \times \left(t_{on} - \frac{W}{PC} - \frac{n_p \times t_p}{60}\right) + n_p \times E_p$$

Where:

- E_{daily} = Daily energy consumption (Btu/day)
- W = pounds of food cooked per day (lbs)
- PC = Production capacity (lbs/hr)
- $q_{gas,h}$ = heavy load cooking gas energy rate (Btu/hr)
- $q_{elec,h}$ = heavy load cooking electric energy rate (kW*)
- $q_{gas,i}$ = idle gas energy rate (Btu/hr)
- $q_{elec,I}$ = idle electric energy rate (kW*)
- t_{on} = total time the appliance is on per day
- n_p = number of preheats per day
- t_p = duration of preheat
- E_p = preheat energy (Btu)

*convert to Btu

Table 59 Automatic Conveyor Broiler Efficiency Values

Conveyor Broilers - Gas	Efficient Models			Market Baseline		
	belt width < 20”	belt width 20” - 26”	belt width > 26”	belt width < 20”	belt width 20” - 26”	belt width > 26”
Cooking Energy Rate (Btu/hr)	28,500	50,938	67,117	55,000	78,240	111,210
Production Capacity (lb/hr)	21	41.7	86	29	47.6	90
Preheat Energy (Btu)	13,500	14,214	13,500	11,500	14,130	42,500
Gas Idle Energy Rate (Btu/hr)	28,000	47,960	57,000	54,500	78,120	104,000
Electrical Idle Energy Rate (kW)	0.20	0.37	1.15	1.84	1.35	4.8

Savings

The savings for all the approved measures are included in Table 1 and Table 2.

Comparison to RTF or other programs

All equipment except broilers are also RTF measures. For those equipment types, there are some differences between RTF and Energy Trust analysis. The Energy Trust analysis is based on the ENERGY STAR calculator, while RTF performed custom engineering calculations for the measure analysis. Additionally, RTF differentiates a variety of sizes (eg: by pan size) for all equipment, while Energy Trust measure offering aligns with the ENERGY STAR specifications and simplifies most equipment to be an average of all sizes. The goal for the Energy Trust analysis was to simplify the measure offering for the market to the extent possible.

Some notable differences include:

- For steam cookers: RTF analysis is based on griddle number of pans (3, 4, 5, 6, 10+ pans) while the Energy Trust analysis is based on the most common pan size found per a CA workpaper of 6 pans.
- For combination ovens: RTF analysis uses sizes of ovens based on different quantities of pans (3-4 pans, 5-14 pans, 15-28 pans, 29-40 pans) while the Energy Trust analysis aligns with ENERGY STAR specifications (3-4 pans, 5-40 pans).
- For griddles: RTF analysis is based on griddle surface area (3ft^2 to 15 ft^2), while Energy Trust analysis aligns with ENERGY STAR specifications based on normalized idle energy per ft^2.
- Measure life: For all equipment, RTF uses a measure life analysis based on the equipment’s total estimated EUL in hours across its lifetime divided by the average annual hours of use of the facility or business type and ranges between 8 to 12.4 years for various equipment types. Energy Trust analysis uses the EUL per the DEER database, which is 12 years for all equipment types.

Measure Life

A useful equipment life of 12 years is used based on the California Database for Energy Efficiency Resources (DEER) for commercial cooking equipment. The DEER IDs for all equipment types are included in the savings calculator for reference. This is also the default measure life used in the Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. The ENERGY STAR calculator cites FSTC research on available models in 2009 as the source for a 12-year measure life.

Load Profile

For Oregon, the electric load profile used is Restaurant Cooking, while the gas load profile used is Flat-gas.

For Washington, the gas load profile is Commercial Cooking.

Cost

For all equipment except broilers, the incremental equipment cost is calculated as the difference between an ENERGY STAR and a full-market or code baseline equipment cost. The costs are sourced from RTF calculators, where available and especially for the Non-ENERGY STAR equipment mix of the full market baseline. When RTF cost data is not available or is out of date, cost data is gathered from online retail websites such as following:

- *https://www.webstaurantstore.com/restaurant-equipment.html*
- *https://www.restaurantsupply.com/restaurant-equipment*

Because market share is unknown beyond the mix of ENERGY STAR and non-ENERGY STAR, a straight average of all models with available pricing was used.

Steam cookers vary widely in size and cost. Many of the available models for cost analysis were not the mid-size equipment assumed in savings calculations. To normalize, steam cooker costs were calculated by multiplying the average cost per pan by an average of 6.4 pans per cooker to match inputs into ENERGY STAR Calculator

Table 60 includes a summary of inefficient, efficient, market baseline based on the weighting shown in Table 46, and incremental costs for all approved equipment. For measures where the incremental cost indicates a negative cost, $1 is used in cost effectiveness testing.

Table 60 - Cost Summary for all equipment types

Equipment Type	Inefficient equipment cost	Full Market Baseline cost	Efficient equipment cost	Incremental Cost
Hot food holding cabinet - Half size	$3,444.50	$3,519.02	$4,017.76	$498.74
Rack Oven - Gas - Single	$11,946.03	$15,011	$17,955.19	$2,944.49
Rack Oven - Gas - Double	$18,843.28	$20,779.48	$22,639.75	$1,860.27
ES v3.0 Convection Oven - Electric - Half-size	$4,452.50	$4,826.93	$5,186.68	$359.75
ES v3.0 Convection Oven - Electric - Full-size	$5,367.22	$6,099.03	$6,802.14	$703.11
ES v3.0 Convection Oven - Gas - Full-size	$5,885.28	$6,661.55	$7,407.38	$745.83
ES v2.2 Convection Oven - Electric- Half-size	$4,452.50	$4,826.93	$5,186.68	$359.75
ES v2.2 Convection Oven - Electric - Full-size	$4,891.67	$5,558.63	$6,199.45	$640.81
ES v2.2 Convection Oven - Gas - Full-size	$4,869	$5,905.20	$6,901.09	$995.88
ES v3.0 Combination Oven - Electric 3-4 pan Capacity	$8,038.43	$6,727.68	$5,468.33	-$1,259.35
ES v3.0 Combination Oven - Electric 5-40 pan Capacity	$21,742.58	$20,206.78	$18,731.20	-$1,475.58
ES v2.2 Combination Oven - Electric	$21,756.40	$21,088.81	$20,447.40	-$641.41
ES v3.0 Combination Oven - Gas	$23,427.90	$26,616.47	$29,680.00	$3,063.53
ES v2.2 Combination Oven - Gas	$23,427.90	$26,616.47	$29,680.00	$3,063.53
Steam Cookers – Electric	$12,133.99	$12,133.99	$11,139.96	-$994.02
Steam Cookers – Gas	$13,335.77	$13,335.77	$11,334.64	-$2,001.13
Conveyor Broilers with belt width < 20”	$8,881.00	$8,881.00	$11,404.00	$2,523.00
Conveyor Broilers with belt width 20” - 26”	$10,752.00	$10,752.00	$13,898.00	$3,146.00
Conveyor Broilers with belt width > 26”	$12,552.00	$12,552.00	$16,210.00	$3,658.00

Non Energy Benefits

Steam cookers: ENERGY STAR rated electric and gas steam cookers save 4,199 gallons and 13,071 gallons of water annually, respectively. These are included as a non-energy benefits in the cost-effectiveness analysis. Combination ovens also save water, though the ENERGY STAR calculator does not quantify how much, so it is not included in this analysis.

In single-fuel territories, customer bill savings for the out of territory fuel are accounted as non-energy benefits. For broilers that use a fuel other than natural gas, such as propane, fuel savings are assumed to be equivalent to natural gas bill savings.

Incentive Structure

The maximum incentives listed in Table 1 and Table 2 are for reference only and are not suggested incentives. Incentives will be structured per unit.

We understand that new equipment, as considered in analysis are not the only options available and customers might be purchasing equipment from other trade allies with different costs. Also, restaurant owners sometimes purchase used equipment. Used equipment is much less expensive than new and our incentives may be necessary to move those customers to efficient equipment, therefore we continue to offer incentives that appear to be above incremental cost.

Follow-Up

- For ovens, ENERGY STAR version 3.0 will go into effect likely in 2022. The timeline for this should be monitored to change the ovens requirements from version 2.2. to version 3.0.
- Any future code changes must be tracked for future revisions.
- Additional cost research including market share and local distributor pricing is recommended.
- The latest ENERGY STAR market penetration rates must be researched and used for future revisions.
- If released, Federal guidelines for broilers should be considered. If available, new field test data should be used to confirm or update the energy parameters used to assess the unit energy consumption.

Supporting Documents

The cost-effective screening for these measures is number 101.4.2. It is attached and can be found along with supporting documentation at: \\Etoo.org\home\Groups\Planning\Measure Development\Commercial and Industrial\Food Service\Cooking Equipment

101.4.2 OR-WA CEC 2022v1.0 Food Servi

2021_MAD 101_All Equipment Savings

Version History and Related Measures

Energy Trust has been offering the food service measure suite for many years. These predate our measure approval documentation process and record retention requirements. Table 13 may be incomplete, particularly for measures approved prior to 2013.

Table 61 Version History

Date	Version	Reason for revision
4/7/05	x.x	Revise gas fryer measures
4/8/05	x.x	Approve gas griddles
12/12/05	x.x	Approve electric hot food holding cabinets and steam cookers
3/22/07	x.x	Revise gas fryer savings, add gas convection oven
10/14/09	101.x	Merge several cooking approvals into single document, revise all savings and costs, remove electric griddles and electric fryers.
7/16/13	101.x	Update fryer costs
9/23/13	101.x	Change format to include maximum incentives
8/7/14	101.1	Update costs. Add electric griddles, electric fryers, electric combination ovens and gas combination ovens. Add multifamily and production efficiency as applicable programs.
7/9/2018	101.2	Update hours of use and latest ENERGY STAR specifications. Cost updates
7/25/18	101.3	Add rack ovens
4/5/2019	233.1	Introduce conveyor broiler measures
4/5/2019	233.2	Update valid dates for immediate launch.
4/16/19	233.3	Correct requirements regarding venthood types
10/12/21	101.4	Removing several equipment types. Update costs and savings. Merged with MAD 233 which will be retired. Fryers moved to MAD 272

Table 62 Related Measures

Measures	MAD ID
Commercial Dishwashers	35
Commercial Ice Machines	90
Venthood Controls Prescriptive	122
Venthood Controls Calculator	184
Commercial Fryers (temporary)	272

Approved & Reviewed by

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Sr. Planning Engineer

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Measure Approval Document for Radiant Infrared Heaters

Valid Dates
1/1/2022-12/31/2024

End Use or Description
Use of direct-fired radiant heaters to heat large open areas.

Applicability
Based on the referenced analysis and associated cost-effectiveness screening, the measures described below are approved for use in the following programs:
- Existing Buildings
- New Buildings
- Production Efficiency

Within these programs, applicability to the following building types or market segments or program tracks are expected:
- Gymnasiums
- Warehouses
- Manufacturing Buildings
- Other buildings with large rooms and high ceilings

Within these programs, the measure is applicable to the following cases:
- Retrofit
- New

Purpose of Re-Evaluating Measure
Incremental costs have decreased compared to the prior version, maximum incentives are also reduced accordingly.

Cost Effectiveness
Cost effectiveness is demonstrated for Oregon in Table 1 and Washington in Table 2. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2022-v1.0. In Oregon the electric avoided cost year is 2022 and the gas avoided cost year is 2022. In Washington the gas avoided cost year is 2020. The values in these tables are per kBtu/h input heating capacity.

Table 63 Cost Effectiveness Calculator Oregon, per kBtu/h

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incr. Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Infrared Radiant Heaters, low intensity, non-modulating, non-condensing	20	2.50	2.93	$1.31	$0	$1.31	37.3	37.3	6%	94%
2	Infrared Radiant Heaters, low intensity, modulating, non-condensing	20	2.44	3.80	$2.44	$0	$2.44	25.6	25.6	4%	96%
4	Infrared Radiant Heaters, low intensity, non-modulating, non-condensing - gas only	20	0	2.93	$1.31	$0.19	$1.31	35.1	37.0	0%	100%
5	Infrared Radiant Heaters, low intensity, modulating, non-condensing - gas only	20	0	3.80	$2.44	$0.19	$2.44	24.5	25.5	0%	100%

Table 64 Cost Effectiveness Calculator Washington, per kBtu/h

#	Measure	Measure Life (years)	Savings (therms)	Incr. Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Infrared Radiant Heaters, low intensity, non-modulating, non-condensing	20	2.93	$1.31	$0.19	$1.31	55.5	57.4	0%	100%
2	Infrared Radiant Heaters, low intensity, modulating, non-condensing	20	3.80	$2.44	$0.19	$2.44	38.65	39.6	0%	100%

Requirements
Infrared Radiant Heater installation must meet all specifications listed below:
- Facility has qualifying gas service. Electric-only projects are not eligible.
- Low intensity type discharge
- Natural gas-fired
- Non-condensing type
- Positive pressure (“standard”) systems
- Only indoor areas qualify for incentives due to building code requirements for outdoor installations.
- Areas greater than 20,000 sq ft are excluded from the offering due to installation complexity and cost and savings variability.

Details
Radiant infrared heaters are an efficient alternative to convective type gas-fired unit heaters in buildings with spaces with high ceilings, such as gymnasiums and warehouses. They reduce heat loss from thermal stratification along the height of the building and require only a minimal amount of fan energy for combustion purposes, as opposed to a convection-based system, which must force the warm air to its destination. With a forced air system, heat escapes as doors are opened and the system must reheat the quantity of air that has escaped as if from a cold startup. However, with infrared heat the floor acts as a reservoir. When doors are opened, the slab loses very little of its heat and when the doors close, this mass acts as a heat sink to continue warming the surrounding air.

The primary design characteristics which distinguish various models of infrared heaters are:
- Modulating, dual stage, or single stage burners
- Condensing or non-condensing
- Low-intensity or high-intensity burners
- Vacuum or positive pressure heaters

Modulating Burners
An advanced feature of low-intensity infrared tube heaters is modulating burners, which optimize combustion by pre-programmed burner controls that adjust both fuel and air, modulating burner input rate with outdoor air temperature to match the heating system's fuel input to the building's heat requirement. Modulation of the burners-in-series occurs by varying the pressure and adjusting gas and combustion air equally which ensures proper combustion.

Vacuum and Positive Pressure Systems
The main difference between a vacuum style heater and a positive pressure tube heater is that the vacuum style heater burner box is under a negative instead of a positive pressure. A vacuum pump located at the end of the system pulls gases down the tube and may be installed as a condensing or non-condensing system. Vacuum-style infrared heater systems may have up to six burners, commonly vented by a single vacuum pump which results in fewer roof or sidewall penetrations, making these installations advantageous when multiple heaters are needed. However vacuum-based systems use more electricity due to the vacuum pump.

Because of the additional electricity along with multi-venting possibilities, vacuum style heaters are not well suited for a prescriptive offering. They are therefore excluded from this measure approval as they are better served in the custom program track.

Condensing vs. Non-Condensing Units
Condensing systems typically allow for longer system lengths and higher system thermal efficiency. However, a non-condensing system more efficiently utilizes the highly emissive black coating on the radiant tubes at a more reasonable equipment cost. Although thermal efficiencies are greater with condensing systems, a vacuum pump is needed for better heat distribution with these longer system lengths resulting in higher electricity usage compared to a non-condensing type.

Because condensing units are a discrete choice over non-condensing units, the increase in savings between the two types is expected to be not cost-effective. Condensing units were not analyzed with this update. Therefore, condensing units are excluded from this prescriptive measure approval.

Baseline
This measure uses a code baseline, assumed to be equivalent the full market baseline.

The baseline system is a gas-fired unit heater that meets the minimum code efficiency requirements of 80% E_c (combustion efficiency).

The data sources we could find, including CBSA, Commercial HVAC market characterization and others do not explicitly discuss radiant heaters, leading us to believe they have little market share. A search of nationwide TRMs and found a similar infrared heater measures that uses a gas-fired unitary heater as the baseline in 12 TRMs (including IL, MA, NY, and WI).

Measure Analysis
An hourly bin analysis for Portland, Bend and Astoria climates were used with the appropriate convection heat transfer coefficient for each bin temperature to determine the gas and electric savings of an infrared radiant heater compared to a typical convective type gas fired unit heater. The analysis solely considers the heat loss through the building envelope, by considering it as a slab, and does not attempt to account for interactive effects between heat losses and the internal loads such as lighting, plug load, pumps, fans, solar gains and miscellaneous equipment.

A fully weatherized building is assumed to isolate the effects of radiant heat on the slab, and uses the following assumptions in the steady state heat transfer analysis:

- Room temperature setpoints - heating season: 68°F (occupied), 65°F (unoccupied)
- Outside temperature when heating starts: 60°F
- Convective gas-fired unit heater efficiency: 80%
- Gas fired radiant heater efficiency – non-condensing, non-modulating: 80%
- Gas fired radiant heater efficiency – non-condensing, modulating: 80%
- Ceiling height: 18 ft
- ACH: 0.35

The analysis shows that even though baseline equipment efficiency levels are essentially the same as the target equipment efficiency levels, gas savings are significant. In addition, because the fan in a radiant system is solely used for combustion purposes as opposed to a convective unit which must move the air to condition the space, significant electric savings are realized as well. For modulating infrared units, it is assumed that the unit functions at 75% capacity when the hourly heating load is <30% of the maximum hourly capacity.

Savings calculations assume the baseline and proposed units will be in operation when there is a difference in temperature between the outside air temperature and the room temperature setpoints regardless of occupancy status.

Savings
Analysis on building sizes of 3,000, 5,000, 10,000, 20,000, 30,000 and 50,000 sq ft were conducted. Applications of radiant heat in spaces larger than 20,000 sq ft were excluded from the final weighted savings estimation as they were found to be inappropriate for a prescriptive measure. Such applications can be expected to require additional design elements (e.g. condensing/non-condensing, single/multi burner, positive/negative pressure, complex gas piping) which will vary costs and are better candidates for a custom measure analysis approach.

The savings presented in **Error! Reference source not found.** and **Error! Reference source not found.** are based on weighting the prevalence of projects in New Buildings across three Oregon cities, as shown in Tables 3 and 4. A straight average was used for the four building sizes appropriate to this measure.

Table 65 Non-Modulating Unit Savings Analysis per kBtu/h

Location		3,000 ft²	5,000 ft²	10,000 ft²	20,000 ft²
Redmond	Ele (kWh)	2.78	1.78	0.95	0.50
10.3%	Gas (therms)	3.37	2.99	2.53	2.13
Portland	Ele (kWh)	4.72	3.00	1.60	0.83
86.6%	Gas (therms)	3.73	3.27	2.70	2.21
Astoria	Ele (kWh)	5.25	3.34	1.78	0.93
3.1%	Gas (therms)	4.38	3.83	3.17	2.60
Weighted	Ele (kWh)	4.53	2.89	1.54	1.03
Weighted	Gas (therms)	3.71	3.25	2.70	2.05
Average	**Ele (kWh)**	**2.50**			
Average	**Gas (therms)**	**2.93**			

Table 66 Modulating Unit Savings Analysis per kBtu/h

Location		3,000 ft²	5,000 ft²	10,000 ft²	20,000 ft²
Redmond	Ele (kWh)	2.78	1.78	0.95	0.50
10.3%	Gas (therms)	4.43	3.99	3.45	2.98
Portland	Ele (kWh)	4.72	3.00	1.60	0.83
86.6%	Gas (therms)	4.60	4.10	3.48	2.95
Astoria	Ele (kWh)	5.25	3.34	1.78	0.93
3.1%	Gas (therms)	5.63	5.00	4.26	3.64
Weighted	Ele (kWh)	4.53	2.89	1.54	0.80
Weighted	Gas (therms)	4.62	4.11	3.50	2.97
Average	**Ele (kWh)**	**2.44**			
Average	**Gas (therms)**	**3.80**			

Measure Life

A standard equipment measure life of 20 years was used in the analysis and aligns with estimates from the Oregon Department of Energy assumptions used in their SEED program. Additionally, since there are few moving parts, equipment life of a radiant system is expected to surpass that of conventional convective air systems. A measure life of 20 years therefore appears conservative when compared with other technologies where maintenance of moving parts may become more of an issue over time

Load Profile

The electric load profile is Warehouse Ventilation and the gas load profile is Commercial Heating.

Cost

Values for cost estimation were obtained from the Overhead and Profit (O&P) values for infrared gas fired units as well as gas fired unit heaters found in RS Means 2021. (The O&P costs includes a percentage increase to the bare material costs and labor costs to include the installing contractor's overhead and profit.) Unit heaters under 30 kBtu/h were excluded from the cost calculations due to radiant heaters sizing data. The baseline and measure cost for modulating and non-modulating units are summarized in Table 67.

Table 67 Incremental Cost

	Baseline Cost ($/kBtu/h)	Measure Cost ($/kBtu/h)	Incremental Cost ($/kBtu/h)
Infrared Radiant Heaters, non-modulating	$19.59	$20.90	$1.31
Infrared Radiant Heaters, modulating		$22.03	$2.44

Incremental costs were calculated based on a $/kBtu/h average for both non-modulating and modulating infrared heaters.

Non Energy Benefits

There are out of territory fuel savings for the electricity savings gas-only territories in Oregon and in Washington.

Incentive Structure

The maximum incentives listed in Table 1 and Table 2 are for reference only and are not suggested incentives. Incentive will be structured by heater capacity (kBtu/h).

The maximum difference between incentives for modulating and non-modulating should not exceed the max incentive as for the difference between the measures, of $1.13, which is based on the expected incremental costs between the equipment types.

Follow-Up

At the next update the analysis should be revised to align with Energy Trust's heating zones and representative cities.

Supporting Documents

The cost effective screening for these measures is number 117.3.2. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Commercial and Industrial\Commercial HVAC\radiant heaters

117_3_2 OR-WA-CE Calculator-2019-v1.1

radiant heater analysis.xlsx

References

- *RSMeans data from Gordian® Version 8.7*, Gordian, https://www.rsmeansonline.com/
- *Grainger Catalog*, W.W.Grainger, Inc., https://www.grainger.com/

Version History and Related Measures

Energy Trust has been offering radiant heaters measure for many years. These predate our measure approval documentation process and record retention requirements. Table 13 may be incomplete, particularly for measures approved prior to 2013.

Table 68 Version History

Date	Version	Reason for revision
4/4/12	117.1	Radiant heaters approved
7/19/18	117.2	Update savings and costs with new set points and climate zones.
7/7/2021	117.3	Update costs based on most recent 2021 RS Means

Approved & Reviewed by

Do not include past approver's signature in drafts. Doing so implies that the measure is approved, is a violation of the disclaimer, and is comparable to forging a signature.

PMCs and program staff are not authorized to approve measures. Do not include "written by" in this section.

Disclaimer

Energy Trust of Oregon

Measure Approval Document for Multifamily In-Unit Clothes Washers and Laundry Centers

Valid Dates
January 1, 2022 – December 31, 2024

End Use or Description
"In-unit" clothes washers and combined washer/dryer laundry centers sold to the multifamily market. This measure is offered as both a buy-down and downstream incentive. A Laundry Center is a consumer product that meets the definition of a Residential Clothes Washer and Electric Clothes Dryer or Gas Clothes Dryer, which cleans and dries clothes in separate, stacked drums.

Applicability
Based on the referenced analysis and associated cost-effectiveness screening, the measures described below are approved for use in the following programs:

- Existing Multifamily
- New Multifamily
- Existing Buildings Washington, where that program serves qualifying multifamily buildings

Within these programs, the measure is applicable to the following cases:

- New
- Replacement

Purpose of Re-Evaluating Measure
Update all aspects of the measure to align with the latest RTF approved data.

ENERGY STAR Laundry Centers which incorporate front load washers and dryers as a single unit are being added to this offering.

Cost Effectiveness
Cost effectiveness is demonstrated for Oregon in Table 1 and Washington in Table 2. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2022-v1.0. In Oregon the electric avoided cost year is 2022 and the gas avoided cost year is 2022. In Washington the gas avoided cost year is 2020. The values in these tables are per clothes washer or laundry center unit.

Table 69 Cost Effectiveness Calculator Oregon

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Ele	% Gas
1	MF Clothes Washer - Electric DHW	14	166.06	0.20	$64.90	$25.74	$64.90	2.0	6.1	99%	1%
2	MF Clothes Washer - Electric DHW EOT	14	166.06	0.0	$64.90	$25.74	$64.90	2.0	6.1	100%	0%
3	MF Clothes Washer - Gas DHW	14	54.29	5.53	$64.90	$25.74	$64.90	0.6	4.6	0%	100%
4	MF Clothes Washer - Gas DHW GOT	14	0	5.53	$64.90	$32.21	$64.90	0.6	5.7	0%	100%
5	MF Clothes Washers - Weighted DHW	14	138.31	1.52	$64.90	$25.74	$64.90	1.8	5.9	91%	9%
6	MF Laundry Center Washer/Dryer - Electric DHW	12	214.19	0.14	$88.24	$25.73	$88.24	1.7	4.3	99%	1%
7	MF Laundry Center Washer/Dryer - Electric DHW EOT	12	214.19	0.0	$88.24	$25.73	$88.24	1.7	4.3	100%	0%
8	MF Laundry Center Washer/Dryer - Gas DHW	12	102.42	5.46	$88.24	$25.74	$88.24	1.2	3.8	69%	31%
9	MF Laundry Center Washer/Dryer - Gas DHW GOT	12	0	5.46	$88.24	$37.94	$88.24	0.4	4.3	0%	100%
10	MF Laundry Center Washer/Dryer - Weighted DHW	12	186.44	1.46	$88.24	$25.74	$88.24	1.6	4.2	94%	6%

Table 70 Cost Effectiveness Calculator Washington

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Ele	% Gas
1	MF WA Clothes Washer - Gas DHW	14	5.53	$64.90	$20.64	$51.96	1.0	4.0	0%	100%
2	MF WA Laundry Center Washer/Dryer - Gas DHW	12	5.46	$88.24	$24.56	$45.10	1.0	3.0	0%	100%

Exceptions
Two exceptions govern this MAD both of which have no defined expiration date:

On November 5, 2012 the OPUC directed Energy Trust to consider incentives for clothes washer measures based on efficiency rating as a group, rather than split by fuel, resulting in a maximum incentive for all fuel combinations of $64.90 for clothes washers and $88.24 for laundry centers in Energy Trust's Oregon service territory.

The OPUC provided an exception on September 2, 2015 for higher incentives on clothes washers in gas service territory that are not cost-effective on the basis of the established exceptions listed in UM-551, Criteria C: "The measure is included for consistency with other demand side management DSM programs in the region." The OPUC directed Energy Trust to consider incentive cost-effectiveness for clothes washer measures based on efficiency rating as a group, rather than separating them into different measures based on territory. The weighting is based on program data showing that 75% of multifamily clothes washer participants have electric DHW while 25% multifamily clothes washer participants have gas DHW.

Requirements

- Residential front-loading clothes washers.
- At least 2.5 cubic feet tub capacity.
- Approved by ENERGY STAR using the 8.0 specification for front loading washers.[48]
- Water heating fuel must be provided by an Energy Trust participating utility.

48 ENERGY STAR Clothes Washer *8.0 Specification*.

- Laundry Center combined washer/dryer units must meet ENERGY STAR 8.1 specification for front loading washers and dryer 1.1 specification to be eligible.[49,50]

Details

Two metrics are used in discussion of clothes washer efficiency. Integrated Modified Energy Factor (IMEF) is a measure of washer efficiency considering the volume of the washer, the mechanical energy used by the washer, water heating, and energy required to remove moisture content remaining after the spin cycle. A higher IMEF indicates higher energy efficiency. Integrated Water Factor (IWF) is the gallons of water per cycle per unit volume of laundry. A lower IWF indicates higher water efficiency. ENERGY STAR's 8.0 washer specification requires residential clothes washers above 2.5 cubic feet to have IMEF ≥ 2.76 and IWF ≤ 3.2, the same as ENERGY STAR's 8.1 washer specification.

Baseline

This measure uses a Full Market Baseline for clothes washers and laundry centers.

The RTF analysis determined the baseline through a combination of Association of Home Appliance Manufacturers' data of top/front load shipments and NEEA's retail product portfolio (RPP) data market data of non-qualifying, ENERGY STAR, and CEE Tier 1+ products to determine average efficiency in the market.

Measure Analysis

Washing Machine Energy

Energy use is determined from the energy used per cycle multiplied by 295 loads per year. Energy per cycle is a function of configuration (front vs top load) and IMEF and calculated using DOE methods modified by the RTF. ENERGY STAR front load washers use slightly more electricity than the market baseline due to higher and longer spin cycles but use less energy overall through decreased dryer energy needed and hot water savings.

Dryer Energy

Dryer savings are determined by the difference in Rated Remaining Moisture Content (RMC) between the efficient machines and the full market baseline. This difference in moisture content is multiplied by the annual cloth weight and typical dryer energy usage per pound of moisture to determine the annual dryer energy savings. For electric dryers, this is a savings of 53 kWh and 1.6 therms for gas dryers. RBSA II data was used to estimate 92% of regional in-unit multifamily dryers are electric. [51] The regional RBSA data was used in lieu of Oregon specific as a single site in the state resulted in an average of over 40% of multifamily units using gas dryers compared to the regional average of 8%.

DHW Energy

DHW savings are the reduction in energy used to heat water resulting from reductions in water used by machines with lower IWF. For electric water heaters, a water heater efficiency of 100% is assumed. For gas DHW, a water heater efficiency of 75% is used. The energy savings for electric DHW is 112 kWh. The savings for gas DHW is 5.3 therms.

Laundry Centers – Dryer Savings

Laundry center savings are a combination of stand-alone clothes washer and stand-alone clothes dryer savings.

As ENERGY STAR laundry center washers have the same requirements as stand-alone clothes washers, the motor and other efficiency requirements and savings are the same. Savings are drawn directly from the RTF's analysis of annual clothes washer consumption for each clothes dryer type. NEEA provided the RTF with market shares and an annual consumption analysis of the dryer types, which were then blended into a market average consumption for gas and electric units. The applicable calculations used in the estimate of dryer annual consumption are:

- Annual consumption: [Annual Pounds Clothes] / [UCEF]
- HVAC Interactive effects: [Annual Infiltration] x { [Infiltration kWh heating per CF] + [Infiltration kWh cooling per CF] }

Blending the efficient unit market shares together and subtracting their weighted annual consumption estimate from the market average annual consumption results in estimated electric, gas and non-utility fuel savings (or penalty) shown in Table 71 below.

Table 71 RTF Dryer Savings and Costs

Dryer Type	Energy Savings, relative to Current Practice Baseline			Incremental Cost (2012$)	Incremental Cost (2022$)
	Electricity (kWh/ year)	Gas (therms/ year)	Other fuels (kWh/ year)		
ENERGY STAR Electric Dryer	53	0	-1	$20	$23.50
ENERGY STAR Gas Dryer	-0.4	1.6	-0.5	$18.42	$21.61

Dryer Fuel Weighting

The RTF uses a regional average of 94% electric dryers sourced from the RBSA II which accounts for all housing types. This analysis uses a 92% electric dryer share based on multifamily only data in the RBSA II.

Savings for clothes dryers were then added to total clothes washer savings to estimate total laundry center savings based on gas or electric domestic hot water, or a blended value (75% electric based on Energy Trust multifamily clothes washer PT data from 2019-April 2021).

Comparison to RTF or other programs

This analysis follows the RTFs analysis in their most recent clothes washer workbook with Energy Trust specific analysis adjustments:

- Dryer fuel splits are unique to Energy Trust, using RBSA data specific to multifamily rather than all housing types used by the RTF.
- Final incremental costs are in 2022 dollars rather than 2012 dollars used by the RTF.

This measure analysis now aligns with the baseline methodology of Energy Trust's retail clothes washer (MAD 4) and differs from Energy Trust's shift model top load clothes washers (MAD 218) as it does not allow top load washers.

49 ENERGY STAR Clothes Washer *8.1 Specification*.
50 ENERGY STAR Clothes Dryer *1.1 Specification*.
51 Northwest Energy Efficiency Alliance Residential Building Stock Assessment II: *https://neea.org/resources/rbsa-ii-combined-database*

Measure Life

For clothes washers measure life is 14 years, consistent with the RTF. For laundry centers a measure life of 12 years is assumed in line with previous Energy Trust dryer MADs and the RTF. When one of the units in a laundry center fails and cannot be repaired, the entire unit is assumed to be replaced so the full units measure life is set equal to the lower of the two equipment types expected lifespan.

Load Profile

These measures use residential sector load profiles; Res Clotheswasher for electric savings and Clotheswasher for gas savings. For laundry centers the washer unit provides the majority of expected savings and load profiles are set to Res Clotheswasher for electric savings and Clotheswasher for gas savings to reflect this.

Cost

Clothes Washers

Costs were collected by the RTF on November 23, 2020 from a Home Depot and Lowe's in Portland, OR. The analysis used the 25th percentile of costs to screen out costs unrelated to energy efficiency improvements and then weighted by NEEA's Retail Product Portfolio data on sales of non-qualified, ENERGY STAR and CEE Tiers and front/top load – resulting in a full market incremental cost of $55.34 (2012$s) for qualifying models. Costs were then adjusted using the GDP deflator found in the RTF's standard information workbook v4.3 to 2022 dollars for a final incremental cost of $64.90.[52]

Laundry Centers

For laundry center units, the RTF incremental cost of $64.90 (2022$s) for washers are added to the RTF weighted incremental cost of $23.34 ($23.50 for electric and $21.61 for gas dryers) for a combined laundry center incremental cost of $88.24 (2022$). The RTF dryer costs were collected via a matched pair analysis of Home Depot and Lowe's stores via online and Portland area in-store data collection.

Non Energy Benefits

Water savings are estimated at Energy Trust's most recent water rates of $17.82/1000 gallons in Oregon, net of embedded energy, and a combined rate of $11.22/1000 gallons in Washington.
kWh savings for non-Energy Trust participating Oregon electric utilities are converted to a NEB at a rate of $0.119 based on an Energy Trust blended residential rate updated 12/8/2020. Electric savings in SW Washington are converted to NEBs at a rate of $0.082/kWh based on a 12/30/2020 update.
The RTF estimated that dryers save a small amount of non-utility fuels (converted to kWh/year) through heat leaking into conditioned space. These values were converted to NEBs based on the Oregon or Washington residential electric rates detailed in the previously.

Incentive Structure

The maximum incentives listed in Table 1 and Table 2 are for reference only and are not suggested incentives. Incentives will be structured per clothes washer or laundry center unit.

Follow-Up

Cost data should be updated as market continues to change from new federal efficiency or ENERGY STAR standards. All changes to RTF analysis should be considered for inclusion.

Supporting Documents

The cost effective screening for these measures is number 152.4.2. It is attached and can be found along with supporting documentation at: *I:\Groups\Planning\Measure Development\Residential\Res Appliances\clothes washer\multifamily clothes washers*

152.4.2 OR-WA CEC 2022_v_1 MF clothes

2021_152.4 ResClothesWashers

Version History and Related Measures

Energy Trust has been offering multifamily clothes washer measures for many years. These predate our measure approval documentation process and record retention requirements. Table 13 may be incomplete, particularly for measures approved prior to 2013.

Table 72 Version History

Date	Version	Reason for revision
7/9/04	x	Residential Clothes washer measure for 1.26 and 1.42 MEF.
1/14/05	x	Residential Clothes washer measure for MEF 1.8.
2006	x	Residential Clothes washer measure for MEF 1.8, updated federal standard.
6/27/07	x	Residential Clothes washer measure for MEF 2.0.
12/3/07	x	Products program clothes washers for tiers at 2.0 and 2.2 MEF.
11/24/10	4.x	Differentiates baseline and savings between single family and multifamily applications. Weighted dryer fuel type. Tiers at 2.2 and 2.46 MEF.
11/21/12	4.x	Multifamily applications removed from MAD 4. Other changes to residential washer requirements.
10/29/15	152.x	Multifamily Clothes washer measures for IMEF 2.74. Cost update. Distributor buy-down only.
11/11/15	152.1	Align with ENERGY STAR specification, IMEF 2.38
8/25/2017	152.2	Update non-energy benefits. Clarifies delivery channel.
6/19/2018	152.3	Align with ENERGY STAR v8.0, IMEF ≥ 2.76 and IWF ≤ 3.2. update costs
9/13/2021	152.4	Updates to align with latest RTF ResClothesWashers_v7_1. Added laundry center measures.

Table 73 Related Measures

Measures	MAD ID
Residential clothes washers	4
Commercial clothes washers (coin-op laundry, commercial laundry, multifamily shared laundry)	89
Retailer shift model clothes washers	218

52 RTF *standard information workbook v4.3*

Approved & Reviewed by

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Disclaimer

Energy Trust of Oregon

Measure Approval Document for Industrial Steam Trap Replacement

Valid Dates
1/1/2022-12/31/2024

End Use or Description
Replacement of steam traps in industrial facilities with gas boilers.

Applicability
Based on the referenced analysis and associated cost-effectiveness screening, the measures described below are approved for use in the following programs:

- Production Efficiency
- Existing Buildings- Washington Industrial Gas Customers Only

Within these programs, applicability to the following building types or market segments are expected:

- Industrial facilities with steam boilers such as food processing, wood products, and manufacturing

Within these programs, the measure is applicable to the following cases:

- Replacement

Purpose of Re-Evaluating Measure
Update to current cost effectiveness calculator.

Cost Effectiveness
Cost effectiveness is demonstrated for Oregon in Table 1 and Washington in Table 2. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2022-v1.0. In Oregon the electric avoided cost year is 2022 and the gas avoided cost year is 2022. In Washington the gas avoided cost year is 2020. The values in these tables are per steam trap.

Table 74 Cost Effectiveness Calculator Oregon, per steam trap

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Ele	% Gas
1	<0.5 inch Orifice, Low Pressure Steam Trap	6	0.00	343.49	$500.00	$0.00	$500.00	2.0	2.0	0%	100%
2	0.5 to <1 inch Orifice, Low Pressure Steam Trap	6	0.00	2,421.62	$550.00	$0.00	$550.00	12.8	12.8	0%	100%
3	1 to 1.5 inch Orifice, Low Pressure Steam Trap	6	0.00	6,984.35	$600.00	$0.00	$600.00	33.9	33.9	0%	100%
4	<0.5 inch Orifice, Medium Pressure Steam Trap	6	0.00	1,768.91	$500.00	$0.00	$500.00	10.3	10.3	0%	100%
5	0.5 to <1 inch Orifice, Medium Pressure Steam Trap	6	0.00	13,487.97	$550.00	$0.00	$550.00	71.4	71.4	0%	100%

Table 75 Cost Effectiveness Calculator Washington, per steam trap

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Ele	% Gas
1	<0.5 inch Orifice, Low Pressure Steam Trap	6	343.49	500.00	$0.00	$500.00	3.1	3.1	0%	100%
2	0.5 to <1 inch Orifice, Low Pressure Steam Trap	6	2,421.62	550.00	$0.00	$550.00	19.9	19.9	0%	100%
3	1 to 1.5 inch Orifice, Low Pressure Steam Trap	6	6,984.35	600.00	$0.00	$600.00	52.5	52.5	0%	100%
4	<0.5 inch Orifice, Medium Pressure Steam Trap	6	1,768.91	500.00	$0.00	$500.00	16.0	16.0	0%	100%
5	0.5 to <1 inch Orifice, Medium Pressure Steam Trap	6	13,487.97	550.00	$0.00	$550.00	110.6	110.6	0%	100%

Requirements

- Must rebuild or replace existing steam trap
- Steam system must operate year-round, at all hours
- Steam trap must be installed at an industrial facility utilizing a natural gas fired steam boiler served by NW Natural, Cascade Natural Gas, or Avista.
- Low Pressure (<15 psig)
    1. Orifice Size ≤1.5 inches
- Medium Pressure (15-200 psig)
    1. Orifice Size ≤ 1 inch

Baseline
This measure uses an Existing Condition Baseline.

Conversations with vendors indicate that approximately 20-30% of the steam traps they audit at industrial sites have failed. This corresponds to the 2007 ICF study which referenced an Enbridge study which showed that 16.3% of steam traps in industrial sites were failed open, and 7.7% of traps surveyed failed closed. Steam traps can fail partially or fully open or closed. Open and partially open traps result in lost steam and closed traps keep air and condensate in the system, causing process issues

Measure Analysis
Armstrong's method is adapted from Masonelian's calculation based on field and test data which showed light condensate loads in drip and tracer applications and higher condensate loads in process applications. This results in different savings per application type, which are then multiplied by a population factor to find the final savings per trap.

$$Steam\ Flow, blow\ thorugh\ (lb/hr) = FS\ x\ CV\ x\ \sqrt{\Delta P\ x\ (Pi + Po)}$$

Where:

- FS: Service Factor, to account for differences in steam flow by application type:
    - $FS_{process}$=0.9
    - FS_{drip}=1.4
- CV: Flow Coefficient, 22.1x orifice diameter (in)2
- P_i = Inlet pressure (psia)
    - Low pressure range: <15 psig, assuming 12 psig for analysis based on participating customers.
    - Medium pressure range: 15-200 psig, assuming 125 psig for analysis based on participating customers.
- P_o = Outlet pressure (psia) assumed at 14.7 psia
- ΔP: $P_i - P_o$

The energy savings from a leaking trap can be calculated using the steam flow with the following equation:

$$Leaking\ Trap\ Savings\ \left(\frac{therms}{yr}\right) = Steam\ flow\ (\frac{lb}{hr})\ x\ Latent\ heat\ of\ vaporization\ \left(\frac{btu}{lb}\right) x\ 10^{-5}\left(\frac{therms}{btu}\right) x\ \frac{hours\ of\ operation\ \left(\frac{hrs}{yr}\right)}{Boiler\ efficiency\ (\%)}$$

Where,

- Steam flow: Calculated utilizing the Armstrong method
- Latent Heat of Vaporization:
- Low Pressure (<15 psig): 956 btu/lb
- Medium Pressure (15-200 psig): 884 btu/lb
- Hours of Operation: 7,600 hours/yr (assumed to be 24/7 operation with occasional down time)
- 85% Boiler efficiency

The savings from the leaking trap population and process trap population are added together to get the total estimated steam trap savings for the population.

$$Leaking\ Trap\ Savings\ \left(\frac{therms}{yr}\right) = FP_{process} xProcess\ savings\ \left(\frac{therms}{yr}\right) + FP_{drip} xDrip\ savings\ \left(\frac{therms}{yr}\right)$$

Where,

- FP: Population Factor
    - FP_{drip}: 25% (Drip and tracer traps make up 25% of the trap population)
    - $FP_{process}$: 75% (Coil and process traps make up 75% of the trap population)

Note that this measure does not require testing. The customer may replace both leaking and not leaking traps. The claimed savings are adjusted, assuming:

- 16.3% of traps are leaking
- 50% leaking traps are open blow, at 100% of calculated steam flow rate
- 50% leaking traps are leaking, at 25% of calculated steam flow rate

Resulting in average savings of 62.5% of calculated steam flow rate. Such that the claimed savings per trap are adjusted to:

$$Savings\ \left(\frac{therms}{yr}\right) = Leaking\ Trap\ Savings\ \left(\frac{therms}{yr}\right) x(16.3\%) x(62.5\%)$$

Savings are analyzed on a per-trap basis, as 5 different measures:

- Low Pressure, <0.5 inch orifice
- Low Pressure, 0.5 inch to <1 inch orifice
- Low Pressure, 1 inch to 1.5 inch orifice
- Medium Pressure, <0.5 inch orifice
- Medium Pressure, 0.5 inch to 1 inch orifice

Savings at various typical orifice sizes within each ranger are averaged to create each measure. Low Pressure applications above 1.5 inch and high pressure applications above 1 inch would be treated as custom projects, as the savings per trap have the potential to be very large.

Comparison to RTF or other programs

The commercial and multifamily measure incentive and savings calculations are based on a per steam trap basis. Savings are higher for industrial steam traps than for commercial or multifamily because industrial steam systems run at all times, rather than only during heating hours. Commercial and multifamily removed repairs from measure eligibility. Industrial allows rebuilding of existing steam traps, since this is common practice for the larger traps seen in industrial settings.

Measure Life

Measure life is 6 years, based on a 2007 study by ICF. This is consistent across Energy Trust's steam trap offerings.

Load Profile

Flat Gas

Cost

Several vendors were interviewed in 2017. The cost estimates were provided as:

- Small (<1") low pressure: $180-$200 +2 hours of labor
- Medium (approx. 1") medium pressure: $300 +2 hour of labor
- Large (approx. 2") medium pressure: $1,500-$2,000 +3 hours of labor
- Labor is $150/hour

These cost estimates are in-line with the costs seen from the completed projects to-date for replacing steam traps.

It is expected that we will start to see some projects where the customer is rebuilding a steam trap, rather than replace it. We expect that the costs will be lower for rebuilding versus replacing. The commercial programs currently allow for rebuilding steam traps. To be conservative for cost effectiveness, the costs assume the steam trap is replaced.

Non-Energy Benefits

Replacing the steam traps will result in reduced steam production, resulting in water savings. The cost savings from this benefit are not included in the analysis.

Incentive Structure

The maximum incentives listed in Table 1 and Table 2 are for reference only and are not suggested incentives. Incentives will be structured per steam trap

Follow-Up

Since incentives are expected to cover a large portion of project costs, a limit on the frequency that a participant may use this offering may need to be put in place if repeat participants become excessive. However, due to the expense of shutting down steam systems this kind of “gaming” is unlikely in an industrial setting.

Supporting Documents

The cost effective screening for these measures is number 200.3.2. It is attached and can be found along with supporting documentation at: *\\etoo.org\home\Groups\Planning\Measure Development\Commercial and Industrial\Process Equipment\steam traps\Industrial steam traps*

200.3.2 OR-WA-CE Calculator_2022_v_1

Version History and Related Measures

Table 13
Table 76 Version History

Date	Version	Reason for revision
7/26/17	200.1	Introduce steam traps for Production Efficiency.
9/26/18	200.2	Update measure to per steam trap rather than per capacity.
10/12/21	200.3	Updated cost effectiveness

Table 77 Related Measures

Measures	MAD ID
Commercial Steam Traps	42
Multifamily Steam Traps	40

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Measure Approval Document for Commercial Condensing Tankless Water Heaters <200kBtu/h

Valid Dates
April 4, 2021 – December 31, 2023

End Use or Description
Single or multiple condensing tankless water heaters (CTWH), sized <200 kBtu/hr, serving as a central domestic hot water (DHW) system.

Applicability
Based on the referenced analysis and associated cost-effectiveness screening, the measures described below are approved for use in the following programs:
- Existing Buildings
- New Buildings

Within these programs, applicability to the following building types or market segments or program tracks are expected:
- Restaurants and Cafeterias (including those within other building types such as campuses or hotels)
- Gyms (including those within other building types such as hotels)
- Coin-op laundries
- Motels (only in the Washington territory)
- Schools (only in the Washington territory)

Within these programs, the measure is applicable to the following cases:
- New
- Replacement

Purpose of Re-Evaluating Measure
During this update, the baseline type, minimum thermal efficiency, incremental costs, measure life, and the hot water demand per market segment are updated for the reasons listed below:

The baseline type is updated from an inefficient market baseline to a full market baseline.
Due to the update to the baseline, the minimum efficiency and the incremental costs are updated.
The hot water demand per market segment is updated to align with MAD 21 (Commercial condensing storage water heaters) and MAD 72 (Commercial Condensing Tankless Water Heaters ≥ 200 kBtu/h).
The measure life is updated from 15 years to 20 years.
In Oregon, use in schools is no longer approved.
In Washington, use in motels is added

Cost Effectiveness
Cost effectiveness is demonstrated for Oregon in Table 1 and Washington in Table 2. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2022-v1.0. In Oregon the electric avoided cost year is 2022 and the gas avoided cost year is 2022. In Washington the gas avoided cost year is 2020.

Table 78 Cost Effectiveness Calculator Oregon

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Restaurant - CTWH 199 kBtu/h	20	0	44.28	$200.53	$0.00	$200.53	2.2	2.2	0%	100%
3	Coin-op Laundry - CTWH 199 kBtu/h	20	0	103.93	$200.53	$0.00	$200.53	5.1	5.1	0%	100%
4	Gym/Fitness Center- CTWH 199 kBtu/h	20	0	21.71	$200.53	$0.00	$200.53	1.1	1.1	0%	100%

Table 79 Cost Effectiveness Calculator Washington

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Restaurant - CTWH 199 kBtu/h	20	0	44.28	$200.53	$0.00	$200.53	3.2	3.2	0%	100%
2	Motel - CTWH 199 kBtu/h	20	0	16.70	$200.53	$0.00	$200.53	1.2	1.2	0%	100%
3	Coin-op Laundry - CTWH 199 kBtu/h	20	0	103.93	$200.53	$0.00	$200.53	7.5	7.5	0%	100%
4	Gym/Fitness Center- CTWH 199 kBtu/h	20	0	21.71	$200.53	$0.00	$200.53	1.6	1.6	0%	100%
5	Schools- CTWH 199 kBtu/h	20	0	14.99	$200.53	$0.00	$200.53	1.1	1.1	0%	100%

Requirements
- The water heater units must function as central water heating.
- Installed equipment should be a condensing tankless water heater with input capacity less than 200kBtu/h.
    1. Commercially sized equipment >200kBtu/h is approved through MAD ID 72 with different savings and requirements.
- Installed equipment Uniform Energy Factor (UEF) should be greater than or equal to 0.93.
- Installed equipment must be on the AHRI certified product list.
- Additional storage tanks are not added.

Building Type Clarifications
- Water heaters serving only the restaurant/café area or pool/gym area of hotels and motels are covered under the Restaurant or Gym end uses
- Water heaters serving only the food service areas in a grocery store are applicable under the Restaurant end use
- Multifamily tankless equipment with an input of 200 kBtu/h or less is approved through MAD 196 with different savings and requirements.

Details
The practice of installing multiple residential sized (typically 199.99 kBtu/h) tankless water heaters in parallel as a central domestic water heating system in commercial buildings is gaining momentum in the water heater market. Within the tankless water heater market, users are purchasing both condensing and non-condensing water heaters. Furthermore, the market share or sales of condensing tankless water heaters is significantly larger than the non-condensing tankless water heaters.

This measure is designed to encourage the use of the high efficiency condensing tankless water heaters rather than non-condensing tankless water heaters or standard efficiency condensing tankless water heaters and discourage the addition of storage tanks which can cause storage losses.

Baseline

This measure uses a full market baseline.

The full market baseline includes a mix of non-condensing and condensing tankless water heaters. It is assumed that these customers would not be considering new tank water heaters. The product mix in the baseline was determined based on an analysis of the market share of condensing and non-condensing water heaters in the tankless water heater market and an analysis of a tankless water heater product list and efficiency through the AHRI database.

- AHRI database findings as of January 2021
    - Tankless Water Heater product data from the AHRI Directory database was analyzed. The dataset included a total of 381 active water heater models.
    - The water heater type (condensing versus non-condensing) within the AHRI dataset was determined by establishing a minimum UEF of 0.87 for condensing tankless water heaters.
        - Of the 381 active models, 240 models (63%) were determined to be condensing while the remaining 141 (37%) were determined to be non-condensing.
    - Once the water heater type was identified, the average recovery efficiency for both condensing and non-condensing tankless water heaters was determined. Recovery efficiency for residential water heaters is equivalent to thermal efficiency (TE) for commercial water heaters; therefore, it was used instead of thermal efficiency.
        - Per the Code of Federal Regulations, Part 430, Subpart B, *recovery efficiency* for residential water heaters is defined as "the ratio of energy delivered to the water to the energy content of the fuel consumed by the water heater". This is analogous to thermal efficiency for commercial water heaters.
    - From this AHRI database analysis, it was found that the average recovery efficiency of non-condensing tankless water heater is 84% and that of condensing tankless water heaters is 96%.

