NW Natural®

Biennial Energy Efficiency Plan

2024-2025

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Executive Summary

In accordance with Washington Utilities and Transportation Commission's requirements, Northwest Natural, dba NW Natural ("NW Natural" or the "Company") presents this 2024-2025 Biennial Energy Efficiency Plan. This Plan outlines the Company's energy efficiency efforts and goals for its Washington service territory for the 2024-2025 program years.

Notable changes for the biennium include the addition of two trial programs: Residential Behavioral Energy Efficiency and Industrial Energy Efficiency. The Residential Behavioral Energy Efficiency Program ("BEE Program") is a Home Energy Report ("HER") style program that will launch Q4 of 2023. The Industrial Program will be developed in 2024 using findings from the Industrial Audit Pilot that will run through the end of 2023. The Industrial Program will be made available to customers on eligible rates in 2025.

The residential and commercial incentive programs continue to play a large role in the Company's savings acquisition. Due to code related changes, new construction savings forecasts have decreased from the previous biennium. NW Natural also plans to continue to support regional efforts through the Northwest Energy Efficiency Alliance ("NEEA") and through the Northwest Power Council's Regional Technical Forum ("RTF").

2024-2025 EE Plan Summary		Biennial Therms Goal	Biennial Cost
Incentive Programs	Commercial	257,066	$3,039,663
	Residential	232,468	$4,425,790
Low-Income	WA-LIEE	8,680	$283,885
Market Transformation	NEEA	60,000	$329,353
Pilots & Trial Programs	Behavioral	205,708	$753,756
	Industrial	TBD	$150,000
Regional Planning	RTF	N/A	$26,100
Conservation Potential Assessment	CPA	N/A	$150,000
Program Validation	Evaluation	N/A	$160,000
	Biennial Savings Goal	763,922	
	EE Plan Total