- Distributor sales data findings
    - Tankless Water Heater annual sales data was obtained from a water heater distributor to understand the market share of condensing versus non-condensing units. The data obtained was Oregon-specific sales data and was available for 3 consecutive years, 2018-2020.
    - It was found that 86% of the tankless water heater sales represents condensing water heaters sales while the remaining 14% represent the non-condensing water heaters sales.

- Vendor sales data findings
    - To corroborate the distributor sales data, sales data from a vendor that participates extensively in the Energy Trust programs and is well-established in the industry was obtained. It was found that 76.5% of the tankless water heater sales represents condensing water heaters sales while remaining 23.5% represent the non-condensing water heaters sales.

Recovery efficiency is the basis of savings analysis. While this does not cover the full water heating cycle, it is accurate for the bulk of the cycle and simplifies analysis.

Combining the average recovery efficiency and market shares of condensing and non-condensing units, the weighted average recovery efficiency gives the baseline recovery efficiency shown in .

Table 80: Baseline Case - Weighted Average Recovery Efficiency

	Percent Sales (%)	Average AHRI Recovery Efficiency (%)	Weighted Average Recovery Efficiency (%)
Condensing	86%	96%	94.5%
Non-Condensing	14%	84%	

Measure Analysis

Savings were modeled using a spreadsheet-based calculation approach. Inputs from several sources such as ASHRAE prototype models, DOE National Building Stock, and AHRI were analyzed. Savings were analyzed for quick service and full-service restaurants, small hotels (motels), schools, coin-op laundry facilities and gyms.

Savings per system are based on annual hot water demand for various market segments and the thermal efficiencies of the baseline and efficient case conditions. Savings are normalized based on the estimated number of tankless water heaters that are needed to meet the peak hot water demand to estimate saving per water heater per market segment. Where necessary, savings per water heater are weighted by percentage of each sub-sector for that market segment.

Heating Load and Energy Savings Calculation Methodology

The total output energy, in British Thermal Units (BTU), for each market segment is calculated using that market segment's estimated total annual hot water demand in gallons, estimated temperature rise, the specific heat capacity of water, and the average density of water.

$$Heat\ Output\ Energy_{[btu]} = V_{[gal]} \times \rho_{[lb/gal]} \times C_{[\frac{btu}{lb} \times °F]} \times \Delta T_{[°F]}$$

Where:
V = Annual Hot Water demand (gallons)
P = Density of Water (lb/gal)
C = Specific Heat Capacity of Water (btu/lb x °F)
ΔT = Temperature Rise (°F)

The total heat output required by the water heaters for each building in BTU is converted to therms. The energy input for the baseline case and proposed measure case water heaters is calculated by dividing the total heat output value by the established thermal efficiencies for the baseline and proposed measure cases, respectively. The savings is obtained by calculating the difference between the baseline and proposed measure case total input therms.

$$Energy\ Savings_{[therms]} = \frac{Heat\ Output\ Energy_{[therms]}}{Baseline\ TE_{[\%]}} - \frac{Heat\ Output\ Energy_{[therms]}}{Proposed\ Measure\ TE_{[\%]}}$$

Where:
TE = Thermal Efficiency

Inputs and Variables
The inputs & variables that impact the savings calculations are detailed below including the sources & methodology to determine them.

1. Hot Water Demand per market segment or sub-sector
The hot water demand for various market segments that was determined from multiple sources are detailed in Table 81.

Table 81: Hot Water Demand by Market Segment

Market Segment	Sub-sector	Annual Hot Water Demand (Gal)	Source
Restaurant	Quick Service Restaurant	204,834	Annual hot water demand from ASHRAE Prototype Building Models, Table 2.2 and model summary.[53] (aligns with MAD 21)
	Full-Service Restaurant	581,527	
Motel	-	681,102	
Schools	Primary School	189,800	
	Secondary School	542,485	
Coin-op Laundry	-	3,302,208	Calculated using several sources for washer count for large[54] and small facilities,[55] loads washed per day,[56] average water gallon per load, and percent hot water per load.[57]
Gym	-	411,897	Calculated using peak demand (gallon per hour) from Table 11 and demand ratio profile from Appendix B (secondary school showers) in the U.S. Department of Energy Commercial Reference Building Models of the National Building Stock.[58]

2. Heat Load Input Assumptions
In addition to the annual hot water consumption, the heat load calculations are based on density of water, specific heat capacity of water, and the temperature rise which is calculated as the difference between the inlet and outlet temperatures of the water heater.

Water heater inlet temperatures were calculated by using the heating zone ground water temperature from RTF's Standard Information Workbook v4.2[59] and taking a weighted average inlet temperature based on the previously installed project locations of this measure in the Existing and New Building program between 2018-2020. Water heating outlet setpoint temperatures are adopted from the RTF's commercial heat pump water heater measure[60].

The physical constants for water (density and specific heat capacity) were found using the Engineering ToolBox website[61,62]. The table below shows the assumptions for these inputs:

Table 82: Heat Load Inputs

Input	Value
Water Heater Inlet Temperature (°F)	55
Water Heater Outlet Temperature (°F)	140
Temperature Rise (°F)	85
Density of Water (lb/gal)	8.33
Specific Heat Capacity, Water (btu/ lb x °F)	1

3. Recovery Efficiency to UEF Conversion
Although recovery efficiency is used to calculate the savings, uniform energy factor (UEF) is used to establish the measure eligibility. This is because federal code requires UEF to be used as the efficiency rating for water heaters of this size. Through trial and error, a target recovery efficiency of 97% for the efficient case was selected.

A three-pronged approach was taken to estimate the minimum qualifying UEF value that corresponds to the efficient case recovery efficiency of around 97%. All approaches are based on exported data from the AHRI Certified Product database.

- Calculate the average UEF value for all units with a 97% TE efficiency. This resulted in an UEF of 0.935.
- Calculate the average UEF to TE ratio for all condensing tankless water heaters and apply that ratio to 97% TE. This resulted in a UEF of 0.937.
- Perform a linear regression of TE and UEF and find the value of UEF on the best fit curve at 97% TE. This resulted in a UEF of 0.936.

Since UEF values are generally only reported to the hundredths place and all approaches agreed, a UEF of just over 0.93, a minimum UEF requirement of 0.93 was selected for this measure. The average TE efficiency of condensing tankless water heaters with a UEF of 0.93 is found to be 96.897% from the AHRI database product analysis. This TE value is used to calculate the efficient case energy consumption.

53 PNNL and DOE. 2014. "Enhancements to ASHRAE Standard 90.1 Prototype Building Models."
54 Super Suds Laundromat. Accessed February 2021. "Our Machines/Equipment." *https://www.supersuds.com/long-beach-laundromat-services/our-machines-and-equipment/*
55 Rheem. News. 2007. "Plumber Connects Three Tankless Water Heaters To Meet Heavy-Duty Demands of Laundromat." *http://63.76.193.160/news/plumber-connects-three-tankless-water-heaters-to-meet-heavy-duty-demands-of-laundromat*. Number of
56 Alliance for Water Efficiency. *http://www.allianceforwaterefficiency.org/laundromats.aspx*. Source link does not work. Unable to verify the six loads per day or 40 average gallons per load values used in calculations.
57 Laundry Consulting. Accessed February 2021. "Hot Water Systems." *http://www.laundryconsulting.com/equipment/water-systems/*. Total water machines at the site.
58 NREL. 2011. "U.S. Department of Energy Commercial Reference Building Models of the National Building Stock." *http://www.nrel.gov/docs/fy11osti/46861.pdf*
59 Regional Technical Forum. 2020. "RTFStandardInformationWorkbook_v4_2.xlsx." *https://rtf.nwcouncil.org/standard-information-workbook*
60 Regional Technical Forum. 2020. "ComHPWH_v1_3.xlsm." , GPD Guide tab, Rows 45-65, Column O. *https://nwcouncil.app.box.com/v/CommercialHPWHv1-3*
61 The Engineering ToolBox. Accessed February 2021. "Water - Density, Specific Weight and Thermal Expansion Coefficient." Water density at 70°F. 2021. *https://www.engineeringtoolbox.com/water-density-specific-weight-d_595.html*
62 The Engineering ToolBox. Accessed February 2021. "Water - Thermophysical Properties." 2021. *https://www.engineeringtoolbox.com/water-thermal-properties-d_162.html*

4. Water Heater Sizing Assumptions
For multi-unit tankless systems, sizing refers to quantity of tankless water heaters operating in parallel rather than the total capacity of the water heaters themselves or the volume of available storage. Since these systems have no storage to handle intermittent spikes in DHW demand, tankless systems are sized based on the expected peak demand per minute in comparison to storage systems which are sized with respect to the peak hourly demand.

This water heater sizing analysis used the Modified Hunter's Method[63] to determine appropriate sizing based on the number of water supply fixture units (WSFU) in gyms, coin-op laundries, motels and schools. The Modified Hunter's Method provides WSFU values for typical equipment such as a shower, bathroom sink, and washing machines. Typical gym fixture count was obtained from the Whole Building Design Guide[64]. For restaurants, manufacturer sizing guidelines are used to determine the number of necessary water heaters. School estimates only included consumption from sinks, but not cafeteria loads. Thus, school peak flows were found by adding the values from the Hunter Method and the flows used for restaurants to simulate cafeteria hot water loads.

The peak flows (in gallons per minute, GPM) were divided by the estimated maximum flow for the proposed measure case tankless water heater to estimate the number of water heaters that would be needed to meet the demand. An analysis of the AHRI database for 97% efficient tankless water heaters of 199 kBtuh capacity showed an average maximum flow equal to 5.72 GPM.

Lastly, the total therms savings per site in each market segment (savings/sites were divided by the number of water heaters per site for that market segment to calculate the therms savings for each water heater (savings/CTWH).

Table 83 GPMs and condensing tankless water heaters in typical central water heat configurations

Market Segment	Sub-sector	Annual Hot Water Demand (gal)	Peak GPM	No. of CTWH	Savings/Site (therms)	Savings/CTWH (therms)
Restaurant	Quick Service Restaurant	204,834	10	2	37.75	21.60
	Full-Service Restaurant	581,527	10	2	107.18	61.32
Motel	-	681,102	43	8	125.53	16.70
Coin-op Laundry	-	3,302,208	34	6	608.62	103.93
Gym	-	411,897	20	3	75.92	21.7
Schools	Primary School	189,800	18	3	34.98	11.12
	Secondary School	542,485	20	3	99.98	28.60

5. Sub-sector Weighting Methodology
As indicated in Table 83, the per CTWH unit savings for the restaurant and schools market segments are estimated for their sub-sectors. To establish, savings across the market segment the weightage associated with the sub-sectors of Schools and Restaurants were estimated.

The number of schools in Oregon were found using the Oregon Department of Education data[65]. In this dataset, Schools were categorized into Primary Schools, Secondary Schools, and some were not well classified. The counts of primary and secondary schools were used to estimate the weightage (%) of each sub-sector under the Schools market segment, shown below.

Similarly, counts of different restaurants were found using US Bureau of Labor Statistics[66]. NAICS codes for "Cafeterias, grill buffets, and buffets" and "Limited-service restaurants" were assigned as Quick Service Restaurants and NAICS codes for "Full-service restaurants" were assigned as Full-Service Restaurants. The counts of quick and full-service restaurants were used to estimate the weightage (%) of each sub-sector under the Restaurant market segment, shown below.

Table 84: Weightage of sub-sectors under Schools and Restaurants market segments

Market Segment	Sub-sector	Weighting (%)
Schools	Primary School	78%
	Secondary School	22%
Restaurants	Quick Service Restaurant	43%
	Full-Service Restaurant	57%

The savings for each sub-sector were weighted and calculated accordingly.

Table 85: Summary of gas savings in therms per market segment

Market Segment	Sub-sector	Annual Hot Water Demand (gal)	Peak GPM	No. of CTWH	Savings/ CTWH (therms)	Weighting per sub-sector	Weighted Savings (therms)
Restaurant	Quick Service Restaurant	204,834	10	2	21.60	43%	44.28
	Full-Service Restaurant	581,527			61.32	57%	
Motel	-	681,102	43	8	16.70	-	16.70
Coin-op Laundry	-	3,302,208	34	6	103.93	-	103.93
Gym	-	411,897	20	3	21.71	-	21.71
Schools	Primary School	189,800	18	3	11.12	78%	14.99
	Secondary School	542,485	20	3	28.60	22%	

Measure Life
Measure life is 20 years based on the DEER database. Reference EUL ID "WtrHt-Instant-Com" for Commercial Instantaneous Water Heater in the DEER database.[67]

63 *ASHRAE Modified Hunter Curve*
64 *Whole Building Design Guide for Gyms, National Institute of Building Sciences*
65 Oregon Department of Education (https://www.oregon.gov/ode/reports-and-data/students/Pages/Student-Enrollment-Reports.aspx)
66 US Bureau of Labor Statistics – Quarterly Census of Employment and Wages (2019 Dataset: https://www.bls.gov/cew/downloadable-data-files.htm)
67 California Public Utility Commission. Access 2021.DEER Database file "SupportTable_EUL.CSV." Accessed via the READI v2.5.1 tool.

Load Profile
The gas load profile for this measure is DHW.

Cost
Equipment costs
A dataset of 120+ tankless water heaters from various online retailers collected in November of 2020 was used to determine the equipment costs of various efficiencies. The water heaters were categorized into different efficiency categories including:

- Non-condensing (≤86% TE)
- Standard efficiency condensing (>0.86%-<96.897% TE)
- High efficiency condensing (≥96.897% TE)

Each of the 120 units was allocated under one of the above categories and the normalized cost per kBtuh was calculated per category and for the 'all condensing' category.

The costs high efficiency condensing units are used for the proposed measure case costs. The normalized costs per kBtuh were multiplied by an assumed system capacity of 199.99 kBtuh to establish the equipment costs per tankless water heater.

Table 86: Water Heater Costs in $/kBtuh

Water Heater Category	Normalized Cost ($/kBtuh)	Equipment Cost ($/unit)
Non-Condensing	$5.63	$1,126.87
All Condensing	$8.13	$1,626.72
High Efficiency Condensing Only	$8.82	$1,763.01

Labor and Ancillary Costs
Labor and ancillary material costs will remain unchanged from the previous version of the MAD 212.3. The costs were adopted from a California Codes and Standards Enhancement (CASE) report for high efficiency water heaters[68].

The costs used in this analysis only include costs that are incremental between the non-condensing and condensing water heaters. For non-condensing water heaters this includes costs of steel venting materials which are required for the hotter exhaust gases. For condensing water heaters this includes costs of PVC venting materials, a drain connection, neutralizer filter and a small condensate pump.

Table 87: Labor and Ancillary Costs per Average Tankless Water Heater Installation

Item	Item Cost	Total Labor + Ancillary Costs
Non-Condensing		
Metal Venting (Type-B Steel)	$482	**$482**
Condensing		
Venting System (PVC)	$204	**$443**
Drain Connection	$113	
Neutralizer Filter	$86	
Condensate Pump	$40	

Cost Weighting and Incremental Cost
The total cost for each water heater category was calculated by adding up the equipment, labor and ancillary costs per category

Table 88: Water Heater Installation Cost

Water Heater Category	Equipment Cost ($)	Labor + Ancillary Costs ($)	Total Cost
Non-Condensing	$1,126.87	$482	$1,608.87
All Condensing	$1,626.72	$443	$2,069.72
High Efficiency Condensing Only	$1,763.01	$443	$2,206.01

The costs for the non-condensing units and average of all condensing units were weighted based on the distributor market shares of each water heater type to find a weighted average cost per kBtuh for the full market baseline. Lastly, the baseline costs were subtracted from the proposed measure cost to find the incremental cost.

Table 89: Baseline Installation Costs

Tankless Water Heater	Condensing	Non-Condensing
Tankless Water Heater Market Sales (%)	86%	14%
Baseline Tankless Water Heater Cost	$2,069.72	$1,608.87
Weighted Average of Baseline Cost	$2,005.48	

The incremental cost difference between a high efficiency condensing unit and the market baseline is $200.53.

Non-Energy Benefits
There are no non-energy benefits estimated for this measure.

Incentive Structure
The maximum incentives listed in Table 1 and Table 2 are for reference only and are not suggested incentives. Incentives will be structured per unit (condensing tankless water heater).

Follow-Up
The full market baseline is a mix of condensing and non-condensing tankless water heaters. This was established based on water heater sales data, which indicated that the market share of condensing tankless water heaters is significantly higher than non-

[68] California Utilities Statewide Codes and Standards Team. 2011. "High-efficiency Water Heater Ready", Figure 8. *http://title24stakeholders.com/wp-content/uploads/2017/10/2013_CASE-Report_High-efficiency-Water-Heater-Ready.pdf*

condensing water heaters. The market share of condensing versus non-condensing units should be analyzed during the next update as it is possible that the non-condensing units market share continues to reduce.

Similarly, baseline efficiency is a weighted average of the thermal efficiency of condensing and non-condensing tankless water heaters and their market share. The AHRI database and market share should both be researched to assess if the baseline efficiency needs to be updated.

The hot water demand per market segment and the costs should be validated in future updates.

Future updates should incorporate UEF into analysis.

Supporting Documents

The cost-effective screening for these measures is number 212.4.2. It is attached and can be found along with supporting documentation at: *I:\Groups\Planning\Measure Development\Commercial and Industrial\Commercial Water Heating\gas tankless water heat\commercial less than 199*

212.4.2_OR-WA_CE_ Calc_2022_v.1_Com_1

MAD 212.4.2 Savings Analysis.xls›

Version History and Related Measures

Table 90 Version History

Date	Version	Reason for revision
1/5/2018	212.1	First approval for condensing tankless water heaters ≤199 kBtu in commercial applications
1/19/2018	212.2	Correct size requirement to <200 kBtu
10/22/2020	212.3	Add UEF requirement, extend expiration date to allow for PMC transition activities in Q1 2021
3/16/2021	212.4	Update to full market baseline, minimum UEF, incremental costs, measure life, and the hot water demand per market segment.

Table 91 Related Measures

Measures	MAD ID
Commercial and Multifamily Condensing Tankless >199 kBtu/h	72
Commercial and Multifamily Condensing Tank Water Heaters	21
Multifamily ≤199 kBtu Condensing Tankless WH	196
New Homes Tankless	178
Residential Tankless Oregon	259
Residential Tankless Washington	197

Approved & Reviewed by

Kenji Spielman
Planning Engineer

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Measure Approval Document for Process Boiler Calculator

Valid Dates
1/1/2022-12/31/2024

End Use or Description
The Process Boiler Tool v.2.0 estimates natural gas savings for upgrades to process boiler and water heater systems.

Process hot water or steam boilers
- Retrofit existing boiler with condensing functionality or adding condensing boiler technology to new boiler
- Thermal efficiency improvements
- Efficient burner (e.g. modulating burner)
- Combustion fan with variable frequency drive (VFD)

Process water heater
- Retrofit existing water heater with condensing functionality or new condensing water heater
- Direct-contact water heater (99% thermal efficiency)

Program Applicability
Based on the referenced analysis and associated cost-effectiveness screening, the measures described below are approved for use in the following programs:
- Production Efficiency

Within these programs, the measure is applicable to the following cases:
- Retrofit
- New

Cost Effectiveness
An integrated cost-effectiveness calculator ensures that the specific installation is cost-effective before an incentive is offered. Projects that are not cost-effective will not qualify.

Requirements
- All projects must pass cost effectiveness to be eligible for incentives.
- Boiler or water heater capacity ≤ 3,000,000 btu/hr
- Boilers and water heaters must serve process loads. Boilers serving domestic hot water (DHW) or HVAC loads do not qualify.

Baseline
The baseline types are:
- existing condition for retrofit
- market baseline for new construction

Baseline will be existing boilers or water heaters for retrofit projects.

The baseline for new construction boiler projects conforms to the following criteria, derived from code and industry standards:
- Boiler heater size is equal to the upgrade boiler size
- Burner type is on/off
- Efficiency rating is according to code
    - For hot water boiler: 80% for boilers < 2,500,000 btu/hr and 82% for boilers ≥ 2,500,000 btu/hr
    - For steam boiler: 75% AFUE for boilers < 300,000 btu/hr and 79% thermal efficiency for boilers ≥ 300,000 btu/hr
    - Efficiency type is defined as either thermal efficiency or AFUE, depending on the boiler nameplate capacity
- For hot water boiler: system has hot water storage
- For steam boiler: system does not have steam storage
- Boiler pump operates continuously

The baseline for new construction water heater projects conforms to the following criteria:
- If the upgrade is a condensing tank water heater or condensing tankless water heater, the baseline is a comparable non-condensing unit.
- If the upgrade is a direct-contact water heater, the baseline should be quoted by the vendor. One vendor explained that a reasonable baseline would be a hydronic boiler and heat exchanger package.

Measure Analysis
Key Tool Inputs and Defaults
Information Inputs
- Hot water boiler or water heater
    - Project type: retrofit or new construction
    - Estimated water flowrate (input directly, or estimated by pipe diameter)
    - Desired process water temperature
    - Boiler combustion fan hp (if combustion fan VFD upgrade included)
- Steam boiler
    - Project type: retrofit or new construction
    - Either deaerator pressure or feedwater temperature
    - Steam operating pressure
    - Boiler combustion fan hp (if combustion fan VFD upgrade included)

Inputs for each boiler:
- Hot water boiler or water heater
    - Boiler size (btu/hr)
    - Boiler type (hydronic or condensing hydronic)
    - Burner type (on/off, high/low (two stage), four stage, or modulating)
    - Turndown ratio (if modulating burner)
    - Efficiency rating
    - Efficiency rating type (AFUE or thermal efficiency)

    - System storage (yes/no)
    - Boiler pump type (continuous or intermittent)
- Steam boiler
    - Maximum steam production
    - Economizer type (none, non-condensing, condensing)
    - Boiler burner type (on/off, high/low (two stage), four stage, or modulating)
    - Turndown ratio (if modulating burner)
    - Efficiency rating
        - By default upgrade efficiency will be calculated based on baseline efficiency and stack temperature reduction, but can be manually input.
    - Efficiency rating type (AFUE or thermal efficiency)
    - System storage (yes/no)
    - Boiler pump type (continuous or intermittent)
    - Blowdown rate
    - Stack temperature

Defaults and inputs for combustion fan VFD upgrades:

- Upgrade average fan speed is entered by the user, or estimated from the weighted average of the process boiler fire rate
    - Minimum fan speed default to 50%, if no input
- Fan motor loading default to 80%
- Fan motor efficiency default to 85%

Production Schedule Inputs (applies for hot water and steam boilers):

- Percent boiler demand for demand mode
    - High – default to 85%, if no input
    - Med – default to 50 %, if no input
    - Low – default to 25 %, if no input
    - None – default to 10%, if no input
    - Off – default to 0%, if no input
- Demand for day, evening, night shifts and weekend by season
    - Inputs correspond to demand modes described above
- Input hours for day, evening, and night shift
    - Defaults to 8 hours each if no input

Natural Gas Consumption

A bin analysis is used in this tool. Average load for each operating mode (High/Med/Low) and boiler size is used to calculate the required boiler fire rate, that is the rate of heat that must be supplied to the water, for each of the operating modes.

For water boilers and water heaters: The required heat input (btu/hr) into the boiler is calculated for each operating bin using water flowrate, boiler hot water outlet temperature, and the physical and thermodynamic properties of water as inputs to the sensible heat equations. The required heat input is divided by boiler efficiency at each operating condition to determine the natural gas consumption rate (btu/hr), which is multiplied by the number of operating hours for each bin to get the total energy consumption for each bin. More details regarding this calculation and its inputs are available in the following sections.

For steam boilers: Boiler energy output (btu/hr) is calculated for each operating bin by calculating the energy flow for steam, feedwater, and blowdown water. If deaerator pressure is not known, boiler energy output is automatically calculated using a method that does not include blowdown energy flow. Based on example cases from the US DOE Steam System Modeler Tool Boiler Calculator, blowdown is generally less than 5% of boiler energy requirement (often only 1% or 2%). Additionally, existing steam boiler measures do not affect blowdown so its energy requirement will likely be constant in baseline and upgrade. For these reasons it is acceptable for blowdown to be omitted from the energy calculation if necessary. For each operating bin boiler energy output is divided by boiler efficiency and multiplied by operating hours to determine energy requirement. More details regarding this calculation and its inputs are available in the following sections.

Boiler efficiency is calculated at each boiler capacity (from 0 to 100% in increments of 5) using polynomial curves for boiler capacity versus efficiency. Each burner control type (i.e. instant, on/off, modulating, two stage, and four stage) has a different efficiency curve. Turndown ratio is used to determine what percentage of time the boiler must fire to meet demand at each capacity.

For each firing rate entered with the operation schedule, the corresponding efficiency value is obtained based on the burner type selected. The efficiency for each operating bin is used to calculate the boiler energy consumption in that bin.

Water Boilers Input Water Temperature

Efficiency at lower firing rates is de-rated based on incoming water temperature (IWT). IWT is calculated using the equation below. An efficiency de-rating factor is calculated using IWT, if IWT is greater than 80°F. The de-rating factor is obtained from a polynomial curve for IWT versus efficiency.

$$T_{IWT} = Tout - \frac{Q}{J\ x\ 60\frac{min}{hr}\ x\ \rho\ x\ C_p}$$

Where:

T_{IWT} = incoming water temperature
T_{out} = outlet water temperature
Q = boiler heat load
J = water flow
ρ = water density
C_p = water specific heat

Water Boilers and Water Heaters: Water Flowrate

The water flowrate, q, for the baseline and upgrade case is assumed to be equal. If the flowrate is input by the user, this value is used. If not, the flowrate is estimated from a user input pipe diameter using the following equation:

$$q = \frac{D_{pipe}}{0.4084} \times V_{water,max}{}^2$$

Where the maximum velocity of water is assumed to be 6 ft/s. This value comes from comparing manufacturer ratings over a wide range of boiler sizes.

Water Boilers and Water Heaters: Physical and Thermodynamic Properties of Water

The heat capacity (Cp) and density (ρ) of water are a function of temperature. For the purposes of this tool, these values are considered constant at the user input outlet temperature. These values are both calculated from a table which provide the density and heat capacity of water at various temperatures. Values not in the table are interpolated from the two nearest values.

Water Boilers and Water Heaters: Sensible Heat Equation

The sensible heat equation was used to calculate the inlet water temperature at the different operating modes. Assuming a constant outlet temperature (as is maintained by boiler controls), as the hot water demand (and subsequent water demand) increases, the inlet water temperature decreases. This corresponds to more heat being removed from the system. This is calculated by rearranging the sensible heat equation:

$$\dot{m}Cp\Delta T = Q \rightarrow T_{in} = T_{out} - \left[\frac{Q}{q \times 60 \times Cp \times \rho}\right]$$

Where:

Q = heat rate (Btu/h)
q = water flowrate
Cp = heat capacity
ρ = fluid density

Water Boilers and Water Heaters: Boiler Efficiency at Operating Conditions

The effective efficiency of a condensing hydronic boiler decreases as the inlet water temperature increases. This is because the higher water temperature is less effective at condensing water vapor in the boiler flue gas. All condensing boiler efficiencies are rated at an 80°F inlet water temperature.

Condensing boiler efficiency is de-rated at calculated inlet water temperatures higher than 80°F. This is calculated using a curve fit to ASHRAE data of boiler efficiency to inlet water temperature. This curve is shown in Figure 1.

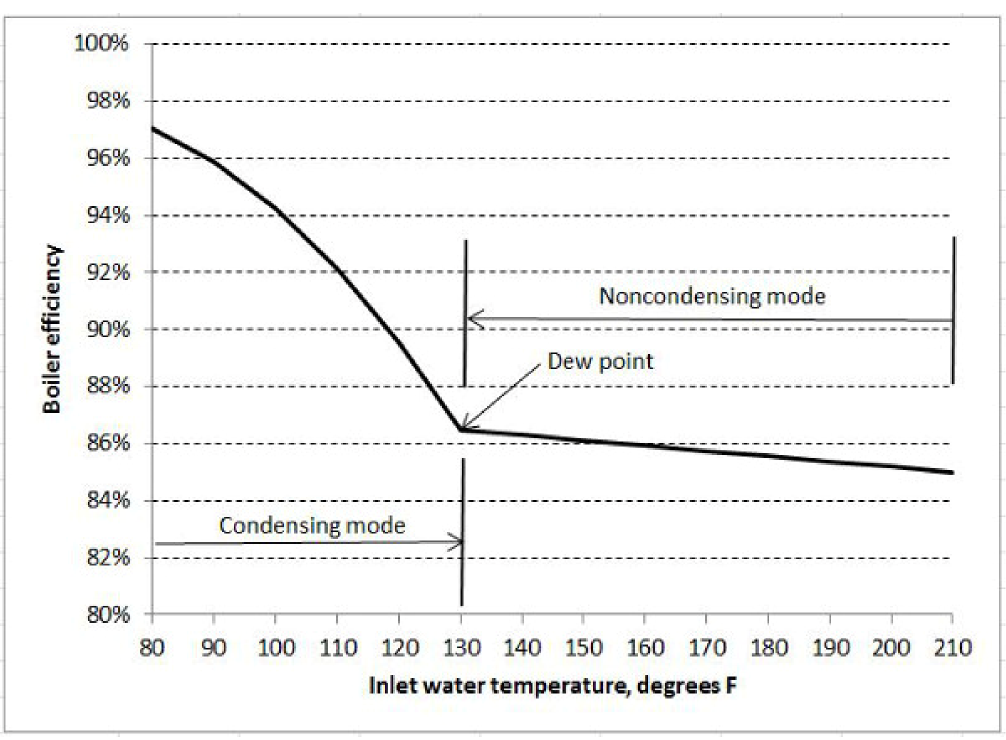

Figure 1 Effect of Inlet Water Temperature on Efficiency of Condensing Boilers (Figure 6, 2012 ASHRAE Handbook - HVAC Systems and Equipment)

This efficiency is converted to a relative efficiency. At 80°F, the relative efficiency is 100%, and at 130°F, it is roughly 87%/97% = 90%. This relative efficiency is calculated for each of the operating mode bins. This de-rating calculation only applies between the 80°F and 130°F temperature range.

Effective thermal efficiency is calculated for all boilers as a combination of rated thermal efficiency and standby losses. Standby losses occur when the boiler is not actively firing, and the boiler instead rejects heat to the atmosphere. This results in increased boiler demand. Standby losses are calculated based on the burner type and firing capacity % using the following equations:

$$\eta_D = \frac{Q(r)\,\eta_t(r)\,t_F - Q(r)\,\eta_{SL}\,t_S}{Q(r)\,t_F}$$

Where:

Q(r) = heat rate
η_t(r) = Thermal efficiency rating
t_f = time firing (%)
t_s = time in standby (%)

The time firing and time in standby values are calculated based on the boiler burner type, its maximum rated firing rate, and required firing rate. An on/off burner, for example, with a maximum firing rate of 100 btu/hr and a demand of 10 btu/hr will fire 10% of the time. Two stage and 4 stage burners are able to more closely match demand, and therefore have reduced standby losses. The thermal efficiency rating in the equation above is assumed to be constant, and equal to the rated thermal efficiency. Note that if the efficiency input type is AFUE, then this calculation is not required, since AFUE takes standby losses into account.

The product of rated thermal efficiency and standby losses is considered the total effective efficiency. The natural gas consumption rate is then calculated for each operating mode bin by dividing the required heat input (btu/h) by the total effective efficiency. Yearly natural gas consumption is calculated by multiplying bin hours by the natural gas consumption rate. The yearly natural gas consumption is determined for both the baseline and upgrade cases.

Steam Boilers: Steam Production

Steam production for each operating bin is calculated by multiplying the fire rate (%) for each bin by the input maximum steam production (which assumes that the input is steam production at 100% fire rate).

Usable efficiency is calculated for each operating bin based on burner type and fire rate. For systems that include storage, boiler efficiency is de-rated for bins at less than 100% fire rate.

Steam Boilers: Boiler Energy Flow

$$Q = Q_s + Q_b - Q_f$$

Where:

- Q = boiler energy flow (btu/hr)
- Q_s = steam energy flow (btu/hr)
- Q_b = blowdown energy flow (btu/hr)
- Q_f = feedwater energy flow (btu/hr)

Steam enthalpy is saturated vapor enthalpy at the input steam pressure.

$$Q_s = h_s \; x \; q_s$$

Where:

- Q_s = steam energy flow (btu/hr)
- h_s = steam enthalpy (btu/lb)
- q_s = steam production (lb/hr)

Feedwater enthalpy is saturated liquid enthalpy at the input deaerator pressure.

$$Q_f = \frac{h_f}{(1 - q_b)} \; x \; q_s$$

Where:

- Q_f = feedwater energy flow (btu/hr)
- h_f = feedwater enthalpy (btu/lb)
- q_b = boiler blowdown rate (%)
- q_s = steam production (lb/hr)

Blowdown water enthalpy is saturated liquid enthalpy at the input steam pressure.

$$Q_b = \frac{h_b}{(1 - q_b)} \; x \; q_b \; x \; q_s$$

Where:

- Q_b = blowdown energy flow (btu/hr)
- h_b = blowdown water enthalpy (btu/lb)
- q_b = boiler blowdown rate (%)
- q_s = steam production (lb/hr)

Steam enthalpy is saturated vapor enthalpy at the input steam pressure. Feedwater enthalpy is specific enthalpy at the input feedwater temperature. Boiler energy output without blowdown is calculated according to the following equation:

$$Q = (h_s - h_f) \; x \; q_s$$

Where:

- Q = boiler energy flow (btu/hr)
- h_s = steam enthalpy (btu/lb)
- h_f = feedwater enthalpy (btu/lb)
- q_s = steam production (lb/hr)

Steam Boilers: Efficiency Increase for Economizer

Savings for installing an economizer (whether non-condensing or condensing) are based on a boiler efficiency increase with the economizer. If the upgrade includes installing an economizer on the boiler, the upgrade efficiency will be calculated using the equation below. If an economizer is not part of the upgrade, the tool will assumed upgrade efficiency is the same as baseline efficiency, unless the user enters an upgrade efficiency.

$$\eta_u = \eta_b + \frac{1\%}{40} \; x \; (t_b - t_u)$$

Where:

- η_u = upgrade boiler efficiency
- η_b = baseline boiler efficiency
- t_b = baseline stack temperature (°F)
- t_u = upgrade stack temperature (°F)

This equation assumes that boiler efficiency is increased by 1% for every 40°F reduction in stack temperature. That assumption is based on the US DOE Steam Tip Sheet #3 (“Use Feedwater Economizers for Waste Heat Recovery”).

Water Boilers and Steam Boilers: Combustion Fan VFD

Electrical energy savings can be achieved by installing a VFD on a boiler combustion fan. These savings are calculated assuming 80% motor load factor, 85% motor efficiency, and minimum fan speed of 50%.

Fan full speed power (kW) is calculated using the following equation.

$$P_{full} = \frac{p \; x \; 0.746 \frac{kW}{hp} \; x \; f_{load}}{\eta_m}$$

Where:

- P_{full} = combustion fan full speed power (kW)

p = combustion fan motor rated power (hp)
f_{load} = motor load factor (assumed 80%)
η_m = motor efficiency (assumed 85%)

A weighted average of fan duty factor is calculated using percent fire rate for all boiler operation hours. Average duty factor represents average fan speed after VFD upgrade. Average duty factor is used to calculated average power (kW) using the following equations.

$$P_{avg,baseline} = P_{full}\ x\ f_{duty,avg}$$

Where:
$P_{avg,baseline}$ = baseline (fixed speed) combustion fan average power (kW)
P_{full} = combustion fan full speed power (kW)
$f_{duty,avg}$ = weighted average fan duty factor

$$P_{avg,upgrade} = P_{full}\ x\ f_{duty,avg}^{\ 2.7}$$

Where:
$P_{avg,upgrade}$ = upgrade (VFD) combustion fan average power (kW)
P_{full} = combustion fan full speed power (kW)
$f_{duty,avg}$ = weighted average fan duty factor, raised to 2.7^{th} power to apply fan affinity law

Operating hours are added for each bin of boiler operation (excluding the "off" bin). Annual electrical energy consumption (kWh) is calculated using the following equation.

$$E_{fan} = P_{avg}\ x\ t$$

Where:
Efan = combustion fan electrical energy consumption (kWh)
Pavg = combustion fan average power (kW)
t = annual operation hours

Savings

Gas savings will be calculated by subtracting the upgrade from the baseline natural gas use. For projects with boiler combustion fan VFDs, electricity savings will be calculated by subtracting the upgrade from the baseline fan energy use.

Measure Life

For new construction projects, measure life is 35 years, consistent with industrial gas boiler replacement measures. For retrofit projects, measure life is 15 years, consistent with capital industrial upgrade measures.

Load Profile

This measure uses the flat gas load profile.

Electric load profile is determined based on operating hours from operating schedule (demand per shift and hours per shift). If operating schedules are entered for both water and steam boilers, the maximum operating hours of the two will be used to determine the electric load profile.

Cost

Costs are based on vendor estimates for the specific project. The vendor must provide incremental costs relative to the baseline for new construction.

Incentive Structure

Incentives are calculated on a case-by-case basis. The incentive will align with the program's custom incentives and incentive caps and will be given per therm and per kWh savings.

Follow-Up

Boiler and water heater technology should be reviewed periodically to ensure this tool remains up-to-date. In addition, code governing process boilers and trends in replaced boiler's efficiencies should be reviewed periodically to ensure the baseline efficiency is current.

Additional steam boiler upgrades may be added later, including reducing excess oxygen in flue gas. There is functionality in the tool to de-rate steam boilers (as for condensing water boilers), which is currently not utilized. In the future a de-rating functionality may be desired for steam boilers.

This tool contains a built-in cost effectiveness calculator. It must be updated with each avoided cost update which may be done without a MAD update. Tool version 2.0 uses 2022 Oregon avoided costs.

Supporting Documents

The cost effective screening for these measures is number 226.2.2. It is attached and can be found by internal staff along with supporting documentation at: *I:\Groups\Planning\Measure Development\Commercial and Industrial\Process Equipment\SI calculators\Process Hot Water Boilers*

226.2.2 OR-WA-CE
C_2022_v_1 process

Version History and Related Measures

Table 92 Version History

Date	Version	Reason for revision
11/30/2018	226.1	First approval of Process Hot Water Boiler Tool, version 1.0
9/15/2021	226.2	Added water heaters and steam boiler measures. Tool version 2.0.

Table 93 Related Measures

Measures	MAD ID
Commercial Condensing Boiler (for HVAC use)	88
Modulating boiler burners (for HVAC use)	142
Commercial Condensing tank water heater (for DHW use)	21
Commercial Condentsing tankless water heater (for DHW use)	72

Approved & Reviewed by

Jackie Goss, PE
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Disclaimer

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Measure Approval Document for Pool Covers

Valid Dates
1/1/2021-12/31/2023

End Use or Description
Pool cover on a heated indoor or outdoor pool during unoccupied hours at a facility without a pre-existing cover.

Program Applicability
Based on the referenced analysis and associated cost-effectiveness screening, the measures described below are approved for use in the following programs:

- Existing Buildings
- Existing Multifamily

Within these programs, applicability to the following building types or market segments are expected:

- Lodging
- Fitness Centers
- Municipal pools
- Multifamily

Within these programs, the measure is applicable to the following cases:

- Retrofit

Cost Effectiveness
Cost effectiveness is demonstrated for Oregon in Table 1 and Washington in Table 2. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2021-v1.1. In Oregon the electric avoided cost year is 2021 and the gas avoided cost year is 2021. In Washington the gas avoided cost year is 2020.

Table 94 Cost Effectiveness Calculator Oregon, per square foot

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Outdoor Pool Cover - Non-Condensing Gas Heater	10	0.07	2.70	$4.99	$0.33	$4.99	2.5	3.0	0%	100%
2	Outdoor Pool Cover - Condensing Gas Heater	10	0.07	2.31	$4.99	$0.33	$4.99	2.1	2.6	0%	100%
3	Outdoor Pool Cover - Electric Resistance Heater	10	65.06	0	$4.99	$0.33	$4.99	7.3	7.8	100%	0%
4	Outdoor Pool Cover - Electric HP Heater	10	13.07	0	$4.99	$0.33	$4.99	1.5	2.0	100%	0%
5	Outdoor Pool Cover - Non-Condensing Gas Heater - Gas Only Territory	10	0	2.70	$4.99	$0.34	$4.99	2.5	3.0	0%	100%
6	Outdoor Pool Cover - Condensing Gas Heater - Gas Only Territory	10	0	2.31	$4.99	$0.34	$4.99	2.1	2.6	0%	100%
7	Indoor Pool Cover - Non-Condensing Gas Heater	10	0.0	1.61	$4.99	$0.23	$4.99	1.5	1.8	0%	100%
8	Indoor Pool Cover - Condensing Gas Heater	10	0.0	1.38	$4.99	$0.23	$4.99	1.3	1.6	0%	100%
9	Indoor Pool Cover - Electric Resistance Heater	10	38.81	0	$4.99	$0.23	$4.99	4.3	4.7	100%	0%
10	Indoor Pool Cover - Electric HP Heater	10	7.80	0	$4.99	$0.23	$4.36	1.0	1.2	100%	0%
11	Indoor Pool Cover - Non-Condensing Gas Heater - Gas Only Territory	10	0	1.61	$4.99	$0.23	$4.99	1.5	1.8	0%	100%
12	Indoor Pool Cover - Condensing Gas Heater - Gas Only Territory	10	0	1.38	$4.99	$0.23	$4.99	1.3	1.6	0%	100%

Table 95 Cost Effectiveness Calculator Washington, per square foot

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#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)		Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Outdoor Pool Cover - Non-Condensing Gas Heater	10	2.70	$4.99		$0.22	$4.99	3.9	4.2	0%	100 %
2	Outdoor Pool Cover - Condensing Gas Heater	10	2.31	$4.99		$0.22	$4.99	3.3	3.6	0%	100 %
3	Indoor Pool Cover - Non-Condensing Gas Heater	10	1.61	$4.99		$0.15	$4.99	2.3	2.5	0%	100 %
4	Indoor Pool Cover - Condensing Gas Heater	10	1.38	$4.99		$0.15	$4.99	2.0	2.2	0%	100 %

Requirements

- The facility must not have had a pre-existing cover for the past 6 months
- The cover must be specifically designed for swimming pools
- Must cover the entire pool surface area
- Liquid evaporation suppressants, solar disks, and mesh covers are ineligible
- Storage reel is required
- Pool heat fuel must be provided by participating utility
- Unheated pools do not qualify
- Residential pools do not qualify

Details

The following cover types have demonstrated the highest level of effectiveness[69] and are expected for participation:

1. **Solid track:** A reel mounted cover deployed using a hand crank and tracks along the pool sides. These covers are constructed from UV-stabilized polyethylene, polypropylene, or vinyl.
2. **Bubble:** A floating cover similar in form to bubble packaging material but constructed from a UV-inhibitor coated, thicker grade plastic.
3. **Foam:** A multi-layer, lightweight floating cover. Each layer is design with a specific function (i.e. UV protection, chemical protection, structural strength, and heat insulation).

These three covers have all demonstrated very similar levels of high performance. Other pool cover types include liquid evaporation suppressants and solar disks. These cover types are relatively ineffective at reducing energy loss and are ineligible. Mesh covers allow water to pass[70] and therefore would not be very effective for reducing evaporation losses and are considered ineligible.

Baseline

This measure uses an Existing Condition Baseline.

The baseline is a heated pool with no cover.

Measure Analysis & Savings

There are four avenues through which heat is lost from a pool and all four are considered in the energy demand equation. These heat loss streams include evaporation, radiation, convection, and conduction. These modes of loss and their relative magnitude[71] are summarized in Figure 2.

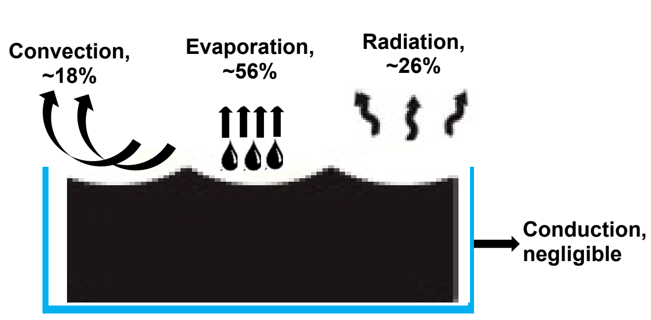

Figure 2 Heat loss from pools

Evaporation losses are estimated using MM Shah Methods Calculation for Evaporation from pools for Indoor and Outdoor swimming pools[72]. This method relies on empirical coefficients for swimming pools and spas, per reference Table 14: Summary of Recommended Calculation Methods for guidance in calculating evaporation rates in unoccupied swimming pools. The following numbered equations from the Shah method are used to calculate evaporation rate in lb/ft^2·h, and the key assumptions for the analysis are displayed in Table 3.

For **outdoor unoccupied** pools, the greater result of the equations 1 through 3 was used:

1. $E_0 = C\mathrm{r}_w(\mathrm{r}_r - \mathrm{r}_w)^{\frac{1}{3}}(W_w - W_r)$

Where:

E_0 = rate of evaporation from unoccupied pools (lb/ft^2.h)
C = 290
r_w = density of air at saturated water surface (lb/ft^3)

[69] Muleta, M., Dept. of Civil and Environmental Engineering, California Polytechnic State University, 2016, ‘Effectiveness of Pool Covers to Reduce Evaporation from Swimming Pools’, *https://rightscapenow.com/images/PDFs/Evaporation-Study-Final-Report_2.pdf*

[70] River Pools, ‘ Solid Vinyl vs. Mesh Inground Winter Pool Covers: Which is Better?’ *https://www.riverpoolsandspas.com/blog/solid-vinyl-versus-mesh-pool-covers#:~:text=A%20solid%20cover%20typically%20lasts,years%20before%20they%20break%20down.*

[71] RSPEC!, Jones, R., US DOE, Smith, C., Solar Energy Applications Lab, Löf, G., Solar Energy Lap Applications, ‘Measurement and Analysis of Evaporation from an Inactive Outdoor Swimming Pool’. Savings come from study performed in Fort Collins, CO. *http://www.rlmartin.com/rspec/whatis/studies_outdoor_inactive.htm*

[72] Shah, Mirza M. ASHRAE. “Methods for Calculation of Evaporation from Swimming Pools and Other Water Surfaces” (July 2014). *https://mmshah.org/publications/ASHRAE%202014%20Evaporation%20paper.pdf*

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r_r = density of air at room temperature and humidity (lb/ft^3)
W_w = specific humidity of air saturated at water surface temperature
W_r = specific humidity of air at room temperature and humidity

2. $E_0 = b(p_w - p_r)$

Where:
b = 0.0346
p_w = partial pressure of water vapor in air at water surface (in.Hg)
p_r = partial pressure of water vapor in air at room temperature and humidity (in.Hg)

3. $E_0 = a(\frac{u}{b})^{0.7}(p_w - p_a)$

Where:
a = 0.0346
b = 30 fpm
u = air velocity (fpm)
p_a = partial pressure of water vapor in air away from the surface of water (in.Hg)

The final evaporation rate for outdoor pools is a sum of the result of Eq. 4 and the greater of Eq. 1, 2, 3.

For **outdoor occupied** pools:

4. $E_{occ} = (1.9 - 21(r_r - r_w) + 5.3N) * E_O$

Where:
N = pool occupants per unit area

Evaporation calculations for **indoor unoccupied** pools are based on assumptions described below and from the Shah whitepaper; Table 5: 'Calculated Evaporation rate from Unoccupied Pools at Typical Design Conditions'. Evaporation rate for indoor occupied pools is calculated using Eq. 4.

Total evaporation heat loss is determined by converting the total evaporation rate in lbs/hr (sum of Eq. 4 and the greater of Eq. 1, 2, 3) into total required heating energy using the following formula:

5. $Heat\ loss_{evap} = ((E_0 * hours_O) + (E_{0cc} * hours_{occ})) \cdot 1048 \frac{btu}{lb}$

Table 96 Input Assumptions Regarding Pool Operation Parameters

Parameter	Source	Application	Value
Scheduling	Estimated from community pools in Portland	Outdoor Pool occupied hours	June-Sept, 10hrs/day
		Indoor Pool unoccupied hours	Year-round, 14 hrs/day
Pool Temperature	US Department of Energy[73]	Indoor & Outdoor Pools	80°F
Outdoor Weather Data	Calculations use dry-bulb temp and wind speed data from TMY3 records. Daily averages are used with the ability to switch between Portland, Grants Pass and Astoria. Savings estimates from Portland are used in cost-effectiveness calculations. Savings from the other two cities are also cost-effective. Air Density Difference: Portland's June-Sept average relative humidity was found to be 60.4% (see tab 'OR Weather' in CEC). While Astoria and Grants Pass had higher and lower relative humidity respectively, a correlation between relative humidity and air density could not be easily established. The Shah paper provided density difference values for 50% and 60% relative humidity. For this analysis, 60% was assumed.	Outdoor Pools	Portland TMY3 weather data 60% RH
Indoor Ambient Conditions	ASHRAE Journal Article[74]	Indoor Pools	82°F ambient air temperature 50% RH
Number of People in Occupied Pool	Assumption made based on low impact to the rate of evaporation equation for which it's used.	Indoor & Outdoor Pools	4

Convection and radiation losses were estimated by taking a percentage of the calculated evaporation loss according to the magnitudes shown in Figure 1. The total heat loss for both occupied and unoccupied periods due to evaporation, radiation, and convection are displayed in Table 4. Both occupied and unoccupied vales are used because the percent reductions in Table 5 are for the total pool usage.

Table 97 Annual Calculated Losses without a Cover, per sf

Parameter	Application	Value	
Total Loss Due to Evaporation	Outdoor Pools	431 Mbtu	49.3 gallons
	Indoor Pools	293 Mbtu	33.6 gallons
Total Loss Due to Radiation and Convection	Outdoor Pools	190 Mbtu	
	Indoor Pools	35 Mbtu	

The assumptions regarding the pool cover's effect on the modes of heat loss are included in Table 5.

73 US Department of Energy. "Managing Swimming Pool Temperature for Energy Efficiency". https://www.energy.gov/energysaver/managing-swimming-pool-temperature-energy-efficiency
74 ASHRAE. "Natatoriums, The Inside Story". Volume 48. (April 2006) https://technologyportal.ashrae.org/journal/articledetail/55

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Table 98 Pool Cover Savings Assumptions

Parameter	Source	Application	Value
Total Reduction of Evaporation Losses	US Department of Energy[75]. This value may be based on residential pools that have lower hours of operation and occupancy.	Indoor & Outdoor Pools	Assume 40% of total evaporation losses will be avoided due to the pool cover.
Reduction of Radiation and Convection Losses	FSEC Energy Research Center[76]	Indoor & Outdoor Pools	Assume that all radiation and convection losses that occur during unoccupied hours will be avoided.
	Nexant outdoor pool study for ETO (La Grande)	Outdoor Pools	26% of total radiation and convection losses occurred during the hour when pool cover will be deployed. Assume that all these losses are avoided due to the pool cover.
	Based on pool operating hours	Indoor Pools	Assume 42% of total radiation and convection losses will be avoided due to the pool cover. Derived from operation hours

The percent savings in Table 5 are applied to the appropriate heat loss values in Table 4 to determine the heat loss savings. The savings for the four types of heating systems are derived by applying the appropriate efficiency, listed in Table 6, to the calculated heat loss savings.

Table 99 Heating System Efficiencies

Fuel Type	Source	Heating Equipment	Efficiencies of Heating Equipment
Gas	ASHRAE 90.1 – 2019 and Code of Federal Regulations 10 CFR 430 Appendix P[77]	Code Non-Condensing Gas Heater Efficiency	82%
	Performance Study of Swimming Pool Heaters[78]	Condensing Gas Heater	96%
Electric	US Department of Energy[79]	Heat Pump	5.0 COP
	US Department of Energy[80]	Resistance	100% or 1.0 COP

In addition to pool water heating savings, ventilation systems can often run less in indoor pool facilities due to pool cover deployment. This savings avenue was not considered for this measure analysis as these savings may require a control system upgrade in order to realize the savings. Also, the savings could vary greatly depending on the facility.

For customers in territories where we claim electric savings, the embedded electricity in water is claimed as electricity savings (3.68 kWh/1000 gallons of water treated). Water savings are shown in Table 97.

Measure Life

10 yrs. This is consistent with the measure life used for pool covers in Energy Trust custom studies.

The pool cover manufacturer that we spoke with indicated that the commercial pool covers they produce do not vary in performance but do vary in lifespan. Their lower cost covers last roughly 5 yrs. For roughly $0.2 more per square foot, customers can purchase the longer lasting covers which achieve a lifespan closer to 10 years. Use of the shorter life covers in not expected.

Load Profile

The load profile is flat-gas and other - process heating for electric.

Cost

Pool Cover costs were determined from looking at past projects from Energy Trust's custom track and speaking with a local vendor and manufacturer. Amongst the custom studies, a recent project cost $1.74/ft^2 for a manual pool cover project at a recreational facility. Another recent custom project cost $5.59 per ft^2 of pool blanket. A local vendor, Pure Water Aquatics, indicated that their customers generally pay $2.05/ft^2 for the blanket itself. SR Smith, a local manufacturer, gave a conservative estimate for blanket cost at $2/ft^2.

Often, there are no labor costs associated with pool cover projects but there are additional costs for shipping (approx. $200) and storage reels which Pure Water Aquatics indicated to be $6,000-$8,000; SR Smith confirmed costs for the reel to range between $5,000 – $8,000. For this measure, the cost scope is around the blanket itself plus the cost of the storage reel. The reel is an essential purchase for first time pool cover buyers; without the reel, the cover will likely go unused. The average reel cost was broken down to a per square footage cost, using a typical recreation pool size of 3,150 ft^2. Given the cost data we received for blankets and reels, the measure cost was determined to be $4.99/ft^2.

There are a variety of pool cover options available through online sellers like Home Depot, however, these products are residential focused and cost data from these sources was not considered applicable to this measure. Commercial pool owners source covers through vendors who specialize in pool products.

Non Energy Benefits

Non-energy benefits are incurred due to the reduction in water loss from the pool cover, as shown in Table 97. Non-energy benefits are based on regionally representative water and wastewater costs. They represent the value of the energy savings reported from water and wastewater treatment and distribution. Water savings are recognized based on whether the customer resides in a territory where ETO can claim kWh savings:

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75 US Department of Energy. "Swimming Pool Covers" *https://www.energy.gov/energysaver/swimming-pool-covers*
76 Florida Solar Energy Center. "Minimizing Heat Loss from Pools and Spas" *http://www.fsec.ucf.edu/en/publications/html/fsec-in-23-83/in-23-83-3.pdf*
77 Electronic Code of Federal Regulations. Title 10: Energy, Part 430- Energy Conservation Program for Consumer Products, Subpart: C Energy and Water Conservation Standards. (Nov. 2020) *https://www.ecfr.gov/cgi-bin/text-idx?SID=408bdd1a8f4d308f0cdc14966fbdb90a&mc=true&node=se10.3.430_132&rgn=div8*
78 Brookhaven National Laboratory. "Performance Study of Swimming Pool Heaters" Section 3: Market Survey of Available Pool Heaters. (Jan. 2009) pg 10 *https://www.bnl.gov/isd/documents/73878.pdf*
79 US Department of Energy. "Heat Pump Swimming Pool Heaters" *https://www.energy.gov/energysaver/heat-pump-swimming-pool-heaters*
80 US Department of Energy. "Electric Resistance Heating" *https://www.energy.gov/energysaver/home-heating-systems/electric-resistance-heating#:~:text=Electric%20resistance%20heating%20is%20100,the%20fuel's%20energy%20into%20electricity* .

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- In Oregon areas where we claim electric savings the Combined Water Rate, net of embedded electricity ($16.94/1000 gal) is used to calculate NEBs.
- For Oregon gas-only territories, we claim a water rate of $17.32/1000 gal, which includes embedded electricity.
- For Washington, the water rate is $11.12/1000 gal.

Incentive Structure

The maximum incentives listed in Table 1 and Table 2 are for reference only and are not suggested incentives. Incentives will be structured per square footage of pool covered. Incentive should not exceed project cost.

Follow-Up

Watersense has interest in developing standards for pool covers.[81] When this measure is up for review, these standards should be considered as a requirement if they have been developed.

If this measure is evaluated, a comparison of water usage before and after would help verify evaporation assumptions.

Costs should also be assessed to ensure they stay up to date.

Supporting Documents

The cost-effective screening for these measures is number 265.1.1. It is attached and can be found along with supporting documentation at: *I:\Groups\Planning\Measure Development\Commercial and Industrial\pools and spas\pool covers*

265.1.1 OR-WA-CE Calculator_2021_v_1_

Version History and Related Measures

Table 100 Measure History

Date	MAD ID	Reason for Revision
12/3/2020	265.1	First approval of pool covers

Table 101 Related Measures

Measures	MAD ID
Commercial Pool Heater	238
Commercial Pool Pump	237
Residential Pool Pumps (inactive)	37
Spa Covers	99

Approved & Reviewed by

Jackie Goss, PE
Sr. Planning Engineer

Disclaimer

81 United States Environmental Protection Agency, 'Pool Covers', *https://www.epa.gov/watersense/pool-covers*

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Energy Trust of Oregon

Measure Approval Document for Commercial Condensing Furnace

Valid Dates
1/1/2022-12/31/2024

End Use or Description
Condensing natural gas AFUE rated furnaces with less than 225,000 Btu/h input capacity installed in small to medium commercial buildings.

Applicability
Based on the referenced analysis and associated cost-effectiveness screening, the measures described below are approved for use in the following programs:

- Existing Buildings
- New Buildings

Within these programs, the measure is provided for existing commercial buildings and new commercial buildings which is applicable to all eligible building types in that program. All small and medium commercial building types except for multifamily are eligible.

Within these programs, the measure is applicable to the following cases:

- New
- Replacement

Cost Effectiveness
Cost effectiveness is demonstrated for Oregon in Table 1 and Washington in Table 2. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2022-v1.0. In Oregon the electric avoided cost year is 2022 and the gas avoided cost year is 2022. In Washington the gas avoided cost year is 2020. The unit for this measure is furnace input capacity in kBtu/hr, sometimes referred to as kBtuh or MBH.

Table 102 Cost Effectiveness Calculator Oregon, per kBtu/hr

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Furnace >=95% AFUE in existing commercial buildings	20	0.97	0.82	$8.44	$0.00	$8.44	1.7	1.7	8%	92%
2	Furnace >=95% AFUE in new commercial buildings	20	0.73	0.51	$8.44	$0.00	$8.44	1.1	1.1	9%	91%
3	Furnace >=95% AFUE in existing commercial buildings - Gas Only	20	0.00	0.82	$8.44	$0.08	$8.44	1.5	1.6	0%	100%
4	Furnace >=95% AFUE in new commercial buildings - Gas Only	20	0.00	0.51	$8.44	$0.06	$8.06	1.0	1.0	0%	100%

Table 103 Cost Effectiveness Calculator Washington, per kBtu/hr

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Furnace >=95% AFUE in existing commercial buildings	20	0.82	8.44	$0.07	$8.44	2.4	2.5	0%	100%
2	Furnace >=95% AFUE in new commercial buildings	20	0.51	$8.44	$0.06	$8.44	1.5	1.6	0%	100%

Requirements

- Natural gas condensing furnace must have input capacity less than 225,000 Btu/h
- Furnace must be used as the primary heating source for the space
- Furnaces must meet minimum 95% AFUE efficiency requirement
- Furnaces must have either a multispeed or variable speed ECM supply fan.

Baseline
This measure uses a Code Baseline.

Based on information from our local outreach team, small and medium building customers are assumed to purchase code efficient furnace products 1) to avoid the extra cost and 2) the potential for added difficulty with condensing system ventilation requirements for retrofits.

Preliminary Market research from the AHRI and California Energy Commissioning (CEC) databases show that most units have AFUEs of 81% or less. This generally aligns with the 80% or 81% AFUE required by codes. Furthermore, online web-scraping from four prominent online retailers shows a similar breakdown of efficiencies available for sale in the market. Although this is not sales data, this database and online retailer analysis shows that minimally code compliant efficiencies make up between 56 and 64% available models in the market.

The Building Codes Division (BCD) adopted ASHRAE 90.1 – 2019 for the upcoming 2021 Oregon Commercial Energy Code update. ASHRAE 90.1- 2019[82] uses the same minimum required furnace efficiency as the outgoing code version OEESC / ASHRAE 90.1-2016[83]. These also correspond to Code of Federal Regulations (CFR) 10 CFR 430 Appendix N[84].

Baseline Furnace Efficiency
Baseline furnace AFUE is 80% based on ASHRAE 90.1 2016 & 2019 Table F-4 minimum required efficiency for non-weatherized gas fired warm air furnaces with input capacity less than 225,000 Btu/h. Although Table F-4 does provide an 81% minimum AFUE for weatherized furnaces, according to the Appliance Standards Awareness Project, non-weatherized units are by far the most common units installed.

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82 Oregon Department of Energy. 2019. 2019 *OREGON ZERO ENERGY READY COMMERCIAL CODE, PART I, Commercial Energy Provisions*

83 American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE). 2016. *ANSI/ASHRAE/IES Standard 90.1-2016, Energy Standard for Buildings Except Low-Rise Residential Buildings (I-P Edition).*

84 United States Department of Energy. 2020. *Title 10: Energy, Part 430 - ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS Subpart C—Energy and Water Conservation Standards*

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Table F-4 Residential Furnaces—Minimum Efficiency Requirements for U.S. Applications (see 10 CFR 430)

Product Class	Size Category (Input)	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure[a]
Furnace, gas fired	<225,000 Btu/h	Nonweatherized excluding mobile home	80% AFUE	10 CFR 430 Appendix N
		Nonweatherized mobile home	80% AFUE	
		Weatherized	81% AFUE	
Furnace oil fired	<225,000 Btu/h	Nonweatherized excluding mobile home	83% AFUE $P_{W,SB} \le 11$ W $P_{W,OFF} \le 11$ W	10 CFR 430 Appendix N
		Nonweatherized mobile home	75% AFUE $P_{W,SB} \le 11$ W $P_{W,OFF} \le 11$ W	
		Weatherized	78% AFUE	
Electric furnace	<225,000 Btu/h	All	78% AFUE $P_{W,SB} \le 10$ W $P_{W,OFF} \le 10$ W	10 CFR 430 Appendix N

a. Section 12 contains a complete specification of the referenced test procedure.

Figure 3 ASHRAE 90.1-2019, Appendix F, Table F-4

Baseline Fan Controls

ASHRAE 90.1 Section 6.5.3.2.1 Supply Fan Airflow Control states that systems should have modulating fan control with minimum speed not exceeding 50%, at which the fan shall draw no more than 30% power. Additional details on this requirement are found in ASHRAE 90.1-2019, Appendix F, Table G3.1.3.15 “Part-Load Performance for VAV Fan Systems.” ASHARE does not require multi-speed or variable speed controls specifically.

Furnaces in the market include several different control capabilities such as single speed, multispeed, and continuously variable speed (also known as variable air volume or VAV). To inform modelling inputs for fan control various sources were reviewed. The AHRI database has no information on the fan control capabilities of each furnace, and the CEC database has very limited information. Based on the online retailer data collected, all units available online have either multispeed or variable speed fans. A weighting of both the multispeed and variable speed units was used in the baseline and efficient case. The unit energy consumption for both fan control types were weighted based on the percentage of baseline efficiency units that use each control type.

Table 104 Fan Control Distribution from Online Retailer Analysis

Description	Percent Multispeed Units (%)	Percent Variable Speed Units (%)
Standard Efficiency, 80% AFUE Rated Furnace	77%	23%
Condensing Furnace, ≥95% AFUE Rated Furnace	52%	48%

Measure Analysis

Energy modeling was completed in OpenStudio (OS) to determine the building energy consumption. The following DOE EnergyPlus (E+) prototype building models were used to estimate savings: Small Office, Strip Mall Retail, Stand-alone Retail, Quick-service Restaurant, Full-service Restaurant, Warehouse and Primary School. Post-1980 building models were used for existing buildings[85] and ASHRAE 90.1 – 2019 building models were used for new buildings[86]. The HVAC components for each prototype were modified in OS to use furnace systems. For each of the prototype buildings, only zones that used packaged HVAC units were modelled to have furnaces. These and other details of the modeling process are detailed in the model summary attachment (See tab ‘Model Troubleshooting’).

AFUE rated packaged furnace systems can be used in either heating only or heating and cooling systems. Generally, in heating and cooling systems, evaporator coils from a split air conditioning system are placed in the furnace duct downstream of the supply fan and heating coils. Thus, in both the heating only and heating and cooling systems the furnace supply fan serve as the main ventilation fan for the space.

Furnace Efficiency

Energy Plus and Open Studio models do not include an input parameter that is exactly analogous to AFUE. Instead, furnace systems use a parameter called burner efficiency, which represents the amount of useful heat that the air absorbs from the burner/heating coil compared to burner input heat. AFUE represents the ratio of total useful heating energy to the total fuel consumption for the system, which includes parameters like parasitic loads and other losses. As a proxy value to burner efficiency, the estimated thermal efficiency (TE) for each unit in the AHRI database was calculated by taking the ratio of its output and input capacities. Subsequently, the average thermal efficiency values for all units within a range of AFUE values associated with the base and efficient cases was found. The values in the table below were used to model the base and efficient case burner efficiencies.

Table 105 Average Thermal Efficiencies from AHRI Database

Efficiency Tier	Average TE (%)
Base Case, 80% AFUE	81%
Efficient Case, ≥95% AFUE	97%

Fan Control Parameters

The EnergyPlus module FanSystemModel models the multispeed and variable speed fans for the furnace system. As described in the baseline section, the fan power is assumed to be 0.266 W/CFM. Part load fan performance for both fans was obtained from ASHRAE 90.1-2019, Appendix F, Table G3.1.3.15 “Part-Load Performance for VAV Fan Systems.”

85 United States Department of Energy. 2020. *Commercial Reference Buildings.* “https://www.energy.gov/eere/buildings/commercial-reference-buildings”
86 United States Department of Energy. 2020. *Commercial Prototype Building Models.* “https://www.energycodes.gov/development/commercial/prototype_models”

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Table G3.1.3.15 Part-Load Performance for *VAV* Fan *Systems*

Method 1—Part-Load Fan Power Data	
Fan Part-Load Ratio	**Fraction of Full-Load Power**
0.00	0.00
0.10	0.03
0.20	0.07
0.30	0.13
0.40	0.21
0.50	0.30
0.60	0.41
0.70	0.54
0.80	0.68
0.90	0.83
1.00	1.00
Method 2—Part-Load Fan Power Equation	

$P_{fan} = 0.0013 + 0.1470 \times PLR_{fan} + 0.9506 \times (PLR_{fan})^2 - 0.0998 \times (PLR_{fan})^3$

where

P_{fan} = fraction of full-load fan power and

PLR_{fan} = fan part-load ratio (current cfm/design cfm).

Figure 4 ASHRAE 90.1-2019, Appendix F, Table G3.1.3.15

For the multispeed fan system, the fan part-load ratio and fractional fan power from Method 1 as shown in Figure 4 was selected, where the fan part-load ratio is assumed to be analogous to fraction of max fan flow. To simplify the analysis, multispeed fans were assumed to operate at just two flows as described in Table 106.

Table 106 Selected Part Load Operating Points for Multi-Speed Fans

Fan Part-Load Ratio (of max flow)	Fraction of Full-Load Power (of max power)
0.50	0.30
1.00	1.00

For the variable speed fan system, the part-load fan power equation in Method 2 from Figure 4 was used to estimate the fan flow and power relationship.

Fan Control Weighting

The market is represented mainly by multispeed and variable speed units. The percentages of multispeed and variable speed units were found based on the online pricing analysis and were used to weight the energy consumption for the base and efficient cases.

Table 107 Model Weighting Percentages for Different Fan Controls and Efficiency Tiers

Efficiency Tier	Multispeed Fan Weight (%)	Variable Fan Weight (%)
Base Case, 80% AFUE	77%	23%
Efficient Case, ≥95% AFUE	52%	48%

Fan Efficiency

ASHRAE 90.1 Section 6.5.3.1.3 Fan Efficiency provides fan efficiency requirements for HVAC systems. However, there is an exception for embedded fans of 5 HP or less. The AFUE rated furnaces applicable to this offer will not have motors greater than 3 or 4 HP, thus ASHRAE's fan efficiency requirements do not apply.

AHRI database includes fan efficiency data in the form of the Fan Energy Rating (FER) and is expressed as watts used per 1000 CFM. After analyzing the data no relationships could be identified between FER and other furnace parameters such as furnace capacity, AFUE, and motor type. Thus, no fan efficiency improvement is assumed between the base and measure case fan efficiencies. The average FER for all units in the AHRI database is 266 W/1000 CFM, or 0.266 W/CFM.

Savings

The difference in models electric energy (kWh) and natural gas (therms) between the weighted baseline and efficient cases was found and then divided by the total modelled furnace capacity (kBtuh) to calculate the normalized unit energy savings for each building type and climate zone permutation, using the formula below.

$$Unit\ Energy\ Savings_{kWh\ or\ therms} = \frac{Baseline\ Energy_{kWh\ or\ therms} - Efficient\ Case\ Energy_{kWh\ or\ therms}}{Total\ Furnace\ Capacity_{kBtuh}}$$

The furnace capacities (kBtuh) are left for Open Studio to autosize for each model. Thus, each permutation of building type, climate zone, and vintage model has a different furnace capacity used in the calculation.

In some cases, the autosized furnace capacities in the ASHRAE new building prototype models are significantly lower than their existing building counterparts. This is attributed to the lower building heating loads for the ASHRAE models due to improved building envelope constructions. The lower capacity furnaces for new buildings leads to instances where the total gas savings are greater for existing building model, but the normalized savings are calculated to be greater for the ASHRAE model.

Climate zone and building type weighting

Energy models were completed for all relevant DOE prototype models for both Post-1980 and ASHRAE 90.1 2019 vintages. Energy consumption values were tabulated based on models run using TMY3 weather files for Portland/Hillsboro and Klamath Falls International Airport, which represent Heating Zones 1 and 2, respectively. Savings per vintage, building type and heating zone are found in Table 108:

Table 108 Modelling Energy Savings

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Vintage	Classification	Heating Zone 1		Heating Zone 2	
		Gas Savings (therms/kBtuh)	Electric Savings (kWh/kBtuh)	Gas Savings (therms/kBtuh)	Electric Savings (kWh/kBtuh)
Existing Building	School	0.70	0.79	1.06	0.84
	Office	0.34	1.06	0.56	0.97
	Retail - Stand Alone	1.43	1.20	2.03	1.16
	Retail - Strip Mall	1.24	1.19	1.78	1.10
	Warehouse	0.70	0.67	1.18	0.64
	Restaurant - Full Service	0.89	1.26	1.58	1.48
	Restaurant - Quick Service	1.03	1.00	1.89	1.09
New Building	School	0.29	0.06	0.47	0.20
	Office	0.56	0.70	0.79	0.68
	Retail - Stand Alone	0.23	1.05	0.42	0.89
	Retail - Strip Mall	1.27	1.35	1.74	1.30
	Warehouse	0.46	0.71	0.70	0.63
	Restaurant - Full Service	0.97	0.76	1.79	0.90
	Restaurant - Quick Service	0.71	1.21	1.35	1.11

Savings are weighted such that the Heating Zone 3 was represented by savings for Heating Zone 2, using the percentages below.

Table 109 Climate Zone Weighting Percentages

Climate Zone	Energy Trust Population Weighting
Heating Zone 1	85.2%
Heating Zone 2 & 3	14.8%

Subsequently, building type weighting was completed based on the percentages in Table 110 for existing and new buildings. Existing building percentages come from program furnace participation from 2005-2019. New building weighting comes from historical participation in the program.

Table 110 Existing and New Building Weighting Percentages

Classification	Existing Buildings Weighting	New Buildings Weighting
School	42.39%	10.96%
Office	26.86%	53.42%
Retail - Stand Alone	17.86%	24.38%
Retail - Strip Mall	2.21%	3.01%
Warehouse	4.53%	5.48%
Restaurant - Full Service	6.15%	2.55%
Restaurant - Quick Service	0.00%	0.19%
Total	**100.00%**	**100.00%**

Measure Life

20 years based on SB1149 guidelines and DEER database for High Efficiency Furnace (EUL ID: HVAC-Frnc).

Load Profile

The electric profile is Small Office Ventilation and the gas profile is Com Heating.

Cost

Equipment costs

A dataset of 480+ AFUE rated furnaces from various online retailers collected in May of 2021 was used to determine the equipment costs of for this measure. The web scraped data included information on furnace efficiency (AFUE), capacities (input and output Btuh), fan blower flow (CFM), and fan blower types. The furnaces were categorized into appropriate efficiency categories and the normalized cost for each unit was found by dividing the equipment cost by its input capacity (kBtuh).

Separate average costs were calculated for the base and efficient case equipment. Based on the collected data, most units in the market place have at least some level of multispeed or variable speed control. Thus, both multispeed and variable speed unit costing was included for both the base and efficient case unit costs. The table below shows a summary of the web scraped data.

Table 111 Online Retailer Equipment Costing Summary

Equipment	Count	Average Normalized Cost ($/kBtuh)	Average Input Capacity (kBtuh)	Average Efficiency (AFUE %)	Average Flow (CFM)	Percent Multispeed Units (%)	Percent Variable Speed Units (%)
Standard Efficiency, 80% AFUE Rated Furnace with multispeed or variable speed supply fan	272	$14.11	75,724	80%	1,620	77%	23%
Condensing Furnace, ≥95% AFUE Rated Furnace with multispeed or variable speed supply fan	206	$23.04	80,068	96%	1,588	52%	48%

Labor and Ancillary Costs

The installation tasks for this analysis include furnace installation, air intake and exhaust venting, and condensate related equipment for the condensing furnaces. Labor hours were taken from RSMeans,[87] while labor rates for HVAC Installers were adopted using information from the Regional Technical Forum's Standard Information Workbook v4.2[88] document for the year 2022. Material pricing for most items comes from RSMeans, while the costs for condensate neutralizers comes from online retailer research.

87 Gordian. (n.d.) *RSMeans Online Data*. 2021.
88 Regional Technical Forum. 2020. *RTF Standard Information Workbook, Version 4.2.*

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Since this analysis is for replacement and new measures, it excludes items which can be assumed to be the same for both installations such as contractor and distributor markups, overhead and profit, project management costs, existing equipment demolition, and permitting costs. Table 112 and Table 113 show the costs included for both installations.

Table 112: Labor and Ancillary Costs: Standard Efficiency Natural Gas Furnace

Install Task	Source(s)	Labor Cost	Material Cost
Install Standard Gas Furnace, ~75 kBtuh, 1200 CFM	RSMeans hours and material, RTF rate	$712.92	$0.00
Vent for air intake and Exhaust Type B Vent Steel, Est 15'	RSMeans hours and material, RTF rate	$105.88	$526.50
Total Cost			**$1,345.30**
Total Normalized Cost, assuming 75 kBtuh			**$17.94/kBtuh**

Table 113: Labor and Ancillary Costs: Condensing Natural Gas Furnace

Install Task	Source(s)	Labor Cost	Material Cost
Install High Efficiency Condensing Gas Furnace, ~75 kBtuh, 1200 CFM	RSMeans hours, RTF rate	$712.92	$0.00
Combustion Air Intake and Flue, PVC, Est 15' each	RSMeans hours and material, RTF rate	$175.66	$204.00
Condensate Neutralizer, Cartridge Style (Inline)	RSMeans hours, RTF rate, Online Retailer Material,	$53.50	$72.43
Condensate Drain Piping, Est 10'	RSMeans hours and material, RTF rate	$68.18	$21.90
Total Cost			**$1,308.59**
Total Normalized Cost, assuming 75 kBtuh			**$17.45/kBtuh**

The total normalized cost for the base and efficient case systems are shown in Table 114 along with the incremental cost.

Table 114 Toal and Incremental Furnace Costs

Case	Description	Material Cost ($/kBtuh)	Install Cost ($/kBtuh)	Total Cost ($/kBtuh)
Base	Standard Efficiency, 80% AFUE Rated Furnace with multispeed or variable speed supply fan	$14.11	$17.94	$32.05
Efficient	Condensing Furnace, ≥95% AFUE Rated Furnace with multispeed or variable speed supply fan	$23.04	$17.45	$40.49
Incremental Cost				**$8.44**

Non Energy Benefits

In gas only territories, customer electric bill savings will be converted to non-energy benefits blended commercial retail rates.

Incentive Structure

The maximum incentives listed in Table 1 and Table 2 are for reference only and are not suggested incentives. Incentives will be structured per kBtuh.

Follow-Up

Participation by building type will be tracked for both existing and new buildings to reestablish weighting and also to inform if additional building types must be modelled. This is particularly important for hotels and outpatient health care buildings types that were not modelled as part of the MAD but included as eligible building types.

Supporting Documents

The cost effective screening for these measures is number 270.1.1. It is attached and can be found along with supporting documentation at: *I:\Groups\Planning\Measure Development\Commercial and Industrial\Commercial HVAC\Furnaces\commercial*

270.1.1 OR-WA-CE Calculator_2022_v_1

Condensing Furnace Model Sum

Furnace Cost Summary_6-28-21.xls

Version History and Related Measures

Table 115 Version History

Date	Version	Reason for revision
7/26/2021	270.1	Introduce commercial furnaces

Table 116 Related Measures

Measures	MAD ID
Condensing Furnaces in Multifamily	203

Approved & Reviewed by

Jackie Goss, PE
Sr. Planning Engineer

Disclaimer

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Measure Approval Document for Condensing Gas Furnaces in SW Washington

Valid Dates
August 1, 2020 – December 31, 2023

End Use or Description
High efficiency gas furnace in southwest Washington

Program Applicability
Based on the referenced analysis and associated cost-effectiveness screening, the measures described below are approved for use in the following programs:

- Existing Small Multifamily
  - 2-4 units and side by side structures
- Home Retrofit

Within these programs, the measure is applicable to the following cases:

- Replacement

Purpose of Re-Evaluating Measure
Savings costs and non-energy benefits are updated.

Cost Effectiveness
Cost effectiveness is demonstrated in Table 1 using Energy Trust's Cost Effectiveness Calculator version 2021 version 1.1 The Washington gas avoided cost year is 2020.

Table 117 Cost Effectiveness Calculator Washington

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Ele	% Gas
3	90-95% AFUE Gas Furnace	25	88	$1,006	$2.15	$1,006	2.38	2.41	0%	100%
2	96%+ AFUE Gas Furnace	25	94	$1,909	$2.16	$1,909	1.34	1.36	0%	100%
1	90% + AFUE Gas Furnace	25	92	$1,607	$2.16	$1,607	1.56	1.58	0%	100%

Requirements

- Installed in Washington only
- 90% or greater AFUE
- Measure #1 is a blended measure assuming a weighted average participation, it is to be used for program designs that provide one option to any furnace above 90%. While, measures #2 and #3 are to be used for program designs that distinguish tiers of efficiency level. Within the same customer group, measure #1 should not be paired with the others since that would skew the weighing used to create measure #1.
  1. At the time of writing, the program anticipates using Measure #1 for savings withing reach customers and measure #2 for market rate customers. As these are distinct customer groups, this is an approved use.

Baseline
This measure uses code baseline of 80% AFUE. Guidance from the Washington Energy Efficiency Advisory Group in April 2018 indicated the use of an 80% AFUE code baseline is appropriate for Washington's regulatory environment.

Measure Analysis
Savings calculations are based on characteristics (efficiency and input capacity) of participating projects in the existing homes program for the years 2017 through 2019.

Table 118 Characteristics of furnaces participating in Washington programs in 2017, 2018 and 2019.

AFUE Tiers	Quantity	Average of AFUE	Average Capacity (kBtu/h)t
AFUE 90-95	214	95.0	61.8
AFUE 96+	427	96.2	65.7
Weighted average		95.8	64.4

Gas Savings
Savings are calculated by a difference in differences method, based on the change in gas consumption pre/post install relative to a comparison group for common instances/bundles of measures.

Gas savings can be estimated using the following equation:

$$therm\ savings\ =\ Baseline\ therms - \left(\frac{Baseline\ therms\ *\ 80\ AFUE}{efficient\ AFUE}\right)$$

Representative efficiencies for each tier are 95AFUE and 96.2AFUE, as demonstrated in Table 118. Baseline heating load is 557 therms, which is a weighted average heating consumption across five 20-year vintages of single-family homes based on a 2021 market profile in Southwest Washington.

Table 119 NW Natural WA 2012 market profile single family normalized annual consumption usage statistics

Age Range	Properties	Base Load	Heating Load	Total Load
Pre-1940	2,074	166	509	602
1940-1960	3,022	160	498	584
1960-1980	3,315	199	580	692
1980-1992	4,720	196	574	686
1992-2012	36,834	206	560	754
Total	49,965	**Weighted Heating Load**	**557**	

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This yields savings 88 therms, and 94 therms in savings for 90-95AFUE and 96+AFUE tiers respectively and 92 therms for the weighted average used for the blended measure #1.

Non-Energy Benefits

Electric savings are included as non-energy benefits in because Energy Trust does not provide electric efficiency services in that region.

Fan energy savings are due to reduced fan runtimes, or lower fan speeds, needed to maintain set point temperatures with a more efficient furnace. Estimated Fan runtime savings:

$$Fan\ kWh\ savings\ = \frac{(therm\ savings\ *\ 100{,}000Btu/therm)}{input\ Btu/h} *\ fan\ input$$

Efficient furnace capacities of 61,800 and 65,700 Btu/h, are based on completed projects as shown in Table 118. The updated fan input energy, 0.185 kW, is from RTF SEEM modeling for electric forced air furnaces. Both systems yield ~26kWh in electric savings.

Electric savings are converted to NEBs at the Washington blended residential billing rate of $0.082/kWh.

Comparison to RTF or other programs

This analysis shares several similarities to MAD 22, gas furnaces for rentals, moderate income track and small multifamily in Oregon.

- Both analyses use identical savings estimation methods but with different baseline heating loads (557therms for WA based on NW Natural's 2012 market profile of consumption vs. 540therms for OR based on Energy Trust's 2009 billing analysis), average AFUEs and furnace capacities as inputs.
- This measure uses the same costs from the same contractor that supplied bids in 2020.

Another comparable measure, condensing furnaces in multi-family, focuses on serving multiple units or common areas and is approved in MAD 203. For systems serving more than one unit, the measures described in MAD 203 are more appropriate than these.

Measure Life

Measure life of 25 years, consistent with Energy Trust gas furnace measures since 2005 based on research on furnace age at retirement conducted in British Columbia (Natural Gas Furnace Market Assessment, August 2005, Haybart and Hewitt).

Cost

Market research conducted by TRC in April 2020 collected bids for 14 gas furnaces from 4 contractors. The bids included furnaces that complied with the federal standard as well as high efficiency furnaces. Baseline furnace costs ranged from $3,671 to $4,942 with an average cost of $4,330 and efficient furnace costs ranged from $4,549 to $7,278. The incremental cost data was weighted using the project tracker installation volume to better reflect the market level incremental cost.

Table 120 Cost Summary

Efficiency tier	2020 Contractor bids	Incremental Cost
80 AFUE	$4,330	-
90 - <= 95 AFUE	$5,336	$1,006
96+ AFUE	$6,238	$1,908
Weighted Average		$1,607

Both baseline and efficient costs have increased significantly since the previous analysis of this measure.

Incentive Structure

The maximum incentives listed in Table 1 are for reference only and are not suggested incentives. Incentives will be per furnace and may be paid to homeowners, property owners, or through contractor instant discounts.

Follow-Up

Electric savings in this measure do not account for fan motor efficiency savings over the baseline. Lack of market data on baseline furnace fans efficiency and lack of energy modeling software that use the FER metric as defined in the federal standard are the key reasons for this omission. Future updates should review baseline furnace fan to determine savings potential, if any.

Cost data for the measure has varied significantly over short periods, frequent cost updates are recommended.

Supporting Documents

The cost-effective screening for these measures is number 23.3.1. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Residential\Res HVAC\furnace\nwn WA furnaces

23.3.1 CEC 2021 v1.1
Res Furnaces WA.xlsx

References

Regional Technical Forum - Residential Single Family Existing HVAC and Weatherization SEEM data – February 2016:
RTF Supporting documents site, SEEM workbook

Version History and Related Measures

Energy Trust has been offering furnaces in Washington for many years. These predate our measure approval documentation process and record retention requirements. Table 13 may be incomplete, particularly for measures approved prior to 2013.

Table 121 Version History

Date	Version	Reason for revision
1/1/2009	23.x	Approve 90%+ AFUE furnaces in SW WA.
9/4/2014	23.1	Add two tiers: 90-94.9% & 95%+ AFUE
5/22/2018	23.2	Update savings analysis and add fan savings value, update cost.
6/22/2020	23.3	Update savings and cost.

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Table 122 Related Measures

Measures	MAD ID
Furnaces in rentals, savings within reach and small multifamily in Oregon	22
Furnaces in large multifamily	203

Approved & Reviewed by

Jackie Goss, PE
Sr. Planning Engineer

Disclaimer

Measure Approval Document for Residential Energy Saver Kits

Valid Dates
1/1/2022-12/31/2023

End Use or Description
Residential Energy Saver Kits – configuration of LED lighting and water devices that customers request online to be mailed for self-install.

Applicability
Based on the referenced analysis and associated cost-effectiveness screening, the measures described below are approved for use in the following programs:

- Residential
  - HES - Existing Homes

Within these programs, applicability to the following building types or market segments or program tracks are expected:

- All residential customers are eligible for this measure, including multifamily and manufactured homes, however the majority of treated sites are expected to be single family homes. The offering will be processed through the residential program.
- This kit measure is intended to serve lagging-market populations in rural communities, income-qualified customers, communities of color and single-family renters.
- Kits to be delivered by request, self-install applications or delivered and/or installed by community-based organizations.

Within these programs, the measure is applicable to the following cases:

- Retrofit

Purpose of Re-Evaluating Measure
Version: 27.7 This MAD updates customer segment served, savings and market analysis updates, and fulfillment cost for kits delivered to residential customers. Additionally, a new device, Low Flow Thermostatic Shower Valves (LFTSV), has been added to the kit offering, while faucet aerators have been removed.

- This kit measure is intended to serve lagging-market populations rather than serving all residential customers. Outreach will focus kit distribution to rural communities, income-qualified customers, communities of color, and single-family renters through coordination with community-based organizations and other community agencies. Previous versions of Residential Kits were open to all customers.
- Savings and market updates reflect Regional Technical Forum (RTF) updates, NEEA market analysis and Energy Trust evaluations.
- Costs in the cost-effectiveness analysis reflect individual device procurement quotes and shipping and handling estimates based on past program costs.
- Low Flow Thermostatic Shower Valves are a new measure for Energy Trust and the Kit measure, this is a showerhead with an integrated thermostatic valve. Analysis reflects the RTF Thermostatic Shower Restriction Valve Planning Measure v4.1[89] analysis with Energy Trust modifications.

Version 27.8: Clarifies multifamily applicability.

Cost Effectiveness
Cost effectiveness is demonstrated for Oregon in Table 1 and Washington in Table 2. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2022-v1.0. In Oregon the electric avoided cost year is 2022 and the gas avoided cost year is 2022. In Washington the gas avoided cost year is 2020.

The values in these cost-effectiveness tables are per single device, incremental cost reflects fulfillment cost (device and shipping and handling costs), and maximum incentive reflects the highest incentive possible to maintain a UCT value of 1.0 and does not indicate actual incentives.

Table 123 Cost Effectiveness Calculator Oregon

89 RTF Thermostatic Shower Restriction Valve Planning Measure v4.1: https://rtf.nwcouncil.org/measure/thermostatic-shower-restriction-valve

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#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	LM General Purpose and Three-Way - 250 to 1049 lumens	12	7.69	-0.06	$2.25	$0.25	4.64	1.0	3.1	100%	0%
2	LM General Purpose and Three-Way - 1050 to 1489 lumens	12	13.57	-0.11	$2.25	$0.37	8.23	1.0	5.1	100%	0%
3	LM General Purpose and Three-Way - 1490 to 2600 lumens	12	12.43	-0.10	$2.70	$0.37	7.60	1.0	4.0	100%	0%
4	LM Reflectors and Outdoor - 250 to 1049 lumens	12	7.88	-0.07	$2.25	$0.47	4.75	1.0	4.0	100%	0%
5	LM Reflectors and Outdoor - 1050 to 1489 lumens	12	11.22	-0.08	$2.25	$0.79	6.88	1.0	6.3	100%	0%
6	LM Reflectors and Outdoor - 1490 to 2600 lumens	12	23.42	-0.10	$2.70	$1.33	15.19	1.0	10.1	100%	0%
7	OR By Request Showerhead - Full Territory Any Electric 1.50 GPM	10	83.6	0.00	$7.20	$11.41	49.66	1.0	19.4	100%	0%
8	OR By Request Showerhead - Full Territory Gas 1.50 GPM	10	2.4	3.74	$7.20	$11.43	21.04	1.0	15.5	7%	93%
9	OR By Request Showerhead - Partial Territory Gas 1.50 GPM	10	0.0	3.74	$7.20	$11.97	$19.64	1.0	15.9	0%	100%
10	OR By Request Shower Wand - Full Territory Any Electric 1.50 GPM	10	237.2	0.00	$13.25	$32.37	$140.84	1.0	30.0	100%	0%
11	OR By Request Shower Wand - Full Territory Gas 1.50 GPM	10	7.3	11.56	$13.25	$35.32	$65.00	1.0	26.0	7%	93%
12	OR By Request Shower Wand - Partial Territory Gas 1.50 GPM	10	0.0	11.56	$13.25	$37.00	$60.67	1.0	26.7	0%	100%
13	OR By Request LFTSV - Full Territory Any Electric 1.50 GPM	10	248.6	0.00	$18.91	$33.48	$147.62	1.0	21.8	100%	0%
14	OR By Request LFTSV - Full Territory Gas 1.50 GPM	10	6.9	11.09	$18.91	$33.52	$62.34	1.0	17.3	7%	93%
15	OR By Request LFTSV - Partial Territory Gas 1.50 GPM	10	0.0	11.09	$18.91	$35.12	$58.23	1.0	17.8	0%	100%

Table 124 Cost Effectiveness Calculator Washington

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	WA By Request Showerhead - Partial Territory Gas 1.50 GPM	10	3.9	7.20	$7.74	$7.20	4.4	12.8	0%	100%
2	WA By Request Shower Wand - Partial Territory Gas 1.50 GPM	10	12.1	13.25	$23.92	$13.25	7.39	21.52	0%	100%
3	WA By Request LFTSV - Partial Territory Gas 1.50 GPM	10	4.4	18.91	8.58	$18.91	1.88	5.43	0%	100%

Requirements

- The maximum number of products distributed in each kit shall be determined by PMC program staff in consultation with Energy Trust.
- In gas-only service territory, showerheads, shower wands and LFTSV should only be distributed to customers with gas water heating.
- In electric only service territory, showerheads, shower wands and LFTSV should only be distributed to customers with electric water heat.
- Lighting products should not be distributed in gas-only service territory.
- Each household should not receive a kit more often than once every two years, with reasonable and agreed upon exceptions, such as residency changes or alterations or additions in kit product content.
- Lamp must be ENERGY STAR® qualified or meet the ENERGY STAR specification at time of distribution.
- Showerheads, shower wands and LFTSV will have a maximum flow rate of 1.5 gallons per minute (GPM)
- Low flow thermostatic shower valves must be a single, integrated device not a separate valve and showerhead.
- Bulbs should only be distributed to homes where they are expected to replace incandescent or halogen bulbs.

LED Baseline

Lighting measures uses an Existing Condition Baseline.

Devices provided in these kits are considered Retrofit measures because the screening criteria for kits only send bulbs to households who self-report above average inefficient bulbs.

LED bulbs have a dramatically longer life than other bulbs on the market. To account for this, Energy Trust has adopted a modified version of the RTF Residential Lighting workbook. The workbook models a shift in the baseline energy usage over time as inefficient bulbs burn out and are replaced. Each bulb type has an assumed life in years, based on rated hours and expected hours of use, rounded to the nearest year, with a minimum life of one year. It is assumed that when a bulb burns out it will be replaced based on the current lagging-market share of all products. Much more detailed description of the methodology is available on the RTF Residential Lighting website[90]. The By Request delivery type used for kit lamps has been modified to use the same existing condition baseline as Direct Install delivery types.

The primary data source to determine market share is Northwest Energy Efficiency Alliance (NEEA) 2020 Residential Lighting Market Analysis91. This annual survey combines Nielsen sales data with a shelf survey of retailers across the region. A key component of the NEEA report is the Chain Logic analysis created by BPA.92 NEEA's survey found that adoption of LED lamps is lagging significantly in the Grocery, Dollar, and Mass Merchandise segment. While additional market research, such as "An Incandescent Truth: Disparities in Energy-Efficient Lighting Availability and Prices in an Urban U.S. County"93, indicates that "…the adoption of energy-efficient lighting is not equitably distributed across socioeconomic groups, with poorer households less likely to adopt than higher-income households."

90 RTF Residential Lighting: https://rtf.nwcouncil.org/measure/residential-lighting
91 NEEA 2020 Residential Lighting Market Analysis: https://azureenergytrust.sharepoint.com/:x:/g/Operations/PandE/measuredevelopment/EefAK0zqQPJOnxUAStiza90BzER06gjDFgFeiXvltfXh6Q?e=QtdVYd&CID=F349A71A-39BA-4984-9674-878458136FCA&wdLOR=c7B1EEFA8-08AD-4F83-BA06-3DECD47D6B8C
92 BPA Moment Savings, Chain Logic Presentation, Sept. 2016: https://www.bpa.gov/EE/Utility/Momentum-Savings/Documents/BPA_Chain_Logic_Presentation.pdf
93 Reames, Tony G., Michael A. Reiner, and M. Ben Stacey. (2018) "An incandescent truth: Disparities in energy-efficient lighting availability and prices in an urban U.S. county." Applied Energy 218:95-103: http://css.umich.edu/publication/incandescent-truth-disparities-energy-efficient-lighting-availability-and-prices-urban

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To address the lagging market segments, a baseline for the Grocery, Dollar, Mass Merchandise segment and Small Hardware segments was calculated as a volume-weighted average of the market share for each lamp type and lumen bin in NEEA's market analysis. This baseline was defined for all lamp types and lumen bins currently included in the program. The resulting LED market shares for the full and lagging markets are shown in Table 125. The rationale behind this is explained in greater detail in the Retail LED MAD (140.4).

Table 125 LED Market Share for Full Market and Lagging Market Subgroups

LED Measures		Full Market	Lagging Market
General Purpose and Three-Way	250 to 1049 lumens	74.5%	68.9%
	1050 to 1489 lumens	42.5%	51.3%
	1490 to 2600 lumens	71.5%	69.5%
Reflectors and Outdoor	250 to 1049 lumens	77.5%	75.4%
	1050 to 1489 lumens	80.1%	73.1%
	1490 to 2600 lumens	47.5%	45.9%

LED Measure Analysis

The measure analysis relies on the RTF's baseline replacement model, the most recent market data available from NEEA, and a few Energy Trust-specific modifications to the RTF Residential Lighting Workbook v9.394. For brevity, a full explanation of the savings analysis is not included here, but a high-level overview follows.

Steps in the RTF process:

- The analysis is based on NEEA shelf survey data
- Lumens are normalized in each lumen bin across technology types
- The baseline is calculated for each individual measure differentiating for:
    - Bulb type
    - Lumen bin
    - Delivery channel
    - Hours of use
- The lifetime savings are determined by calculating the baseline in each individual year of the measure life for each individual measure, to which the efficient product is compared.
- Similar methodology is used to calculate savings for stored bulbs as well as avoided replacement costs.

LED Savings

Savings for lighting measures are the difference in wattage between the efficient LED and the shifting market baseline in each calculated year multiplied by the average wattage of the efficient LED. Savings are adjusted by hours of use, HVAC interaction, and removal and storage rates. Table 126 shows annualized full measure life savings values, as calculated in the Energy Trust modified RTF workbook for By Request lamps, *ResLighting_v9_3 ETO MOD draft.xlsx*.

Table 126 LED measure savings

Lamp Type	Lumen Category	Electric Savings (kWh)	Gas Savings (therms)
General Purpose and Three-Way	250 to 1049 lumens	7.69	-0.06
General Purpose and Three-Way	1050 to 1489 lumens	13.57	-0.11
General Purpose and Three-Way	1490 to 2600 lumens	12.43	-0.10
Reflectors and Outdoor	250 to 1049 lumens	7.88	-0.07
Reflectors and Outdoor	1050 to 1489 lumens	11.22	-0.08
Reflectors and Outdoor	1490 to 2600 lumens	23.42	-0.10

Showerhead and Shower Wand Baselines

Showerhead and shower wand devices use an Existing Condition Baseline.

Devices provided in these kits are considered Retrofit measures under the assumption that the kit fulfilment logic only sends shower devices to homes that have inefficient products. In past kit analysis, savings were calculated based on a weighted average baseline flow rate calculated based on RBSA showerhead/wand flow rate data and Energy Trust housing type distribution.

Showerhead and Shower Wand Measure Analysis

Gas water heating end-use energy savings for showerheads and shower wands reflect previous MAD methodology. Primary analysis for MAD 27.6 was based on the RTF Commercial and Residential Showerheads v3.1 workbook with Energy Trust modifications. Realization rates from the Energy Trust Low Flow Gas Showerhead Analysis from Sept. 2020 are applied to the savings results. The 2020 Gas Showerhead analysis compares billing analysis from matched comparison set regression analysis, performed by Recurve Analytics, to savings from the previous Kit MAD 27.6.

Installation rates from the program's 2018 Energy Saver Kit Survey are shown in Table 127Table 127 Installation Rates from 2018 ESK Survey. Realization rates of 38% and 99% are used for showerheads and wands, respectively. Previous MAD 27.6 analyses methodology are summarized below, additional details can be found in Energy Saver Kit MAD 27.6.

Table 127 Installation Rates from 2018 ESK Survey

Kit Component	Net Install Rate
A-lamps	71%
Reflectors	73%
Shower wands	61%
Showerheads	55%
1.75 GPM aerator	58%
1.50 GPM aerator	53%
Kitchen Aerators	49%
Bath Aerators	59%

94 RTF Residential Lighting Workbook v9.3: https://nwcouncil.box.com/v/ResLightingv9-3

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Savings analysis is based on a modified version of the RTF's Commercial and Residential Showerhead Workbook v3.1. The RTF uses the following equations to develop unit energy consumptions, UECs, for each water heater technology, flow rate of showerhead/wand and housing type:

- [Water consumption] = [rated flow rate (gallons/minute)] x [in use flow adjustment] x [# of events/yr] x [event duration (minutes/event)]
- [End-use Energy consumption] = [water consumption] x [mixed hot water energy intensity (kWh/gallon)]
- [Embedded water/waste water energy consumption] = [water consumption] x [water/waste water energy intensity (kWh/gallon)]

Combined water consumption, water heating energy and embedded energy saving, and costs are summarized in Table 128; these are savings before installation rates and realization rates are applied.

Table 128 Combined water, water heating energy and embedded energy savings and NEBs before installation and realization rates.

Based On Evaluated Savings and 2021 RTF, RBSAii, NEAA, and Energy Trust CEC factors/rates	Savings: Water Consumption (gal/year)	Savings: Water Heat Energy		Savings: Embedded Water/Wastewater		Combined Savings (before installation and realization rates)		
		Annual Energy Savings (kWh/yr)	Annual Energy Savings (therms/yr)	Annual Energy Savings (kWh/yr)	Energy Trust Water/ Wastewater cost ($/yr)	kWh Savings (DHW + WW/yr)	Therm Saving (DHW)	***NEBs Waste water costs and elec. saving in gas only territory***
OR By Request Showerhead - Full Territory Any Electric 1.50 GPM	3,065	388.8	0	11.3	$54.61	400	0.0	$54.61
OR By Request Showerhead - Full Territory Gas 1.50 GPM	3,069	0	17.9	11.3	$54.69	11	17.9	$54.69
OR By Request Showerhead - Partial Territory Gas 1.50 GPM	3,069	0	17.9	0.0	$55.95	0	17.9	$57.29
OR By Request Shower Wand - Full Territory Any Electric 1.50 GPM	3,008	381.7	0	11.1	$53.60	393	0.0	$53.60
OR By Request Shower Wand - Full Territory Gas 1.50 GPM	3,282	0	19.1	12.1	$58.48	12	19.1	$58.48
OR By Request Shower Wand - Partial Territory Gas 1.50 GPM	3,282	0	19.1	0.0	$59.83	0	19.1	$61.26
WA By Request Showerhead - Partial Territory Gas 1.50 GPM	*3,213*	*0*	*18.7*	*11.8*	*$36.05*	*12*	*18.7*	*$36.05*
WA By Request Shower Wand - Partial Territory Gas 1.50 GPM	*3,438*	*0*	*20.0*	*12.7*	*$38.58*	*13*	*20.0*	*$38.58*

Low Flow Thermostatic Shower Valve (LFTSV) Baseline

Low Flow Thermostatic Shower Valves use an Existing Condition Baseline.

The RTF Thermostatic Shower Restriction Valve v4.1 Planning Measure is referenced for baseline and savings. The baseline equipment is a standard showerhead that does not already have a low flow or restriction device installed, the baseline flow rate is 2.15 gpm.

Low Flow Thermostatic Shower Valve (LFTSV) Measure Analysis and Savings

The LFTSV measure includes the evaluated low flow savings for showerheads, as described above, and adds additional savings associated with the thermostatic valve that slows hot unused water before customers begin showering. Savings analysis is based on a modified version of the RTF's ThermostaticShowerRestrictionValve_v4.1.xlsx.

Water heating end-use energy savings for the LFTSV are calculated based on "hot water saving" while other embedded energy and water consumption related savings are based on "all water savings" from the RTF analysis. Water savings calculations are based on flow rates, minutes of behavior waste (how long shower runs hot before a customer uses the shower), shower/tub configurations, and other parameters defined within the RTF analysis. The RTF breaks out savings for the valve-only and low-flow showerhead separately, valve-only details are pulled from RTF for this measure. Key factors used in the RTF analysis and valve-only savings are shown in Table 129. Savings for thermostatic valve-only, low flow showerhead, and combined LFTSV are provided in Table 130; these savings are before installation rates are applied. The showerhead installation rate of 55% is used for these LFTSV devices in place of the RTF storage and removal rates.

Table 129 RTF Thermostatic Shower Restriction Valve v4.3 planning measure, valve-only water savings assumptions and totals

Water savings per event - valve				Water savings per event - total			
Baseline showerhead flow rate (gpm)	Behavior waste savings (minutes)	% Hot Water (during warm-up)	% of Shower (vs. tub) start	Valve - water savings per event (gallons)	Valve - Hot water savings per event (gallons)	Total water savings per event (gallons)	Total hot water savings per event (gallons)
2.15	0.63	80%	78%	1.06	0.85	1.06	0.85

Water savings per year			Water savings per year, with removal and storage rate			
Showers per year, per showerhead	All water savings (gallons/year)	Hot water savings (gallons/year)	Storage rate	Removal rate	All water savings (gallons/year)	Hot water savings (gallons/year)
333	351	281	Energy Trust Showerhead installation rate of 55% used instead		351	281

Table 130 LFTSV component and combined savings and NEBs before installation and realization rates.

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Thermostatic Valve, Showerhead and Combined LFTSV Savings	Savings: Water Consumption (gallons/year)	Savings: Water Heating Energy		Savings: Embedded Water/Waste Water		Final Combined Savings		
		Annual Energy Savings (kWh/yr)	Annual Energy Savings (therms/yr)	Annual Energy Savings (kWh/yr)	Energy Trust water/ Wastewater cost ($/yr)	kWh Savings (DHW + WW/yr)	Therm Saving (DHW)	*NEBs Wastewater costs and elec. saving in gas only territory*
Thermostatic Shower Valve - WITHOUT LOW FLOW SHOWERHEAD								
OR By Request TSV - Full Territory Any Electric	351.3	50.6	0.0	1.3	6.26	51.9	0.0	$6.26
OR By Request TSV - Full Territory Gas	351.3	0.0	2.3	1.3	$6.26	1.3	2.3	$6.26
OR By Request TSV - Partial Territory Gas	351.3	0.0	2.3	0.0	$6.40	0.0	2.3	$6.56
WA By Request TSV - Partial Territory Gas	*351.3*	*0.0*	*2.3*	*1.3*	*$3.94*	*1.3*	*2.3*	*$3.94*
Low Flow Showerhead Measure Savings								
OR By Request Showerhead - Full Territory Any Electric 1.50 GPM	3064.6	388.8	0	11.3	$54.61	400.1	0.0	$54.61
OR By Request Showerhead - Full Territory Gas 1.50 GPM	3069.0	0	17.9	11.3	$54.69	11.3	17.9	$54.69
OR By Request Showerhead - Partial Territory Gas 1.50 GPM	3069.0	0	17.9	0.0	$55.95	0.0	17.9	$57.29
WA By Request Showerhead - Partial Territory Gas 1.50 GPM	*3213.1*	*0*	*18.7*	*11.8*	*$36.05*	*11.8*	*18.7*	*$36.05*
Combined Thermostatic Shower Valve and LF Showerhead Savings								
OR By Request LFTSV - Full Territory Any Electric 1.50 GPM	3415.9	439.4	0.0	12.6	$60.87	452.0	0.0	$60.87
OR By Request LFTSV - Full Territory Gas 1.50 GPM	3420.3	0.0	20.2	12.6	$60.95	12.6	20.2	$60.95
OR By Request LFTSV - Partial Territory Gas 1.50 GPM	3420.3	0.0	20.2	0.0	$62.35	0.0	20.2	$63.85
WA By Request LFTSV - Partial Territory Gas 1.50 GPM	*3564.4*	*0.0*	*21.0*	*13.1*	*$39.99*	*13.1*	*21.0*	*$39.99*

Comparison to RTF or other programs

- LED analysis is based on "By Request" lamps from RTF Residential Lighting Workbook v9.3 and NEEA's 2020 Residential Lighting Market Analysis. However, Energy Trust modification use the Direct Installation existing condition baseline for By Request lamps.
- Showerheads and wands are based on evaluated water heating end-use saving but use realization rates from Energy Trust evaluations and installation rates.
- Low flow thermostatic shower valves are based on the "Mail by request" RTF Thermostatic Shower Restriction Valve v4.1 Planning Measure with Energy Trust modifications including using evaluated showerhead installation rates instead of RTF storage and removal rates.

Measure Life

- LED measure life: 12 years, aligned with RTF measure of 12.1 years but rounded to 12.0
- Showerhead and wand measure life: 10 years, aligned with RTF measure
- Low flow thermostatic shower valve measure life: 10 years, aligned with RTF measure

Load Profile

Table 131 Load Profiles

Measure Type	Electric Load Profile	Gas Load Profile
LED lamps	Res Lighting	Res Heating
Showerheads and wands	Res Water Heat	DHW
Low flower thermostatic shower valve	Res Water Heat	DHW

Cost

Costs reflect the per-item cost of the product, handling and shipping to a consumer. These are represented as the incremental cost in Table 1**.**

Non Energy Benefits

LED NEBs

The NEBs associated with these measures are the prevented need to purchase new bulbs based on the longer life of the LED lamps. The avoided equipment cost to purchase replacement bulbs follows the baseline replacement methodology used for savings, see Table 132.

Table 132 LED avoided equipment replacement cost NEBs

Lamp Type	Lumen Category	Annualized lamp replacement savings (2020$)
General Purpose and Three-Way	250 to 1049 lumens	$0.25
General Purpose and Three-Way	1050 to 1489 lumens	$0.37
General Purpose and Three-Way	1490 to 2600 lumens	$0.37
Reflectors and Outdoor	250 to 1049 lumens	$0.47
Reflectors and Outdoor	1050 to 1489 lumens	$0.79
Reflectors and Outdoor	1490 to 2600 lumens	$1.33

Low Flow Water Device NEBs

Reduced water consumption due to low flow rates and valves are used as NEBs in the analysis.

Combined water rates net of embedded electricity is used in Oregon for gas and electric territories, and total water rates without removing embedded energy for Oregon gas only territory. Washington uses the combined rate of water including embedded energy use for wastewater treatment

Oregon full territory $17.82 / 1,000 gallons (rate is net of embedded energy)
Oregon gas only territory $18.23 / 1,000 gallons
Washington $11.22/1,000 gallons

Incentive Structure

The maximum incentives listed in Table 1 and Table 2 are for reference only and are not suggested incentives, if negotiated fulfillment prices exceed maximum incentives, the measure must be re-approved. Incentives will be structured per device (e.g., showerhead/wand, LFTST or LED lamp) and are provided directly to the kit vendor, and not to customers.

Follow-Up

LED lamps:

- When MAD is next updated, any updates to the RTF Residential Lighting Workbook should be reviewed and aligned to the methodology used in Energy Trust modification to the v9.3 tool.
- Lagging market status should be reviewed at next MAD to incorporate shifts to the baseline product mix, market shares and savings.

Low flow thermostatic shower valves:

- RTF Thermostatic Restriction Valve planning measure should be reviewed for updates or changes.
- Given this is a new offering, if available, program feedback regarding these new products should be reviewed and taken into consideration. Particularly any feed back on satisfaction or removal/non-installation of these devices.

Lagging market participation:

- Participation will be tracked and reviewed throughout MAD life to verify that kit measures are being delivered to lagging market participants.

Supporting Documents

The cost effective screening for these measures is number 27.8.4. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Residential\Res Kits\Energy Saver Kit

27_8_4_OR_WA_CEC_2022_v_1_Energy_   ESK 27.7-Reference-ResL   ESK 27.7-Reference-Ther

Version History and Related Measures

Energy Trust has been offering Kit measure for many years. These predate our measure approval documentation process and record retention requirements. Table 13 may be incomplete, particularly for measures approved prior to 2013.

Table 133 Version History

Date	Version	Reason for revision
2/28/2013	27.X	New kitchen aerator flow rate
11/1/2013	27.X	Updated costs
8/26/2014	27.X	Updated baseline, sink water temperature
11/7/2014	27.X	RBSA and RTF alignment, LEDs replace CFLs
9/22/2015	27.X	RBSA and RTF alignment on showerhead and LED costs and savings
10/11/2016	27.X	Updating savings, installation rates for 2017 program year, added 1.5 GPM showerhead
6/13/2017	27.2	Updating savings, household occupants, showerhead/wand baseline flow rates, aerator usage duration, aerator annual occupancy days, installation rates for 2017 program year based on new form design, added 1.5 GPM shower wand, new incremental costs
6/21/2017	27.3	Fixed error in incremental costs for shower wands
10/5/2017	27.4	Updated avoided costs, lighting savings for 2018
10/24/2018	27.5	Updated avoided costs and savings for all kit components for 2019
10/17/2019	27.6	Updated savings, NEBs and max incentives for bulbs based on new market data and a baseline change. Updated cost.
9/30/21	27.7	Updated savings to reflect RTF lighting measure updates and Energy Trust showerhead analysis. Added new low flow thermostatic shower valve measures. Defined kit delivery to lagging market customers with targeted outreach mechanism.
10/5/21	27.8	Clarify applicability to multifamily

Table 134 Related Measures

Measures	MAD ID
Single family direct install lighting	16
Multifamily direct install lighting	139
Direct Install Showerheads and Shower wands	157
Retail lighting	140
Retail showerheads and shower wands	26
Multifamily Kits	251

Approved & Reviewed by

Kenji Spielman
Planning Engineer

Disclaimer

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EnergyTrust of Oregon

Measure Approval Document for Residential Windows

Valid Dates
July 1, 2020 to December 31st, 2022

End Use or Description
Three tiers of windows measures installed in existing single family, existing manufactured, and small multifamily structures.

Program Applicability
Based on the referenced analysis and associated cost-effectiveness screening, the measures described below are approved for use in the following programs:
- Existing Homes
- Existing Manufactured Homes
- Existing Multifamily

Within these programs, applicability to the following building types or market segments or program tracks are expected:
- Contractor installed

Within these programs, the measure is applicable to the following cases:
- Replacement

Purpose of Re-Evaluating Measure
Version 3 of this document: This measure is being re-evaluated in order to restructure the measure offering into 3 tiers of efficiency and incentives, defined according to U-value as follows;
- Tier 1: U-value 0.28 to 0.30
- Tier 2: U-value 0.25 to 0.27
- Tier 3: U value ≤ 0.24

Incremental cost assumptions have been updated to reflect the findings of a 2018 Market Research Report by Apex Analytics[95].

Savings for gas heated homes have been updated to include electric fan savings, which were not previously included in the measure analysis.

Version 4 of this document: correct error in CEC regarding max incentives in Washington.

Cost Effectiveness
Cost effectiveness is demonstrated for Oregon in Table 1 and Washington in Table 2. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2021-v1.1. In Oregon the electric avoided cost year is 2021 and the gas avoided cost year is 2021. In Washington the gas avoided cost year is 2020.

Table 135 Cost Effectiveness Calculator Oregon

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Ele	% Gas
1	U-value 0.30 to 0.28, Electric Heat	45	1.84	0	$0.71	$0	$4.00	1.0	5.8	100%	0%
2	U-value 0.30 to 0.28, Gas Heat	45	0.11	0.13	$0.71	$0	$2.00	1.6	4.4	6%	94%
3	U-value 0.30 to 0.28, Gas Heat, G.O.T.	45	0	0.13	$0.71	$0.01	$2.00	1.5	4.4	0%	100%
4	U-value 0.25 to 0.27, Electric Heat	45	3.87	0	$1.50	$0	$8.00	1.1	5.8	100%	0%
5	U-value 0.25 to 0.27, Gas Heat	45	0.22	0.27	$1.50	$0	$4.00	1.6	4.4	6%	94%
6	U-value 0.25 to 0.27, Gas Heat, G.O.T.	45	0	0.27	$1.50	$0.03	$4.00	1.5	4.4	0%	100%
7	U-value ≤ 0.24, Electric Heat	45	6.66	0	$2.57	$0	$15.00	1.0	5.8	100%	0%
8	U-value ≤ 0.24, Gas Heat	45	0.38	0.46	$2.57	$0	$8.00	1.4	4.4	6%	94%
9	U-value ≤ 0.24, Gas Heat, G.O.T.	45	0	0.46	$2.57	$0.05	8.00	1.3	4.4	0%	100%

Table 136 Cost Effectiveness Calculator Washington

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Ele	% Gas
1	U-value 0.30 to 0.28, Gas Heat, G.O.T.	45	0.13	$0.71	$0.01	$4.81	1.00	6.98	0%	100%
2	U-value 0.25 to 0.27, Gas Heat, G.O.T.	45	0.27	$1.50	$0.02	$10.12	1.00	6.98	0%	100%
3	U-value ≤ 0.24, Gas Heat, G.O.T.	45	0.46	$2.57	$0.03	$17.39	1.00	6.98	0%	100%

Requirements
- Windows, glass doors or skylights with;
  1. Tier 1: NFRC U-factor rating of 0.28 to 0.30
  2. Tier 2: NFRC U-factor rating of 0.25 to 0.27
  3. Tier 3: NFRC U-factor of 0.24 or less
- Window/ door/ skylight is installed between a conditioned space and an unconditioned space

Baseline
This measure uses a full market baseline.

The sales-weighted average market baseline efficiency level, which is defined in terms of U-factor or U-value. The 2018 Apex Market Research presents total windows market share estimates by U-value bin for the years 2017 and 2022, which are shown in Table 137.

Table 137 Market Share Estimates from 2018 Market Research

[95] https://www.energytrust.org/wp-content/uploads/2019/02/Energy-Trust-of-Oregon-Windows-2018-Market-Research-final.pdf

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U-value Range	2017 Market Share	2022 Market Share
> 0.35	4%	4%
0.31 - 0.35	30%	24%
0.28 - 0.30	51%	40%
0.25 - 0.27	11%	24%
0.20 -0.24	3%	6%
< 0.20	1%	2%

The market share values shown in Table 137 represent the total windows market in Oregon, including new construction & retrofit/ remodel market segments, including sales to both program participants and non-participants. The portions of the market belonging to new construction and/or Energy Trust programs were removed from the overall market shares in order to calculate the applicable baseline efficiency for the Existing Homes windows measures.

The new construction market share is estimated to be between 40% and 60% according to market actor interviews from the 2018 Apex Windows Market Research, with the majority of respondents estimating a 50% market share. This analysis assumes that all new construction windows have a U-value of 0.30 or better due to code requirements and market share for new construction is distributed across the U ≤ 0.30 bins in the same proportions as the overall market.

Existing Homes program windows are assumed to represent 6% of total windows market sales in Oregon, based on 2014 market analysis. The 2018 Windows Market Research by Apex provides an estimate of the total number of windows sold annually but does not present the total square footage of windows. Since PT projects are recorded in terms of square footage, it is not possible to compare program volume to the total market size presented in the 2018 Apex market research. For this reason, the 6% Existing Homes program market share assumption has been carried over from the prior analysis. The distribution of Existing Homes program windows across u-value bins is taken from 2017 Energy Trust projects, since this is the most recent year where u-value was recorded by the program.

The remaining baseline market shares and U-values, after new construction and existing homes program windows have been removed, are as follows shown in Table 138. Since this offering will be in place from 2020 to 2022, an average of the 2017 and 2022 baselines are used. The final weighted baseline is U-value 0.317.

Table 138 Replacement Baseline Market Share Estimates and Average U-values

U-Value Range	Average U-value	2017	2022	2017/2022 Average
> 0.35	0.35	4.0%	4.0%	4.0%
0.31 - 0.35	0.33	30.0%	24.0%	27.0%
0.28 - 0.30	0.29	51.0%	40.0%	45.5%
0.25 - 0.27	0.26	11.0%	24.0%	17.5%
0.20 -0.24	0.22	3.0%	6.0%	4.5%
< 0.20	0.20	1.0%	2.0%	1.5%
Weighted Average U-value		**0.322**	**0.311**	**0.317**

For reference, the ENERGYSTAR version 6.0 specification for windows requires U-factor of 0.27 or less for the Northern climate zone, as shown in Figure 5.

Figure 5 ENERGY STAR Program Requirements for Residential Windows, Doors, and Skylights: Version 6.0

Table 1: Energy Efficiency Requirements for Windows		
Climate Zone	**U-Factor**[1]	**SHGC**[2]
Northern*	≤ 0.27	Any
North-Central	≤ 0.30	≤ 0.40
South-Central	≤ 0.30	≤ 0.25
Southern	≤ 0.40	≤ 0.25

* The effective date for the Northern Zone prescriptive criteria for windows is January 1, 2016.

Measure Analysis

Calculation of savings

Savings for windows in electrically heated homes are based on an electric impact analysis conducted by EcoNorthwest using Energy Trust program data from 2005 and 2006[96]. That analysis found 564 kWh per year savings. Savings for windows in gas heated homes are based on a gas impact analysis completed in 2007 and 2008 by Opinion Dynamics Corporation[97] which found savings of 39 annual therms. This finding was corroborated by billing analysis done by Energy Trust evaluation staff for gas heated homes that installed windows in 2009.

The average area of windows replaced for both evaluations was 151 square feet, which corresponds to savings of 3.76 kWh per square foot, and 0.26 therms per square foot for windows with a U-factor equal to or less than 0.30. In order to translate those energy savings into values that would apply to the current tiering structure and baseline, a linear fit is assumed in relation to the change in U-factor, as described in the following formulas:

*Electric Savings =3.76 * (Baseline U value - Average Tier U Value) / (0.35-0.3)*

*Gas Savings = 0.26 * (Baseline U value - Average Tier U Value) / (0.35-0.3)*

The resulting energy savings after applying the above savings formulas to the weighted average 2017 and 2022 baseline are shown in Table 139 for electrically heated homes and Table 140 for gas heated homes.

Table 139 Energy Savings (kwh) for Electrically Heated Homes

Tier	Average U-value	Savings (kwh)
U-value 0.30 to 0.28	0.292	1.84
U-value 0.27 to 0.25	0.265	3.87
U-value ≤ 0.24	0.228	6.66

96 https://www.energytrust.org/wp-content/uploads/2016/11/080715_HES_Process_Impact_Report.pdf
97 https://www.energytrust.org/wp-content/uploads/2016/11/ETO_HES_Process_and_Impact_Report_Volume_1.pdf

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Table 140 Energy Savings for Gas Heated Homes

Tier	Average U-value	Savings (therms)	Savings (kwh)
U-value 0.30 to 0.28	0.292	0.127	0.11
U-value 0.27 to 0.25	0.265	0.266	0.22
U-value ≤ 0.24	0.228	0.457	0.38

Additionally, there are electric fan savings associated with window installations in homes heated by gas furnaces which are not captured in the gas impact evaluation results. Fan savings in gas heated homes are calculated according to the following formula;

$$Fan\ kWh\ savings = \frac{(therm\ savings * 100{,}000Btu/therm)}{input\ Btu/h} * fan\ input$$

Applying the fan savings formula to the gas savings shown in Table 140 results in the electric fan savings.

Electric fan savings are valued according to their avoided cost value for installations within Energy Trust electric service territory, and as a non-energy benefit according to the value of utility bill savings for installations outside of Energy Trust electric service territory.

Comparison to RTF or other programs

The RTF has a UES measure for windows. The RTF uses a calibrated SEEM modelling approach to estimate energy savings and assumes a retrofit project type with a current conditions baseline. Due to the RTF's work not including an analysis of gas savings, or a baseline that reflects our understanding of customer window purchases, this analysis instead employs Impact Evaluation results from Energy Trust's program to estimate savings.

Energy Trust's multifamily program has windows offerings from stacked structures. These have different savings and baselines due to different construction assumptions and other building and purchasing characteristics.

Measure Life

Measure life is 45 years, consistent with other residential Energy Trust windows measures.

Cost

The 2018 Windows Market Research by Apex Analytics provided incremental cost values by U-value bin and as a linear regression. The hedonic model approach is used in order to control for impacts on price related to attributes other than energy efficiency. Incremental costs in that research which were determined using a hedonic modelling approach based on window prices obtained through web-scraping from three large home improvement retailers. The linear hedonic model results were selected for use in cost effectiveness testing rather than the binned U-value results due to unrealistically high incremental costs found for windows with U-value ≤ 0.24 in the binned model results. The linear hedonic model found that a 0.05 reduction in U-value is associated with an increase in window cost of $1.45 per square foot. Applying this finding to the 2017 & 2022 market baseline u-values results in the incremental cost values shown in Table 141. The simple average of 2017 and 2022 incremental costs has been used for cost-effectiveness testing in this measure analysis.

Table 141 Incremental Measure Costs by Tier ($/sqft)

Tier	Average U-value	2017	2022	Average of 2017/2022
U-value 0.30 to 0.28	0.292	$0.87	$0.55	$0.71
U-value 0.27 to 0.25	0.265	$1.66	$1.34	$1.50
U-value ≤ 0.24	0.228	$2.73	$2.41	$2.57

Apex also created a cost regression using U-value bins. The model that isolates by efficiency bins shows a dramatic increase in cost at the highest efficiency bin and a non-linear cost model. We interpret this difference to mean that other high-cost factors are more prevalent in the most efficient cost bin. We expect that as high efficiency windows become more prevalent, their other characteristics and options will become more equivalent to other efficiencies and they will be available in the same range of frame material, types and at equivalent retailers. As the market adjusts, this model will become less relevant. The results are markedly different for the most efficient tier of products.

Since our market research produced such dramatically different results, we attempted to compare them to other sources as summarized in the attached cost analysis. 2017 is the last year that we have u-value data and costs in for our own projects. After removing extreme outliers, we found no correlation between u-value and project costs. The RTF's Standard Information workbook provides limited installed cost data for windows sourced from BPA projects. That data does show some correlation between costs and U-value. We assumed and created a linear extrapolation of that information based on their mean and 25th percentile costs. The mean costs have a flatter slope, indicating that on average, U-value was not a primary driver of costs, similar to the Energy Trust results. The steeper slope for the 25th percentile indicates that at the low end, efficiency does have an impact on cost.

The range of incremental costs calculated by the Apex Report, Energy Trust project data and BPA project data, when applied to the tiering structure presented in this MAD, are as shown in Table 142. When a model provided a negative incremental cost, we assumed $0 as the minimum.

Table 142 Range of Incremental Costs by Tier ($/sqft)

Tier	Low End of Cost Range	High End of Cost Range
U-value 0.30 to 0.28	$0.00	$15.87
U-value 0.27 to 0.25	$1.16	$25.15
U-value ≤ 0.24	$0.00	$43.22

Non Energy Benefits

Fan savings for gas heated homes outside of Energy Trust territory are valued as a non-energy benefit, according to the most recent statewide average residential electric retail rate of $0.12/ kWh in Oregon and local residential rate of $0.082 in Washington.

Incentive Structure

The maximum incentives listed in Table 1 and Table 2 are for reference only and are not suggested incentives. Incentives will be per square foot of window area.

As Energy Trust sets incentives, we attempt to influence customer purchasing decisions and dealer stocking practices without overspending by paying more than incremental cost. In situations where incremental costs are hard to define, such as windows, this is a challenge. As customers are choosing between products with a wide range of costs, we need an incentive high enough to get customers' attention and to influence decision making and stocking practices.

All incentives are within the range of incremental costs that we are aware of. The cost effectiveness calculator shows very high incentives intended electrically heated homes in special circumstances, such as TLM initiatives or projects with complementary funders who may be influencing customers who would not otherwise replace windows at all. The incentives shown in Table 143 have been discussed with the OPUC because they exceed the incremental costs used in testing the TRC. If programs exceed these incentives for standard projects, the new incentive must be discussed with the OPCU.

Table 143 Expected 2020 incentives and maximums

Tier	Standard Incentive	Max Incentive for special circumstances (Electric only)
U-value 0.30 to 0.28	$2.00	$4.00
U-value 0.27 to 0.25	$4.00	$8.00
U-value ≤ 0.24	$6.00	$15.00

Supporting Documents

The cost effectiveness calculator number 28.4.3. It is attached and can be found along with other supporting documents at I:\Groups\Planning\Measure Development\Residential\Res Weatherization\windows

28.4.3 CEC_2021_v_1_1 res \

windows incremental cost analysis.docx

Follow-Up

Baseline should be updated at next revision, either by updated market study or using 2022 baseline assumptions rather than blends.

Costs for the most efficient tier of windows are estimated and expected the shift at these become more available.

This analysis does not include cooling savings in gas heated homes. Customers with cooling will achieve higher savings than estimated. The electric savings do include some cooling savings, though prevalence of cooling has changed since the billing analysis was completed 15 years ago. If possible, cooling savings should be quantified.

Measure History and Related Measures

Energy Trust has been offering incentives for residential windows for many years. These offerings predate our record retention and approval processes. Table 13 may be incomplete, particularly for approvals prior to 2013.

Table 144 Version History

Date	Version	Reason for revision
7/29/10	x	Residential windows approval tiers at 0.22 and 0.30
10/31/11	28.x	Update tiers to 0.25 and 0.30
6/20/14	28.x	Updated baseline. New tiers at 0.27 and 0.30
8/15/14	28.x	Adds small multifamily windows.
5/9/16	28.1	Update definition of small multifamily.
10/18/17	28.2	Update avoided costs resulting in updated max incentives. Minor clarifications throughout
5/29/20	28.3	Update baseline. New tiers at 0.30, 0.27 and 0.24
6/22/20	28.4	Correct error in cost effectiveness calculator Washington tab

Table 145 Related Measures

Measures	MAD ID
Multifamily windows	171

Approved & Reviewed by

Jackie Goss, PE
Sr. Planning Engineer

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Measure Approval Document for Efficient Gas Fireplaces and Electronic Fireplace Ignitions

Valid Dates
January 1, 2021 to December 31, 2023

End Use or Description
Installation of thermally efficient gas fireplaces in existing single and multifamily construction and sales of electronic ignition equipped units in new and existing construction.

Program Applicability
Based on the referenced analysis and associated cost-effectiveness screening, the measures described below are approved for use in the following programs:
- Electronic Ignitions
  - New Homes
  - Existing Homes
- Fireplace Efficiency Upgrades
  - Existing Homes
  - Existing Multifamily (2-4 living units and side-by-side units)

Purpose of Re-Evaluating Measure
Inputs updated in this MAD:
- Updated fireplace efficiency baseline based on manufacturer and distributor forecasts for 2020, sourced from Energy Trust's 2015 Market Transformation Report[98]
- Updated electronic ignition savings calculation process
- Net to Gross calculations incorporated into working savings

Cost Effectiveness
Cost effectiveness is demonstrated for Oregon in Table 1 and Washington in Table 2. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2021-v1.1. In Oregon the gas avoided cost year is 2021. In Washington the gas avoided cost year is 2020.

Table 146 Cost Effectiveness Calculator Oregon

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% ele	% gas
1	Electronic Ignition	20	7.41	$105	$105.00	1.0	1.0	0%	100%
2	Thermal Efficiency 70 to 74.9 FE	20	48.54	$0	$150.00	4.6	68,558	0%	100%
3	Thermal Efficiency 75+ FE	20	60.51	$0	$250.00	3.4	85,476	0%	100%

Table 147 Cost Effectiveness Calculator Washington

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% ele	% gas
1	Electronic Ignition	20	7.41	$105	$105.00	1.6	1.6	0%	100%
2	Thermal Efficiency 70 to 74.9 FE	20	48.54	$0	$150.00	7.3	109,794	0%	100%
3	Thermal Efficiency 75+ FE	20	60.51	$0	$250.00	5.5	136,888	0%	100%

Requirements
Downstream Fireplace Efficiency Upgrade Measures
- Model listed on the Canadian EnerGuide list with natural gas specific FE rating[99]
- 70 or greater fireplace efficiency rating with ignition system identified as "Intermittent" or "Pilot on Demand"

Midstream Electronic Ignitions
- Model listed on the Canadian EnerGuide list with natural gas specific FE rating
- Model ignition system identified as "Intermittent" or "Pilot on Demand"

Baseline
This measure uses a market baseline.

Thermal Efficiency Improvement Baseline
The common market fireplace efficiency baseline for existing homes is determined by removing the portion of the total fireplaces installed in new residential construction and the associated efficiency distribution of these fireplaces.

Table 148 describes the estimate of total fireplace units sold in Oregon and the splits between new and existing homes. In 2016, an estimated 7,515 gas heated homes were completed in Oregon. Energy Trust surveys of builders and new home owners, with findings in both studies being given equal, indicate an average of 0.92 fireplaces are installed per home in new gas heated construction, resulting in an estimated market size of 6,913. Results from the Energy Trust 2015 Gas Fireplace Market Transformation Study indicated the total market at that time was 10,500 units. Analysis from 2018 estimated the existing homes market to be 4,047 units in Energy Trust territory, or approximately 37% of the total market.

Table 148 New and Existing Home Market Share Estimates

Annual market Share Estimate Inputs		Estimated Market Shares
2016 Energy Trust Single and 2-4 dwelling homes completed	9,243	
Gas share of new homes	7,515	
Average of builder/new home owner survey reported fireplaces per new home	0.92	
Estimated unit installations in new homes	6,913	63%
Estimated unit installations in existing homes	4,047	27%
Total estimated Oregon gas fireplace market	10,960	100%

98 https://www.energytrust.org/wp-content/uploads/2016/12/Energy_Trust_GF_MT_Report_2010142015.pdf
99 Natural Resources Canada gas fireplace energy efficiency ratings search

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Since 2015, the volume of program delivered fireplace & electronic ignition incentives has increased significantly due primarily to a shift from a downstream program design to a midstream focused program design. However, there has not been a updated market study conducted for fireplaces since the 2015 study, and so it is unknown whether the size of the overall fireplace market in Energy Trust Territory has changed, and if so, whether the change was driven by the existing homes or the new homes segment of the market. Due to that uncertainty, this analysis will continue to assume a total market size of 10,960 fireplaces, with existing homes and new homes claiming a 27% and 63% market shares, respectively.

Midstream fireplace data collected from January 2018 to July 2020 include a variable for whether the equipment was installed in an existing home or a new home. New Homes midstream units are used as a proxy in this analysis for the overall fireplace efficiency (FE) distribution in the new homes market. Table 149 presents the midstream distribution of fireplace efficiency applied to the estimated total units installed in new homes.

Table 149 New Home Fireplace Efficiency Distribution

Efficiency Tier	Count of Midstream Units	FE Distribution	Annual New Homes Market
75+ FE	20	.3%	19
70-74.9 FE	119	1.6%	113
65-69.9 FE	208	2.8%	197
50-64.9 FE	6,773	92.7%	6,410
0-49.9 FE	184	2.5%	174
Total	7,304	100.0%	6,913

In 2015 gas fireplace manufacturers and regional distributors were asked to forecast the distribution of fireplace efficiency both in Energy Trust territory and in a comparison territory in eastern Washington and northern Idaho where incentives were not offered. This comparison territory forecast is the basis for the baseline fireplace calculation.

Table 150 and Table 151 detail the manufacturer and distributor forecasts of fireplace efficiency for 2020, applied to the total estimated fireplace market less the new home market share (based on new home unit distribution in Table 149). The Average FE values shown in the tables are based on midstream data collected from January 2018 to July 2020. The result is an estimated weighted baseline fireplace efficiency (FE) for the existing homes market of 59.8 FE.

Table 150 Manufacturer Forecasted Existing Homes Baseline Fireplace Efficiency

Efficiency Tier	Average FE	Estimated 2020 Distribution	Estimated Market Size	Less New Homes	Existing Homes Distribution	Weighted FE
75+ FE	75.9	1.9%	208	189	5%	
70-74 FE	71.9	10.1%	1,112	999	25%	
65-69 FE	67.1	24.2%	2,651	2,454	61%	
50-64 FE	53.8	59.9%	6,562	152	4%	
0-49 FE	43.6	3.9%	428	254	6%	
Totals	**60.4**	**100%**	**10,960**	**4,047**	**100%**	**66.72**

Table 151 Distributor Forecasted Existing Homes Baseline Fireplace Efficiency

Efficiency Tier	Average FE	Estimated 2020 Distribution	Estimated Market Size	Less New Homes	Existing Homes Distribution	Weighted FE
75+ FE	75.9	2.1%	232	213	5%	
70-74 FE	71.9	0.0%	0	0	0%	
65-69 FE	67.1	4.4%	484	287	7%	
50-64 FE	53.8	81.1%	8,891	2,480	60%	
0-49 FE	43.6	12.4%	1,354	1,180	28%	
Totals	**60.4**	**100.0%**	**10,960**	**4,160**	**100%**	**52.98**

Electronic Ignition Baseline

Distributors interviewed for the market transformation study forecasted 82% of fireplaces sold in 2020 to have electronic ignition.

Savings Analysis

Energy Savings from Thermal Efficiency Improvements

The efficiency rating is the Fireplace Efficiency score from the Canadian P4 test.[100] Savings are calculated according to the following formula:

$$\Delta therm = hr\ x\ \frac{kBtu}{hr}\ x\ (\frac{1}{baseline} - \frac{1}{FE})$$

A total of 525 annual hours of use were extrapolated from the Energy Trust gas fireplace metering study for Existing Homes based on 15 hours of use per week for 35 weeks.[101] These figures match well with an estimated based on the study's finding of 0.18 hours of use per base 60 heating degree day multiplied by 2,955 (TMY3 base 60) long run heating degree days for Portland, where the majority of fireplaces are installed in Energy Trust service territory.

Table 152 shows the final savings for gas fireplace efficiency upgrades in existing homes. Average existing homes fireplace capacity and efficiency within incented tiers are derived from midstream program data.

Table 152 Existing Homes Fireplace Efficiency Savings

Efficiency Tier	Total Annual Hours of Use	Average Unit Capacity kbtu/hr	Baseline FE	Efficient FE	Savings (therms)
70 - 74.9 FE	525	33.07	59.89	71.90	**48.41**
75+ FE	525	32.61	59.89	75.60	**59.38**

100 CAN/CSA-P.4.1-15 - Testing method for measuring annual fireplace efficiency
101 Gas Fireplace Market Research & Metering Study

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Energy Savings from Electronic Ignitions

Unlike the thermal efficiency improvement measure, electronic ignition savings are applied in both new and existing applications.

The savings equation for electronic pilot light ignitions is:

$$\Delta therm = (8760 - Annual\ fireplace\ HOU)\ x\ (1 - disabled\ ignitions\ fraction)\ x\ (1 - standing\ units\ disabled\ fraction)\ x\ \frac{1\ kbtu}{hr}$$

Table 153 details the inputs used to calculate both gross and net savings for electronic ignitions on gas fireplaces.

Table 153 Full Electronic Ignition Savings Inputs

Electronic Ignition Variables (IPI and On-demand)	**Input**
Weeks in heating season	35
Weighted Hours of use (15 HOU/27% Existing Homes, 6.1 HOU/63% New Homes)	7.9
Total annual fireplace hours of Use	276
Annual fireplace off hours	8,484
Ignition therm savings (pilot light usage 1 kbtu/h)	84.8
NEEA Study reported fraction of customers disabling EI	11.8%
Electronic Ignition Savings (IPI and On-demand)	74.8
Fraction of Standing Pilot Units left on in the off-season	56.4%
Program incentivized pilot use (therms)	8.51
Baseline ignition assumptions	
Percent Standing pilot light always on	12.4%
Percent Standing pilot light, turned off for non-heating season	9.6%
Comparison territory percent electronic ignition capable	82%
After program influence	
Percent Electronic ignition capable	98%
Percent Electronic ignition enabled	78%

Energy Trust's metering study in existing homes determined incented, efficient fireplaces are used for an average of 15 hours per week during the heating season, while new home occupants reported 6.1 weekly hours of use. A heating season duration of 35 weeks is assumed, in line with the thermal efficiency savings calculations. Based on the new and existing home market share reported in Table 148, average heating season hours of use per week is 7.9, or 276.4 hours of use per year.

US DOE technical support documentation identified the average pilot light in standing mode is one kbtu/hr resulting in 84.8 therms saved over the 8,484 annual hours of off time for electronic ignitions compared to standing pilot lights.

Research by the Northwest Energy Efficiency Alliance (NEEA) in 2017 found that 12% of owners with electronic ignition equipped fireplaces disable the units resulting in standing pilot light operation. Additional NEEA research found just under 50% of owners with standing pilot light units left the pilots running during the non-heating season in Energy Trust service territory while, regionally this figure was 63%. Due to uncertainty in the Energy Trust territory estimate and the wide interval the average, the average of these figures 56.4% of the estimates is used in this analysis. Additional calculations show that 12.4% of the market uses pilot lights all year with 84.8 therms/year of pilot light use. 9.6% of units have a standing pilot light but is turned off outside of the heating season with 56.3 therms per year of pilot light use. 78% of units are found with enabled electronic ignition after the influence of the program. The weighted average system uses 15.92 therms/year of pilot light consumption. Savings are reduced after considering the program's influence on qualifying thermally efficient models, with pilot lights. Distributors interviewed for the market transformation study forecasted a difference in prevalence of electronic ignitions between Energy Trust and its comparison territory of 16% for the 2020 program year. These market actors also estimated that the existence of Energy Trust's program and incentives are responsible for 60% of the difference. These factors combine to yield a savings estimate of 7.41 therms per electronic ignition.

Measure Life

US DOE technical support documentation estimates an effective useful life of 20 years for gas fireplaces.

Cost

Thermal Efficiency Improvement Costs

The market baseline cost for fireplace efficiency upgrades is based on average midstream unit costs, from January 2018 to July 2020, by efficiency tier. Those midstream costs were used to calculate a weighted average Existing Homes baseline cost by removing the estimated new homes market share, using manufacturer and distributor forecasts of 2020 FE distributions, weighted equally. Table 260 shows the resulting average midstream unit costs, by efficiency tier. Weighting the manufacturer and distributor cost baselines equally yields a common market baseline cost of $2,987**.**

Table 154 Midstream Unit Costs January 2018 to July 2020

Efficiency Tier	**Quantity Sold**	**% Distribution**	**Average Unit Cost**
75+ FE	326	9%	$2,763
70-74.9 FE	2,833	77%	$2,868
65-69.9 FE	205	6%	$3,204
50-64.9 FE	320	9%	$2,796
0-49.9 FE	13	0%	$3,059
Grand Total	3,697	100%	**$2,872**

Market studies spanning 2009 to 2017 have consistency found fireplace unit aesthetics, including the flame, are the most important factor when purchasing a gas fireplace, with efficiency and price being other important factors. These studies have also found a persistent and negative or negligible incremental cost for qualifying fireplaces, which is corroborated by recent midstream program data from 2018 to 2020. Despite this, the existing homes market is still dominated by lower efficiency units, suggesting that incentives can play a role in further increasing the prominence of price and efficiency in the purchasing decision for a long-lived piece of heating equipment. Table 261 shows the median incremental cost for both fireplace efficiency upgrade tiers.

Table 155 Fireplace Efficiency Upgrade Incremental Costs by Tier

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Efficiency Tier	Median Tier Cost	Market baseline cost	Median Incremental Cost
70 to 74.9 FE	$2,031	$2,987	-$751
75+ FE	$2,236	$2,987	$-956

As there are no indications that this negative/zero incremental cost scenario will change, the program is using hard caps on incentives in order to maintain a substantive presence and endorsement in the retail fireplace marketplace to continue influencing efficiency decisions but constraining incentive outlays.

In cost effectiveness testing, a placeholder incremental cost of $0.01 is used.

Electronic Ignition Costs

US DOE Technical Support Documentation for the rulemaking process gives the incremental manufacturing cost of electronic ignitions at $28 for vented fireplaces and $70 for vented log sets. This analysis takes the higher number and applies a 50% contractor mark-up for a 2015 incremental cost of $105.

Incentive Structure

Fireplace Efficiency Upgrades

The maximum incentives for upgrades are capped at $150 for the 70-74.9 FE tier and $250 for the 75+ FE units. Fireplace efficiency upgrade incentives are currently paid to consumers through downstream application submission. Future program design may shift fireplace efficiency upgrade incentives to midstream and utilize a payment method similar to electronic ignitions.

Electronic Ignitions

The maximum incentives listed in Table 1 and Table 2 are for reference only and are not suggested incentives. Incentives for electronic ignitions will be paid on a per fireplace unit basis via midstream channels to distributors and retailers.

Follow-Up

Updated information about the fireplace market in Energy Trust Territory will be needed at the next measure update.

A Fireplace Market Study should provide updated values for the following input variables, which are the ones most likely to change,

- Common market fireplace efficiency baseline
- Total fireplace units sold in Oregon
- Estimated market share of electronic ignitions in new and existing homes
- Estimated market share of new and existing homes
- Common market baseline costs as non-electronic ignition equipped unit data becomes available
- Energy Trust percent influence on the difference between Energy Trust territory baselines and comparison region baselines

Supporting Documents

The cost effective screening for these measures is number 29.3.2. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Residential\Res HVAC\fireplace

29_3_2_Or-Wa-CEC_
2011_v_1_1_Gas_Fire

Version History and Related Measures

Table 156 Version History

Date	Version	Reason for revision
2/28/2013	29.x	Approve fireplace efficiency tiers of 65-<70 and 70+ FE
8/11/2014	29.x	Approve electronic ignition savings and updated baseline for fireplace efficiency tiers of 70-<75 and 75+ FE
5/4/2015	29.x	Approve small multifamily applications
8/17/2015	29.1	Approve new fireplace efficiency and electronic ignition savings based on 2015 market transformation study baseline findings
10/27/2017	29.2	Approve new fireplace efficiency baseline, savings and cost calculations. Update savings for electronic ignitions based on Energy Trust and regional research findings
9/29/2020	29.3	Updated FE baseline and savings for both FE improvement and ignition. Net to gross adjustment incorporated directly into working savings.

Table 157 Related Measures

Measures	MAD ID
New Homes EPS	181

Approved & Reviewed by

Kenji Spielman
Planning Engineer

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EnergyTrust of Oregon

Measure Approval Document for Existing Single Family and Small Multifamily Insulation Retrofit

Valid Dates
January 1, 2020 – December 31, 2022

End Use or Description
Insulation for ceilings or attics, walls (includes knee wall and rim joist applications) and floors to reduce overall space conditioning energy consumption.

Program Applicability
Based on the referenced analysis and associated cost-effectiveness screening, the measures described below are approved for use in the following programs:

- Residential Program
- Existing Multifamily

Within these programs, applicability to the following building types or market segments or other program tracks are expected:

- Residential – Existing Single Family
- Small Multifamily – 2-4 and side-by-side units

Within these programs, the measure is applicable to the following cases:

- Retrofit

Purpose of Re-Evaluating Measure
This analysis updates gas and electric heating savings. Cooling savings and fan savings are now included in the analysis.

Costs are updated to reflect more recent program data.

Knee wall insulation, which had a separate MAD, is now included under wall insulation savings.

Cost Effectiveness
Table 158 Cost Effectiveness Calculator Oregon

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Ele Allo	% Gas Allo
1	Attic insulation Gas Heat (R0-R11 starting condition) HZ1	45	0.195	0.074	$1.50	$0.010	$1.50	1.4	1.5	34%	66%
2	Attic insulation Gas Heat (R0-R11 starting condition) HZ2	45	0.179	0.074	$1.50	$0.008	$1.50	1.3	1.4	32%	68%
17	Attic insulation Gas Heat (R0-R11 starting condition) HZ1 - Gas Only	45	-	0.074	$1.50	$0.088	$1.37	1.0	2.0	0%	100%
18	Attic insulation Gas Heat (R0-R11 starting condition) HZ2 - Gas Only	45	-	0.074	$1.50	$0.084	$1.37	1.0	2.0	0%	100%
9	Attic insulation Ele Heat (R0-R11 starting condition) Any Zone	45	0.726	-	$1.38	$0.014	$1.38	1.2	1.4	100%	0%
5	Wall insulation Gas Heat HZ1	45	0.080	0.052	$3.07	$0.021	$1.26	1.0	0.5	23%	77%
6	Wall insulation Gas Heat HZ2	45	0.101	0.057	$3.07	$0.022	$1.43	1.0	0.6	26%	74%
21	Wall insulation Gas Heat HZ1 - Gas Only	45	-	0.052	$3.07	$0.069	$0.96	1.0	0.7	0%	100%
22	Wall insulation Gas Heat HZ2 - Gas Only	45	-	0.057	$3.07	$0.076	$1.06	1.0	0.8	0%	100%
11	Wall insulation Ele Heat Any Zone	45	1.339	-	$1.89	$0.029	$1.89	1.6	1.9	100%	0%
7	Floor insulation Gas Heat HZ1	45	(0.021)	0.042	$2.18	$0.005	$0.74	1.0	0.4	0%	100%
8	Floor insulation Gas Heat HZ2	45	(0.031)	0.046	$2.18	$0.005	$0.79	1.0	0.4	0%	100%
23	Floor insulation Gas Heat HZ1 - Gas Only	45	-	0.042	$2.18	$0.034	$0.78	1.0	0.7	0%	100%
24	Floor insulation Gas Heat HZ2 - Gas Only	45	-	0.046	$2.18	$0.035	$0.85	1.0	0.7	0%	100%
12	Floor insulation Ele Heat Any Zone	45	0.610	-	$1.98	$0.014	$1.25	1.0	0.8	100%	0%

Table 159 Cost Effectiveness Calculator Washington

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR
1	Attic insulation Gas Heat WA (R0-R11 starting condition)	45		0.074	$1.46	$0.025	$1.46	1.1	1.3
2	Wall insulation Gas Heat WA	45		0.052	$2.52	$0.027	$1.09	1.0	0.6
3	Floor insulation Gas Heat WA	45		0.042	$2.07	$0.004	$0.88	1.0	0.5

Exceptions
A minor cost effectiveness exception was granted by the Oregon Public Utility Commission on September 26, 2019 for specific single and small multifamily gas and electric measures:

Wall insulation gas heat HZ1 (single family/small multifamily)
Wall insulation gas heat HZ2 (single family/small multifamily)
Floor insulation gas heat HZ1 (single family/small multifamily)
Floor insulation gas heat HZ2 (single family/small multifamily)
Floor insulation electric heat any zone (single family/small multifamily)

The exception was granted based on Exception Criteria A: This measure produces significant non-quantifiable non-energy benefits and Exception Criteria G: The measure is required by law or is consistent with Commission policy and/or direction. Furthermore, the exception is consistent with past Orders addressing insulation.

Energy Trust must study potential demand response benefits of insulation with other technologies. Energy Trust must report this information within a year of the exception.

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The exception is granted through December 31, 2022 or unit the measure savings exceed 5% of the program's savings.

OPUC order 15-140 entered April 30, 2015 put limits on incentives for non-cost effective insulation measures. Several of these are no longer in place since the measures are now cost effective. The incentive for standard track wall and floor insulation for gas heated homes in Oregon is capped at $150 and must be done at the same time as attic insulation for standard market rate offers. This cap does not apply to multifamily, rentals or savings within reach projects.

Measure-level cost effectiveness is not a requirement in Washington.

Requirements

Ceiling and Attic Insulation Requirements:

- Existing insulation must be R-11 or less. Must insulate to R-38 or greater or fill cavity.

Wall Insulation Requirements:

- Standard track homes heated by gas can receive wall insulation incentives that are capped at $150,and must be installed with qualifying ceiling insulation.
    - Multifamily, moderate income and renter tracks have no incentive cap.
- If home is primarily heated by gas, must be installed with qualifying attic insulation.
- Existing wall, rim joist, and knee wall insulation must be R-4 or less.
- Exterior Walls must be insulated to R-11 or fill cavity. All heated exterior wall surfaces must be insulated.
- Rim joists, if existing condition is R-4 or less, must be insulated to R-15 or fill cavity
- Knee walls must be insulated to R-15 for 2x4 cavities or R-21 for 2x6 cavities. Attic insulation must be R-19 or higher in order for knee wall insulation to be eligible for an incentive.

Floor Insulation Requirements

- Existing insulation must be R-0. Must insulate to R-30 or greater or fill cavity. Standard track homes heated by gas can receive up to $150 total and must be installed with qualifying attic insulation.
    - Multifamily, moderate income and renter tracks have no incentive cap.

Baseline

This measure uses an Existing Condition Baseline.

The baseline is a dwelling with little to no insulation.

Measure Analysis

Ceiling and attic insulation serve the same purposes and are used interchangeably in this document. Small multifamily buildings are expected to have similar heating and cooling characteristics to single family.

For Wall and Floor insulation, the analysis uses RBSA II data on the distribution of electric heating systems in order to create weights for the RTF's zonal, eFAF and heat pump measures. Table 160 shows the weight values used in the savings analysis.

Table 160 RBSA II Electric Heating System Distribution for RTF Savings Weighting

RBSA II Oregon Electric Heating and Cooling Systems	Electric Heating System Prevalence	Electric Heating System Category	Electric Heating System Category Prevalence
Electric Furnace - Central AC	4.80%	Electric FAF	9.6%
Electric Furnace - None	3.70%		
Electric Furnace - Permanent Room AC	0.30%		
Electric Furnace - Portable Room AC	0.80%		
Electric Heat Pump - Central AC	35.60%	Heat Pump	47.9%
Electric Heat Pump - None	0.30%		
Electric Heat Pump - Permanent Room AC	12.00%		
Electric Zonal - None	37.10%	Zonal or DHP	42.5%
Electric Zonal - Permanent Room AC	0.60%		
Electric Zonal - Portable Room AC	4.80%		

While the RTF does calculate heating zone 3 savings, heating zone 3 customers may use measures designed for heating zone 2, as the fraction of Energy Trust's rate payer base in heating zone 3 is quite small. For electric measures a blending of zones 1 and 2 are used to create any zone measures, this was done based on recent Energy Trust Project Tracker information about the distribution of insulation projects, by type, to create single territory wide measures. For gas measures, this same approach was applied, however, due to the OPUC exception specifying separate gas heating zone measures, the weighted measures are not approved.

Ceiling and Attic Insulation Heating

Energy Trust's billing analysis of ceiling insulation for 2009-2014 was used for ceiling insulation heating (and for the electric measure, embedded cooling) savings per site.[102] Only 2014 savings estimates were used as 2013 was a transition year where the market rate maximum starting condition of R18 was lowered to R12 – potentially biasing the sample for projects occurring in the first few months of the year. These site savings were divided by average treatment square footage from the project database with the top and bottom two percentiles removed, leading to estimated average savings per square foot of 0.074 therms and 0.73 kWh. The analysis did not differentiate savings by heating zones.

Table 161 2014 Energy Trust Ceiling Insulation Impact Evaluation Results

Fuel	Average Project Savings	2014 Average Project Square Footage	Savings per Square Foot
Gas (therms)	86	1,162	0.074
Electricity (kwh)	865	1,192	0.73

[102] Energy Trust: Ceiling Insulation 2009-2014 draft final 4 (internal document)

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Wall Insulation Heating
Gas heating savings are from an Energy Trust billing analysis103, where wall insulation projects from 2007 to 2009 show varying amounts of energy savings, from 0.038 to 0.062 annual therms per square foot. As there is a fairly wide range between the results, this analysis uses 0.052 annual therms from the 2007 impact evaluation, which is the median amount. The analysis did not distinguish between heating zones, but heating zone 1 made up nearly 100% of the sample. A ratio of heating degree days was used to estimate a heating zone 2 savings of 0.046 therms/sqft.

Electric heating savings are based on RTF modeling from the single family weatherization workbook v3.7 and weighted according to Table 160.

Floor Insulation Heating
Energy Trust billing analysis of floor insulation projects from 2007 to 2009 show varying amounts from 0.035 to 0.051 therms per square foot. As there is a fairly wide range between the results, this analysis uses 0.036 therms from the 2009 impact evaluation, which is the median amount.104 The analysis did not distinguish between heating zones, but zone 1 made up nearly 100% of the sample. A ratio of heating degree days was used to estimate a heating zone 2 savings of 0.057 therms/sqft.

Electric heating savings are based on RTF modeling from the single family weatherization workbook v3.7 and weighted according to Table 160.

Gas Furnace Fan
Fan savings use inputs and an engineering equation from prior Energy Trust gas furnace analysis and are added to the evaluated savings for gas insulation measures:105

$$Fan\ kWh\ savings\ = \frac{(therm\ savings * 100{,}000Btu/therm)}{input\ Btu/h} * fan\ input$$

Average furnace kBtu/hr input from project data used in the prior analysis was 63, with an estimated fan input of 0.53 kW sourced from the RTF's SEEM modeled electric forced air furnace fan input. These values lead to the estimates fan savings per square foot of gas insulation in Table 162. Fan savings for electrically heated homes are embedded in the RTF's modeled analysis.

Table 162 Gas Furnace Fan Savings Calculation by Insulation Type

Measure	Gas Savings (therms/sqft)	Fan Savings (kWh/sqft)
Attic insulation Gas Heat (R0-R11 starting condition) HZ1	0.074	0.06
Attic insulation Gas Heat (R0-R11 starting condition) HZ2	0.074	0.06
Wall insulation Gas Heat HZ1	0.052	0.04
Wall insulation Gas Heat HZ2	0.057	0.05
Floor insulation Gas Heat HZ1	0.042	0.04
Floor insulation Gas Heat HZ2	0.046	0.04

Cooling
The RTF estimates cooling savings or penalties based on starting and ending conditions of insulation for various heating systems. Cooling zones are weighted into heating zones to facilitate the deployment of fewer measures. RBSA II data on saturation of cooling system prevalence was used in conjunction with the RTF analysis to create final estimates of cooling season reductions or increases in air conditioning usage. All cooling savings (or penalties) for electric measures stem from RTF analysis in their weatherization workbook v3.7.106 For gas heated wall and floor insulation measures, cooling savings are based on RTF SEEM modeling runs used in the weatherization workbook.107

Total savings
Table 163 shows the savings components and total savings for gas and electric insulation measures.

Table 163 Savings Components

Measure	Fan Savings (kWh/sqft)	Electric Heating Savings (kWh/sqft)	Cooling Savings (kWh/sqft)	Total Electric Savings (kWh/sqft)	Total Gas Savings (therms/sqft)
Attic insulation Gas Heat (R0-R11 starting condition) HZ1	0.06	0	0.133	0.195	0.074
Attic insulation Gas Heat (R0-R11 starting condition) HZ2	0.06	0	0.116	0.179	0.074
Attic insulation Ele Heat (R0-R11 starting condition) Any Zone	Not disaggregated	Not disaggregated	Not disaggregated	0.726	0
Wall insulation Gas Heat HZ1	0.04	0	0.037	0.080	0.052
Wall insulation Gas Heat HZ2	0.05	0	0.053	0.101	0.057
Wall insulation Ele Heat Any Zone	Not disaggregated	1.31	0.0283	1.339	0
Floor insulation Gas Heat HZ1	0.04	0	(0.056)	(0.021)	0.042
Floor insulation Gas Heat HZ2	0.04	0	(0.070)	(0.031)	0.046
Floor insulation Ele Hea– Any Zone	Not disaggregated	0.648	(0.0388)	0.610	0

Comparison to RTF or other programs
The RTF's analysis estimates savings by heating/cooling zones, electric HVAC system and beginning/ending R values for attic, floor, wall insulation as separate measure identifiers. This analysis blends these measures based on RBSA and Energy Trust project information on the distribution of these inputs specific to Energy Trust or Oregon.

Measure Life
Insulation measures carry a 45-year measure life, in line with previous Energy Trust analysis and RTF regional estimates.

103 DRAFT Energy Trust of Oregon 2008 Existing Homes Gas Impact Analysis – See Appendix C: Energy Trust 2006-2007 Existing Homes Impact Analysis – Table 16.
104 DRAFT Energy Trust of Oregon 2009 Existing Homes Gas Impact Analysis – Table 6
105 Energy Trust: Gas Furnace in small multifamily and savings within reach, measure approval document 22
106 RTF Residential single family workbook v3.7
107 RTF Single family SEEM runs Feb 2016

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Cost

Energy Trust project tracker data for small multifamily and single family insulation costs in 2018 were used in this analysis. Median cost per square foot of insulation by heating fuel was used to reduce the influence of outliers, poorly itemized invoices and potential data entry errors. These costs are shown in Table 164.

Table 164 Median Costs by Insulation Type and Fuel in Small Multifamily and Single Family Applications in 2018

Insulation and Fuel Type	Cost per Sqft.
Electric Ceiling Insulation	$1.38
Electric Floor Insulation	$1.98
Electric Wall Insulation	$1.89
Gas Ceiling Insulation	$1.50
Gas Floor Insulation	$2.18
Gas Wall Insulation	$3.07

Non Energy Benefits

Non-electric fuel displacement

The RTF models estimates kWh-equivalent displacement of non-electric supplemental fuels (e.g., wood, oil propane), which is then converted to dollars based on electric rates. Table 165 shows the estimated non-utility fuel savings.108 For electric measures, NEBs are taken from the RTF Single Family Weatherization workbook v3.7.

Table 165 Non-electric Fuel displacement NEB, per sqft

Measure	Non-Electric Savings (kWh equivalent)	Total NEB (Annual $)
Attic insulation Gas Heat (R0-R11 starting condition) HZ1	0.08	$0.01
Attic insulation Gas Heat (R0-R11 starting condition) HZ2	0.07	$0.01
Wall insulation Gas Heat HZ1	0.18	$0.02
Wall insulation Gas Heat HZ2	0.18	$0.02
Floor insulation Gas Heat HZ1	0.04	$0.01
Floor insulation Gas Heat HZ2	0.04	$0.00
Attic insulation Ele Heat (R0-R11 starting condition) Any Zone		$0.014
Wall insulation Ele Heat Any Zone		$0.029
Floor insulation Ele Heat Any Zone		$0.014

Partial Service Territory

For gas measures installed outside Energy Trust's electric service territory, fan and cooling savings are converted to a NEB at a rate of $0.119/kWh. These are identified as 'gas only' in Table 158 Cost Effectiveness Calculator Oregon.

Incentive Structure

The maximum incentives listed in Table 1 and Table 159 *are for reference only and are not suggested incentives.*

Incentives will be structured per square foot of insulation installed. The incentive for standard track wall and floor insulation for gas heated homes in Oregon is capped at $150 and must be done at the same time as attic insulation for standard market rate offers.

SRAF

Standard program SRAFs are applied to these measures. Negative savings are recorded as SRAF components and do not count against the programs' accomplishments.

Follow-Up

Further billing analysis is expected to be complete in 2020, and updated RTF analysis should be reviewed with the next update for updates to heating, cooling and non-energy impacts to measures.

Cost trends, should be monitored to ascertain patterns and if possible, identify causes of increases.

Supporting Documents

The cost effective screening for these measures is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Residential\Res Weatherization\insulation\existing homes and small mf

Single Family
Insulation Retrofit -

Version History and Related Measures

Energy Trust has been incenting residential and small multifamily insulation since at least 2004. The measures have been updated numerous times and predate our current measure approval documentation and record retention processes. Table 166 may be incomplete, particularly for activities prior to 2013.

Table 166 Version History

108 SEEMruns_SingleFamilyExistingHVACandWeatherization_Feb2016

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Date	Version	Reason for revision
3/7/2007	x	Approval for insulation measures on a per square foot basis
3/9/2007	106.1	Knee wall insulation approved as a type of wall insulation
11/29/2012	58.x	Update costs and savings for all measures. Change starting condition requirement to less than R12.
12/20/2012	58.x	Update savings for wall and floor insulation.
8/6/2013	58.x	Adds heating zone 2 analysis for gas measures. Update format to show maximum incentives.
9/9/2014	58.x	Includes Washington-specific measure with starting condition R19. OPUC Reauthorization of 12-394 exceptions and requirements to develop approaches to improve cost effectiveness and shift resources to highest savings/TRC measures.
6/11/2015	58.1	Updated to include requirements dictated by OPUC order 15-140 including incentive caps on some measures.
10/24/2019	58.2	Updated savings, costs and addition of cooling savings. Knee wall included in wall insulation. MAD 106 to be retired.

Table 167 Related Measures

Measures	MAD ID
Multifamily Insulation	110
Residential Knee Wall Insulation (inactive for 2020)	106

Approved & Reviewed by

Jackie Goss, PE
Sr. Planning Engineer

Disclaimer

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Measure Approval Document for Gas Storage Water Heaters

Valid Dates
January 1, 2022 to December 31, 2023

End Use or Description
Residential ENERGY STAR® non-condensing, non-power vented, gas storage water heaters in Oregon and SW Washington, replacing an existing gas water heater.

Program Applicability
Based on the referenced analysis and associated cost-effectiveness screening, the measures described below are approved for use in the following programs:

- Residential
  - EHP Products
  - HES Existing Homes
  - HPF Home Performance
  - XMH Existing Manufactured Homes
- Commercial
  - BEM Existing Multifamily, 2-4 units and side-by-side
- Other programs referencing this MAD include:
  - ENH New Homes

Within these programs, applicability to the following building types or market segments or program tracks are expected:

- Residential customers in single family, multifamily, and/or manufactured homes
- Customer self-installation and/or contractor installation
- Downstream, to customers
- Midstream at retailers, distributors, or contractors

Within these programs, the measure is applicable to the following cases:

- Replacement
- New

Purpose of Re-Evaluating Measure
This update specifies ENERGY STAR certification and a single qualifying equipment configuration (non-condensing and non-power vented). Previous versions of this MAD qualified measures based on specific UEF and capacity. Savings, costs, maximum incentives, and requirements are all updated accordingly.

Cost Effectiveness
Cost effectiveness is demonstrated for Oregon in Table 168 and in Washington Table 169.Table 2 Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2022-v1.1. In Oregon the electric avoided cost year is 2022 and the gas avoided cost year is 2022. In Washington the gas avoided cost year is 2020. The values in these tables are per water heater.

Incremental cost of $0.01 is used in the cost screening as the tool does requires positive incremental costs. The incremental cost for this measure is negative $61.06.

Table 168 Cost Effectiveness Calculator Oregon - Max Incentive

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Gas Storage WH - ESTAR non-power non-cond	13	6.38	15.1	$0.01	$0.00	**$100.00**	1.1	10670	4%	96%
2	Gas Storage WH - ESTAR non-power non-cond - Gas Only	13	0	15.1	$0.01	$0.76	**$100.00**	1.0	10927	0%	100%

Table 169 Cost Effectiveness Calculator Washington - Max Incentive

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Gas Storage WH - ESTAR non-power non-cond	13	15.1	$0.01	$0.52	**$100.00**	1.5	15748	0%	100%

Exceptions
This measure is cost-effective and does not require exception. However, notification of the OPUC for an incentive exceeding incremental cost is required.

Additionally, OPUC notification was provided to indicate that an exception is no longer needed. Exception history:

- Energy Trust originally received an exception for Gas Storage Water Heaters on October 1st, 2014 as part of the UM 1622 major cost-effectiveness docket for gas measures. This exception was based on UM551 Criteria B: Inclusion of the measure will increase market acceptance and is expected to lead to reduced cost of the measure.
- An extension to the 2014 exception was approved by the OPUC in August 2015, again based on UM 551 Criteria B.
- On 12/29/2016 Energy Trust requested a two-year exception extension for Gas Storage Water Heaters. The exception request was approved by OPUC staff with a stipulation that the exception decision needs to be revisited in October 2017. UM 551 Criteria B was also the basis of this exception request.
- On 11/8/2017 Energy Trust received an extension through the minor exception process. When the exception was approved, OPUC Staff stated that "This exception is good for three years or until either of these measures become > 5% of the Program's savings or a new MAD is produced and the TRC drops.". It appears that UM 551 Criteria B continued to be used as the basis of the exception request.
- On 7/16/2020 Energy Trust was granted an extension of the previous minor cost effectiveness exception for Gas Storage Water Heaters in order to continue to make the measure available until new analysis is available through the RTF. The exception was granted based on UM 551 Criteria C: "The measure is included for consistency with other demand side management (DSM) programs in the region". The exception expires December 31, 2021 or if the measure becomes >5% of the Program's savings or a new MAD is produced and the TRC drops.

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Requirements

- Residential gas storage water heater, ENERGY STAR qualified at time of purchase
- Non-condensing and non-power vented equipment only
- Replacing existing gas water heater, storage or tankless replacement allowed
- Used for domestic hot water only, combination space-water heating equipment are excluded from this measure
- May not be combined with any new home or new multifamily bundle that can include water heating, such as EPS or Market Solutions.

Details

The ENERGY STAR rated, non-condensing, and non-power vented equipment type is a new to the market product. Currently, there is one manufacturer, A. O. Smith, producing this equipment type. While this limits the market availability of this equipment, the program anticipates additional manufacturers will bring qualifying products to market during the life of this MAD. This equipment type is an opportunity to offer improved efficiency to customers who are replacing equipment that was not previously plumbed or wired, as adding these to enable efficiency features is cost prohibitive.

ENERGY STAR Eligibility Criteria will be updating from Version 3.0 to 4.0 effective Jan. 5, 2022. Version 4.0 is effectively the same for gas water heaters, with only the First Hour Rating changing from FHR ≥ 67 gallons per hour in Version 3.0 to FHR ≥ 51 gallons per hour in Version 4.0[109]. ENERGY STAR specifications have been updated to reflect Uniform Energy Factor, UEF, product rating which are now used throughout the industry. Table 170 is a comparison of ENERGY STAR Product Criteria eligibility details between versions.

Table 170 ENERGY STAR Product Criteria Version 3.0 Compared to Version 4.0

ENERGY STAR Criteria for Gas Storage Water Heaters		**v3.0**	**v4.0 (Effective Jan 5, 2022)**
Uniform Energy Factor (UEF)	≤ 55 gallons	Medium Draw UEF ≥ 0.64	Medium Draw UEF ≥ 0.64
		High Draw UEF ≥ 0.68	High Draw UEF ≥ 0.68
	> 55 gallons	Medium Draw UEF ≥ 0.78	Medium Draw UEF ≥ 0.78
		High Draw UEF ≥ 0.80	High Draw UEF ≥ 0.80
Fist Hour Rating		FHR ≥ 67 gallons per hour	**FHR ≥ 51 gallons per hour**
Warranty		Warranty ≥ 6 years on system (including parts)	Warranty ≥ 6 years on system (including parts)
Safety		ANSI Z21.10.1/CSA 4.1	ANSI Z21.10.1/CSA 4.1

This analysis reflects the non-condensing, non-powered residential ENERGY STAR gas storage equipment type and cost and savings that align with the Regional Technical Forum, RTF, Residential Gas Water Heaters v1.1 measure approved April 13, 2021[110].

Baseline

This measure uses Full Market Baseline.

Water heaters are primarily replaced on burnout and the purpose of this offering to help the customer choose this more efficient unit. Per the RTF review and analysis of the 2018 Northwest Energy Efficiency Alliance water heater market study, gas water heaters are being replaced by both storage and tankless water heaters and with various sized equipment, regardless of original equipment type and capacity. Because the consumer is purchasing across equipment types and sizes, a market baseline that incorporated storage water heaters of various capacity and tankless units is appropriate.

Per the RTF measure analysis of 2019-2020 NEEA distributor sales data, the market baseline is composed of 11 prototype equipment types, including three storage water heaters with three different capacities and two efficiency tiers of tankless water heaters. Storage, non-ENERGY STAR units still dominate the market with 81.4% market share, while this measure accounts for 2.7% of the market (Storage, ENERGY STAR, Non-Condensing units) as summarized below in Figure 6 and Table 171 from the RTF Residential Gas Water Heaters: New Measure Proposal presentation from 4/14/2021[111] and RTF measure analysis.

Figure 6 RTF Residential Gas Water Heaters - Baseline Configuration

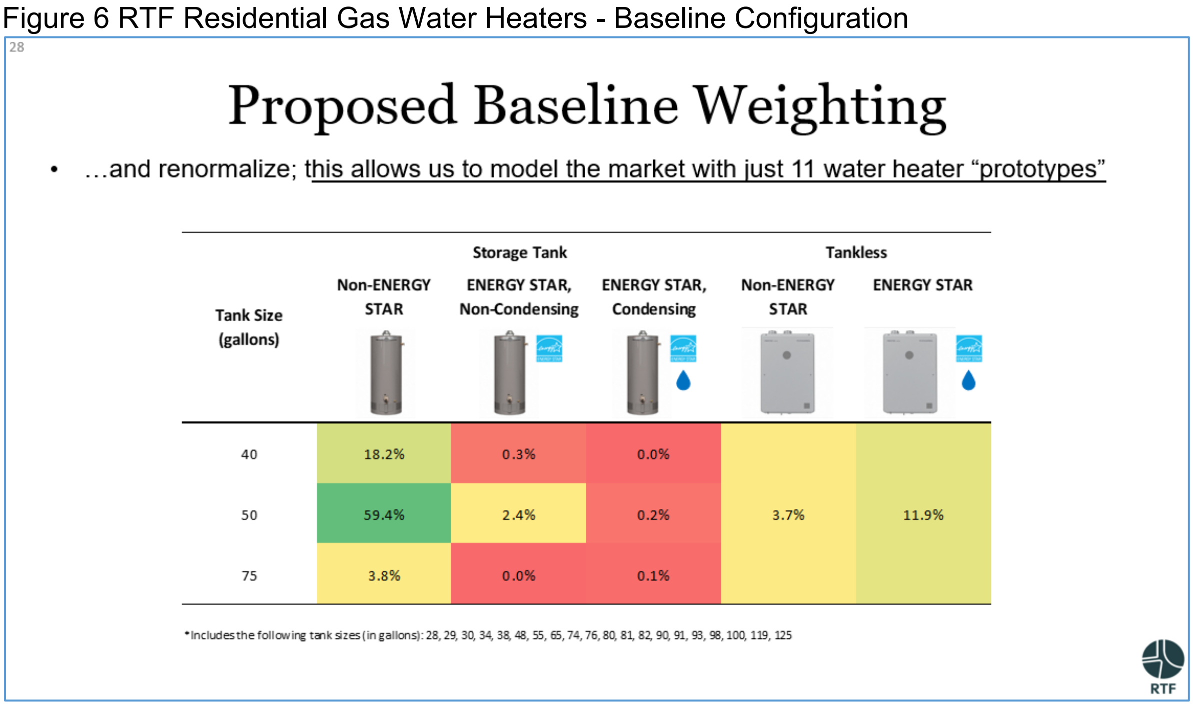

Table 171 RTF Residential Gas Water Heaters – Market Share Equipment Distribution

109 ENERGY STAR® Program Requirements, Product Specification for Residential Water Heaters, Eligibility Criteria Version 4.0 https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%204.0%20Water%20Heaters%20Final%20Specification%20and%20Partner%20Commitments_0.pdf
110 Regional Technical Forum, Residential Gas Water Heaters measures: https://rtf.nwcouncil.org/measure/residential-gas-water-heaters-0
111 RTF Residential Gas Water Heaters Presentation, April 14, 2021: https://nwcouncil.app.box.com/v/20210414GasWaterHeaterPres

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Current Practice Baseline	Distribution
40 gal non-ENERGY STAR	18.2%
50 gal non-ENERGY STAR	59.4%
75 gal non-ENERGY STAR	3.8%
40 gal ENERGY STAR, non-condensing	0.3%
50 gal ENERGY STAR, non-condensing	2.4%
75 gal ENERGY STAR, non-condensing	0.0%
40 gal ENERGY STAR, condensing	0.0%
50 gal ENERGY STAR, condensing	0.2%
75 gal ENERGY STAR, condensing	0.1%
Tankless, non-ENERGY STAR	3.7%
Tankless, ENERGY STAR	11.9%

Measure & Savings Analysis

Annual energy consumption for each of the RTF prototype water heaters is calculated using the Lawrence Berkeley National Laboratory Water Heater Analysis Model (WHAM)[112]. This calculation provides total water heater energy consumption in BTU/day based on recovery efficiency, energy factor, rated input power, pilot input power, standby losses, set points, inlet water temperature, ambient air temperature water draw, water density, specific heat, and a performance adjustment factor for tankless water heaters. The WHAM equations and terms for storage and tankless water heater consumption calculations are provided below in Equation 2 and Equation 3, respectively.

Equation 2 Storage Water Heater WHAM

The WHAM equation yields average daily water heater energy consumption (Q_{in}). The equation is expressed as follows.

$$Q_{in} = \frac{vol \times den \times C_P \times (T_{tank} - T_{in})}{RE} \times \left(1 - \frac{UA \times (T_{tank} - T_{amb})}{Pon}\right) + 24 \times UA \times (T_{tank} - T_{amb})$$

Where:

Q_{in} = total water heater energy consumption in British thermal units per day, Btu/day,
RE = recovery efficiency, %,
P_{ON} = rated input power, Btu/h,
UA = standby heat-loss coefficient, Btu/h-°F,
T_{tank} = thermostat set point temperature, °F,
T_{in} = inlet water temperature, °F,
T_{amb} = temperature of the ambient air, °F,
vol = volume of hot water drawn in 24 hours, gal/day,
den = density of stored water, set constant at 8.29 pounds per gallon, lb/gal, and
C_P = specific heat of stored water, set constant at 1.000743, Btu/lb-°F.

$$UA = \frac{\left(\frac{1}{EF} - \frac{1}{RE}\right)}{(T_{tank} - T_{amb}) \times \left(\frac{24}{Q_{out}} - \frac{1}{RE \times Pon}\right)}$$

Where:

UA = standby heat loss coefficient, Btu/h-°F,
EF = energy factor,
RE = recovery efficiency; %.
T_{tank} = temperature of the air surrounding the water heater, °F;
T_{amb} = thermostat set point temperature, °F;
Q_{out} = heat content of the water drawn from the water heater, Btu/h, and
P_{ON} = the rated input power, Btu/h.

Equation 3 Tankless Water Heater WHAM

The resulting equation is:

$$Q_{in} = \frac{vol \times den \times C_p \times (T_{tank} - T_{in})}{RE \times (1 + PA_{iwh})} \times \left(1 - \frac{Q_p}{P_{ON}}\right) + 24 \times Q_p \times (T_{Tank} - T_{amb})$$

Where:

Q_{in} = total water heater energy consumption, Btu/day,
vol = daily draw volume, gal/day,
den = density of water, lb/gal,
C_p = specific heat of water, Btu/lb-°F,
T_{tank} = set point of tank thermostat, °F,
T_{in} = inlet water temperature, °F,
RE = recovery efficiency, %,
PA_{iwh} = performance adjustment factor,
Q_p = pilot input rate, Btu/h,
P_{ON} = rated input power, Btu/h.

The RTF analysis computes annual consumption using the WHAM calculation for each of the 11 baseline prototypes in both conditioned and buffer spaces, in each of the RTF heating zones. These consumption results are then weighted by prototype market share, heating zone, and install location to determine an average baseline consumption. Savings are determined by subtracting the annual consumption of the weighted measure case from the weighted average annual consumption of the market baseline.

112 https://www.regulations.gov/document?D=EERE-2006-STD-0129-0149

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Heating zone and water heater location were weighted based on 2016-2017 Residential Building Stock Assessment (RBSA) II113 data as follows in Table 172, market share is noted in Table 171.

Table 172 RTF Residential Gas Water Heaters - Heating Zone and Water Heater Location

Heating Zone Distribution	
HZ1	76.0%
HZ2	14.9%
HZ3	9%

Tank Location Distribution	Conditioned	Buffer
HZ1	18.2%	81.8%
HZ2	19.4%	80.6%
HZ3	31%	69%

Savings

Baseline and efficient case gas and electric consumption and savings from the RTF analysis are provided in Table 173, this measure uses the analysis and savings for "Tank, ENERGY STAR, non-condensing, non-powered". This gas water heater has electric savings when compared to the market baseline which includes power vented equipment.

Table 173 RTF Residential Gas Water Heaters - Consumption and Savings per Water Heater Type

WH Type and Efficiency	Gas Energy Only (therm)			Electric Energy Only (kWh)		
	Baseline UEC, Gas	Efficient UEC, Gas	Gas Savings	Baseline UEC, Electric	Efficient UEC, Electric	Electric Savings
Tank, ENERGY STAR, non-condensing, non-powered	162	147	**15**	6	-	**6**
Tank, ENERGY STAR, non-condensing, powered	162	137	**25**	6	64	**(57)**
Tank, ENERGY STAR, non-condensing	162	137	**25**	6	64	**(57)**
Tank, ENERGY STAR, condensing	162	106	**55**	6	41	**(35)**
Tankless, non-ENERGY STAR, No Gas Line Upgrade	162	116	**46**	6	29	**(23)**
Tankless, non-ENERGY STAR, With Gas Line Upgrade	162	116	**46**	6	29	**(23)**
Tankless, ENERGY STAR, No Gas Line Upgrade	162	101	**61**	6	29	**(23)**
Tankless, ENERGY STAR, With Gas Line Upgrade	162	101	**61**	6	29	**(23)**

Comparison to RTF or other programs

This measure aligns with the "Tank, ENERGY STAR, non-condensing, non-powered" measure within the Residential Gas Water Heaters measure approved by the RTF on April 13, 2021. While the RTF analysis has other gas storage water heater configurations, this configuration is the only one offered within this MAD as it is the only cost-effective storage water heater measure. The RTF analysis workbook *ResGasWH_v1_0.xlsm*114 is referenced directly, including the market analysis and product weights, Lawrence Berkeley National Laboratory Water Heater Analysis Model (WHAM) calculations and analysis, equipment and installation costs, measure life and other relevant attributes.

Measure Life

The lifetime of this measure is 13 years, from the DOE Technical Support Document for the 2015 federal standards change. This aligns with past measure life for gas storage water heaters and reflects the RTF measure life.

Load Profile

Residential, gas "DHW" and electric "Res Water Heat" load profiles are used to screen this measure.

Cost

Equipment and installation costs align with RTF measure analysis for Residential Gas Water Heaters. Table 174 is a summary of installations costs, Table 175 is the combined install and equipment costs, and Table 176 includes baseline and incremental costs.

Installation costs are based on RTF cited 2010 DOE Life-Cycle Cost analysis and cost data from NEEA, *Lab Testing of Tankless Water Heater Systems*115, Sept. 6, 2019 and reflect plumbing, electrical, venting, condensate, gas line upgrades as needed by equipment type.

Table 174 RTF Residential Gas Water Heaters - Installation Cost by Water Heater Type ($2020)

113 2016-2017 Regional Building Stock Assessment (RBSA) II https://neea.org/resources/rbsa-ii-combined-database
114 RTF Residential Gas Water Heaters Workbook v1.0: https://nwcouncil.box.com/v/ResGasWaterHeaterv1-0
115 NEEA Lab Testing of Tankless Water Heater System, Sept. 6, 2019: https://neea.org/resources/lab-testing-of-tankless-water-heater-systems

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WH Type	Identifier 1	Identifier 2	Plumbing	Electrical	Venting	Condensate Mgmt	Gas Line Upgrade	Total Installation Cost
Tank		non-ENERGY STAR	$578	$0	$0	$0	$0	$578
		ENERGY STAR, non-condensing, non-powered	$578	$0	$0	$0	$0	$578
		ENERGY STAR, non-condensing, powered	$578	$270	$342	$0	$0	$1,190
		ENERGY STAR, non-condensing	$578	$270	$342	$0	$0	$1,190
		ENERGY STAR, condensing	$578	$270	$342	$102	$0	$1,292
Tankless	non-ENERGY STAR	w/out Gas Upgrade	$509	$241	$473	$0	$0	$1,222
		w/ Gas Upgrade	$509	$241	$473	$0	$1,200	$2,422
	ENERGY STAR	w/out Gas Upgrade	$509	$241	$251	$102	$0	$1,102
		w/ Gas Upgrade	$509	$241	$251	$102	$1,200	$2,302

Equipment costs are based on 2019-2020 NEEA distributor sales data for all water heater prototypes, except this measure which is new to the market. Equipment costs for this ENERGY STAR non-condensing, non-powered equipment is based on online retail pricing for the single available model which is available through Lowe's. RTF's GDP adjustment factor of 1.1247 (2012 to 2020) was applied per RTF Standard Information Workbook v4.2

Table 175 RTF Residential Gas Water Heaters - Total Costs per Water Heater Type

WH Type	Identifier 1	Identifier 2	Total Installation Cost (2020$)	Equipment Cost (2020$)	Total Cost, Unadjusted (2020$)	Total Costs, Unadjusted (2012$)
Tank		non-ENERGY STAR	$578	$530	$1,108	$985
		ENERGY STAR, non-condensing, non-powered	$578	$672	$1,250	$1,112
		ENERGY STAR, non-condensing, powered	$1,190	$1,300	$2,490	$2,214
		ENERGY STAR, non-condensing	$1,190	$1,300	$2,490	$2,214
		ENERGY STAR, condensing	$1,292	$2,236	$3,528	$3,137
Tankless	non-ENERGY STAR	w/out Gas Upgrade	$1,222	$662	$1,884	$1,675
		w/ Gas Upgrade	$2,422	$662	$3,084	$2,742
	ENERGY STAR	w/out Gas Upgrade	$1,102	$1,107	$2,210	$1,965
		w/ Gas Upgrade	$2,302	$1,107	$3,410	$3,032

Baseline costs reflect the weighted average cost of the protype equipment. To account for different measure lives of storage and tankless water heaters, 13 and 20 years respectively, baseline costs are adjusted to reflect longer life of tankless units and earlier replacement of storage units. For storage water heater baselines, tankless water heater cost is discounted to account for remaining tankless life at the end of the 13 year storage measure life. Similarly, for the tankless water heater baseline, the storage water heater cost is increased to account for early replacement of storage units over the 20 year tankless measure life. These adjustments reflect present value of remaining life or additional cost of equipment annualized over the length of the analyzed measure.

Table 176 RTF Residential Gas Water Heaters - Incremental Cost per Water Heater Type (2020$)

WH Type	Identifier 1	Identifier 2	Baseline Cost	Efficient Cost	Incremental Cost
Tank		non-ENERGY STAR			
		ENERGY STAR, non-condensing, non-powered	$1,311	$1,250	($61)
		ENERGY STAR, non-condensing, powered	$1,311	$2,490	$1,179
		ENERGY STAR, non-condensing	$1,311	$2,490	$1,179
		ENERGY STAR, condensing	$1,311	$3,528	$2,217
Tankless	non-ENERGY STAR	w/out Gas Upgrade	$1,760	$1,884	$124
		w/ Gas Upgrade	$1,760	$3,084	$1,324
	ENERGY STAR	w/out Gas Upgrade	$1,760	$2,210	$450
		w/ Gas Upgrade	$1,760	$3,410	$1,650

Incremental cost for this measure is negative $61 based on a blend of all the inefficient and efficient gas water heaters available. It is important to note that this measure has total cost of $1,250, while a code storage water heater is $1,108. Thus, there is a $142 price difference from a minimally compliant unit, which represents 81% of the market. Cost information for these units will be reviewed throughout this offering to verify costs used in this analysis and determine an appropriate incentive level. Tankless water heaters have higher installation costs and account for roughly 16% of the market. Other ENERGY STAR storage water heaters include power venting, which makes the equipment more expensive and more expensive to install compared to a code unit

Non Energy Benefits

Past gas water heater measures have referenced financial benefits related to extended warranty coverage for higher efficiency equipment. As this measure analysis incorporates blended measure life across the market, differences in warranty are not clear. Additionally, this measure is new to the market and while its ENERGY STAR certification requires warranty coverage for 6 years, the equipment has not been in the market long enough to establish the confidence to claim extended lifetime/warranty NEBs.

In gas-only territory, electric savings are claimed as electric bill savings non-energy benefits.

Incentive Structure

The maximum incentives listed in Table 168 and Table 169 Table 2*are for reference only and are not suggested incentives.* Incentives will be paid per qualifying gas storage water heater. Incentives can be paid at midstream (to retailers, distributors or contractors) or downstream (to customers). If another program implements a downstream offering, incentive overlap between this offering and the downstream offer will need to be accounted for through a corrective measure accounting or other mitigation strategy.

Approved incentives for this measure exceed incremental costs. **This measure technology is new to the market, is currently only made by one company and meets higher ENERGY STAR standards without marked increases in cost. We are hopeful that if we and other program providers across the US encourage sales of these units, other companies will follow suit.** Incentives will not exceed the max incentive of $100 as communicated to the OPUC.

Follow-Up

The measure expiration date of 12/31/2023 is selected to align with expiration date of MAD 259 – Residential Tankless Water Heaters in Oregon and pending updates to MAD 197.3 – Residential Tankless Water Heaters in SW WA. We intend to align analysis for storage and tankless water heaters with the RTF Residential Gas Water Heater measure across these measures as they expire and are updated.

- Review of RTF measure analysis if updates/revisions have been made, the RTF measures is approved through 4/30/2026
- Review of ENERGY STAR version and specifications; v4.0 is effective 1/5/2022
- Review of equipment cost from retail, NEEA and program data as this equipment type grows in the market

Supporting Documents

The cost-effective screening for these measures is number 102.4.3. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Residential\Res Water Heating\gas storage water heat

102_4_3-OR-WA-CEC_2022_v_1_Res_Gas

Version History and Related Measures

Energy Trust has been offering efficient Gas Storage Water Heater measures for many years. These predate our measure approval documentation process and record retention requirements. Table 13 may be incomplete, particularly for measures approved prior to 2013.

Table 177 Version History

Date	Version	Reason for revision
5/26/2010	102.x	Introduce 0.67 EF water heaters for existing and manufactured homes
5/27/2010	102.x	Include small multifamily homes in prior approval.
6/2/2010	102.x	Include condensing tank units.
8/10/2010	102.x	Included distributor incentive.
1/6/2012	102.x	Update cost and incentives.
6/19/2012	102.x	Update approval to include maximum incentive.
9/2/2015	102.x	Update savings due to federal standard influence of baseline. Removes condensing units.
9/15/2015	102.x	Includes small multifamily.
2/16/2016	102.x	Includes the products program.
12/30/2016	102.1	Update costs and non-energy benefits.
11/8/2017	102.2	Updated costs, NEBs. Change qualifying criteria to ENERGY STAR. Clarifies mid-stream program design.
9/16/2020	102.3	Updated requirements and analysis for new UEF test method, differentiated volumes
8/23/2021	102.4	Change qualifying criteria to ENERGY STAR for a single qualified equipment type

Table 178 Related Measures

Measures	MAD ID
Residential and existing small multifamily heat pump water heaters	52
New small multifamily heat pump water heaters	176
New homes and small multifamily tankless water heaters	178
Commercial condensing tank water heaters	21
Commercial tankless water heaters	72
Residential Tankless Oregon	259
Residential Tankless Water Heaters in SW WA	197

Approved & Reviewed by

Kenji Spielman
Planning Engineer

Disclaimer

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Measure Approval Document for New ENERGY STAR and NEEM+ Manufactured Homes

Valid Dates
January 1, 2020 – December 31, 2023

End Use or Description
New Manufactured Homes

Program Applicability
Based on the referenced analysis and associated cost-effectiveness screening, the measures described below are approved on a prospective basis for use in the following programs in Oregon and Washington:

- Residential

Purpose of Re-Evaluating Measure
The Northwest Energy Efficiency Manufactured Housing Program (NEEM) is discontinuing the Eco-Rated label, so it is removed from this offering. Also the efficiency label NEEM 2.0 has been rebranded as NEEM+. This document is updated accordingly.

Savings and costs have been updated.

At the request of the Public Utility commission, this update blends all gas heated homes into one measure regardless of efficiency rating or heating zone.

Washington participation is now included.

Cost Effectiveness
Cost effectiveness values are demonstrated in Table 1 for Oregon and Table 180 for Washington. Cost effectiveness was tested using the OR-WA CE Calculator 2021 v1.1. In Oregon the Electric and Gas avoided cost year is 2021. In Washington the gas avoided cost year is 2020.

Table 179 Cost Effectiveness Calculator Oregon, per home

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Ele	% Gas
1	ENERGY STAR Electric Zone 1	45	2,067	0	$3,097	$0.00	$3,096.67	1.3	1.3	100%	0%
2	ENERGY STAR Electric Zone 2	45	3,021	0	$3,097	$0.00	$3,096.67	1.8	1.8	100%	0%
7	NEEM+ Electric Zone 1	45	2,608	0	$5,063	$0.00	$4,905.33	1.0	1.0	100%	0%
8	NEEM+ Electric Zone 2	45	3,734	0	$5,063	$0.00	$5,063.39	1.4	1.4	100%	0%
14	ENERGY STAR or NEEM+ Gas Any Zone	45	24	126	3,097	$0.00	$2,930.81	1.0	0.9	1%	99%
15	ENERGY STAR or NEEM+ Gas Any Zone Gas only	45	0	126	$3,097	$2.91	$2,889.34	1.0	1.0	0%	100%

Table 180 Cost Effectiveness Calculator Washington, per home

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Ele	% Gas
1	ENERGY STAR Gas Zone 1	45	106	3,097	$1.99	$3,096.67	1.3	1.3	0%	100%
2	NEEM+ Gas Zone 1	45	124	5,063	$17.98	$4,706.71	1.0	1.0	0%	100%
3	ENERGY STAR or NEEM+ Gas Zone 1	45	106	3,097	$1.99	$3,096.67	1.3	1.3	0%	100%

Exceptions
Energy Trust was granted an exception from the Oregon Public Utilities Commission (PUC) on 7/16/20 to continue to offer incentives gas heated manufactured homes meeting the ENERGY STAR and NEEM+ Specifications. The exceptions used the minor exception process. The PUC staff suggested that all gas heated qualifying homes be blended into a single measure because the cost effectiveness of rarely built gas heated NEEM+ homes was below the minor exception threshold. Cost effectiveness analysis for each of efficiency type is available in the attached cost effectiveness calculator. The exception was granted under UM551 exception criteria:

C. Measure is included for consistency with other programs in the region. Including Energy Trust, there are twenty-eight utility programs in Oregon that offer incentives for homes certified as ENEGY STAR or NEEM+, many of these are in territory that Energy Trusts serves as gas-only. The NEEM program is a regional effort, supported by NEEA and NW Energy Works, to increase efficiency of manufactured homes throughout the northwest.

D. Measure helps to increase participation in a cost effective program. Energy Trust pays retailers a SPIFF to encourage an upsell to energy-efficient models. Restricting the incentive to electrically heated homes would complicate the retailer's sales process and they would be less likely to take the time to upsell energy-efficient models, including the cost effective electrically-heated homes which make up more than 90 percent of the program volume.

PUC staff also acknowledged that manufactured homes are more prevalent in rural areas, and that many manufactured homes are owned by lower income customers. By supporting the availability of new, efficient manufactured homes, it is expected to improve the overall housing stock for lower income and rural customers.

The exception expires on 12/31/2023 or in or when the measure become >5% of the Products Program's savings or a new MAD is produced with a TRC drop. Energy Trust shall notify PUC Staff if gas heated homes increase to 25% of incented new manufactured

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homes. The OPUC encourages Energy Trust to monitor uptake of these measures as a method to monitor fuel mix in new manufactured homes.

Similar exceptions for gas heated ENERGY STAR, Eco-Rated and NEEM 2.0 homes were granted on 11/8/17 and 11/21/18. Those expired at the end of 2020.

Requirements

- Homes must be sold and sited within Energy Trust service territory.
- Electrically heated homes must be served by Portland General Electric or Pacific Power.
- Gas-heated homes must be served by NW Natural, Cascade Natural Gas or Avista.
- Homes heated with another fuel do not qualify.
- All homes must be certified by Northwest Energy Efficiency Manufactured Housing Program as ENEGY STAR, or NEEM+.
- In Oregon, where gas heated homes are blended by efficiency tier and heating zone, tier and zone information must continue to be collected.
- If offered in Washington, the program may decide to either offer different measures for each efficiency tier, or use the blended measure.

Details

New ENERGY STAR and NEEM+ manufactured homes save electricity and natural gas through built-in efficiency upgrades across various home components. The current ENERGY STAR certification is based on the NEEM 1.1 specification. Home certification is verified by the NEEM certificate issued by NW Energy Works. The assumed building components to achieve each specification are listed in Table 181.

Table 181 Measure Specifications and SEEM inputs

Component	Baseline (average non-NEEM house)	ENERGY STAR	NEEM 2.0
Heating System	Electric Resistance Furnace, 7.7 HSPF Heat Pump or 84.4% AFUE Gas FAF	Electric Resistance Furnace, 7.7 HSPF Heat Pump or 84.4% AFUE Gas FAF	Electric Resistance Furnace, 7.7 HSPF Heat Pump or 90% AFUE Gas FAF
Floors	R-25 Nominal	R-33 (longitudinal framing)	R-33 (transverse framing)
Walls	R-13 Nominal	R-21	R-21 + R-1 foam sheathing and 2.5-stud corners and R-5 insulated headers
Ceilings	Avg. R-33 Nominal	Flat: R-49 Nominal Vaulted: R-40 Nominal	R-49 Nominal
Glazing	Avg. U = 0.40	U = 0.35 (SHGC assumed at 0.32)	U = 0.28 (SHGC assumed at 0.30)
Envelope Tightness	4.8 ACH_{50}	3.9 ACH_{50} (2009 field study) Spec calls for 5.0 ACH_{50}	3.9 ACH_{50} (2009 field study) Spec calls for 5.0 ACH_{50}
Duct Leakage	13%	5% supply leakage fraction	5% supply leakage fraction
Lighting	50% LED	50% LED	100% LEDs
Appliances	Standard Dishwasher and Refrigerator	ENERGY STAR Dishwasher and Refrigerator	ENERGY STAR Dishwasher and Refrigerator

Baseline

This measure uses a Market Baseline.

The baseline case is the average components of non-NEEM homes, referred to as “HUD Code” in the SEEM modeling tool, though with a few improvements from the actual code, including 40% prevalence of heat pumps in electrically heated homes and 50% LED lighting.

Savings

The RTF’s SEEM modeling tool was used to estimate savings

Heating and Cooling

The majority of the savings comes from heating end uses, which are heavily influenced by building shell measures. The baseline for ceilings, walls, floors and glazing is based on the weighted average efficiency of all non-NEEM homes built by manufacturers, per the “High Performance Manufactured Home Project: State of the Industry Report” prepared for Bonneville Power Administration. The baseline for envelope tightness and duct leakage is based on the average of NEEM homes in the 2000-01, 1997-98, and 1992-93 studies shown in the “Summary of 2006 NEEM Manufactured Homes: Field Data and Billing Analysis” prepared for NEEA. This is based on the fact that the NEEM program did not prioritize air sealing or duct sealing in those years, so they should reflect the baseline non-NEEM homes of today.

Multiple runs of the SEEM modeling tool were conducted. Iterations included each heating and cooling climate zone, the baseline and each efficient specification, each primary heating system (electric forced air furnace, heat pump, and gas forced air furnace). Runs were then weighed based on the average conditioned floor area of 1,572 sq.ft. To calculate one savings value for electrically heated homes, electric forced air furnaces and heat pumps were combined to assume 40% of electrically heated homes have a heat pump installed, in the baseline and in the efficient cases. Although the RTF has differentiated savings between the three dominant cooling zones, Energy Trust determined that the majority of installs would be occurring in areas designated as cooling zone 1. Therefore, the heat pump measure savings are assumed to be occurring in cooling zone 1, which is also the most conservative case

Lighting

The baseline is based on the RTF baseline, weighted to the RBSA mix of lamp types installed in manufactured homes. Savings are calculated as the difference in baseline and efficient case Lighting Power Consumption per lamp multiplied by 36 lamps per house and 1.9 hours of use per day in alignment with other residential lighting measures. This lighting method is not in alignment with other Energy Trust residential lighting measures as it only estimates first year savings and does not account for changes in baseline over time. However, lighting savings are a small component of total home savings so this method is sufficient. Only NEEM+ homes have lighting savings.

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Appliances
Savings are calculated as the difference between annual consumption of the baseline case and the energy efficiency case. End-use savings are de-rated by the HVAC interaction factor assigned to the appliance type.

Gas Homes Weighting
For Oregon, measures for gas heated homes have been blended based on past program participation in dual fuel territory. In 2019, there were no participating Gas Heated NEEM+ homes, so they are weighted at 0%. In 2019 10 gas heated ENERGY STAR homes participated in heating zone 1 and 8 participated in heating zone 2.

In Washington, where Energy Trust's territory is only in heating zone 1, the blended measure is identical to the ENERGY STAR measure.

Comparison to RTF or other programs
This analysis is drawn directly from RTF savings and baseline calculations. RTF has more measure identifiers for Manufactured Homes than Energy Trust. For programmatic efficiency, we combine similar measures and weight them based on prevalence.

Measure Life
RTF and current Energy Trust new manufactured homes use a 45-year measure life, reflecting majority of savings are associated with shell improvements.

Cost
Incremental costs were estimated based on the RTF's conversation with NW Energy Works staff on February 16, 2017 and additional conversations with NEEA staff. RTF assumes costs increased 10% between 2017 and 2020 based on manufacturer reporting.

Non Energy Benefits
In gas only territory the electric bill savings are claimed as a non-energy benefit because the electric energy savings are not claimed.

Additional non-energy benefits may be experienced if manufacturers include low flow water devices. These are not included in this analysis because they are not included in the RTF analysis and are not requirements.

Incentive Structure
The maximum incentives listed in Table 1 and Table 180 are for reference only and are not suggested incentives. Incentives will be paid to retailers per qualifying home. Incentives may be split between customers and retailers with a total not to exceed the maximum.

Follow-Up
Baseline home components should be considered at next update, in particular baseline lighting and appliances are expected to change, or if HUD revises its standards. The RTF is expected to update their UES, which this measure is based on in 2023, aligning with Energy Trust's next planned update. RTF's changes should be considered at that time. Recommendation to engage RTF in Q4 2022 or Q1 2023 in effort to update analysis in early 2023.

Weighting of gas homes by efficiency rating and heating zone should be reexamined at next update.

Supporting Documents
The cost effective screening for these measures is number 109.4.2. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Residential\Manufactured homes\new manufactured homes

109.4.2 CEC
2021v1.1 New Manf H

References
RTF Res New MH UES Workbook v4.0: https://rtf.nwcouncil.org/measure/new-manufactured-homes

Version History and Related Measures
Energy Trust has been offering measures for new manufactured homes for many years. These offerings pre-date our measure approval documentation process and our record retention policy. Table 182 may be incomplete, especially for activities prior to 2013.

Table 182 Version History

Date	Version	Reason for revision
7/21/2005	x	Approved specific stand-alone shell and appliance measures for new manufactured homes.
Unknown	x	Approve ENERGY STAR new manufactured homes
12/19/2008	109.x	Incentive changes
6/15/2009	109.x	Adds Eco Rated homes and homes with heat pumps. Updated savings to 2009 RTF savings.
12/8/2009	109.1	Incentive changes
11/13/2017	109.2	Update to align with latest ENERGY STAR and Eco Rated specs and with 2017 RTF savings.
12/10/2018	109.3	Update to add NEEM 2.0 specs
8/27/2020	109.4	Update to align with 2020 RTF assumptions. Remove Eco-rated spec. Add Washington

Table 183 Related Measures

Measures	MAD ID
Manufactured homes early retirement pilot in electrically heated homes	199
Manufactured homes early retirement pilot in gas heated homes	225

Approved & Reviewed by

Jackie Goss, PE
Sr. Planning Engineer

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Disclaimer

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Energy Trust of Oregon

Measure Approval Document for EPS™ New Homes in Washington

Valid Dates

October 1, 2021 to December 31, 2024 or until implementation of a substantial Washington code update

Description

New construction single family, duplex, townhome

The New Homes EPS program in SW Washington utilizes a framework similar to Oregon EPS measure (MAD 181). This offer allows builders to select a custom combination of measures that exceed Washington residential energy code and provides incentives beyond code compliance. This measure provides flexibility when designing new homes, allowing builders and raters to compare multiple packages to find feasible and cost-attractive options.

The cost effectiveness is demonstrated by screening example pathways of the most likely combination of measures based on historical performance trends and market intelligence. These examples may be provided to builders as demonstrations of how to achieve above code home performance.

Although WSEC 2018 began enforcement on February 1, 2021, the program baseline will change starting October 1, 2021. This is to account for construction timelines. EPS typically allows a 6-month lag time between permitting and construction but because COVID-19 is expected to continue to delay construction schedules, the program extended the timeline to 8 months.

Program Applicability

Based on the referenced analysis and associated cost-effectiveness screening, the measures described below are approved for use in the following programs:

- New Homes

Reason for updating measure

The offering is updated to reflect the new 2018 WSEC which is set to be enforced in February 2021.

Cost Effectiveness

Cost effectiveness is demonstrated in Table 1. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2022-v1.0. The Washington gas avoided cost year is 2020.

This is a semi-prescriptive measure. Each participating home in the program will have calculated savings based on its actual location, size, and characteristics. It is impossible to test each home for cost effectiveness individually, instead cost effectiveness is tested and demonstrated using the example paths. Configurations are identified by their heating equipment and water heat fuel as follows: "GH" gas heat/furnace compared against the central baseline, "EW" electric water heat, "GW" gas water heat.

Table 184 Cost Effectiveness Calculator Washington, per home

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Path 1 - GHGW	44	22.98	$699	$2.41	$878	1.0	1.3	0%	100%
2	Path 1 - GHEW	45	16.86	$588	$1.69	$650	1.0	1.2	0%	100%
3	Path 2 - GHGW	37	35.93	$1,271	$4.14	$1,271	1.0	1.1	0%	100%
4	Path 2- GHEW	38	29.98	$713	$4.37	$1,075	1.0	1.6	0%	100%
5	Path 3 - GHGW	39	53.01	$2,177	$5.29	$1,924	1.0	0.9	0%	100%
6	Path 3 - GHEW	41	42.33	$1,472	$4.02	$1,571	1.0	1.1	0%	100%
7	Path 4 - GHGW	41	66.41	$2,463	$7.96	$2,465	1.0	1.1	0%	100%
8	Path 4- GHEW	41	52.80	$2,197	$4.52	$1,960	1.0	0.9	0%	100%

All pathways and fuel configurations pass the UCT and Path 3 GHGW and Path 4 GHEW do not pass the TRC. In Washington, measure-level TRC cost effectiveness is not required.

Requirements

- Homes must be built in Washington and have primary heat provided by Northwest Natural Gas service. Dual fuel heat pumps do not qualify.
- Homes must meet current code requirements and follow the program's requirements as described in the most current EPS Field Guide for quality installation, performance testing, health/safety and qualifying products.
- Homes will be simulated using program approved modeling software, following program modeling requirements.
- Energy models and supporting documentation will be submitted to the program via the Axis database to determine incentives and savings.
- Homes must be field verified by a program verifier
- Homes must achieve a minimum of five percent gas improvement over code to participate
- Homes participating in this offer cannot participate in the New Homes Code Credits offer (MAD 267)

Baseline

This measure uses a Code Baseline.

The 2018 Washington Energy Code requires builders to select from a menu of shell and mechanical upgrades. Small homes under 1,500 square feet of conditioned floor area are required to achieve 3 credits, and medium homes up to 5,000 square foot must achieve 6 credits. 2018 WSEC Table R406.2 awards additional fuel normalization credits for homes heated with heat pumps. Heat pumps with gas back up (dual fuel heat pumps) are considered system type 2 (electric heat pumps), and do not qualify under EPS New Homes in Washington.

The program consulted with builders, verifiers, and other stakeholders to determine the most likely sets of credits builders will select to achieve the required credits. The code baseline for program approved simulation engine models and savings include the following options from the 2018 Washington State Energy Code section R406, table 406.3:

- Small homes, gas water heating (GHGW) (3 credits required)
    - 2.1: Reduced air leakage (3.0 ACH@50Pa) – 0.5 credit

-
    - 3.1: High efficiency HVAC equipment (95 AFUE) – 1.0 credit
    - 4.1: Deeply buried ducts – 0.5 credit
    - 5.3: Efficient water heater (UEF 0.91) – 1.0 credit
- Small homes, electric water heating (GHEW) (3 credits required)
    - 3.1: High efficiency HVAC equipment – 1.0 credit
    - 5.5: Efficient water heater (2.6 EF) – 2.0 credits
- Medium homes, gas water heating (GHGW) (6 credits required)
    - 1.4: Efficient building envelope (~15% UA reduction) – 1.0 credit
    - 2.2: Reduced air leakage (2.0 ACH@50Pa) – 1.0 credit
    - 3.1: High efficiency HVAC equipment (95 AFUE) – 1.0 credit
    - 4.2: Deeply buried ducts – 1.0 credit
    - 5.1: Drain water heater recovery – 0.5 credit
    - 5.3: Efficient water heater (UEF 0.91) – 1.0 credit
    - 7.1: High efficiency appliance package – 0.5 credit
- Medium homes, electric water heating (GHEW) (6 credits required)
    - 1.4: Efficient building envelope (~15% UA reduction) – 1.0 credit
    - 2.2: Reduced air leakage (2.0 ACH@50Pa) – 1.0 credit
    - 3.1: High efficiency HVAC equipment (95 AFUE) – 1.0 credit
    - 4.2: Deeply buried ducts – 1.0 credit
    - 5.5: Efficient water heater (2.6 EF) – 2.0 credits

Measure Analysis

EPS is a whole building performance-based program offering. Savings for each participating home are derived from whole-home modeling software to demonstrate performance above a program baseline based on 2018 WSEC. Incentives are based on the modeled energy efficiency performance, independent of the measures employed. Therefore, builders have flexibility to pursue any combination of measures depending on their preferences and what they find to be economical within their business strategies to go beyond the baseline.

The EPS paths are meant to serve as guidance for builders to achieve various levels of percentage improvement over code. In 2020, the program conducted a trends analysis and interviews with builders. These trends were reviewed and used to select measures for the paths that represent likely measures included in program homes. There are four paths ranging from 5% improvement to 20% improvement from the baseline in roughly 5% increments. The EPS team determined the measures making up the paths for each of the four baseline configurations described above (small GHGW, small GHEW, medium GHGW, medium GHEW). The resulting 16 pathway configurations were modeled using REM/Rate v15.7.1. These paths are used to illustrate methods of achieving savings, budgeting and planning purposes and testing cost effectiveness. Builders are not required to follow pathways

The saving values for each path and fuel configuration were calculated for small (<1,500 sf) and medium (1,500-4,999 sf) example homes. The two home sizes were combined based on the distribution of participating homes under 2015 WSEC through April 7, 2020 to screen each path and configuration combination as one measure. The small and medium home prototypes are the RTF approved 1,380 square feet and 2,509 square feet single family new home models respectively. .

Tables 2-5 show the measures selected for each pathway for small and medium homes with gas and electric water heating. Measures in green are above code measures.

Table 185 Small GHGW Pathway

	Small Home Based on 2018 WSEC w/ 2.1, 3.1, 4.1, 5.3	Path 1 Small	Path 2 Small	Path 3 Small	Path 4 Small
Slab	R-10 2' Perimeter	Baseline	Baseline	Baseline	Baseline
Framed Floor	R-30 (U-0.35)	Baseline	Baseline	Baseline	Baseline
Basement Wall	R-21 Int. (U-0.056) 10 ext/15 int. continuous/21 int framed	Baseline	Baseline	Baseline	Baseline
Above Grade Wall	R-21 int. 16 in c.i. (U-0.056)	**R21 + R4 (U0.44)**	**R21 + R4 (U0.44)**	**R21 + R4 (U0.44)**	**R21 + R4 (U0.44)**
Window	U-0.30/SHGC-0.30	Baseline	Baseline	**U-0.28**	**U-0.24**
Ceiling	R-49 (U0.025)	Baseline	Baseline	Baseline	**R-60 RH**
Gas Water Heater	0.91 EF tankless	Baseline	Baseline	**0.95 EF tankless**	**0.95 EF tankless**
Furnace	95 AFUE	Baseline	Baseline	Baseline	**97 AFUE**
Duct & HVAC Location	Duct - Attic under Insulation, HVAC inside	Baseline	**Duct - Attic under Insulation, HVAC inside**	**Duct - Attic under Insulation, HVAC inside**	**50% ducts in conditioned space**
Duct Insulation	R8	Baseline	Baseline	Baseline	Baseline
Duct Leakage	0.02797 CFM25/CFA	Baseline	Baseline	Baseline	Baseline
Infiltration	3 ACH50	Baseline	Baseline	**2 ACH50**	**2 ACH50**
Mechanical Ventilation	Exhaust, standard efficiency (2.8 CFM/W)	Baseline	Baseline	Baseline	Baseline
Lights and Appliances	Refrigerator: 549 kWh/yr Dishwasher: 302 kWh/yr Washer: High efficiency Dryer CEF 2.8 with moisture sensing Lighting: 90 LED 10 CFL	**100% LED**	**100% LED**	**100% LED**	**100% LED**
Low Flow	Low flow fixtures	Baseline	Baseline	Baseline	Baseline
Drain Water Recovery	No	Baseline	Baseline	Baseline	Baseline
Thermostats	Programmable	Baseline	**Smart Tstat**	**Smart Tstat**	**Smart Tstat**

Table 186 Small GHEW Pathway

Component	Small Home 2018 WSEC w/ 3.1, 5.5	Path 1 Small	Path 2 Small	Path 3 Small	Path 4 Small
Slab	R-10 2' Perimeter	Baseline	Baseline	Baseline	Baseline
Framed Floor	R-30 (U-0.35)	Baseline	Baseline	Baseline	Baseline
Basement Wall	R-21 Int. (U-0.056) 10 ext/15 int. continuous/21 int framed	Baseline	Baseline	Baseline	Baseline
Above Grade Wall	R-21 int. 16 in c.i. (U-0.056)	**R23, FG 6-16 U053**	**R23, FG 6-16 U053**	**R23, FG 6-16 U053**	**R21 + R4 (U0.44)**
Window	U-0.30 (SHGC 0.30 no req.)	**U0.28**	**U0.28**	**U0.28**	**U0.28**
Ceiling	R-49 (U0.025)	Baseline	Baseline	Baseline	Baseline
Gas Water Heater	0.61 EF storage	-	-	-	-
Electric Water Heater	HPWH 2.6 EF	Baseline	Baseline	Baseline	Baseline
Furnace	95 AFUE (3.1)	Baseline	Baseline	Baseline	Baseline
Duct & HVAC Location	Unconditioned Space	Baseline	Baseline	Baseline	Baseline
Duct Insulation	R8	Baseline	Baseline	Baseline	Baseline
Duct Leakage	4% CFM25/CFA (89.7 CFM)	Baseline	Baseline	Baseline	Baseline
Infiltration	5 ACH50	Baseline	Baseline	**3 ACH50**	**3 ACH50**
Mechanical Ventilation	Exhaust, standard efficiency 24 hours 13 watts (2.8 CFM/W)	Baseline	Baseline	Baseline	Baseline
Lights and Appliances	Refrigerator: 549 kWh/yr Dishwasher: 302 kWh/yr Washer: High efficiency Dryer CEF 2.8 with moisture sensing Lighting: 90 LED 10 CFL	**Lighting: 100% LED**	**Lighting: 100% LED**	**Lighting: 100% LED**	**Lighting: 100% LED**
Low Flow	Low flow fixtures	Baseline	Baseline	Baseline	Baseline
Drain Water Recovery	No	Baseline	Baseline	Baseline	Baseline
Thermostats	Programmable	Baseline	**Smart Tstat**	**Smart Tstat**	**Smart Tstat**

Table 187 Medium GHGW Pathway

Component	Medium Home Based on 2018 WSEC w/ 1.4, 2.2, 3.1, 4.2, 5.3, 7.1, 5.1	Path 1 Med	Path 2 Med	Path 3 Med	Path 4 Med
Slab	R-10 full (1.4)	Baseline	Baseline	Baseline	Baseline
Framed Floor	R-38 (U-0.28) (1.4)	Baseline	Baseline	Baseline	Baseline
Basement Wall	R-21 + R-4 ci U0.043 (1.4) 10 ext/15 int. continuous/21 int framed	Baseline	Baseline	Baseline	Baseline
Above Grade Wall	R-21 + R-4 c.i. FG1, 6-16 (U-0.044)	Baseline	Baseline	**R-23 + R5, Adv (U0.039)**	**R-23 + R5, Adv (U0.039)**
Window	U-0.25/SHGC-0.3 (1.4)	Baseline	Baseline	**U-0.24**	**U-0.24**
Ceiling	R-49 (U0.025)	**R-60 Adv.**	**R-60 Adv.**	**R-60 Adv.**	**R-60 Adv.**
Gas Water Heater	Tankless 0.91 (5.3)	**0.95 EF tankless**	**0.95 EF tankless**	**0.99 EF tankless**	**0.99 EF tankless**
Furnace	95 AFUE (3.1)	Baseline	**96 AFUE**	**97 AFUE**	**97 AFUE**
Duct & HVAC Location	Ducts and HVAC Inside (4.2)	Baseline	**Ducts and HVAC Inside (4.2)**	**Ducts and HVAC Inside (4.2)**	**Ducts and HVAC Inside (4.2)**
Duct Insulation	R8	Baseline	Baseline	Baseline	Baseline
Duct Leakage	0.02797 CFM25/CFA	Baseline	Baseline	Baseline	Baseline
Infiltration	2 ACH50 (2.2)	**1.5 ACH50**	**1.5 ACH50**	**1.5 ACH50**	**1 ACH50**
Mechanical Ventilation	HRV (65% ASRE 65%, 1.2 CFM/W) (2.2)	Baseline	Baseline	Baseline	**HRV (80% SRE 1.4 CFM/w)**
Lights and Appliances	ENERGY STAR Dishwasher, clothes washer/dryer, and refrigerator (7.1) Lighting: 90 LED 10 CFL	**100% LED**	**100% LED**	**100% LED**	**100% LED**
Low Flow	Low flow fixtures	Baseline	Baseline	Baseline	Baseline
Drain Water Recovery	40% EF (5.1)	Baseline	Baseline	Baseline	Baseline
Thermostats	Programmable	Baseline	**Smart Tstat**	**Smart Tstat**	**Smart Tstat**

Table 188 Medium GHEW Pathway

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Component	2018 WSEC w/ 1.4, 2.2, 3.1, 4.2, 5.3, 7.1, 5.1	Path 1 Med	Path 2 Med	Path 3 Med	Path 4 Med
Slab	R-10 full (1.4)	Baseline	Baseline	Baseline	Baseline
Framed Floor	R-38 (U-0.28) (1.4)	Baseline	Baseline	Baseline	Baseline
Basement Wall	R-21 + R-4 ci U0.043 (1.4) 10 ext/15 int. continuous/21 int framed	Baseline	Baseline	Baseline	Baseline
Above Grade Wall	R-21 + R-4 c.i. FG1, 6-16	Baseline	Baseline	**R-23 + R5, Adv (U0.039)**	**R-23 + R5, Adv (U0.039)**
Window	U-0.25 (1.4)	Baseline	Baseline	**U-0.24**	**U-0.24**
Ceiling	R-49 (U0.025)	**R-60 RH**	**R-60 RH**	**R-60 RH**	**R-60 RH**
Gas Water Heater	Tankless 0.91 (5.3)	-	-	-	-
Electric Water Heater	HPWH 2.6 EF	Baseline	Baseline	Baseline	Baseline
Furnace	95 AFUE (3.1)	Baseline	Baseline	Baseline	**97 AFUE (3.1)**
Duct & HVAC Location	Ducts and HVAC Inside (4.2)	Baseline	Baseline	Baseline	Baseline
Duct Insulation	R8	Baseline	Baseline	Baseline	Baseline
Duct Leakage	40 CFM50	Baseline	Baseline	Baseline	Baseline
Infiltration	2 ACH50 (2.2)	**1.5 ACH 50**	**1.5 ACH 50**	**1.5 ACH 50**	**1 ACH 50**
Mechanical Ventilation	HRV (2.2) (65% ASRE 65%, 1.2 CFM/W)	Baseline	Baseline	Baseline	Baseline
Lights and Appliances	ENERGY STAR Dishwasher, clothes washer/dryer, and refrigerator (7.1) Lighting: 90 LED 10 CFL	**Lighting: 100% LED**	**Lighting: 100% LED**	**Lighting: 100% LED**	**Lighting: 100% LED**
Low Flow	Low flow fixtures	Baseline	Baseline	Baseline	Baseline
Drain Water Recovery	No	Baseline	Baseline	Baseline	Baseline
Thermostats	Programmable	Baseline	**Smart Tstat**	**Smart Tstat**	**Smart Tstat**

Savings are calculated using REM/Rate v15.7.1 by modeling the example path homes against the baseline. Although the measure is screened using example homes that assume the most likely and most cost-effective measures, less common measures in participating homes may also claim savings, such as slab insulation, drain water heat recovery, and doors.

Lights and appliances are dictated by either RESNET Standards or the NW Modeling Requirements and include consumption for the following features based on the home size, number of bedrooms and limited appliance inputs: interior, exterior and garage lighting, refrigerator, range, washer/dryer, dishwasher, mechanical ventilation, ceiling fans and residual miscellaneous end use loads. Participants can claim savings from these end uses if the installation is field verified.

Additional Savings Calculations

To capture savings from these measures, the program leverages the AXIS platform that modifies the modeled software output to integrate the savings.

Smart Thermostats provide 6% of the gas consumption as savings for furnaces. These savings are based on analysis summarized in MAD 153.5 based on Energy Trust's 2016 Smart Thermostat piloti.

Gas Fireplace savings is based on Energy Trust's study on fireplaces in new homesii and project data. An analysis was performed to determine fireplace baseline, savings over the baseline for multiple efficiency bins. Baseline determination, cost data, and proposed case was determined using the sales data. Hours of use (HOU) were obtained from the study of fireplaces in new homes. The savings methodology is:

$$Therms\ savings = HOU * Capacity * \left(\left(\frac{1}{Baseline\ FE}\right) - \left(\frac{1}{Proposed\ FE}\right)\right)$$

Savings for fireplaces are estimated at 18.3 therms annually for 70FE+ system over a blended market baseline of 57FE, with 213.5 expected hours of use in new homes and a market average capacity of 23 kBTU/hr.

Savings

Table 6 shows the gas and electric consumption, savings, and gas percent improvement for each of the 16 path configurations. The analysis by size was subsequently consolidated, weighted by expected proportion of homes in each bin.

Table 189 EPS Consumption and Savings by Path, Home Size and Fuel Configuration

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	2022 Path 1	2022 Path 2	2022 Path 3	2022 Path 4
Small GHGW				
Total Therm Consumption	310	297	281	258
Total kWh Consumption	4193	4164	4177	4129
Total Therm Savings	22	35	51	258
Total kWh Savings	12	41	28	4129
% Gas Improvement Above Baseline	7%	10%	15%	22%
Small GHEW				
Total Therm Consumption	275	260	242	226
Total kWh Consumption	4916	4889	4904	4904
Total Therm Savings	11	26	44	60
Total kWh Savings	11	38	23	23
% Gas Improvement Above Baseline	4%	9%	15%	21%
Medium GHGW				
Total Therm Consumption	317	304	287	274
Total kWh Consumption	5823	5802	5787	5755
Total Therm Savings	23	36	53	66
Total kWh Savings	30	51	66	98
% Gas Improvement Above Baseline	7%	11%	16%	19%
Medium GHEW				
Total Therm Consumption	249	236	224	213
Total kWh Consumption	7015	6982	6986	6980
Total Therm Savings	17	30	42	53
Total kWh Savings	21	54	50	56
% Gas Improvement Above Baseline	6%	11%	16%	20%

Measure Life

Weighted average measure lives are presented in Table 184 Cost Effectiveness Calculator Washington*. Each improvement pathway has its own estimated measure life. This is calculated by weighting each end-use's measure life by its savings.*

Cost

Costs in Table 184 Cost Effectiveness Calculator Washington*are based on a variety of sources for individual improvements in the modeled pathways for the selected prototype homes. Specific end-use cost sources came from the following sources with a brief discussion of assumptions employed in the analysis. Incremental costs for each measure are adjusted for each fuel configuration and home size in accordance with the baseline assigned for the arrangement.*

Weatherization and Windows

- **Ceiling Insulation R49 Raised Heel –** $0.20/sqft (both configurations & home sizes) WSEC Proposaliii, Table 4
- **Ceiling Insulation R-60 Adv. -** $0.23/sqft $0.20/sqft (both configurations & home sizes) WSEC Proposal, Table 4
- **Wall R-23 BIB (U-0.053) –** Below baseline for medium homes, $0.23/sqft for small homes. 2019 EPS MAD 181.4
- **Wall R-21 + R4 c.i. –** Baseline for medium homes, $0.96/sqft for small homes, WSEC Proposal, Table 4
- **Wall R-R23 + R5 c.i. Advanced -** $0.30/sqft for medium homes, $1.26/sqft for medium homes, WSEC Proposal, Table 4 for R23 and 2019 EPS MAD 181 for continuous insulation
- **Window U-0.25 –** Baseline for medium homes, $4.50/sqft, WSEC Proposal, Table 4
- **Window U-0.24** – $0.00/sqft for medium homes, $4.50/sqft. No incremental cost from U-0.25, WSEC Proposal, Table 4
- **Window U-0.22 -** $2.10/sqft for medium homes, $6.60/sqft, WSEC Proposal, Table 4
- **Window U-0.20 -** Energy Trust PT data shows a negative incremental cost based on $60.74/sqft. $0 is used in the analysis for incremental cost.
- **Infiltration 3 ACH50 -** $0.20/sqft for small GHEW, at or below baseline for all other configurations, Interpolated from WSEC Proposal
- **Infiltration 2.0 ACH50 –** baseline for medium homes, $0.30/sqft for small GHGW, $0.50/sqft for small GHEW, Interpolated from WSEC Proposal
- **Infiltration 1.5 ACH50 -** $0.11/sqft for medium homes, $0.41/sqft for small GHGW, $0.61/sqft for small GHEW, Interpolated WSEC Proposal**Infiltration 1.0 ACH50 -** $0.21/sqft for medium homes, $0.51/sqft for small GHGW, $0.71/sqft for small GHEW, Interpolated from WSEC Proposal

Space and Water Heating Systems

- **Gas Furnace 96+ AFUE -** $458 incremental cost from 95 AFUE, 2019 EPS MAD 181
- **0.95 EF Tankless Water Heater -** $85/unit for small and medium GHGW, Professional judgment of Swiftsure Energy Services [Verifier]
- **0.97 EF Tankless Water Heater -** $225/unit for small and medium GHGW, Professional judgment of Swiftsure Energy Services [Verifier]
- **0.99 EF Tankless Water Heater -** $225/unit for small and medium GHGW, No incremental cost above 0.97EF, Swiftsure Energy Services [Verifier]

Mechanical Ventilation

- **Heat Recovery Ventilator 80% ASRE (adjusted sensible recovery efficiency), 1.2 CFM/W –** No incremental cost for HRV efficiency. An internet survey of website including suplyhouse.com did not show a prep associated to the 80% ASRE compared to the 60% ASRE

Thermostats

- **Program Qualified Smart Thermostat -** $125 incremental cost; Incremental cost of program qualifying smart thermostat is based on interviews with high volume builders. Nearly half of builders install web enabled programmable thermostat without the influence of the program. The incremental cost above the web enabled programmable thermostat is $50 and the incremental cost over a non-connected programmable thermostat is $200. Average incremental cost is $125.

Non-Energy Benefits

Non-energy benefits are based on electric savings at Clark Public Utility's residential rates. The non-energy benefit is the reduction in electric bills for the customer.

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Incentive Structure

The maximum incentives listed in Table 1 are the maximum incentives allowed for the measure. Incentives will be developed based on percent savings above code. For modeled homes that have savings which fall between the defined pathways a "sliding scale" approach will be used to estimate the savings to be claimed by the program and the incentive level to be paid.

Incremental costs in new construction can vary significantly. The program requested to allow incentives to exceed the incremental cost, up to a UCT of 1.0. The Energy Efficiency Advisory Group (EEAG) granted this request on May 19, 2021.

Follow-Up

This measure is directly related to New Homes WA's code-based approach offering. It is suggested that these offerings be updated in coordination with assumptions or pertinent data to be kept in sync.

If new information about thermostat or fireplace savings becomes available, it should be incorporated at next update.

Supporting Documents

The cost-effective screening for these measures is number 145.4.2. It is attached along with the analysis workbook. These can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Residential\New Homes\EPS\WA EPS

145.4.2 or wa CEC 2022v1.0 _SWWA_EF

2021_SWWA_EPS-145.4-WholeHome_Pa

Version History and Related Measures

Energy Trust has been offering EPS New Homes in Washington measure for many years. These predate our measure approval documentation process and record retention requirements. Table 13 *may be incomplete, particularly for measures approved prior to 2013.*

Table 190 Version History

Date	Version	Reason for revision
6/30/2012	124.x	Introduce NW Energy Star BOPs in Washington
3/4/2014	124.x	Allowed Earth Advantage as "equivalent path"
9/22/2014	124.x	Transition from BOPs to Performance Paths, update for 2012 building code
10/1/2015	145.x	Introduce EPS in Washington, replace MAD ID 124
9/7/2016	145.1	Updates for 2015 building codes, redesigned pathways
10/7/2017	145.2	Update savings and requirements for newer REM/Rate version and modeling protocol
9/23/2020	145.3	Extend valid date due to delay in code adoption
6/21/2021	145.4	Updated for *2018 WSEC residential building code*

Table 191 Related Measures

Measures	MAD ID
EPS in Oregon	181
Washington New Homes Code Credits	267

Approved & Reviewed by

Jackie Goss, PE
Sr. Planning Engineer

Disclaimer

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EnergyTrust of Oregon

Measure Approval Document for Retail Web Enabled Smart Thermostats

Valid Dates
March 12, 2021 to December 31st, 2022

End Use or Description
Web-enabled smart thermostats with occupancy detection provide energy savings through reduced run time of heating and/or cooling systems. Some models achieve additional savings when paired with heat pumps through changes in strip heat control.

Program Applicability
Based on the referenced analysis and associated cost-effectiveness screening, the measures described below are approved for use in the following programs:

- Residential Program
- Existing Multifamily Program

Within these programs, applicability to the following building types or market segments or program tracks are expected:

- Retail Downstream via consumer applications or instant coupon platforms – for self install or contractor install
- Purchased from a contractor

Within these programs, the measure is applicable to the following cases:

- Retrofit

Purpose of Re-Evaluating Measure
Add purchase from a contractor as approved delivery channel.

Cost Effectiveness
Cost effectiveness is demonstrated for Oregon in Table 1 and Washington in Table 2. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2022-v1.0. In Oregon the electric avoided cost year is 2022 and the gas avoided cost year is 2022. In Washington the gas avoided cost year is 2020.

Table 192 Cost Effectiveness Calculator Oregon

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Ele	% Gas
7	Smart Tstat Any Home - Electric	11	525	0.0	$170	$0	$170.00	2.2	2.2	100%	0%
8	Smart Tstat Any Home - Gas	11	51	39.7	$170	$0	$170.00	2.6	2.6	15%	85%
9	Smart Tstat Any Home - Gas Only	11	0	39.7	$170	$6.09	$170.00	2.2	2.5	0%	100%

Table 193 Cost Effectiveness Calculator Washington

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Ele	% Gas
1	Smart Tstat Any Home - Gas	11	39.7	$170	$4.17	$170	3.2	3.4	0%	100%

Requirements

- Thermostat must be on Smart Thermostat Qualified Products List.116
- Home must be heated with fuel provided by a participating Energy Trust utility or allocated appropriately through one of the allocation platforms.

Baseline
This measure uses an Existing Condition Baseline.

The baseline assumes a standard programmable or manual thermostat, that is not enrolled in a thermostat optimization service, in a home with average HVAC loads.

Measure Analysis
Energy savings in this analysis have been divided into two categories, thermostat "device" savings and "optimization" savings.

Device savings here refers to the energy savings that are driven by features of the thermostat device, such as occupancy detection, scheduling, maintenance alerts, and an engaging user interface.

Optimization savings, on the other hand, are defined here as incremental savings driven by proprietary manufacturer set-point optimization algorithms. These savings occur as a result of small changes to scheduled heating and/or cooling setpoints, which are designed to be sufficiently small as to not impact customer comfort.

Device Savings- Electric Heating Systems

Electric forced air furnace and air source heat pump baseline loads and savings percentages are from the RTF's connected thermostat workbook.117 The analysis applies the Energy Trust evaluated gas furnace heating savings estimate of 6% to electric forced air furnace heating and cooling loads. Heat pumps save an estimated 14% of heating loads based on RTF assumptions. RTF cooling saving estimates for heat pumps and forced air furnaces is 6%, based on the assumption that the driver of savings is reduced run times similar to heating savings for forced air furnaces. RTF savings estimates are shown in Table 194.

Table 194 RTF Electric Furnace and Air Source Heat Pump Home Savings

116 Energy Trust Thermostat QPL
117 RTF Connected Tstats v1.3

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Home Size	Heating System Type	Heating Zone	% Heating Savings – Smart Tstat	% Cooling Savings - Smart Tstat	Heating Savings (kWh)	Cooling Savings (kWh)
SF and MH =< 1600 sq ft and all MF	Electric FAF	HZ1	6%	6%	377	0
SF and MH > 1600 sq ft	Electric FAF	HZ1	6%	6%	539	0
SF and MH =< 1600 sq ft and all MF	Electric FAF	HZ2	6%	6%	496	0
SF and MH > 1600 sq ft	Electric FAF	HZ2	6%	6%	672	0
SF and MH =< 1600 sq ft and all MF	Heat Pump	HZ1	14%	6%	458	8
SF and MH > 1600 sq ft	Heat Pump	HZ1	14%	6%	558	7
SF and MH =< 1600 sq ft and all MF	Heat Pump	HZ2	14%	6%	723	20
SF and MH > 1600 sq ft	Heat Pump	HZ2	14%	6%	807	22

Given the nature of retail midstream and downstream delivery, accurate data collection on these attributes can be difficult to obtain from participants leading to a weighted approach to savings estimates. The RTF modeled heating and cooling loads by housing type, size, heating zone and heating type, which were weighted based on RTF and RBSA II data were used to collapse savings estimates into blended values. Weighting factors are shown in Table 195. Thermostat Device savings levels for electric heating systems by housing type and blended are presented in Table 196.

Table 195 Heating Zone, Housing Size and Heating System Weights

Home Size	Heating System Type	Heating Zone	SF/MH/MF Heating Zone Weight	SF/MH Heating System and Size Weight	MF Heating System Weight
SF and MH =< 1600 sq ft and all MF	Electric FAF	HZ1	95%	33%	65%
SF and MH > 1600 sq ft	Electric FAF	HZ1	95%	18%	0%
SF and MH =< 1600 sq ft and all MF	Electric FAF	HZ2	5%	33%	65%
SF and MH > 1600 sq ft	Electric FAF	HZ2	5%	18%	0%
SF and MH =< 1600 sq ft and all MF	Heat Pump	HZ1	95%	17%	35%
SF and MH > 1600 sq ft	Heat Pump	HZ1	95%	32%	0%
SF and MH =< 1600 sq ft and all MF	Heat Pump	HZ2	5%	17%	35%
SF and MH > 1600 sq ft	Heat Pump	HZ2	5%	32%	0%

Table 196 Thermostat Device Electric Heating System Savings

Measure	Savings (kWh)	Housing Weight
Smart Tstat Single/Manufactured Home - Electric	487	94%
Smart Tstat Multifamily - Electric	413	6%
Smart Tstat Any Home - Electric	482	100%

Device Savings- Gas Furnace Heating Systems

Energy Trust's pilot evaluation of homes heated by a gas furnace resulted in heating savings of 6%.[118] For single family homes, the average annual heating loads are derived from the RBSA I.[119] The average heating loads for Oregon gas heated homes was 583 therms. These values include both heating zone 1 and heating zone 2.

For multifamily dwelling units, the average annual heating load for electrically heated units is derived from the RTF's Connected thermostat measure analysis. To determine the annual heating load for multifamily gas heated units, the ratio of the multifamily electric heating load to the single family electric heating load was calculated and applied to the single family average gas heating load of 583 therms. The electric heating ratio was found to be 0.79 which resulted in a multifamily average gas heating load of 458 therms.

Device Savings- Gas Furnace Fan Electric Savings

Fan energy savings are due to reduced fan runtimes, or lower fan speeds, needed to maintain set point temperatures with a more efficient furnace. Furnace fan savings are based on the RTF's estimate of fan input energy of 0.53 kW and Energy Trust residential project data on average furnace input energy of 63,000 Btu/hr. Estimated Fan runtime savings are based on the following equation:

$$Fan\ kWh\ savings\ = \frac{(therm\ savings\ *\ 100{,}000 Btu/therm)}{input\ Btu/h} *\ fan\ input$$

Inputs result in fan savings of 29 kWh for single family/manufactured homes and 23 kWh for multifamily.

Device Savings- Cooling Savings for homes with Gas Furnaces

Cooling loads for gas furnace homes are based on an average estimated cooling load from Energy Trust's heat pump pilot and runtime analysis in Energy Trust's Nest seasonal savings pilot. Annual cooling load estimates were 200 and 787 kWh for single family dwellings, given the large range this analysis uses the mid-point of 494 kWh/year for single and manufactured housing. Applying the ratio used to estimate multifamily gas loads above, multifamily cooling loads are 388 kWh annually.

RBSA II data for single family, manufactured homes and multifamily was used to estimate prevalence of central AC equipped gas furnace homes. Single family and manufactured home combined central AC saturation is 57% and multifamily is 30%.

Thermostat Device savings estimates for gas furnace are shown in Table 197.

Table 197 Thermostat Device Base Gas Furnace Heating, Fan and Cooling Savings

Housing Type	Fuel	Heating Savings Therms*	Fan Savings kWh*	Cooling Savings kWh*	Total kWh Savings*	NEB	Cooling Savings %
Single/Manufactured Home	Gas	32.2	27	16	43	$0.00	37%
Single/Manufactured Home	Gas Only Territory	32.2	-	-	-	$5.07	-
Multifamily	Gas	25.3	21	6	28	$0.00	23%
Multifamily	Gas Only Territory	25.3	-	-	-	$3.29	-

**Includes a 92% install rate adjustment, discussed on page 3*

118 Energy Trust of Oregon Smart Thermostat Pilot Evaluation (Gas Furnaces). Apex analytics, 2016.
119 NEEA 2011-12 RBSA I

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Thermostat Optimization Savings.

Beginning in summer 2020, Nest's Seasonal Savings optimization service transitioned to a free service available to all qualified Nest customers. Energy Trust partnered with Google Nest from 2017 to 2019 to deliver a proprietary thermostat optimization service to Nest devices located in Energy Trust territory on a "fee per participating device" basis. Energy Trust previously claimed energy savings for the devices that opted-in to participating in the service using stand-alone Thermostat Optimization measures that were separate and distinct from any thermostat device savings. Customers must have a heating and/or cooling schedule established in order to participate in the service. Similarly, ecobee has also recently announced that launch of similar thermostat optimization service that will also be delivered free-of-charge to all ecobee thermostats. Since these services are now essentially embedded in the thermostat device itself, this update incorporates optimization savings into thermostat measures directly, rather than as a standalone thermostat optimization measure, as had been past practice. This analysis assumes the newer Google Nest product has the same optimization capabilities as other Nest devices.

Heating season optimization savings for Nest devices are based on the per opt-in unit savings results from Energy Trust's 2016/2017 Nest Seasonal Savings pilot evaluation[120]. Average energy savings by heating system type, are shown in Table 198.

Table 198 Pilot Results for Nest Winter Seasonal Savings

Heating System Type	Savings Source	Savings per Opt-in
Gas Furnace	Heating Energy	17.80 therms
	Fan Energy	15.34 kWh
Electric Furnace	Heating Energy	195.89 kWh
	Fan Energy	15.34 kWh
Heat Pump	Heating & Fan Energy	120.90 kWh

Energy Trust's 2016/2017 Nest Seasonal Savings pilot also evaluated summer cooling season savings and found an average of 4.1 kWh annual savings per opt-in participant. Previously, Energy Trust did not participate in summer season optimization because the offering was not cost-effective.

Ecobee conducted a pilot study of their *eco+* optimization service in summer 2019 and found an average of 40 kWh summer cooling savings per device[121]. That savings assumption is used to calculate ecobee optimization savings in this analysis. Ecobee has not yet published an equivalent winter heating season savings value because not all winter season efficiency features were deployed to devices during the pilot period. Ecobee is expected to publish a follow-up pilot report in the near future that details the magnitude of winter season optimization savings.

Average thermostat optimization savings for both heating and cooling across ecobee and Nest devices are weighted using the 2018-2019 prevalence of those thermostat brands in retail program offerings. Nest devices represented 82% of total retail thermostat volume, and ecobee device represented 18% of total retail thermostat volume over the program years 2018-2019.

RBSA II heating/cooling system distributions for Oregon are also factored into calculations of average optimization cooling savings. 65% of gas furnace homes and 44% of electric furnace homes are assumed to have cooling equipment, according to RBSA II values. Homes without cooling equipment are assigned zero cooling savings in this analysis.

Thermostat Optimization Opt-in Rates

A 59.5% opt-in rate assumption is applied to Nest heating season optimization savings, which is the average opt-in rate observed for the service during the program years 2018-2019. A slightly lower opt-in rate is applied to Nest cooling optimization savings, 46.9%, which comes from the 2016/2017 Nest Seasonal Savings pilot. Opt-in rates for Nest devices are effectively a combined participation rate that reflect both the portion of qualified/ eligible devices for the service, as well as the percentage that choose to participate in the service. Ecobee cooling savings are treated with the same opt-in rate as Nest cooling savings, 46.9%, since that information was not reported in ecobee's pilot study report.

Table 199 shows weighted average thermostat optimization savings by heating system type including opt-in rate adjustments.

Table 199 Weighted Average Thermostat Optimization Savings

Heating System Type	Weighted Average Heating & Fan Savings	Weighted Average Cooling Savings
Electric Furnace	102.5 kWh	1.6 kWh
Heat Pump	58.7 kWh	5 kWh
Gas Furnace*	8.64 therms	10.3 kWh

**Gas Furnace Fan savings are shown in cooling column.*

Install rate

The 2014 gas thermostat pilot, which depended on self-install, yielded 415 total purchased thermostats, of which 32 were returned. This represents a 92% install rate. This factor is applied to device heating, device cooling, device fan, and optimization savings to account for products that are purchased and either not installed or later uninstalled and is embedded in the previous analysis tables.

Housing Type Blending

Data for from Energy Trust Project Tracker from January 2018 to March 2019 on incented midstream smart thermostats was used to determine the relative weighting between Single Family/ Manufactured homes and Multifamily dwellings.

Table 200 Distribution of Energy Trust Mid/Downstream Incented Smart Thermostats Between Housing Types

Housing Type	Distribution
Multifamily	6%
Single Family/Manufactured Homes	94%

Final thermostat savings and NEBs by housing type and HVAC type are shown in Table 201.

Table 201 Final Smart Thermostat Savings

120 https://www.energytrust.org/wp-content/uploads/2017/12/Energy-Trust-of-Oregon-Nest-Seasonal-Savers-Pilot-Evaluation-FINAL-wSR.pdf
121 https://www.ecobee.com/en-us/ecoplusemv/

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	Device Savings		Optimization Savings		Final Savings	
Housing Type- HVAC Configuration	**kWh**	**Therms**	**kWh**	**Therms**	**kWh**	**Therms**
Single Family/Manufactured Home - Electric	452	0.0	77	0.0	529	0.0
Single Family /Manufactured Home - Gas	43	32.2	9	7.9	52	40.1
Single Family/Manufactured Home - Gas Only	0	32.2	0	7.9	0	40.1
Multifamily - Electric	383	0.0	83	0.0	466	0.0
Multifamily - Gas	28	25.3	8	7.9	35	33.2
Multifamily - Gas Only	0	25.3	0	7.9	0	33.2
Any Home - Electric	447	0.0	78	0.0	**525**	**0.0**
Any Home - Gas	42	31.8	9	7.9	**51**	**39.7**
Any Home - Gas Only	0	31.8	0	7.9	**0**	**39.7**

Comparison to RTF or other programs

Energy Trust uses a longer measure life than the RTF and includes gas heated measures which are not included in the RTF workbooks. RTF analysis identifies specific heating zone measures whereas this MAD blends RTF savings estimates by zone together for these measures. RTF's measure has not been updated for the change in optimization delivery.

Energy Trust also offers smart thermostats in direct install and direct ship scenarios co-funding partners. Those offerings have higher costs and more site-specific savings, including different heat pump savings based on Energy Trust's 2015 pilot122 and are approved through MADs 222 and 250. Contractor installed smart thermostats in homes with heat pumps are approved through MADs 148.

Measure Life

The California Database for Energy Efficiency Resources (DEER) lists the expected lifespan of a programmable thermostat as 11 years.

Cost

The Nest E represents the base cost of a thermostat with the features associated with proven energy savings. These products have averaged $170 from online retail sites (accessed March & June 2019).

Non Energy Benefits

In both Oregon and Washington, unclaimed electric savings are included as non-energy benefits valued at the retail rate of electricity for those territories ($0.120/kWh OR, $0.082/kWh SW WA).

Incentive Structure

The maximum incentives listed in Table 1 and Table 2 are for reference only and are not suggested incentives. Incentives will be structured per purchased thermostat.

Follow-Up

Updated impact evaluation results should be incorporated in the next measure update, including the evaluation that completed in Q4 2019.

Prevalence of ecobee and Nest devices should be revisited at the next measure update. Distribution of incented thermostats between single family, multifamily and manufactured home should be refreshed in subsequent updates to maintain blended savings accuracy. Baseline type, equipment and cost for contractor purchases should be reconsidered depending on common choices at time of such a purchasing decision.

This MAD should be updated on a similar schedule to MADs 222 and 250 and the analysis methods and assumptions between the three should be aligned.

Supporting Documents

The cost effective screening for these measures is number 153.5.3. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Residential\Res HVAC\thermostat\web enabled thermostat\Self installed

153.5.3 OR-WA CEC 2022 v1.0 Retail Tstat

Version History and Related Measures

Table 202 Version History

Date	Version	Reason for revision
9/12/13	x	Nest heat pump pilot
10/9/14	132	Web-enabled thermostat gas heated homes pilot
8/17/15	138	Retail and contractor installed web-enabled thermostats, electric and gas
10/22/15	148	Contractor installed web-enabled thermostats for heat pumps only
4/1/16	153.1	Retail-only web-enabled thermostat measure, electric and gas. Update avoided costs. Supersedes MAD 138.
5/15/17	153.2	Specifies savings for multifamily. Fan savings added. Contractor install included, may be offered concurrently with MAD 148.
7/11/2019	153.3	Update to electric savings based on RTF analysis. Move from incremental to retrofit baseline and costs. Blending Res/MF. Addition of cooling savings to gFAF measures.
10/13/2020	153.4	Updated to include thermostat optimization savings for Nest and ecobee devices. Thermostat device savings were updated to include install rate adjustment.
3/12/2021	153.5	Add contractor purchase as approved delivery channel

Table 203 Related Measures

122 Energy Trust Follow-up Billing Analysis for the Nest Thermostat Heat Pump Control Pilot, 2015

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Measures	MAD ID
DI Smart Thermostats with Funding Partners	222
DI Commercial Smart Thermostats Pilot	235
Automated Thermostat Optimization (inactive)	173
Residential Thermostat Optimization Pilot (inactive)	217
Direct Ship Smart Thermostats	250
Contractor Installed Thermostats for New Heat Pumps (inactive)	19
Contractor Installed Thermostats on Heat Pumps	148

Approved & Reviewed by

Jackie Goss, PE
Sr. Planning Engineer

Disclaimer

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Measure Approval Document for Residential Gas Tankless Water Heaters in SW Washington

Valid Dates
January 1, 2022 to December 31, 2023

End Use or Description
Residential ENERGY STAR® gas tankless water heaters in SW Washington replacing existing gas water heaters.

Program Applicability
Based on the referenced analysis and associated cost-effectiveness screening, the measures described below are approved for use in the following programs:

- Residential
  - HES Existing Homes
  - XMH Existing Manufactured Homes
- Commercial
  - BEM Existing Multifamily, 2-4 units and side-by-side

Within these programs, applicability to the following building types or market segments or program tracks are expected:

- Residential customers in single family, multifamily, and/or manufactured homes
- Customer self-installation and/or contractor installation
- Downstream, to customers

Within these programs, the measure is applicable to the following cases:

- Replacement

Purpose of Re-Evaluating Measure
This tankless gas water heater measure update reflects cost and savings that align with the Regional Technical Forum, RTF, Residential Gas Water Heaters measure approved April 13, 2021[123]. Requirements have been updated to suit the new analysis.

This update reflects changing this measure to a Full Market Baseline rather than an Inefficient Market Baseline. Savings and cost analysis reflect this baseline change.

This update removes the minimum 0.81 UEF (or equivalent 0.81 EF) efficiency qualification and replaces equipment specification to ENERGY STAR certification for residential tankless water heaters installed in Southwest Washington Energy Trust territory. Additionally, this measure distinguishes between units needing a gas line upgrade and those that do not, the previous measures did not distinguish between these installations. These measures can be replacing storage or tankless gas water heaters.

Cost Effectiveness
Cost effectiveness is demonstrated for Washington in Table 2. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2021-v1.1. In Washington, the gas avoided cost year is 2020.

Table 204 Cost Effectiveness Calculator Washington

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	SW WA Gas ESTAR Tankless WH	20	60.69	449.77	-$1.84	$449.77	1.9	1.9	0%	100%
2	SW WA Gas ESTAR Tankless WH - w/ Gas Upgrade	20	60.69	1649.77	-$1.84	$873.52	1.0	0.5	0%	100%

Exceptions
Measure configurations that require gas line upgrades have total resource cost effectiveness, TRC, 0.5. However, measure-level TRC is not required in NW Natural Washington's portfolio. If the WUTC changes policy within the valid dates of this analysis, the MAD will need to be revisited.

Requirements
- Installed in SW Washington homes served by Northwest Natural Gas
- Manufacturers have created a category of "hybrid" gas water heaters between tankless and storage that have a tank with a capacity over two gallons burner with a rating greater than 75 kBtu/hr. These hybrid units are excluded from eligibility under this MAD.
- Input less than 200 kBtu/hr
- Replacing existing gas water heater, storage or tankless replacement allowed
- Used for domestic hot water only, combination space-water heating equipment are excluded from this measure
- ENERGY STAR qualified at time of purchase

Details
Tankless gas water heaters have improved efficiency compared to storage water heaters as they do not have standby losses associated with stored water. Some gas tankless water heaters require an upgrade in gas line size from ½ inch to ¾ inch. These installations have an increased cost of $1200 which is reflected in the incremental measure cost for these instances.

ENERGY STAR Eligibility Criteria will be updated from Version 3.0 to 4.0 effective Jan. 5, 2022. Version 4.0 is effectively the same for gas water heaters, with only the Maximum Gallons per Minute rating is changing from Max GPM ≥ 2.9 in Version 3.0 to Max GPM ≥ 2.8 in Version 4.0[124]. ENERGY STAR specifications have been updated to reflect Uniform Energy Factor, UEF, product rating which are now used throughout the industry. See Table 170 for a comparison of ENERGY STAR Product Criteria eligibility details between versions.

Table 205 ENERGY STAR Product Criteria Version 3.0 Compared to Version 4.0

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123 Regional Technical Forum, Residential Gas Water Heaters measures: https://rtf.nwcouncil.org/measure/residential-gas-water-heaters-0

124 ENERGY STAR® Program Requirements, Product Specification for Residential Water Heaters, Eligibility Criteria Version 4.0 https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%204.0%20Water%20Heaters%20Final%20Specification%20and%20Partner%20Commitments_0.pdf

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	ENERGY STAR v3.0	ENERGY STAR v4.0 (Effective Jan 5, 2022)
Uniform Energy Factor (UEF)	UEF ≥ 0.87	UEF ≥ 0.87
Max Gallons Per Minute	Max GPM ≥ 2.9 over a 67°F rise	Max GPM ≥ 2.8 over a 67°F rise
Warranty	Warranty ≥ 6 years on heat exchanger and ≥ 5 years on parts	Warranty ≥ 6 years on heat exchanger and ≥ 5 years on parts
Safety	ANSI Z21.10.3/CSA 4.3	ANSI Z21.10.3/CSA 4.3

Baseline

This measure uses Full Market Baseline.

Water heaters are primarily replaced on burnout and the purpose of this offering to help the customer choose this more efficient unit. Per the RTF review and analysis of the 2018 Northwest Energy Efficiency Alliance water heater market study, gas water heaters are being replaced by both storage and tankless water heaters and with various sized equipment, regardless of original equipment type and capacity. Because the consumer is purchasing across equipment types and sizes, a market baseline that incorporated storage water heaters of various capacity and tankless units is appropriate.

Per the RTF measure analysis of 2019-2020 NEEA distributor sales data, the market baseline is composed of 11 prototype equipment types, including three storage water heaters with three different capacities and two efficiency tiers of tankless water heaters. Storage, non-ENERGY STAR units still dominate the market with 81.4% market share, while all gas tankless measures account for 15.6% and ENERGY STAR tankless units are 11.9% of the market as summarized in Figure 6 and Table 171 from the RTF Residential Gas Water Heaters: New Measure Proposal presentation from 4/14/2021[125] and RTF measure analysis.

Figure 7 RTF Residential Gas Water Heaters - Baseline Configuration

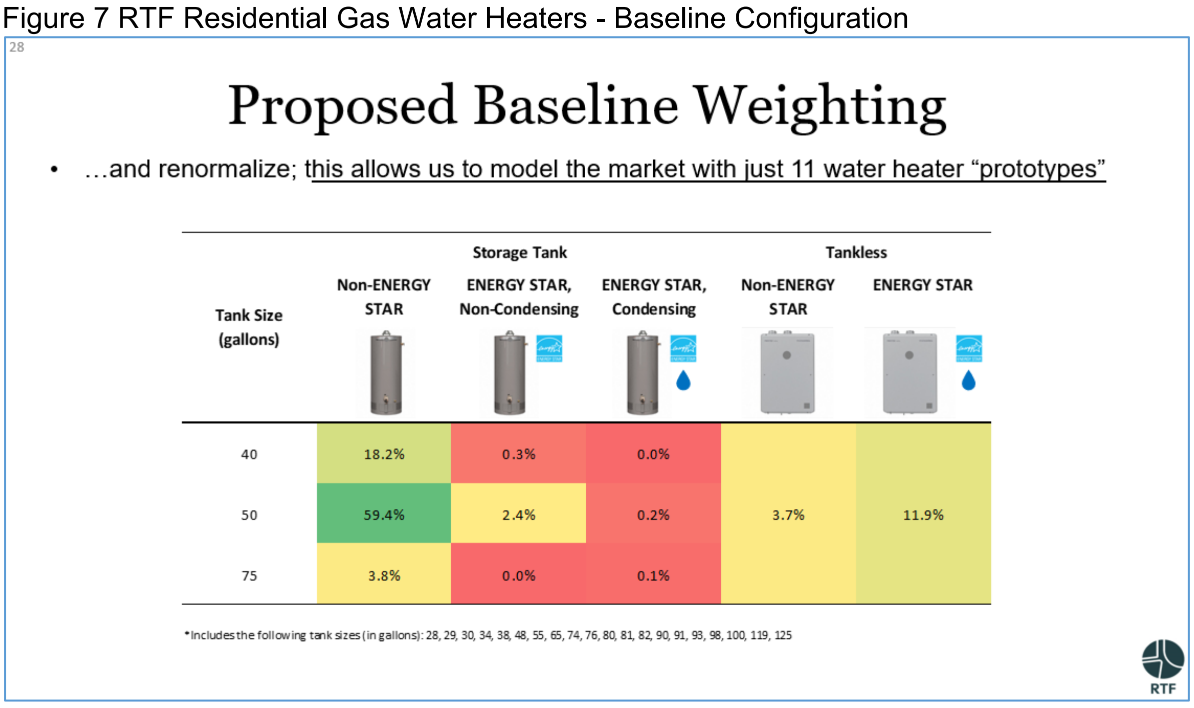

Table 206 RTF Residential Gas Water Heaters – Market Share Equipment Distribution

Current Practice Baseline	Distribution
40 gal non-ENERGY STAR	18.2%
50 gal non-ENERGY STAR	59.4%
75 gal non-ENERGY STAR	3.8%
40 gal ENERGY STAR, non-condensing	0.3%
50 gal ENERGY STAR, non-condensing	2.4%
75 gal ENERGY STAR, non-condensing	0.0%
40 gal ENERGY STAR, condensing	0.0%
50 gal ENERGY STAR, condensing	0.2%
75 gal ENERGY STAR, condensing	0.1%
Tankless, non-ENERGY STAR	3.7%
Tankless, ENERGY STAR	11.9%

Measure & Savings Analysis

Annual energy consumption for each of the RTF prototype water heaters is calculated using the Lawrence Berkeley National Laboratory Water Heater Analysis Model (WHAM)[126]. This calculation provides total water heater energy consumption in BTU/day based on recovery efficiency, energy factor, rated input power, pilot input power, standby losses, set points, inlet water temperature, ambient air temperature water draw, water density, specific heat, and a performance adjustment factor for tankless water heaters. The WHAM equations and terms for storage and tankless water heater consumption calculations are provided below in Equation 2 and Equation 3, respectively.

Equation 4 Storage Water Heater WHAM

125 RTF Residential Gas Water Heaters Presentation, April 14, 2021: https://nwcouncil.app.box.com/v/20210414GasWaterHeaterPres
126 https://www.regulations.gov/document?D=EERE-2006-STD-0129-0149

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The WHAM equation yields average daily water heater energy consumption (Q_{in}). The equation is expressed as follows.

$$Q_{in} = \frac{vol \times den \times C_P \times (T_{tank} - T_{in})}{RE} \times \left(1 - \frac{UA \times (T_{tank} - T_{amb})}{Pon}\right) + 24 \times UA \times (T_{tank} - T_{amb})$$

Where:

Q_{in} = total water heater energy consumption in British thermal units per day, Btu/day,
RE = recovery efficiency, %,
P_{ON} = rated input power, Btu/h,
UA = standby heat-loss coefficient, Btu/h-°F,
T_{tank} = thermostat set point temperature, °F,
T_{in} = inlet water temperature, °F,
T_{amb} = temperature of the ambient air, °F,
vol = volume of hot water drawn in 24 hours, gal/day,
den = density of stored water, set constant at 8.29 pounds per gallon, lb/gal, and
C_P = specific heat of stored water, set constant at 1.000743, Btu/lb-°F.

7.2.4.1 Approach to Calculating Water Heater Energy Use

The WHAM equation yields average daily water heater energy consumption (Q_{in}). The equation is expressed as follows.

$$Q_{in} = \frac{vol \times den \times C_P \times (T_{tank} - T_{in})}{RE} \times \left(1 - \frac{UA \times (T_{tank} - T_{amb})}{Pon}\right) + 24 \times UA \times (T_{tank} - T_{amb})$$

Where:

Q_{in} = total water heater energy consumption in British thermal units per day, Btu/day,
RE = recovery efficiency, %,
P_{ON} = rated input power, Btu/h,
UA = standby heat-loss coefficient, Btu/h-°F,
T_{tank} = thermostat set point temperature, °F,
T_{in} = inlet water temperature, °F,
T_{amb} = temperature of the ambient air, °F,
vol = volume of hot water drawn in 24 hours, gal/day,
den = density of stored water, set constant at 8.29 pounds per gallon, lb/gal, and
C_P = specific heat of stored water, set constant at 1.000743, Btu/lb-°F.

$$UA = \frac{\left(\frac{1}{EF} - \frac{1}{RE}\right)}{(T_{tank} - T_{amb}) \times \left(\frac{24}{Q_{out}} - \frac{1}{RE \times Pon}\right)}$$

Where:

UA = standby heat loss coefficient, Btu/h-°F,
EF = energy factor,
RE = recovery efficiency; %.
T_{tank} = temperature of the air surrounding the water heater, °F;
T_{amb} = thermostat set point temperature, °F;
Q_{out} = heat content of the water drawn from the water heater, Btu/h, and
P_{ON} = the rated input power, Btu/h.

Equation 5 Tankless Water Heater WHAM

The resulting equation is:

$$Q_{in} = \frac{vol \times den \times C_P \times (T_{tank} - T_{in})}{RE \times (1 + PA_{iwh})} \times \left(1 - \frac{Q_P}{P_{ON}}\right) + 24 \times Q_p \times (T_{Tank} - T_{amb})$$

Where:

Q_{in} = total water heater energy consumption, Btu/day,
vol = daily draw volume, gal/day,
den = density of water, lb/gal,
C_p = specific heat of water, Btu/lb-°F,
T_{tank} = set point of tank thermostat, °F,
T_{in} = inlet water temperature, °F,
RE = recovery efficiency, %,
PA_{iwh} = performance adjustment factor,
Q_p = pilot input rate, Btu/h,
P_{ON} = rated input power, Btu/h.

The RTF analysis computes annual consumption using the WHAM calculation for each of the 11 baseline prototypes in both conditioned and buffer spaces, in each of the RTF heating zones. These consumption results are then weighted by prototype market share, heating zone, and install location to determine an average baseline consumption. Savings are determined by subtracting the annual consumption of the weighted measure case from the weighted average annual consumption of the market baseline.

Heating zone and water heater location were weighted based on 2016-2017 Residential Building Stock Assessment (RBSA) II[127] data as follows in Table 172, market share is noted above in Table 171.

127 2016-2017 Regional Building Stock Assessment (RBSA) II https://neea.org/resources/rbsa-ii-combined-database

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Table 207 RTF Residential Gas Water Heaters - Heating Zone and Water Heater Location

Heating Zone Distribution	
HZ1	76.0%
HZ2	14.9%
HZ3	9%

Tank Location Distribution	Conditioned	Buffer
HZ1	18.2%	81.8%
HZ2	19.4%	80.6%
HZ3	31%	69%

Savings

Baseline and efficient case gas and electric consumption and savings from the RTF analysis are provided in Table 173, these ENERGY STAR tankless measures use the analysis and savings for RTF measures:

- Tankless, ENERGY STAR, No Gas Line Upgrade
- Tankless, ENERGY STAR, With Gas Line Upgrade

Tankless water heaters have negative electric savings when compared to the market baseline which includes both non-powered and power vented units and electric ignition consumption.

Table 208 RTF Residential Gas Water Heaters - Consumption and Savings per Water Heater Type

WH Type and Efficiency	Gas Energy (therm)			Electric Energy (kWh)		
	Baseline UEC, Gas	Efficient UEC, Gas	Gas Savings	Baseline UEC, Electric	Efficient UEC, Electric	Electric Savings
Tank, ENERGY STAR, non-condensing, non-powered	162	147	**15**	6	-	**6**
Tank, ENERGY STAR, non-condensing, powered	162	137	**25**	6	64	**(57)**
Tank, ENERGY STAR, non-condensing	162	137	**25**	6	64	**(57)**
Tank, ENERGY STAR, condensing	162	106	**55**	6	41	**(35)**
Tankless, non-ENERGY STAR, No Gas Line Upgrade	162	116	**46**	6	29	**(23)**
Tankless, non-ENERGY STAR, With Gas Line Upgrade	162	116	**46**	6	29	**(23)**
Tankless, ENERGY STAR, No Gas Line Upgrade	162	101	**61**	6	29	**(23)**
Tankless, ENERGY STAR, With Gas Line Upgrade	162	101	**61**	6	29	**(23)**

Comparison to RTF or other programs

This measure aligns with two tankless measures within the Residential Gas Water Heaters measure approved by the RTF on April 13, 2021. The RTF analysis workbook *ResGasWH_v1_0.xlsm*128 is referenced directly, including the market analysis and product weights, Lawrence Berkeley National Laboratory Water Heater Analysis Model (WHAM) calculations and analysis, equipment and installation costs, measure life and other relevant attributes.

Energy Trust's measure for tankless water heaters, MAD 259, is currently based on other analysis methods and requirements. It will be updated in 2023 or earlier. The measures will be aligned at that time.

Measure Life

The lifetime of this measure is 20 years, from the DOE Technical Support Document for the 2015 federal standards change. This aligns with past measure life for gas tankless water heaters and reflects the RTF measure life.

Load Profile

Residential, gas "DHW" and electric "Res Water Heat" load profiles are used to screen this measure.

Cost

Equipment and installation costs align with RTF measure analysis for Residential Gas Water Heaters. Table 174 is a summary of installations costs based on DOE LCCs and RTF CAT judgment, Table 175 shows the combined install and equipment costs, and Table 176 shows baseline and incremental costs. Installation costs are based on RTF cited 2010 DOE Life-Cycle Cost analysis and cost data from NEEA, *Lab Testing of Tankless Water Heater Systems*129, Sept. 6, 2019 and reflect plumbing, electrical, venting, condensate, gas line upgrades as needed by equipment type.

Table 209 RTF Residential Gas Water Heaters - Installation Cost by Water Heater Type

WH Type	Identifier 1	Identifier 2	Plumbing	Electrical	Venting	Condensate Mgmt	Gas Line Upgrade	Total Installation Cost
Tank		non-ENERGY STAR	$578	$0	$0	$0	$0	$578
		ENERGY STAR, non-condensing, non-powered	$578	$0	$0	$0	$0	$578
		ENERGY STAR, non-condensing, powered	$578	$270	$342	$0	$0	$1,190
		ENERGY STAR, non-condensing	$578	$270	$342	$0	$0	$1,190
		ENERGY STAR, condensing	$578	$270	$342	$102	$0	$1,292
Tankless	non-ENERGY STAR	w/out Gas Upgrade	$509	$241	$473	$0	$0	$1,222
		w/ Gas Upgrade	$509	$241	$473	$0	$1,200	$2,422
	ENERGY STAR	w/out Gas Upgrade	$509	$241	$251	$102	$0	$1,102
		w/ Gas Upgrade	$509	$241	$251	$102	$1,200	$2,302

Equipment costs are based on 2019-2020 NEEA distributor sales data for all water heater prototypes, except for Storage ENERGY STAR non-condensing, non-powered equipment cost which are based on online retail pricing for the single available model which is

128 RTF Residential Gas Water Heaters Workbook v1.0: https://nwcouncil.box.com/v/ResGasWaterHeaterv1-0
129 NEEA Lab Testing of Tankless Water Heater System, Sept. 6, 2019: https://neea.org/resources/lab-testing-of-tankless-water-heater-systems

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available through Lowe's. All costs are blended for a market baseline cost based on market shares. Costs are adjusted to 2020 dollars according to RTF guidelines.

Table 210 RTF Residential Gas Water Heaters - Total Costs per Water Heater Type

WH Type	Identifier 1	Identifier 2	Total Installation Cost (2020$)	Equipment Cost (2020$)	Total Cost, Unadjusted (2020$)	Total Costs, Unadjusted (2012$)
Tank		non-ENERGY STAR	$578	$530	$1,108	$985
		ENERGY STAR, non-condensing, non-powered	$578	$672	$1,250	$1,112
		ENERGY STAR, non-condensing, powered	$1,190	$1,300	$2,490	$2,214
		ENERGY STAR, non-condensing	$1,190	$1,300	$2,490	$2,214
		ENERGY STAR, condensing	$1,292	$2,236	$3,528	$3,137
Tankless	non-ENERGY STAR	w/out Gas Upgrade	$1,222	$662	$1,884	$1,675
		w/ Gas Upgrade	$2,422	$662	$3,084	$2,742
	ENERGY STAR	w/out Gas Upgrade	$1,102	$1,107	$2,210	$1,965
		w/ Gas Upgrade	$2,302	$1,107	$3,410	$3,032

Baseline costs reflect the weighted average cost of the protype equipment. To account for different measure lives of storage and tankless water heaters, 13 and 20 years respectively, baseline costs are adjusted to reflect longer life of tankless units and earlier replacement of storage units. For storage water heater baselines, tankless water heater cost is discounted to account for remaining tankless life at the end of the 13 year storage measure life. Similarly, for the tankless water heater baseline, the storage water heater cost is increased to account for early replacement of storage units over the 20 year tankless measure life. These adjustments reflect present value of remaining life or additional cost of equipment annualized over the length of the analyzed measure.

Table 211 RTF Residential Gas Water Heaters - Incremental Cost per Water Heater Type

			Costs (2012$)			Costs (2020$)		
WH Type	Identifier 1	Identifier 2	Baseline Cost	Efficient Cost	Incremental Cost	Baseline Cost	Efficient Cost	Incremental Cost
Tank		non-ENERGY STAR						
		ENERGY STAR, non-condensing, non-powered	$1,166	$1,112	($54)	$1,311	$1,250	($61)
		ENERGY STAR, non-condensing, powered	$1,166	$2,214	$1,048	$1,311	$2,490	$1,179
		ENERGY STAR, non-condensing	$1,166	$2,214	$1,048	$1,311	$2,490	$1,179
		ENERGY STAR, condensing	$1,166	$3,137	$1,971	$1,311	$3,528	$2,217
Tankless	non-ENERGY STAR	w/out Gas Upgrade	$1,565	$1,675	$111	$1,760	$1,884	$124
		w/ Gas Upgrade	$1,565	$2,742	$1,178	$1,760	$3,084	$1,324
	ENERGY STAR	w/out Gas Upgrade	$1,565	$1,965	$400	$1,760	$2,210	$450
		w/ Gas Upgrade	$1,565	$3,032	$1,467	$1,760	$3,410	$1,650

Non Energy Benefits

Past gas water heater measures have referenced financial benefits related to extended warranty coverage for higher efficiency equipment. As this measure analysis incorporates blended measure life across the market, differences in warranty are not clear and are no longer included.

This measure produces small negative electric impacts which are represented as negative NEBs.

Incentive Structure

The maximum incentives listed in Table 2 are for reference only and are not suggested incentives. Incentives will be paid per qualifying gas tankless water heater. Incentives are likely to vary by program and sales channel and may be paid to end customers, home builders or passed through or kept by retail channels or distributers.

Follow-Up

The measure expiration date of 12/31/2023 to selected to align with expiration date of MAD 259 – Residential Tankless Water Heaters in Oregon and pending updates to MAD 102.4 – Residential Gas Storage Water Heaters. We intend to align analysis for storage and tankless water heaters with the RTF Residential Gas Water Heater measure across these measures as they expire and are updated. The following items should be considered at the next update.

- Review of RTF measure analysis if updates/revisions have been made, the RTF measures is approved through 4/30/2026
- Review of ENERGY STAR version and specifications; v4.0 is effective 1/5/2022
- Review of equipment cost from retail, NEEA and program data as this equipment type grows in the market
- Review of gas line upgrade prevalence and pricing would be helpful to assess the weighting used for these measures in the market
- If the WUTC reinstates TRC screening requirements this measure will need to be revisited.
- As Energy Trust's Washington territory is entirely in heating zone 1, future updates should attempt to disaggregate the RTF's weighted heating zone results.

Supporting Documents

The cost-effective screening for these measures is number 197.3.3. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Residential\Res Water Heating\tankless\Existing homes\Wa only

197_3_3_Res_Gas_Tankless_WH_SW_W/

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Version History and Related Measures

Energy Trust has been offering efficient Gas Tankless Water Heater incentives in Oregon and Washington for many years. These predate our measure approval documentation process and record retention requirements. Table 13 may be incomplete, particularly for measures approved prior to 2013.

Table 212 Version History

Date	Version	Reason for revision
2007	x	Tankless in existing homes approved
12/31/2011	x	Tankless measure canceled for existing homes
04/24/2017	197.1	Re-introduce tankless water heaters to existing homes in SW Washington
12/4/2018	197.2	Update expected efficiency rating to 0.92 EF. Include UEF specification.
7/26/2021	197.3	Update savings costs and requirements. Change qualifying criteria to ENERGY STAR gas tankless water heater with or without gas line upgrade. Replacing tankless or storage allowed.

Table 213 Related Measures

Measures	MAD ID
Residential and existing small multifamily heat pump water heaters	52
New small multifamily heat pump water heaters	176
New homes and small multifamily tankless water heaters	178
Commercial condensing tank water heaters	21
Commercial tankless water heaters	72
Residential Tankless Oregon	259
Residential Gas Storage Water Heaters	102

Approved & Reviewed by

Kenji Spielman
Planning Engineer

Disclaimer

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EnergyTrust of Oregon

Measure Approval Document for Resideo Thermostat

Valid Dates
5/1/2020 through 12/31/2022

End Use or Description
Thermostat optimization is a service where a company applies optimization algorithms to internet-connected thermostats on central heating and air conditioning systems to reduce energy consumption. This approval is for the Resideo optimization service, currently exclusive to Honeywell products, to be applied continuously for one year.

Program Applicability
Based on the referenced analysis and associated cost-effectiveness screening, the measures described below are approved for use in the following programs:

- Home Retrofit

Within these programs, the measure is applicable to the following cases:

- Retrofit

Purpose of Re-Evaluating Measure
This measure was previously approved for use during the winter heating season only. This update adds year-round use including cooling season savings.

Cost Effectiveness
Cost effectiveness is demonstrated for Oregon in Table 1 and Table 215 and in Washington in Table 2 and Table 2. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2021-v1.1. In Oregon the electric avoided cost year is 2021 and the gas avoided cost year is 2021. In Washington, the gas avoided cost year is 2020.

Table 1 and Table 216 show the approved measures with the cost per installation. One in ten enrolled participants will be in a control group. Table 215 and Table 2 demonstrate the offering is cost effective when the cost of control groups are included allowing for control group participants.

Summer only participation was analyzed and is included in workbooks and documentation but is not cost-effective and not approved.

Table 214 Cost Effectiveness Calculator Oregon – Resideo Measures

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Resideo Tstat Optimization - annual - gFAF	1	42	15	$12.00	$0.56	$12.00	1.1	1.2	19%	81%
2	Resideo Tstat Optimization - annual - gFAF + AC	1	69	15	$12.00	$0.92	$12.00	1.4	1.4	33%	67%
3	Resideo Tstat Optimization - annual - eFAF	1	441	0	$12.00	$0.00	$12.00	2.2	2.2	100%	0%
4	Resideo Tstat Optimization - annual - eFAF + AC	1	471	0	$12.00	$0.00	$12.00	3.1	3.1	100%	0%
5	Resideo Tstat Optimization - annual - Heat Pump	1	198	0	$12.00	$0.00	$12.00	1.3	1.3	100%	0%
6	Resideo Tstat Optimization - Winter - gFAF	1	42	15	$8.00	$0.56	$8.00	1.7	1.8	19%	81%
7	Resideo Tstat Optimization - Winter - eFAF	1	441	0	$8.00	$0.00	$8.00	3.3	3.3	100%	0%
8	Resideo Tstat Optimization - Winter - Heat Pump	1	169	0	$8.00	$0.00	$8.00	1.3	1.3	100%	0%

Table 215 Cost Effectiveness Calculator Oregon - Resideo program design

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
11	Resideo Tstat Optimization - annual - gFAF - Including control group costs	1	42	15	$13.33	$0.56	$13.33	1.0	1.1	19%	81%
12	Resideo Tstat Optimization - annual - gFAF + AC -Including control group costs	1	69	15	$13.33	$0.92	$13.33	1.2	1.3	33%	67%
13	Resideo Tstat Optimization - annual - eFAF - Including control group costs	1	441	0	$13.33	$0.00	$13.33	2.0	2.0	100%	0%
14	Resideo Tstat Optimization - annual - eFAF + AC - Including control group costs	1	471	0	$13.33	$0.00	$13.33	2.8	2.8	100%	0%
15	Resideo Tstat Optimization - annual - Heat Pump- Including control group costs	1	198	0	$13.33	$0.00	$13.33	1.2	1.2	100%	0%
16	Resideo Tstat Optimization - Winter - gFAF - Including control group costs	1	42	15	$8.89	$0.56	$8.89	1.5	1.6	19%	81%
17	Resideo Tstat Optimization - Winter - eFAF- Including control group costs	1	441	0	$8.89	$0.00	$8.89	3.0	3.0	100%	0%
18	Resideo Tstat Optimization - Winter - Heat Pump - Including control group costs	1	169	0	$8.89	$0.00	$8.89	1.1	1.1	100%	0%

Table 216 Cost Effectiveness Calculator Washington - Resideo Measures

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#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Resideo Tstat Optimization – annual - gFAF	1	15.2	$12.00	$3.81	$12.00	1.8	2.1	0%	100%
2	Resideo Tstat Optimization – annual - gFAF + AC	1	15.2	$12.00	$6.25	$12.00	1.8	2.3	0%	100%
3	Resideo Tstat Optimization – Winter gFAF	1	15.2	$8.00	$3.81	$8.00	2.7	3.1	0%	100%

Table 217 Cost Effectiveness Calculator Washington – Resideo Program Design

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
5	Resideo Tstat Optimization – annual - gFAF - Including control group costs	1	15.2	$13.33	$3.81	$13.33	1.6	1.9	0%	100%
6	Resideo Tstat Optimization – annual - gFAF + AC- Including control group costs	1	15.2	$13.33	$6.25	$13.33	1.6	2.0	0%	100%
7	Resideo Tstat Optimization – Winter gFAF - Including control group costs	1	15.2	$8.89	$3.81	$8.89	2.4	2.8	0%	100%

Requirements

- Household must have an internet-connected Honeywell Thermostat or other thermostat compatible with Honeywell's Resideo platform.
- Primary heating system must be a gas forced-air furnace, electric forced-air furnace, or heat pump.
- Primary heating fuel must be provided by Energy Trust participating utility, as determined by size address or assumed at zip code level.
- Annual and winter-only participation are approved. Summer-only participation is not approved.

Details

Program implementers pay Resideo for each device that is enrolled in the optimization program. The program will receive data about the each enrolled device including street address, zip code, heating system type (gas FAF, electric FAF, heat pump), and cooling system type (AC, heat pump, none) from Resideo. Initially, a utility split will be applied at the zip code level to determine the savings that will be recorded in PT for each utility, using virtual sites. The program may transition to a site-based method since this would increase the accuracy of reported savings by utility and overall.

Resideo's optimization algorithm will be applied throughout the year. We expect that all homes will have savings during the winter heating season and that homes with cooling systems will also have savings during the summer. Despite few summer savings, annual participation is preferred because of reduced recruitment efforts.

Participants are notified of their enrollment and can opt-out of the service once enrolled. Resideo reported a 4.8% winter attrition rate and a 3.4% summer attrition rate for pilot participants. These rates have been applied to the savings values presented here. Participant attrition was due to customer opt-outs, disconnected service, move-outs, and disqualification.

Baseline

This measure uses an Existing Condition Baseline.

The baseline condition is the existing settings of internet-connected Honeywell thermostats.

Measure Analysis

Energy Trust implemented this measure through the Connected Savings pilot program in 2018 and 2019. Energy Trust hired Apex Analytics (Apex) to estimate the winter and summer electric and natural gas savings associated with the pilot. The evaluation was based on findings from the 2018/2019 winter and 2019 summer. This analysis relies on the Apex evaluation report[130] for energy savings and participant attrition values.

The key evaluation finding are:

- For thermostats connected to furnaces 3.2% primary heating fuel savings and 5.1% fan electric savings.
- For heat pumps, reductions of 4.0% of heating electric use.
- For central air conditioning systems and heat pumps, reductions of 3.9% of cooling electric use.

These reductions are shown in absolute and percentage energy savings in Table 218.

Table 218 Combined Per-Thermostat Energy Savings for the Connected Savings Pilot, by System and Fuel Type

System	Season	Fuel	TMY* Savings	90% CI*	Relative Precision	Savings as % of TMY Heating or Cooling Load
Gas Furnace	Winter	Therms	16	±7	±44%	3.2%
Electric Furnace**	Winter	kWh	414	±170	±41%	3.2%
Furnace Fan***	Winter	kWh	49	±22	±45%	5.1%
Heat Pump	Winter	kWh	177	±146	±82%	4.0%
Air Conditioner	Summer	kWh	31	±26	±84%	3.9%

* TMY–Typical meteorological year; CI–Confidence interval.
** Electric Furnace values calculated using Gas Furnace values converted to kWh.
*** Furnace fan savings are calculated from the weather-dependent electricity consumption of homes with gas furnaces

The per-thermostat savings apply to homes that were participating for the entire heating or cooling season. Since some participants stop participating during each season, attrition rates were applied. These attrition values are shown in Table 219, and savings were adjusted accordingly.

Table 219 Summary of Connected Savings Pilot Attrition

130 Energy Trust of Oregon Resideo Thermostat Optimization Pilot Report. Apex Analytics, 2/25/2020 https://www.energytrust.org/wp-content/uploads/2020/04/Energy-Trust-of-Oregon-Resideo-Pilot-Final-Report-wSR-Final.pdf

Season	Winter		Summer	
Setting	Control	Treatment	Control	Treatment
Initial Total	965	1,427	1,009	1,468
Opted-out	0	32	3	16
Disconnected	15	24	9	7
Other	2	13	20	27
Total Attrition	17	69	32	50
Active users	948	1,358	977	1,438
Attrition percent	1.8%	4.8%	3.2%	3.4%

Measure Life

A one year measure life is used in this analysis, as fee paid to Resideo for each device covers deployment for one year.

Participating devices must be re-enrolled each year. Persistence of savings has not been studied.

Load Profile

The load profile is Res Ele Resistance Heat for the and eFAF only and the electric portion of gFAF only scenarios since there are no cooling savings in these cases. We used the Res Air Source HP load profile for the other three cases since there include both heating and cooling savings in proportion to the HP load profile.

Cost and Incentive

The cost of deploying the optimization algorithm is $12 for one full year and $8 for the eight month winter heating season. This fee is charged to Energy Trust and payment of this fee is our incentive. The service is free to the end use customer. There are no incentives paid to the customer.

Ten percent of enrollees are designated to be “Control” sites and do not receive treatment. Cost effectiveness including control sites is demonstrated in Table 215 and Table 2.

Non Energy Benefits

Electric bill savings for gas only customers is a non-energy benefit.

- In Oregon, electric savings for the 10% of gas sites expected to be out of Energy Trust electric territory are converted to a customer bill savings NEB at the Energy Trust blended electric rate of $0.120/kWh.
- In Washington, electric savings for all sites are converted to a customer bill savings NEB at the Clark County PUD electric rate of $0.082/kWh.

Follow-Up

Future evaluations may identify persistence of savings beyond one year which can be incorporated into the analysis.

Winter savings for heat pumps and summer savings for air conditioners (or heat pumps) have high uncertainty. If future evaluations find more certain results, those should be incorporated.

The program will monitor winter and summer opt-out rates and adjust at next update.

If the offering moves to site-based measures with known utilities, rather than zip-code based utility assumptions, gas measures must be re-calculated to account for gas only customers.

Supporting Documents

The cost effective screening for these measures is CEC 217.3.3 and is attached. It can be found along with supporting documents at: I:\Groups\Planning\Measure Development\Residential\Res HVAC\thermostat\web enabled thermostat\optimization\Resideo

217.3.3 CEC 2020_v_1_1 Resideo.x

Version History and Related Measures

Table 220 Version History

Date	Version	Reason for revision
6/12/2018	217.1	Approval for Whisker Labs pilot
10/23/2019	217.2	Transition to standard measure. Winter only.
5/1/2020	217.3	Expansion to include annual savings.

Table 221 Related Measures

Measures	MAD ID
Retail web-enabled thermostats	153
Direct Ship web-enabled thermostats	250
Co-funded direct install and direct ship web-enabled thermostats	222
Nest Seasonal Savings Winter	173

Approved & Reviewed by

Jackie Goss, PE
Sr. Planning Engineer

Disclaimer

This Energy Trust document and its attachments may be used by you or shared, at no cost, with other parties who are interested in our work and analyses. Should you or anyone with whom this document is shared, have suggestions for improvement of our work,

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Measure Approval Document for Direct Install Web Enabled Smart Thermostats with Co-Funding

Valid Dates
10/13/20 – 12/31/2022

End Use or Description
This document approves web-enabled thermostats where complimentary funding is provided by a utility, community-based organization or low-income agency. Web-enabled thermostats with occupancy detection provide energy savings through reduced run time of heating and/or cooling systems. Some models achieve additional savings when paired with heat pumps through changes in strip heat control.

This document does not demonstrate cost effectiveness for general use, but instead provides the bounds of incentives and participant payments that are cost effective when combined with eligible complimentary funding. Energy Trust expects each scenario to have unique costs, complimentary funding levels and installation parameters.

Program Applicability
Based on the referenced analysis and associated cost-effectiveness screening, the measures described below are approved for use in the following programs:

- Residential
- Existing Multifamily

Within these programs, the measure is applicable to the following cases:

- Retrofit

Purpose of Re-Evaluating Measure
- Added incremental savings from thermostat optimization services for Nest and ecobee devices to the savings.
- Added measure configurations for unspecified or unknown cooling
- PGE's installs in MF with gas heat and cooling at a remaining cost of $250 are now cost effective.

Cost Effectiveness
Cost effectiveness was demonstrated using the tool: OR-WA CE Calculator 2021 v1.1. The Oregon avoided costs year is 2021 for electric and gas. The Washington gas avoided cost year is 2020.

Energy Trust has received guidance from the Oregon PUC that complimentary funding may be subtracted from the incremental cost of a measure, and the remaining cost used in the cost effectiveness calculations. For this measure, we anticipate this will be most often understood as the customer payment plus Energy Trust incentive. For each HVAC system type, the remaining cost column in the cost effectiveness tables indicates the maximum remaining cost after complementary funding that is cost effective.

Table 222 Cost Effectiveness Calculator Oregon

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Max Remaining Cost ($)	Total NEBs (Annual $)	Max Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Ele	% Gas
1	SF DI Tstat gFAF w/CAC - Comp Funding	11	60	41.4	$414	$0	$414.07	1.0	1.0	21%	79%
2	SF DI Tstat gFAF no CAC- Comp Funding	11	22	41.4	$342	$0	$342.33	1.0	1.0	4%	96%
3	SF DI Tstat gFAF - Gas Only - Comp Funding	11	0	41.4	$372	$5.27	$327.12	1.0	1.0	0%	100%
4	SF DI Tstat eFAF w/CAC - Comp Funding	11	474	0.0	$403	$0	$402.51	1.0	1.0	100%	0%
5	SF DI Tstat eFAF no CAC- Comp Funding	11	435	0.0	$298	$0	$297.69	1.0	1.0	100%	0%
6	SF DI Tstat ASHP - Comp Funding	11	646	0.0	$442	$0	$441.76	1.0	1.0	100%	0%
7	MF DI Tstat gFAF w/CAC - Comp Funding	11	51	33.9	$341	$0	$340.51	1.0	1.0	21%	79%
8	MF DI Tstat gFAF no CAC- Comp Funding	11	19	33.9	$281	$0	$280.61	1.0	1.0	5%	95%
9	MF DI Tstat gFAF - Gas Only - Comp Funding	11	0	33.9	$297	$3.73	$267.85	1.0	1.0	0%	100%
10	MF DI Tstat eFAF w/CAC - Comp Funding	11	390	0.0	$332	$0	$331.63	1.0	1.0	100%	0%
11	MF DI Tstat eFAF no CAC- Comp Funding	11	358	0.0	$245	$0	$245.01	1.0	1.0	100%	0%
12	MF DI Tstat ASHP - Comp Funding	11	519	0.0	$441	$0	$440.90	1.0	1.0	100%	0%
13	SF DI Tstat gFAF unspecified CAC - Comp Funding	11	44	41.4	$391	$0	$390.55	1.0	1.0	16%	84%
14	MF DI Tstat gFAF unspecified CAC - Comp Funding	11	28	33.9	$292	$0	$291.84	1.0	1.0	8%	92%
15	SF DI Tstat eFAF unspecified CAC - Comp Funding	11	447	0.0	$380	$0	$380.25	1.0	1.0	100%	0%
16	MF DI Tstat eFAF unspecified CAC - Comp Funding	11	368	0.0	$313	$0	$312.67	1.0	1.0	100%	0%
17	SF DI Tstat unspecified electric heat unspecified CAC - Comp Funding	11	594	0.0	$505	$0	$505.24	1.0	1.0	100%	0%
18	MF DI Tstat unspecified electric heat unspecified CAC - Comp Funding	11	398	0.0	$338	$0	$338.31	1.0	1.0	100%	0%

Table 223 Cost Effectiveness Calculator Washington

	Measure	Measure Life (years)	Savings (therms)	Max Remaining Cost ($)	Total NEB (Annual $)	Max Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Ele	% Gas

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1	SF SWWA DI Tstat gFAF w/CAC - Comp Funding	11	41	$606	$4.93	$564.71	1.0	1.0	0%	100%
2	SF SWWA DI Tstat gFAF no CAC - Comp Funding	11	41	$580	$1.82	$564.71	1.0	1.0	0%	100%
3	MF SWWA DI Tstat gFAF w/CAC - Comp Funding	11	34	$497	$4.12	$462.39	1.0	1.0	0%	100%
4	MF SWWA DI Tstat gFAF no CAC- Comp Funding	11	34	$475	$1.52	$462.39	1.0	1.0	0%	100%
5	SF DI Tstat gFAF unspecified CAC - Comp Funding	11	41	$595	$3.60	$564.71	1.0	1.0	0%	100%
6	MF DI Tstat gFAF unspecified CAC - Comp Funding	11	34	$552	$2.30	$462.39	1.0	1.0	0%	100%

Requirements

- Thermostats must be on the Smart Thermostat qualified products list.
- Home must be heated with fuel provided by a participating Energy Trust utility.
- Where home HVAC configuration is not fully known, program may use the applicable unspecified measures.
- The following equations describe the limits cost effectiveness eligibility for any complimentary funding agreement as shown in Table 1 and **Error! Reference source not found.Error! Reference source not found.**. Any complimentary funding arrangements which do not conform to this equation are not approved through this MAD. Those agreements would require an OPUC exception specific to that funding model and measure. Internal Energy Trust Program staff must review each proposed application of these measures to ensure compliance with OPUC direction on measures utilizing other funding sources.

Max Remaining Cost ≥ Energy Trust Incentive + Customer Payment
Max Remaining Cost ≥ Total Cost – Co-funding

Baseline

This measure uses an Existing Condition Baseline.

The baseline for this measure is an existing programmable or manual thermostat. There is reasonable certainty that homes will not have an existing qualified thermostat under the assumption that a complimentary funding entity would not pay for the installation of a second qualified thermostat.

Baseline loads for heating and cooling

For single family homes, the average annual heating loads are derived from the 2011 RBSA.[131] The average heating loads for Oregon homes are 5,992 kWh and 583 therms for electric and gas heated homes, respectively. These values include both heating zone 1 and 2 and are used for electric furnace and gas furnace heated homes in this analysis. The heating load for heat pump homes are sourced from Energy Trust's follow up billing analysis from the 2013-2014 Nest thermostat pilot evaluation.[132]

Cooling loads are less well established, however the same Nest pilot evaluation found 200 kWh of cooling usage while the 2016 summer Seasonal Savings billing analysis found 787 kWh of Portland summer cooling load, which straddles cooling zones 1 and 2.[133] Due to the large difference between these values, this analysis uses the average of these two loads.

For multifamily dwelling units the average annual heating load for electrically heated units is derived from the RTF's Connected Thermostat measure analysis workbook v1.3.[134] To determine the annual heating load for multifamily gas heated units the ratio of the multifamily electric heating load to the single family electric heating load, a factor of 0.79, was applied to the single family average gas heating load of 583 therms resulting in an estimated multifamily gas heating load of 458 therms.

Savings and Measure Analysis

Where not otherwise specified, sources for this analysis match those used in the Retail Web-Enabled Thermostat MAD 153.

RBSA II data for single family, manufactured homes and multifamily is used to estimate prevalence of central AC equipment for gas and electric furnace homes, as well as the relative prevalence of electric furnaces and heat pumps. The RBSA II values employed in this analysis are shown in the table below.

Table 224 RBSA II Housing Type and HVAC Type Assumptions

Housing Type	% of Homes	gFAF Cooling Prevalence	eFAF Cooling Prevalence	eFAF/Heat Pump Split
Single Family	94%	57%	31%	26%
Multifamily	6%	30%	30%	80%

Energy savings in this analysis have been divided into two categories; thermostat "device" savings and "optimization" savings.

Device savings refer to the energy savings that are driven by features of the thermostat device, such as occupancy detection, scheduling, maintenance alerts, and an engaging user interface.

Optimization savings are defined here as incremental savings driven by proprietary manufacturer set-point optimization algorithms. These savings occur as a result of small changes to scheduled heating and/or cooling setpoints, which are designed to be sufficiently small as to not impact customer comfort.

Device Savings – Electric Heating Systems

Electric forced air furnace and air source heat pump baseline loads and savings percentages are from the RTF's connected thermostat workbook.[135] The analysis applies the Energy Trust evaluated gas furnace heating savings estimate of 6% to electric forced air furnace heating and cooling loads. Heat pumps save an estimated 12% of heating loads, also sourced from Energy Trust research.[136] RTF cooling saving estimates for heat pumps and forced air furnaces is 6%, based on the assumption that the driver of savings is reduced run times similar to heating savings for forced air furnaces. RTF savings estimates are shown in Table 225.

131 2011 RBSA: Single Family Characteristics and Energy Use. Ecotope, 2012. https://neea.org/resources/2011-rbsa-single-family-characteristics-and-energy-use
132 Evaluation of Nest Thermostat Heat Pump Control Pilot. Apex Analytics, 2014. https://www.energytrust.org/wp-content/uploads/2016/12/Nest_Pilot_Study_Evaluation_wSR.pdf
133 Nest Thermostat Seasonal Savings Pilot Evaluation. Apex Analytics, 2017. https://www.energytrust.org/wp-content/uploads/2017/12/Energy-Trust-of-Oregon-Nest-Seasonal-Savers-Pilot-Evaluation-FINAL-wSR.pdf
134 RTF Connected Thermostats v1.3. https://rtf.nwcouncil.org/measure/connected-thermostats
135 RTF Connected Tstats v1.3
136 Energy Trust Follow-up Billing Analysis for the Nest Thermostat Heat Pump Control Pilot, 2015 https://www.energytrust.org/wp-content/uploads/2016/12/nest_heat_pump_control_pilot_follow-up_billing_analysis.pdf

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Table 225 Savings Estimates by ElectricHeating and Cooling System Combinations

Housing Type	HVAC Configuration	Heating Savings	Cooling Savings	Total Annual Savings
		kWh	kWh	kWh
Single Family	Electric Furnace with AC	360	30	389
Single Family	Electric Furnace (no CAC)	360	0	360
Single Family	Heat Pump	n/a	n/a	594
Multifamily	Electric Furnace with AC	282	23	306
Multifamily	Electric Furnace (no CAC)	282	0	282
Multifamily	Heat Pump	n/a	n/a	467
Single Family	Electric Furnace unspecified CAC	360	9	369
Multifamily	Electric Furnace unspecified CAC	282	7	289
Single Family	Unspecified Electric Heat Unspecified CAC	533	2	536
Multifamily	Unspecified Electric Heat Unspecified CAC	319	6	325

Device Savings- Gas Heating Systems

The average heating loads are assumed to be 583 therms for a single-family home and 458 therms for a multifamily home, based on RBSA results for heating zones 1 and 2. Applying a 6% savings assumption results in average annual savings of 35 therms per single-family home and 27.5 therms per multifamily home.

Cooling loads for gas furnace homes are based on an average estimated cooling load from Energy Trust's heat pump pilot and runtime analysis in Energy Trust's Nest seasonal savings pilot. Annual cooling load estimates were 200 and 787 kWh for single family dwellings, given the large range this analysis uses the mid-point of 494 kWh/year for single and manufactured housing. Applying the ratio used to estimate multifamily gas loads, 0.79, multifamily cooling loads are estimated to be 388 kWh annually.

The average annual fan energy usage is derived from the Regional Technical Forum's (RTF) Residential Single-Family Existing HVAC and Weatherization analysis. Since gas furnace fan savings are achieved through runtime reduction, savings are also assumed to be six percent, equivalent to gas heating load savings. Fan savings are not included as a separate component in electric measures as runtime reduction savings are already captured in the overall heating load and usage reductions.

Thermostat Device savings for gas furnace homes are shown in the table below.

Table 226 Thermostat Device Gas Furnace Heating, Fan and Cooling Savings

Housing Type	HVAC Configuration	Heating Savings		Cooling Savings	Total Annual Savings	
		kWh	Therms	kWh	kWh	Therms
Single Family	Gas Furnace with CAC	17	35.0	30	46	35
Single Family	Gas Furnace (no CAC)	17	35.0	0	17	35
Multifamily	Gas Furnace with CAC	13	27.5	23	36	27.5
Multifamily	Gas Furnace (no CAC)	13	27.5	0	13	27.5
Single Family	Gas Furnace Unspecified CAC	17	35.0	17	34	35.0
Multifamily	Gas Furnace Unspecified CAC	13	27.5	7	20	27.5

Thermostat Optimization Savings.

Energy Trust partnered with Google Nest from 2017 to 2019 to deliver a proprietary thermostat optimization service to Nest devices located in Energy Trust territory on a "fee per participating device" basis. Energy Trust claimed energy savings for the devices that opted-in to participating in the service using stand-alone Thermostat Optimization measures that were separate and distinct from any thermostat device savings. Beginning in summer 2020, Nest's Seasonal Savings optimization service transitioned to a free service available to all qualified Nest customers. Customers must have a heating and/or cooling schedule established in order to participate in the service. Similarly, ecobee has also recently announced that launch of similar thermostat optimization service that will also be delivered free-of-charge to all ecobee thermostats. Since these services are now essentially embedded in the thermostat device itself, this update incorporates optimization savings into thermostat measures directly, rather than as a standalone thermostat optimization measure, as had been past practice.

Heating season optimization savings for Nest devices are based on the per opt-in unit savings results from Energy Trust's 2016/2017 Nest Seasonal Savings pilot evaluation137. Average energy savings by heating system type, are shown in Table 227.

Table 227 Pilot Results for Nest Winter Seasonal Savings

Heating System Type	Savings Source	Savings per Opt-in
Gas Furnace	Heating Energy	17.80 therms
	Fan Energy	15.34 kWh
Electric Furnace	Heating Energy	195.89 kWh
	Fan Energy	15.34 kWh
Heat Pump	Heating & Fan Energy	120.90 kWh

Energy Trust's 2016/2017 Nest Seasonal Savings pilot also evaluated summer cooling season savings and found an average of 4.1 kWh annual savings per opt-in participant. Between 2018 and 2020, Energy Trust did not participate in summer season optimization as a measure because the offering was not cost-effective.

Ecobee conducted a pilot study of their *eco+* optimization service in summer 2019 and found an average of 40 kWh summer cooling savings per device138. That savings assumption is used to calculate ecobee market transformation savings in this analysis. Ecobee has not yet published an equivalent winter heating season savings value because not all winter season efficiency features were deployed to devices during the pilot period. Ecobee is expected to publish a follow-up pilot report in the near future that details the

137 https://www.energytrust.org/wp-content/uploads/2017/12/Energy-Trust-of-Oregon-Nest-Seasonal-Savers-Pilot-Evaluation-FINAL-wSR.pdf
138 https://www.ecobee.com/en-us/ecoplusemv/

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magnitude of winter season optimization savings, which could potentially serve as an additional source of Market Transformation savings for 2020-2022, beyond the ecobee cooling savings calculated here.

Average thermostat optimization savings for both heating and cooling across ecobee and Nest devices are weighted using the 2019 prevalence of those thermostats in the DI thermostat offing. Nest devices represented 60% of total direct-install thermostat volume, and ecobee device represented 40% of total direct-install thermostat volume over the 2019 program year.

RBSA II heating/cooling system distributions for Oregon are also factored into calculations of average optimization cooling savings. 65% of gas furnace homes and 44% of electric furnace homes are assumed to have cooling equipment, according to RBSA II values. Homes without cooling equipment are assigned zero cooling savings in this analysis.

Thermostat Optimization Opt-in Rates

A 59.5% opt-in rate assumption is applied to Nest heating season optimization savings, which is the average opt-in rate observed for the service during the program years 2018-2019. A slightly lower opt-in rate is applied to Nest cooling optimization savings, 46.9%, which comes from the 2016/2017 Nest Seasonal Savings pilot. Opt-in rates for Nest devices are effectively a combined participation rate that reflect both the portion of qualified eligible devices for the service, as well as the percentage that choose to participate in the service. Ecobee cooling savings are treated with the same opt-in rate as Nest cooling savings, 46.9%, since that information was not reported in ecobee's pilot study report.

Table 228 Weighted Average Thermostat Optimization SavingsTable 228 below shows the weighted average thermostat savings by heating system type, including opt-in rate adjustments.

Table 228 Weighted Average Thermostat Optimization Savings

Housing Type	HVAC Configuration	Heating & Fan Savings		Cooling Savings	Total Annual Savings	
		kWh	Therms	kWh	kWh	Therms
Single Family	Gas Furnace with CAC	7	8.64	5	12	8.64
Single Family	Gas Furnace (no CAC)	7	8.64	0	7	8.64
Single Family	Electric Furnace with AC	76	0	9	84	0
Single Family	Electric Furnace (no CAC)	76	0	0	76	0
Single Family	Heat Pump	43	0	9	52	0
Multifamily	Gas Furnace with CAC	7	8.6	5	12	8.64
Multifamily	Gas Furnace (no CAC)	7	8.6	0	7	8.64
Multifamily	Electric Furnace with AC	76	0	9	84	0
Multifamily	Electric Furnace (no CAC)	76	0	0	76	0
Multifamily	Heat Pump	43	0	9	52	0
Single Family	Gas Furnace Unspecified CAC	7	8.64	3	10	8.64
Multifamily	Gas Furnace Unspecified CAC	7	8.64	1	9	8.64
Single Family	Electric Furnace Unspecified CAC	76	0	3	79	0
Multifamily	Electric Furnace Unspecified CAC	76	0	3	78	0
Single Family	Unspecified Electric Heat Unspecified CAC	52	0	7	59	0
Multifamily	Unspecified Electric Heat Unspecified CAC	69	0	4	73	0

Install rate

A 100% installation rate is assumed for direct-install thermostats. Thermostats will be installed by a contractor or other authorized installer. At this time, the only known thermostat co-funding entity who will be using the direct-ship option is PGE as part of their DR thermostat program (aka RTDIP). PGE will provide verification of installation and heating fuel and other HVAC specifics such as presence of central air conditioning, when possible. Energy Trust will only pay incentives and claim savings for installed thermostats.

Comparison to RTF or other programs

Energy Trust uses a longer measure life than the RTF and includes gas heated measures which are not included in the RTF workbooks. RTF analysis identifies specific heating zone measures whereas this Energy Trust blends all zones together for thermostat measures.

Energy Trust also offers residential smart thermostats without co-funding. Thermostats sold are retail locations are approved in MAD 153, and those direct shipped to customers are approved in MAD 250. The measures for retail are blended by heating systems due to uncertainties in heating system reporting, while this program design anticipates greater certainty in heating, and cooling system reporting of the home. The self-install measures have reduced savings due to a lower installation rate.

Measure Life

This measure uses an 11-year measure life, consistent with other Energy Trust smart thermostat measures.

Cost

Costs for each thermostat installation will vary based on the detail of complimentary funding agreements.

Energy Trust has received guidance from the Oregon PUC that complimentary funding may be subtracted from the incremental cost of a measure, and the remaining cost used in the cost effectiveness calculations. For this measure, we anticipate remaining cost will be most often understood as the customer payment plus Energy Trust incentive. For each HVAC system type, the maximum remaining cost column in the cost effectiveness tables indicates the maximum remaining cost after complementary funding that is cost effective.

This document specifies the maximum allowable "Remaining Cost" which can be calculated as either:

$$\text{Max Remaining Cost} \geq \text{Energy Trust Incentive} + \text{Customer Payment}$$

$$\text{Max Remaining Cost} \geq \text{Total Cost} - \text{Co-funding}$$

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Non Energy Benefits

In both Oregon and Washington, unclaimed electric savings are included as non-energy benefits valued at the retail rate of electricity for those territories ($0.120/kWh OR, $0.082/kWh SW WA).

Incentive Structure

The maximum incentives listed in Table 1 *and* ***Error! Reference source not found.*** *are for reference only and are not suggested incentives.* These values represent the maximum allowable Energy Trust incentives.

Incentives will be determined for each specific co-funding partnership as the level of complimentary funding will vary between offers. Incentives will be paid per thermostat installed.

Follow-Up

Updated evaluation results should be considered for the next measure update.

This MAD should be kept on a similar update schedule to MADs 153 and 250 and analysis should be aligned between the three as much as possible.

Supporting Documents

The cost effective screening for these measures is number 222.3.3. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Residential\Res HVAC\thermostat\web enabled thermostat\co funded

222.3.3 OR-WA CEC 2021 v 1.1. DI Tstat v

Version History and Related Measures

Table 229 Version History

Date	Version	Reason for revision
9/25/2018	222.1	Creation of direct install smart thermostats with copayments for PGE direct install demand reduction program in Oregon, and installations in in SW Washington with or without co-funding.
6/12/2019	222.2	Expanded eligibility of MAD. Corrected load profiles. Added gas only service territory measures.
10/13/20	222.3	Updated to include Thermostat Optimization savings for Nest and ecobee devices. Unspecified HVAC and unspecified cooling measure configurations have also been added. No longer need any exceptions

Table 230 Related Measures

Measures	MAD ID
Retail Web-Enabled Thermostats	153
Direct Ship Web-Enabled Thermostats	250
Automated Thermostat Optimization (inactive)	173
Residential Thermostat Optimization Pilot (inactive)	217
Strip heat lock out for heat pumps (inactive)	19
Contractor installed thermostats on heat pumps	148
Commercial DI thermostat pilot	235

Approved & Reviewed by

Jackie Goss, PE
Sr. Planning Engineer

Disclaimer

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Measure Approval Document for Direct Ship Web Enabled Smart Thermostats

Valid Dates
January 1, 2021 – December 31, 2022

End Use or Description
Web-enabled smart thermostats sold or provided directly to customers. Qualifying thermostats provide savings via reduced run time of heating/cooling systems due to occupancy sensing, setpoint optimization and heat pump strip heat control.

Program Applicability
Based on the referenced analysis and associated cost-effectiveness screening, the measures described below are approved for use in the following programs:

- Residential Program
- Existing Multifamily Program

Within these programs, applicability to the following program tracks are expected:

- Products provided free of charge to customers
- Products sold online directly to customers at discounted rate

Within these programs, the measure is applicable to the following cases:

- Retrofit

Purpose of Re-Evaluating Measure
- Additional, incremental savings from thermostat optimization services for Nest and ecobee devices (have been added to the savings and cost analysis

Cost Effectiveness
Cost effectiveness is demonstrated for the most costly approved thermostat in Table 1 and Table 2. Cost effectiveness was tested using the tool OR-W-CE Calculator 2021 v 1.1. The Oregon electric and gas avoided cost year is 2021. The Washington gas avoided cost year is 2020.

Table 231 Cost Effectiveness Calculator Oregon

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Ele	% Gas
1	DS Tstat - gFAF w/CAC	11	54	39.7	$249	$0.00	$249.00	1.6	1.6	20%	80%
2	DS Tstat - gFAF noCAC	11	22	39.7	$249	$0.00	$249.00	1.3	1.3	5%	95%
3	DS Tstat - gFAF - Gas Only	11	0	39.7	$249	$2.86	$249.00	1.3	1.4	0%	100%
4	DS Tstat - gFAF Unspecified Cooling	11	40	39.7	$249	$0.00	$249.00	1.5	1.5	15%	85%
5	DS Tstat - eFAF w/CAC	11	452	0.0	$249	$0.00	$249.00	1.5	1.5	100%	0%
6	DS Tstat - eFAF noCAC	11	421	0.0	$249	$0.00	$249.00	1.2	1.2	100%	0%
7	DS Tstat - eFAF Unspecified Cooling	11	431	0.0	$249	$0.00	$249.00	1.5	1.5	100%	0%
8	DS Tstat - ASHP	11	598	0.0	$249	$0.00	$249.00	2.0	2.0	100%	0%
9	DS Tstat - Unspecified Elec HVAC	11	550	0.0	$249	$0.00	$249.00	1.9	1.9	100%	0%

Table 232 Cost Effectiveness Calculator Washington

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Ele	% Gas
2	DS Tstat - Any - gFAF - Gas Only	11	39.7	$249	$1.80	$249.00	2.2	2.2	0%	100%

Requirements
- Thermostat must be on Smart Thermostat Qualified Products List.[139]
- Home must be heated with fuel provided by a participating Energy Trust utility.
- Orders will be limited to one thermostat per central HVAC system, up to two per residence.
    1. If possible, property managers should be able to order products for residences they manage.
- Incentive cannot exceed total product cost.
- Products provided through the direct ship offering with PGE co-funding should use the measures approved in MAD 222, rather than these.

Implementation may choose to offer HVAC specific measures or blended savings for 'unspecified' HVAC scenarios, but cannot use both together in the same offering.

- Measures 4 and 7 can be used if/when heating fuel is known and cooling details are unknown
- Measure 3 should be used for all gas heated homes in gas only territory, regardless of cooling presence/configuration
- Measure 9 should be used if/when heating is known to be electric, but the system type is unknown, regardless of heating presence/configuration
- Remaining HVAC specific measure configurations should be used whenever HVAC details are known

Baseline
This measure uses an Existing Condition Baseline.

The baseline assumes a standard programmable or manual thermostat, that is not enrolled in a thermostat optimization service, in a home with average HVAC loads.

139 Energy Trust Thermostat QPL

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Baseline loads for heating and cooling
For single family homes, average annual heating loads are derived from the 2011 RBSA.[140] The average heating loads for Oregon homes are 5,992 kWh and 583 therms for electric and gas heated homes, respectively. These values include both heating zone 1 and 2 and are used for electric furnace and gas furnace heated homes in this analysis. The heating load for heat pump homes are sourced from Energy Trust's follow up billing analysis from the 2013-2014 Nest thermostat pilot evaluation.[141]

Cooling loads are less well established, however the same Nest pilot evaluation found 200 kWh of cooling usage while the 2016 summer Seasonal Savings billing analysis found 787 kWh of Portland summer cooling load, which straddles cooling zones 1 and 2.[142] Due to the large difference between these values, this analysis uses the average of these two loads.

For multifamily dwelling units the average annual heating load for electrically heated units is derived from the RTF's Connected Thermostat measure analysis workbook v1.3.[143] To determine the annual heating load for multifamily gas heated units the ratio of the multifamily electric heating load to the single family electric heating load, a factor of 0.79, was applied to the single family average gas heating load of 583 therms resulting in an estimated multifamily gas heating load of 458 therms.

Housing Type and HVAC Configuration Blending
Dwelling type data comes from Energy Trust Project Tracker from January 2018 to March 2019 on qualified, incented midstream smart thermostats. Multifamily applications are lower than the general population because they are more likely to have incompatible zonal heating systems. Distribution of HVAC systems is based on RBSA II. Weighting factors are shown in Table 200.

Table 233 Distribution of Energy Trust mid/downstream incented smart thermostats housing types and RBSA HVAC system data

		Cooling Prevalence in Central Furnace Homes		Central Electric Heating System Distribution	
Housing Type	**Dwelling Type Distribution**	**Gas Furnace w/ CAC**	**Electric Furnace w/ CAC**	**Electric Furnace**	**ASHP**
Single Family/Manufactured Homes	94%	57%	31%	26%	74%
Multifamily	6%	30%	30%	80%	20%

Savings and Measure Analysis
Energy savings in this analysis have been divided into two categories: thermostat "device" savings and "optimization" savings.

Device savings refers to the energy savings that are driven by features of the thermostat device, such as occupancy detection, scheduling, maintenance alerts, and an engaging user interface.

Optimization savings are defined here as incremental savings driven by proprietary manufacturer set-point optimization algorithms. These savings occur as a result of small changes to scheduled heating and/or cooling setpoints, which are designed to be sufficiently small as to not impact customer comfort.

Device Savings – Electric Heating & Cooling
Electric forced air furnace and air source heat pump baseline loads are based on values used in the RTF connected thermostat workbook.[144] This analysis applies the Energy Trust evaluated gas furnace heating savings estimate of 6% to electric forced air furnace heating and cooling loads. Additionally, the RTF smart thermostat analysis attributes 6% cooling load saving for heat pumps and forced air furnaces, based on the assumption that the driver of savings is reduced run times similar to heating savings for forced air furnaces. This analysis uses 12% heating load savings for heat pumps heating savings.[145]

Device Savings - Gas Heating & Cooling
Gas savings. The average heating loads are assumed to be 583 therms for a single-family home and 458 therms for a multifamily home, based on RBSA results for heating zones 1 and 2. Applying a 6% savings assumption results in average annual savings of 35 therms per single-family home and 27.5 therms per multifamily home.

Cooling electric savings. Cooling loads for gas furnace homes are based on an average estimated cooling load from Energy Trust's heat pump pilot and runtime analysis in Energy Trust's Nest seasonal savings pilot. Where cooling equipment is present, savings as a percent of load are assumed to be the same as forced air furnace heating load savings of six percent. Annual cooling load estimates were 200 and 787 kWh for single family dwellings, given the large range this analysis uses the mid-point of 494 kWh/year for single family homes. Applying the ratio used to estimate multifamily gas loads, 0.79, multifamily cooling loads are estimated to be 388 kWh annually.

Fan energy electric savings. The average annual fan energy usage is derived from the Regional Technical Forum's (RTF) Residential Single-Family Existing HVAC and Weatherization analysis. Since gas furnace fan savings are achieved through runtime reduction, savings are also assumed to be six percent, equivalent to gas heating load savings. Fan savings are not included as a separate component in electric measures as runtime reduction savings are already captured in the overall heating load and usage reductions.

Where not otherwise specified, sources for device savings are derived from the 2013-2014 Nest thermostat pilot evaluation; and is summarized in Table 234.

Table 234 Thermostat device savings by HVAC configuration, non-optimization, without installation rates

140 2011 RBSA: Single Family Characteristics and Energy Use. Ecotope, 2012. https://neea.org/resources/2011-rbsa-single-family-characteristics-and-energy-use
141 *Evaluation of Nest Thermostat Heat Pump Control Pilot*. Apex Analytics, 2014. https://www.energytrust.org/wp-content/uploads/2016/12/Nest_Pilot_Study_Evaluation_wSR.pdf
142 *Nest Thermostat Seasonal Savings Pilot Evaluation*. Apex Analytics, 2017. https://www.energytrust.org/wp-content/uploads/2017/12/Energy-Trust-of-Oregon-Nest-Seasonal-Savers-Pilot-Evaluation-FINAL-wSR.pdf
143 *RTF Connected Thermostats v1.3.* https://rtf.nwcouncil.org/measure/connected-thermostats
144 RTF Connected Tstats v1.3
145 Energy Trust Follow-up Billing Analysis for the Nest Thermostat Heat Pump Control Pilot, 2015

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Housing Type	HVAC Configuration	Device Heating & Fan Savings			Device Cooling Savings	Total Annual Device Savings	
		Heating kWh	Heating Fan kWh	Therms	kWh	kWh	Therms
Single Family	Gas Furnace with CAC		16.7	35.0	30	46	35
Single Family	Gas Furnace (no CAC)		16.7	35.0	0	17	35
Single Family	Gas Furnace (no CAC) Gas Only		16.7	35.0	0	0	35
Single Family	Gas Furnace unspecified CAC		16.7	35.0	17	34	35
Single Family	Electric Furnace with CAC	360			30	389	0
Single Family	Electric Furnace (no CAC)	360			0	360	0
Single Family	Electric Furnace Unspecified CAC	360			9	369	0
Single Family	Heat Pump	594		594		0	
Single Family	Unspecified Electric HVAC	536		536		0	
Multifamily	Gas Furnace with CAC		13.2	27.5	23	36	27
Multifamily	Gas Furnace (no CAC)		13.2	27.5	0	13	27
Multifamily	Gas Furnace (no CAC) Gas Only		13.2	27.5	0	0	27
Multifamily	Gas Furnace unspecified CAC		13.2	27.5	7	20	27
Multifamily	Electric Furnace with CAC	282			23	306	0
Multifamily	Electric Furnace (no CAC)	282			0	282	0
Multifamily	Electric Furnace Unspecified CAC	282			7	289	0
Multifamily	Heat Pump	467				467	0
Multifamily	Unspecified Electric HVAC	325				325	0

**Savings do not include installation rate discount or weightings for single housing type. Heat pump savings are not disaggregated which results in a single savings value for Heat Pumps and Unspecified Electric HVAC.*

Thermostat Optimization Savings

Energy Trust partnered with Google Nest from 2017 to 2019 to deliver a proprietary thermostat optimization service to Nest devices in Energy Trust territory on a “fee per participating device” basis. Energy Trust claimed energy savings for the devices that opted-in to participating in the service using stand-alone Thermostat Optimization measures that were separate and distinct from any thermostat device savings. Beginning in summer 2020, Nest’s optimization service transitioned to a free service available to all qualified Nest customers. Customers must have a heating and/or cooling schedule established in order to participate in the service. Similarly, ecobee has also recently announced that launch of similar thermostat optimization service that will also be delivered free-of-charge to all ecobee thermostats. Since these services are now essentially embedded in the thermostat device itself, this measure update incorporates optimization savings into thermostat measures directly, rather than as a standalone thermostat optimization measure as had been past practice. This analysis assumes the newer Google Nest product has the same optimization capabilities as other Nest devices.

Heating season optimization savings for Nest devices are based on the per opt-in unit savings described Energy Trust’s 2016/2017 Nest Seasonal Savings pilot evaluation[146]. Average optimization savings by heating system type, are shown in Table 235.

Table 235 Pilot results for Nest winter seasonal savings, original data before opt-in and product weightings

Heating System Type	Savings Source	Savings per Opt-in
Gas Furnace	Heating Energy	17.80 therms
	Fan Energy	15.34 kWh
Electric Furnace	Heating Energy	195.89 kWh
	Fan Energy	15.34 kWh
Heat Pump	Heating & Fan Energy	120.90 kWh

Energy Trust’s 2016/2017 Nest Seasonal Savings pilot also evaluated summer cooling season savings and found an average of 4.1 kWh annual savings per opt-in participant. Previously, Energy Trust did not participate in summer season optimization because the offering was not cost-effective.

Ecobee conducted a pilot study of their *eco+* optimization service in summer 2019 and found an average of 40 kWh summer cooling savings per device[147]. That savings assumption is used to calculate ecobee market transformation savings in this analysis. Ecobee has not yet published an equivalent winter heating season savings value because not all winter season efficiency features were deployed to devices during the pilot period. Ecobee is expected to publish a follow-up pilot report in the near future that details the magnitude of winter season optimization savings, which could potentially serve as an additional source of Market Transformation savings for 2020-2022, beyond the ecobee cooling savings calculated here.

Average thermostat optimization savings across ecobee and Nest devices are calculated using the 2018-2019 prevalence of those thermostat brands as weights. Nest devices represented 82% of total retail thermostat volume, and ecobee device represented 18% of total retail thermostat volume over the program years 2018-2019.

RBSA II heating/cooling system distributions for Oregon are also factored into calculations of average optimization cooling savings. Fifty-seven percent of gas furnace homes and 31% of electric furnace homes have central air conditioning according to RBSA II values, as shown in . Homes without cooling equipment are assigned zero cooling savings in this analysis.

Optimization Opt-In Rate

A 59.5% opt-in rate assumption is applied to Nest heating optimization savings, which is the average opt-in rate observed for that service during the years 2018-2019. A slightly lower opt-in rate is applied to Nest cooling optimization savings, 46.9%, which comes from the 2016 Nest Seasonal Savings pilot. Opt-in rates for Nest devices are effectively a combined participation rate that reflect both the portion of qualified/ eligible devices for the service, as well as the percentage that choose to participate in the service.

The ecobee cooling savings are treated with the same opt-in rate as Nest cooling savings, as this data was not reported in the ecobee pilot study report. Heating savings are not currently available from ecobee.

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146 https://www.energytrust.org/wp-content/uploads/2017/12/Energy-Trust-of-Oregon-Nest-Seasonal-Savers-Pilot-Evaluation-FINAL-wSR.pdf
147 https://www.ecobee.com/en-us/ecoplusemv/

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Weighted average thermostat optimization savings by heating system type, including opt-in rate deductions and device weightings are shown in Table 236.

Table 236 Weighted average thermostat optimization savings by HVAC configuration, including opt-in deduction and device weightings

Housing Type	HVAC Configuration	Optimization Heating & Fan Savings		Optimization Cooling Savings	Total Annual Optimization Savings	
		kWh	Therms	kWh	kWh	Therms
Single Family	Gas Furnace with CAC	7	8.6	5	12	8.6
Single Family	Gas Furnace (no CAC)	7	8.6	0	7	8.6
Single Family	Gas Furnace (no CAC) Gas Only	0	8.6	0	0	8.6
Single Family	Gas Furnace unspecified CAC	7	8.6	3	10	8.6
Single Family	Electric Furnace with CAC	102	0	5	107	0
Single Family	Electric Furnace (no CAC)	102	0	0	102	0
Single Family	Electric Furnace unspecified CAC	102	0	2	104	0
Single Family	Heat Pump	59	0	5	64	0
Single Family	Unspecified Electric HVAC	70	0	4	74	0
Multifamily	Gas Furnace with CAC	7	8.6	5	12	8.6
Multifamily	Gas Furnace (no CAC)	7	8.6	0	7	8.6
Multifamily	Gas Furnace (no CAC) Gas Only	0	8.6	0	0	8.6
Multifamily	Gas Furnace unspecified CAC	7	8.6	1	9	8.6
Multifamily	Electric Furnace with CAC	102	0	5	107	0
Multifamily	Electric Furnace (no CAC)	102	0	0	102	0
Multifamily	Electric Furnace unspecified CAC	102	0	1	104	0
Multifamily	Heat Pump	59	0	5	64	0
Multifamily	Unspecified Electric HVAC	94	0	2	96	0

Device Install Rate

The 2014 gas thermostat pilot, which depended on self-install, yielded 415 total purchased thermostats, of which 32 were returned. This is a 92% install rate. This factor is applied to heating, cooling, fan, and optimization energy savings to account for products that are purchased and either not installed or later uninstalled. This analysis uses the same 92% installation rate for direct ship measures.

Comparison to RTF or other programs

Energy Trust uses a longer measure life than the RTF and includes gas heated measures which are not included in the RTF workbooks. RTF analysis identifies specific heating zone measures whereas this MAD blends RTF savings estimates by zone together for these measures.

Energy Trust offers self-installed thermostats sold at retail, approved through MAD 153. Those measures a limited to unspecified HVAC configurations since Energy Trust has less interaction with these customers and less opportunity to verify their configuration details. Energy Trust also offers smart thermostats through PGE's demand response direct install pilot and may in the future, participate in further direct install offerings with other partners. Direct install thermostats with co-funding are offered and approved via MAD 222. Contractor installed smart thermostats in homes with heat pumps are approved through MADs 148 and 19.

Measure Life

This measure uses an 11-year measure life, consistent with other Energy Trust smart thermostat measures.

Cost

For this offering, Energy Trust expects to provide the following products, at up to the cost shown in Table 237 based on online manufacturer pricing September 2020. Shipping and other transaction costs are included. Additional smart thermostat products may be added up to cost of $249. Online retail prices as of September 2020.

Table 237 Thermostat selection and cost

Model Name	Cost
Ecobee 5	$ 249
Nest 3rd Gen	$ 249
Google Nest	$ 129

Non-Energy Benefits

In both Oregon and Washington, unclaimed electric savings are included as non-energy benefits valued at the retail rate of electricity for those territories ($0.120/kWh OR, $0.082/kWh SW WA). NEB are calculated for electric fan savings in gas only territory.

Incentive Structure

The maximum incentives listed in Table 1 and Table 2 are for reference only and are not suggested incentives. Incentives will be structured per thermostat. Incentives will be applied directly to purchases.

Follow-Up

Distribution of incented thermostats between single family, multifamily and manufactured home should be refreshed in subsequent updates to maintain blended savings accuracy, based on RBSA HVAC data. Install rates may change and should be monitored and updated as possible.

To the extent possible, this MAD should be updated on the same schedule as MADs 153 and 222 and assumptions aligned wherever possible. The next update should include any relevant evaluation findings.

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Supporting Documents

The cost-effective screening for these measures is CEC number 250.2.2. It is attached and can be found along with supporting documentation at: I:\Groups\ Planning\Measure Development\Residential\Res HVAC\thermostat\web enabled thermostat\Self installed

250.2.2
OR-WA-CEC-2021 v1

Version History and Related Measures

Table 238 Version History

Date	Version	Reason for revision
4/20/2020	250.1	New offer for direct ship
10/13/2020	250.2	Updated to include Thermostat Optimization savings for Nest and ecobee devices. Unspecified HVAC and unspecified cooling measure configurations have also been added.

Table 239 Related Measures

Measures	MAD ID
Retail smart thermostats	153
DI Smart Thermostats with Funding Partners	222
DI Commercial Smart Thermostats Pilot	235
Automated Thermostat Optimization (inactive)	173
Residential Thermostat Optimization Pilot (inactive)	217
Contractor Installer Thermostats for New Heat Pumps (inactive)	19
Contractor Installer Thermostats for Existing Heat Pumps	148

Approved & Reviewed by

Jackie Goss, PE
Sr. Planning Engineer

Disclaimer

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Measure Approval Document for Residential Direct Install Ceiling Insulation with Co-Funding

Valid Dates
July 1st, 2020 to December 31st, 2022

End Use or Description
Direct installed or self-installed insulation for ceilings and/or attics to reduce space conditioning energy consumption.

This measure is expected to be delivered primarily through Community Based Organizations (CBOs), though other delivery partnerships are also approved. Complimentary Funding may come from outside of the utility system (e.g., community development block grants, Community Energy Project), or project incentives may be entirely funded by Energy Trust. The measure may also be delivered as part of co-funding collaborations with low-income weatherization agencies.

The measure may be delivered as a free service with no out-of-pocket costs to the customer, or the customer may be required to pay a small portion of project costs.

Program Applicability
Based on the referenced analysis and associated cost-effectiveness screening, the measures described below are approved for use in the following programs in Oregon and Washington:

- Home Retrofit
- Existing Manufactured Homes
- Existing Multifamily
    - Small Multifamily (2-4 and side-by-side units)

Within these programs, the measure is applicable to the following cases:

- Retrofit

Cost Effectiveness
Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2021-v1.1. In Oregon the electric avoided cost year is 2021 and the gas avoided cost year is 2021. In Washington the gas avoided cost year is 2020.

Energy Trust has received guidance from the Oregon Public Utility Commission that Complimentary Funding may be subtracted from the incremental cost of a measure, and the Remaining Cost used in cost effectiveness calculations. The *Max Remaining Cost* column in Table 1 and Table 2 describes the maximum remaining cost that is cost effective for each heating system type.

Total Cost = Customer Payment + Complimentary Funding + Energy Trust Incentive

Remaining Cost = Total Cost - Complimentary Funding = Customer Payment + Energy Trust Incentive

Table 240 Cost Effectiveness Calculator Oregon Insulation, per square foot

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Max Remaining Cost ($)	Total NEB (Annual $)	Max Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Electric	% Gas
1	R0-R11 Ceiling Insulation- Gas Heat	45	0.15	0.09	$2.41	$0	$2.41	1.0	1.0	14%	86%
2	R0-R11 Ceiling Insulation- Gas Heat GOT	45	0	0.09	$2.41	$0.02	$2.08	1.0	1.0	0%	100%
3	R0-R11 Ceiling Insulation- Electric Heat	45	1.49	0	$3.38	$0	$3.36	1.0	1.0	100%	0%
4	R12-R18 Ceiling Insulation- Gas Heat	45	0.10	0.06	$1.67	$0	$1.67	1.0	1.0	14%	86%
5	R12-R18 Ceiling Insulation- Gas Heat GOT	45	0	0.06	$1.67	$0.01	$1.44	1.0	1.0	0%	100%
6	R12-R18 Ceiling Insulation- Electric Heat	45	1.03	0	$2.33	$0	$2.33	1.0	1.0	100%	0%

Table 241 Cost Effectiveness Calculator Washington Insulation, per square foot

#	Measure	Measure Life (years)	Savings (therms)	Max Remaining Cost ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Electric	% Gas
1	R0-R11 Ceiling Insulation- Gas Heat GOT	45	0.09	$3.65	$0.01	$3.44	1.0	1.0	0%	100%
2	R2-R18 Ceiling Insulation- Gas Heat GOT	45	0.06	$2.55	$0.01	$2.38	1.0	1.0	0%	100%

Requirements
- Existing condition must be R-19 or less
- Must insulate to R-38 or greater, or fill cavity
- Program must verify that each project or agreement with co-funder is within the maximum remaining cost limits.

Baseline
This measure uses an Existing Condition Baseline.

Savings are calculated for two existing condition ranges of existing insulation:

- R-0 to R-11
- R-12 to R-19

Savings
This measure development is based on evaluation results from Recurve's 2019 Residential Ceiling Insulation Impact Analysis[148], which provides average project energy savings for ceiling insulation projects in single family homes with a starting condition of R-11 or less. The energy savings measured in Recurve's evaluation reflect the average savings across both heating zone 1, 2 and 3, weighted naturally by the relative participation in each heating zone. As such, the measures shown in Table 1 and Table 2 are applicable to all heating zones. The evaluation did not distinguish savings by HVAC system type beyond heating fuel. Therefore, savings reflect the

148 https://www.energytrust.org/wp-content/uploads/2020/02/Recurve-Ceiling-Insulation-Impact-Analysis-Reports-2013-2017.pdf

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participation weighted prevalence of various heating and cooling technologies. The final Recurve evaluation results are summarized in Table 242.

Table 242 Recurve Ceiling Insulation Impact Evaluation Results (starting condtion R0 to R11)

Home Heating Fuel	Savings Type	N	Average Savings per Project	Units
Gas	Gas Heating	477	105	Therms
	Furnace Fan & Cooling Energy	238	170	kWh
Electric	Electric Heating & Cooling	107	1,730	kWh

Energy Savings for the R-12 to R-19 existing condition scenario are calculated by translating the R-0 to R-11 Recurve Impact Analysis results into units of 'energy savings per delta R-value', for each savings type. In gas heated homes, this was 0.0028 therms from gas heating and 0.0045 kWh from furnace fans and cooling per delta R. In electrically heating homes this was 0.0459 kWh per delta R. Those values are then used to calculate savings per project for R-12 to R-19 starting conditions where the average increase in R-value is 23. Extrapolated savings are shown in Table 243.

Table 243 Starting Condition R-12 to R-19 Energy Savings- Extrapolated Recurve Results

Home Heating Fuel	Savings Type	Average Savings per Project	Units
Gas	Gas Heating	73	Therms
	Furnace Fan & Cooling Energy	118	kWh
Electric	Electric Heating & Cooling	1,198	kWh

To calculate energy savings per square foot of insulation, project level savings results are divided by the average project insulation area. The average areas of ceiling insulation projects in the evaluation period was 1,161 sf.

Table 244 Final Ceiling Insulation Savings

Starting Condition	Home Heating Fuel	Savings Type	Savings per Square Foot	Units
R-0 to R-11	Gas	Gas Heating	0.09	Therms
		Furnace Fan & Cooling Energy	0.15	kWh
	Electric	Electric Heating & Cooling	1.49	kWh
R-12 to R-19	Gas	Gas Heating	0.06	Therms
		Furnace Fan & Cooling Energy	0.10	kWh
	Electric	Electric Heating & Cooling	1.03	kWh

Comparison to RTF or other programs

Energy Trust maintains a separate Single Family and Small Multifamily Insulation offering approved through MAD 58, which also includes ceiling/attic insulation for R0-R11 starting condition. The key differences this offering and the standard offer are summarized in Table 245.

Table 245 Comparison of direct install and standard insulation measures

	Direct Install Ceiling Insulation	Standard Insulation
MAD ID	252	58
Measures Included	Ceiling/Attic Insulation	Ceiling/Attic, Floor, Wall and Knee Wall Insulation
OPUC Cost-Effectiveness Exception and incentive caps	No	Yes
Addresses Co-funding	Yes	No
Delivery Pathways	Self Install, Professional Install, Direct Install	Self Install, Professional Install
Source of Savings values	2013-2017 Recurve Impact Study	2009-2014 Energy Trust Billing Analysis

The RTF also maintains ceiling insulation measures for both single family and manufactured homes which describe savings by heating/cooling zone, electric HVAC system and beginning/ending R-values[149]. The Recurve-based savings values in in this analysis are similar to the RTF's savings values for ceiling insulation for both the R-0 to R-11 and the R-12 to R-19 starting condition scenarios. The RTF's analysis also assumes a 45 year measure life.

Measure Life

This measure uses a 45 year measure life, consistent with Energy Trust's other residential insulation and weatherization measures.

Load Profile

Gas savings have been assigned to the load profile *Residential Gas Heat.*

Electric savings in gas heated homes derived from furnace fan and cooling savings have been assigned to the electric load profile *Res Air Source HP,* which is used in situations when cooling savings represent between 2-29% of total annual savings. The same load profile has also been assigned to value the energy savings in electrically heated homes.

Cost

Costs for Direct Install Ceiling Insulation projects will vary based on the details of complimentary funding agreements with individual CBOs. Energy Trust will verify that each project or funding agreement is within the maximum remaining costs. Depending on the details of the funding agreements, remaining cost may be calculated as either:

- The total cost of a project minus complementary funding, or
- The customer's portion of the cost plus Energy Trust's incentive

These requirements are for complimentary funds that are not derived from the public purpose charge (PPC), or from utility ratepayers. Ratepayer funding for the purpose of the cost effectiveness testing is not treated as "complimentary funding".

Costs incurred during a direct install ceiling insulation project, but that are unrelated to energy efficiency, may be excluded from the total cost for purposes of calculating remaining cost. These exclusions must be approved by Energy Trust Program staff. In these instances, the incidental costs must be made up via additional qualifying complimentary funds or through participant payments.

149 https://rtf.nwcouncil.org/measure/single-family

Similar to other retrofit measures, the actual total cost for projects will be recorded in Project Tracker (PT) for use in program level cost-effectiveness testing at year end and other uses.

Non Energy Benefits

In both Oregon and Washington, unclaimed electric savings are included as non-energy benefits valued at the retail residential rate of electricity for those territories, $0.120/kWh in Oregon and $0.082/kWh in SW Washington.

Incentive Structure

The maximum incentives listed in Table 1 and Table 2 are for reference only and are not suggested incentives. In projects with complementary funds sourced from the PPC or other ratepayer sources the total of complementary funding and energy trust incentives must not exceed the maximum incentives.

Incentives may be structured on a per square foot basis or a per project basis but must not exceed the per square foot maximums listed in Table 1 and Table 2. Incentives may be paid directly to contractors, co-funding partners, or customers.

Follow-Up

Aligning methods and sources between this MAD and MAD #58 should be considered. The expiration date on this document is set to align with MAD 58 to encourage concurrent updates.

If Energy Trust is successful in quantifying health related NEBs for weatherization projects they should be considered in the next update

The savings used in this analysis reflect the distribution HVAC system types and efficiencies for the standard offing in the period of 2013-2017, however this is likely to change over time as households replace heating equipment, or if the direct install offering reaches customers with different home characteristics. Cooling savings captured in the 2013-2017 Recurve evaluation reflect the prevalence of cooling for that period. As cooling becomes more prevalent, cooling savings can be expected to increase.

Supporting Documents

The cost effective screening for these measures is number CEC 252.1.1. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Residential\Res Weatherization\insulation\existing homes and small mf

252_1_1 CEC OR WA
2021v1_1 Res DI Insu

Version History and Related Measures

Table 246 Version History

Date	MAD ID	Revision Summary
7/3/2020	252.1	Introduce Direct Install Insulation

Table 247 Related Measures

Measures	MAD ID
Single Family and Small Multifamily Insulation	58

Approved & Reviewed by

Jackie Goss, PE
Sr. Planning Engineer

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Measure Approval Document for New Homes Code Credits in Washington

Valid Dates
October 1, 2021 to December 31, 2024 or until implementation of a substantial Washington code update

Description
This measure leverages the 2018 Washington State Energy Code (WSEC) structure which assigns for credits energy efficiency features and requires new homes to achieve a minimum number of credits. To participate, in addition to complying with code, homes must achieve a minimum of 0.5 additional gas focused credit in the WSEC 2018 table 406.3. Fireplaces and smart thermostats are not included in the code credit structure and are included as additional measures.

Program Applicability
Based on the referenced analysis and associated cost-effectiveness screening, the measures described below are approved for use in the following program in Washington only:
- New Homes

Cost Effectiveness
Cost effectiveness is demonstrated for Washington in Table 1. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2021-v1.1. In Washington the gas avoided cost year is 2020.

Efficinct gas fireplaces have negative incremental cost. In Table 2, an incremental cost of $1 is used as a placeholder.

Table 248 Cost Effectiveness Calculator Washington

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	0.5 Credits above code	44	34.28	$1,104	$0.00	$1,103.50	1.2	1.2	0%	100%
2	Smart thermostat	11	14.10	$125	$0.78	$125.00	1.5	1.6	0%	100%
3	Fireplace >70 FE	15	18.30	$1	$0.00	$251.81	1.0	251.8	0%	100%

Requirements
- Homes must be built in Washington and have primary heat provided by Northwest Natural Gas service.
- Homes participating in this offering cannot participate in the EPS New Homes offering in Washington.
- Homes must achieve a minimum of 0.5 credits associated with gas consumption above the code minimum credits to participate, including use of the smart thermostat or fireplace measures.
- Above code credits must be associated to gas consumption to apply.
- Homes must be heated by a 95% AFUE or higher furnace.
- Homes with gas water heating must have a gas tankless with a 0.91 UEF or higher.
- Smart thermostats must be on Energy Trust's list of approved smart thermostat.
- Gas fireplaces must have fireplace efficiency greater than 70 FE.

Baseline
This measure uses a code baseline.

The baseline is a gas heated home that complies with WSEC 2018.

To comply with the code, homes must achieve minimum code credits from table 406.3 required for the size of the home as described in table 2. In addition to code, the program requires the selection of option 3.1 (95% AFUE furnace). If the home's water heating is gas, the program requires option 5.3 (0.91 UEF tankless water heater). These credits count toward the home's required credits and therefore effectively the baseline and does not qualify for incentives.

Table 249 2018 WSEC Credit Requirements

Small	<1,500	3
Medium	1,500 - 4,999	6
Large	>5,000	7

The credit value of each option varies between 0.5 – 2.5 credits. The available credits are separated by the following seven categories, each with one or more options:
- Efficient Building Envelope; 7 options
- Air Leakage Control and Efficient Ventilation; 4 options
- High Efficiency HVAC Equipment; 6 options
- High Efficiency HVAC Distribution System; 2 options
- Efficient Water Heating; 6 options including 1 stackable option
- Renewable Electric Energy; 1 option
- Appliance Package; 1 option

Figure 8 excerpt from Table 406.3 showing first 4 options for category 1. Efficient Building Envelope

TABLE 406.3
ENERGY CREDITS

OPTION	DESCRIPTION	CREDIT(S)	
		All Other	Group R-2
1. EFFICIENT BUILDING ENVELOPE OPTIONS Only one option from Items 1.1 through 1.7 may be selected in this category. Compliance with the conductive UA targets is demonstrated using Section R402.1.4, Total UA alternative, where [1-(Proposed UA/Target UA)] > the required %UA reduction			
1.1	Prescriptive compliance is based on Table R402.1.1 with the following modifications: Vertical fenestration U = 0.24.	0.5	0.5
1.2	Prescriptive compliance is based on Table R402.1.1 with the following modifications: Vertical fenestration U = 0.20.	1.0	1.0
1.3	Prescriptive compliance is based on Table R402.1.1 with the following modifications: Vertical fenestration U = 0.28 Floor R-38 Slab on grade R-10 perimeter and under entire slab Below grade slab R-10 perimeter and under entire slab **or** Compliance based on Section R402.1.4: Reduce the Total conductive UA by 5%.	0.5	N/A
1.4	Prescriptive compliance is based on Table R402.1.1 with the following modifications: Vertical fenestration U = 0.25 Wall R-21 plus R-4 ci Floor R-38 Basement wall R-21 int plus R-5 ci Slab on grade R-10 perimeter and under entire slab Below grade slab R-10 perimeter and under entire slab **or** Compliance based on Section R402.1.4: Reduce the Total conductive UA by 15%.	1.0	1.0

Measure Analysis

This measure leverages the analysis performed by Ecotope in SEEM as part of the code proposal submitted through the Washington Technical Assistance Groupiv (WA-TAG) to the State Building Codes Council (SBCC).v The proposal includes measure-level savings and costs.

Credit calculation methodology

To be eligible for participation, the home must exceed the code-required credits by at least 0.5 credits associated with gas savings. Since all participating homes are gas heated, envelope credits and efficient HVAC distribution credits count toward qualifying gas credits. Additionally, if the home has gas water heating, drain water heat recovery is an eligible gas credit. Efficient water heating and efficient furnace are not eligible for above code credits because they are assumed to be in baseline.

The total number of credits that are eligible for incentive is the lesser of the following:

- Total number of credits above the code requirement
- Total number of eligible gas credits

Table 250 shows an example of the code credit calculator for a small home. Although the home exceeds the code minimum by 4 credits, only the two bolded measures are eligible gas credits.

Table 250 Example code credit calculator for a small home

Credit Calculation Methodology		
Space Heating Fuel	Gas (Required)	
Water Heating Fuel	Electric	
Home Size	Small	
Additional Savings	None	
Savings Category	**Achieved Credits**	**Credit Description**
Efficient Building Envelope	**1**	**Eligible Gas Credit: 5% UA reduction**
Air Leakage Control and Efficient Ventilation	0	
High Efficiency HVAC Equipment	1	95% AFUE furnace
High Efficiency HVAC Distribution System	**1**	**Eligible Gas Credit: Ducts in conditioned spaces**
Efficient Water Heater distribution	0.5	Drain water heat recovery
Efficient Water Heater	2	Heat pump water heater
Renewable Electric Energy	1	Solar PV
Appliances	0.5	High efficiency appliances
Total Credits Achieved	7	
Total Credits Required	3	
Credits Eligible for Incentives	**2**	

Savings for each 0.5 credits above code is the weighted average of the savings determined by WA-TAG and SBCC. Savings for code options are shown in Table 251. Most of the therm savings values in Table 251 are from the WSEC code proposal. However, the proposal did not include two options:

1. Option 1.7 savings is assumed to be equal to option 1.3. Both options are deemed equivalent by WSEC and have similar features.
2. Option 4.1 savings are assumed as 61% of code option 4.2. This is based on a REM/Rate simulation of deeply buried ducts as a percentage of ducts inside.

Table 251 Savings and Probability of adoption for applicable code options

1.1	402.1.1 + U0.24 windows	0.5	33.1	33.1	100%
1.2	402.1.1 + U0.20 windows	1.0	28.5	28.5	50%
1.3	402.1.1 + U0.28 windows + R38 floor or R10 slabs or 5% UA reduction	0.5	38.6	38.6	100%
1.4	402.1.1 + U0.25 windows, R21+R4ci walls, R38 floor or R10 slabs or 15% UA reduction	1.0	46.7	46.7	100%
1.5	402.1.1 + U0.22 windows, ceiling/vaults R49, R21+R12ci walls, R38 floor or R10 slabs or 30% UA reduction	2.0	39.6	39.6	50%
1.6	402.1.1 + U0.18 windows, ceiling/vaults R60, R21+R16ci walls, R48 floor or R20 slabs or 40% UA reduction	3.0	35.8	35.8	0%
1.7	Adv Framing, U.28 windows, Full R49 ceiling	0.5	38.6	38.6	100%
2.1	3 ACH Eff ventilation fan, R402.4.1.2	0.5	38.6	38.6	100%
2.2	2 ACH Eff, 65% HRV vent., R402.4.1.2	1.0	25.2	25.2	100%
2.3	1.5 ACH Eff, 75% HRV vent., R402.4.1.2	1.5	22.9	22.9	25%
2.4	0.6 ACH Eff, 80% HRV vent, R402.4.1.3	2.0	22.9	22.9	0%
4.1	Deep buried ducts	0.5	35.5	35.5	100%
4.2	HVAC inside	1	28.9	28.9	100%
5.1	Drain WH Recovery	0.5	18.7	18.7	50%

The therm savings are weighted by the home size distribution and the probability of adoption and final savings are 34.28 therms per 0.5 credits. The home size distribution aligns with the distribution forecasted by SBCC in the code proposal.

Probability of adoption is an estimate to identify the likelihood of any participant choosing a specific credit option over the life of this offering. It is determined based on a combination of historical data, market intelligence on expected builder trends, NEEA's emerging technologies, and best guess estimate on measure adoption.

Other measures

Smart thermostat savings are assumed to be 6% of a home's space heating therms and kWh consumption, which is consistent with assumptions in other smart thermostat measures based on Energy Trust's 2016 Smart Thermostat Pilot[vi]. Average furnace consumption is estimated to be 235 therms and 160 kWh as calculated in REM/Rate simulations for the analysis in MAD 145.4. Applying 6% reduction to the 235 therms, yields savings of 14.1 therms and 9.6kWh.

Fireplace savings are based on sales data and Energy Trust evaluation[vii] of fireplace use in New Homes as used in MAD 181.5. Baseline efficiency from sales data is 57FE with 214 hours of use annually. Savings against a 71.9FE weighted improved case yields 18.3 therms of savings.

Measure Life

Measure life for shell measures of 45 years is consistent with other New Homes weatherization measures.

Measure life for options 2.2 through 2.4 are a weighted average based on proportion of HRV savings to air sealing savings as determined in REM/Rate models developed for MAD 145.4. HRV measure life is estimated at 20 years based on PNNL life cycle cost assessment[viii]. The measure life is also weighted by the probability of adoption.

Table 252 Measure Life for applicable code credits

1.1	402.1.1 + U0.24 windows	0.5	100%	45
1.2	402.1.1 + U0.20 windows	1.0	50%	45
1.3	402.1.1 + U0.28 windows + R38 floor or R10 slabs or 5% UA reduction	0.5	100%	45
1.4	402.1.1 + U0.25 windows, R21+R4ci walls, R38 floor or R10 slabs or 15% UA reduction	1.0	100%	45
1.5	402.1.1 + U0.22 windows, ceiling/vaults R49, R21+R12ci walls, R38 floor or R10 slabs or 30% UA reduction	2.0	50%	45
1.6	402.1.1 + U0.18 windows, ceiling/vaults R60, R21+R16ci walls, R48 floor or R20 slabs or 40% UA reduction	3.0	0%	45
1.7	Adv Framing, U.28 windows, Full R49 ceiling	0.5	100%	45
2.1	3 ACH Eff ventilation fan, R402.4.1.2	0.5	100%	45
2.2	2 ACH Eff, 65% HRV vent., R402.4.1.2	1.0	100%	39
2.3	1.5 ACH Eff, 75% HRV vent., R402.4.1.2	1.5	25%	39
2.4	0.6 ACH Eff, 80% HRV vent, R402.4.1.3	2.0	0%	39
4.1	Deep buried ducts	0.5	100%	45
4.2	HVAC inside	1	100%	45
5.1	Drain WH Recovery	0.5	50%	45

Load Profile

The ‘Res heating’ gas load profile most accurately captures the bulk of the savings in the offering. Fireplace measures use the ‘Hearth’ load profile.

Cost

The code proposal contains cost estimates based on various sources available in the analysis workbook of this measure. Additionally, the Building Industry Association of Washington (BIAW) also developed cost estimates for its builder members. This analysis uses an average of the two as shown in Table 253, and normalized on a 0.5 credit basis by dividing the total cost by the total number of credits by 0.5.

Table 253 Incremental Cost for applicable code credits

1.1	402.1.1 + U0.24 windows	0.5	$1,546	$1,197	$1,372
1.2	402.1.1 + U0.20 windows	1.0	$3,093	$1,667	$1,190
1.3	402.1.1 + U0.28 windows + R38 floor or R10 slabs or 5% UA reduction	0.5	$1,110	$1,102	$1,106
1.4	402.1.1 + U0.25 windows, R21+R4ci walls, R38 floor or R10 slabs or 15% UA reduction	1.0	$4,274	$4,311	$2,146
1.5	402.1.1 + U0.22 windows, ceiling/vaults R49, R21+R12ci walls, R38 floor or R10 slabs or 30% UA reduction	2.0	$7,871	$7,947	$1,977
1.6	402.1.1 + U0.18 windows, ceiling/vaults R60, R21+R16ci walls, R48 floor or R20 slabs or 40% UA reduction	3.0	$11,809	$11,889	$1,975
1.7	Adv Framing, U.28 windows, Full R49 ceiling	0.5	$-	$1,814	$1,814
2.1	3 ACH Eff ventilation fan, R402.4.1.2	0.5	$506	$517	$511
2.2	2 ACH Eff, 65% HRV vent., R402.4.1.2	1.0	$2,655	$2,727	$1,345
2.3	1.5 ACH Eff, 75% HRV vent., R402.4.1.2	1.5	$5,946	$6,108	$2,009
2.4	0.6 ACH Eff, 80% HRV vent, R402.4.1.3	2.0	$8,495	$8,725	$2,153
4.1	Deep buried ducts	0.5	$0	$0	$0
4.2	HVAC inside	1	$414	$300	$179
5.1	Drain WH Recovery	0.5	$400	$400	$400

Non-credited measures

Program Qualified Smart Thermostat - $125 incremental cost; Incremental cost of program qualifying smart thermostat is based on interviews with high volume builders. Nearly half of builders install web enabled programmable thermostat without the influence of the program. The incremental cost above the web enabled programmable thermostat is $50 and the incremental cost over a non-connected programmable thermostat is $200. Average incremental cost is $125.

Efficient Fireplace – Efficient fireplaces do not have an incremental cost above a standard fireplace. The CEC has $1 as a placeholder for incremental cost because the calculator tool requires a positive value.

Non-Energy Benefits

Electric bill savings from smart thermostats are calculated as NEBs based on Clark Public Utility’s residential rates.

Incentive Structure

The maximum incentives listed in Table 1 are for reference only and are not suggested incentives. Incentives are per half credit, per thermostat or per fireplace.

To maintain an influence and endorsement of efficient fireplaces in new construction, the program requested permission of the Washington Energy Efficiency Advisory Group (EEAG) for incentives to exceed incremental cost up to a UCT of 1.0. The request was granted on March 19, 2021.

Follow-Up

The 2018 WSEC code change is significant and produces many uncertainties in participation and measure adoption. It is recommended that this measure is closely tracked to ensure alignment with choices of program participants. If participants are gravitating towards a specific set of measures, the weightings used in this measure analysis should be updated.

If Energy Trust develops stand along fireplace or smart thermostat measures for new homes, the program should use those instead of the measures approved here. If new information becomes available regarding savings for smart thermostats or fireplaces, these measures should be update at the next revision.

Supporting Documents

The cost-effective screening for these measures is number 267.1.1. It is attached along with the analysis workbook used to develop this offering. These can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Residential\New Homes\WA code credits

267.1.1 Or-wa cec 2021 v1.1 SWWA Co

CodeCredits_Analysis_V3_2021-06-14.xls

Version History and Related Measures

Table 254 Version History

Date	Version	Reason for revision
6/21/2021	267.1	Introduce code credit offering in WA

Table 255 Related Measures

Measures	MAD ID
EPS Oregon	181
EPS Washington	145

Approved & Reviewed by

Jackie Goss, PE
Sr. Planning Engineer

EnergyTrust of Oregon

Measure Approval Document for Smart Thermostat in New Homes Washington

Valid Dates
January 1, 2022 to December 31, 2022

End Use or Description
Installation of web-enabled smart thermostats with occupancy detection in new home construction with natural gas furnace heating systems. This is a stand alone measure and is not intended to be combined with EPS.

Applicability
Based on the referenced analysis and associated cost-effectiveness screening, the measures described below are approved for use in the following programs in Washington only:

- Residential New Construction

Within these programs, the measure is applicable to the following cases:

- New

Cost Effectiveness
Cost effectiveness is demonstrated for Washington in Table 2. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2022-v1.0. In Washington the gas avoided cost year is 2020. The values in these tables are per thermostat.

Table 256 Cost Effectiveness Calculator Washington

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Smart thermostat gas heat	11	14.10	$125.00	$0.78	$125.00	1.6	1.6	0%	100%

Requirements
- Thermostat must be on Smart Thermostat Qualified Products List.[150]
- Homes must be heated by a 95% AFUE or higher furnace.
- Programs must ensure that participants in this offer are not also participating in the Existing Homes or retail offer for the similar measure, or EPS Washington which includes thermostats, or the similar measure included in the Washington Code Credits offering.

Baseline
This measure uses a Full Market Baseline.

The baseline assumes a standard programmable or manual thermostat, that is not enrolled in a thermostat optimization service, in a home with average HVAC loads.

Savings Analysis
Smart thermostat savings are assumed to be 6% of a home's space heating therms and kWh consumption, which is consistent with assumptions in other smart thermostat measures based on Energy Trust's 2016 Smart Thermostat Pilot[151]. Average furnace consumption is estimated to be 235 therms and 160 kWh as calculated in REM/Rate simulations for the analysis in MAD 145.4. Applying 6% reduction to the 235 therms, yields savings of 14.10 therms and 9.6kWh.

Comparison to RTF and other offers
RTF Connected Thermostats measure with sunset date 12/31/21, is for retail or direct install to replace an existing non-qualifying thermostat. All other Energy Trust smart thermostat measures (MADs 153, 250, 222, and 148) are for retrofit applications in existing homes and multifamily. There is no new homes option in these existing Energy Trust measures.

The new home Energy Trust MADs 181 and 267 are for whole home applications in Oregon and Washington whereas this measure is a standalone option to incentivize smart thermostats in Washington

Measure Life
The California Database for Energy Efficiency Resources (DEER) lists the expected lifespan of a programmable thermostat as 11 years.

Cost
Incremental cost of program qualifying smart thermostat is based on interviews with high volume builders. Nearly half of builders install web enabled programmable thermostat without the influence of the program. The incremental cost above the web enabled programmable thermostat is $50 and the incremental cost over a non-connected programmable thermostat is $200. Average incremental cost is $125.

Non-Energy Benefits
Electric bill savings from smart thermostats are calculated as NEBs based on Clark Public Utility's residential rates.

Incentive Structure
The maximum incentives listed in Table 2 is for reference only and are not suggested incentives. Incentives will be structured per thermostat.

Follow-Up
This document is set to expire when MAD 153 expires and should be updated using any relevant methods, information or assumptions for that update. This MAD may be combined with 153.

If new information becomes available regarding savings for smart thermostats, this measure should be updated at the next revision.

150 Energy Trust Thermostat QPL
151 Energy Trust Smart Thermostat Pilot Evaluation Energy Trust of Oregon Smart Thermostat Pilot Evaluation (Gas Furnaces). Apex analytics, 2016.

Supporting Documents

The cost-effective screening for these measures is number 274.1.1. It is attached and can be found along with supporting documentation at: \\etoo.org\home\Groups\Planning\Measure Development\Residential\Res HVAC\thermostat\web enabled thermostat\new homes

274.1.1 CE Calcuator v1.0 WA N

Version History and Related Measures

Table 257 Version History

Date	Version	Reason for revision
10/6/2021	274.1	Introduce standalone thermostat offering for new homes in WA

Table 258 Related Measures

Measures	MAD ID
New Homes Code Credits in Washington	267
Retail Web Enabled Smart Thermostats	153
EPS Oregon	181
EPS Washington	145

Approved & Reviewed by

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Measure Approval Document Washington New Homes Fireplaces

Valid Dates
January 1, 2022 to December 31, 2023

End Use or Description
Thermally efficient gas fireplaces in new home construction. This is a stand alone measure and is not intended to be combined with EPS.

Applicability
Based on the referenced analysis and associated cost-effectiveness screening, the measures described below are approved for use in the following programs in Washington:

- Residential New Construction

Within these programs, the measure is applicable to the following cases:

- New

Cost Effectiveness
Cost effectiveness is demonstrated Washington in Table 2Table 2. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2022-v1.0. In Washington the gas avoided cost year is 2020. The values in these tables are per fireplace.

Table 259 Cost Effectiveness Calculator Washington, per fireplace

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Fireplace > 70 FE	20	18.28	$1.00	$0.00	$339.50	1.0	339.5	0%	100%

Requirements
- Model listed on the Canadian EnerGuide list with natural gas specific FE rating[152]
- 70 or greater Fireplace Efficiency (FE) rating
- Installed in new home
- Programs must ensure that participants in this offer are not also participating in the existing homes offer for the similar measure, or EPS Washington which includes fireplaces, or the similar measure included in the Washington Code Credits offering.

Baseline
This measure uses a Full Market Baseline.

Baseline assumes fireplace with 57 FE based data collected during Energy Trust's study on fireplaces in new homes153.

Savings Analysis
Fireplace savings are based on sales data and Energy Trust evaluation of fireplace use in New Homes. An analysis was performed to determine fireplace baseline, savings over the baseline for multiple efficiency bins. Baseline determination, cost data, and proposed case was determined using the sales data. Hours of use (HOU) were obtained from the study of fireplaces in new homes. The savings methodology is:

$$Therms\ savings = HOU * Capacity * \left(\left(\frac{1}{Baseline\ FE}\right) - \left(\frac{1}{Proposed\ FE}\right)\right)$$

Savings for fireplaces is estimated at 18.3 therms annually for 70FE+ system over a market baseline of 57FE, with 213.5 expected hours of use and a market average capacity of 23 kBTU/hr.

Comparison to RTF or other programs
The RTF does not have a fireplace measure. This baseline and savings are in line other new construction fireplace measures.

Load Profile
The load profile is Hearth, which is only defined for Washington. So this differs from the similar Oregon measures.

Measure Life
US DOE technical support documentation estimates an effective useful life of 20 years for gas fireplaces.

Cost
Thermal Efficiency Improvement Costs
The market baseline cost for fireplace efficiency upgrades is based on average midstream unit costs by efficiency tier gathered in 2017. Those midstream costs were used to calculate a weighted average New Homes baseline cost using new homes market share. Table 260 shows the resulting average midstream unit costs. Weighting the manufacturer and distributor cost baselines equally yields a market baseline cost of $2,350. Incremental cost of fireplaces in new homes are assumed to be the same or similar to existing homes.

Table 260 Midstream Unit Costs 2017

Efficiency Tier	Quantity Sold	% Distribution	Average Unit Cost
75+ FE	15	0.3%	$2,643
70-74.9 FE	129	2.2%	$1,937
65-69.9 FE	491	8.5%	$2,799
50-64.9 FE	5,107	88.4%	$2,020
0-49.9 FE	36	0.6%	$4,600
Grand Total	**5,778**	**100%**	**$2,350**

152 Natural Resources Canada gas fireplace energy efficiency ratings search
153 New Homes Gas Fireplace Study https://www.energytrust.org/wp-content/uploads/2016/12/NewHomes_Gas_Fireplace_Studies.pdf

Market studies spanning 2009 to 2017 have consistency found fireplace unit aesthetics, including the flame, are the most important factor when purchasing a gas fireplace, with efficiency and price being other important factors. These studies have also found a persistent and negative or negligible incremental cost for qualifying fireplaces, which is corroborated by recent midstream program data from 2018 to 2020. Despite this, the existing homes market is still dominated by lower efficiency units, suggesting that incentives can play a role in further increasing the prominence of price and efficiency in the purchasing decision for a long-lived piece of heating equipment. Table 261 shows the median incremental. As there are no indications that this negative/zero incremental cost scenario will change, the program is using hard caps on incentives in order to maintain a substantive presence and endorsement in the retail fireplace marketplace to continue influencing efficiency decisions but constraining incentive outlays.

In cost effectiveness testing, a placeholder incremental cost of $1.00 is used.

Table 261 Fireplace Efficiency Upgrade Incremental Costs

Efficiency Tier	Median Tier Cost	Market baseline cost	Median Incremental Cost
70 +	$2,009	$2,102	-$93

Incentive Structure

The maximum incentives listed in Table 2 is for reference only and are not suggested incentives. Incentives will be structured per fireplace.

To maintain an influence and endorsement of efficient fireplaces in new construction, the program requested permission of the Washington Energy Efficiency Advisory Group (EEAG) for incentives to exceed incremental cost up to a UCT of 1.0. The request was granted on March 19, 2021.

Follow-Up

This MAD is set to expire when MAD 29.3 expires and should be updated when MAD 29.3 or MAD 267 is updated depending on which occurs first. If new information becomes available regarding savings for fireplaces, this measure should be update at the next revision.

Supporting Documents

The cost-effective screening for these measures is number 275.1.1. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Residential\Res HVAC\fireplace\New Homes

275.1.1 OR-WA CEC 2022 v1.0 WA new h

Measure History and Related Measures

Table 262 Version History

Date	Version	Reason for revision
10/8/2021	275.1	Introduce standalone fireplace offering for new homes in WA

Table 263 Related Measures

Measures	MAD ID
New Homes Code Credits in Washington	267
Efficient Gas Fireplaces and Electronic Fireplace Ignitions	29
EPS Oregon	181
EPS Washington	145

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i Energy Trust of Oregon Smart Thermostat Pilot Evaluation (Gas Furnaces). Apex analytics, 2016.
ii New Homes Gas Fireplace Study https://www.energytrust.org/wp-content/uploads/2016/12/NewHomes_Gas_Fireplace_Studies.pdf
iii Washington State Building Code Council, Standard Energy Code Proposal Form, May 2018 WA Standard Energy Code Proposal Form - 2018
iv 2018 WSEC TAG WASHINGTON STATE ENERGY CODE Progress toward 2030
v Washington State Code Proposal 17-Credit-updates.pdf (aiawa.org)
vi Energy Trust Smart Thermostat Pilot Evaluation Energy Trust of Oregon Smart Thermostat Pilot Evaluation (Gas Furnaces). Apex analytics, 2016.
vii New Homes Gas Fireplace Study https://www.energytrust.org/wp-content/uploads/2016/12/NewHomes_Gas_Fireplace_Studies.pdf
viii PNNL: HRV life cycle cost assessment PNNL Technical Brief on HRVs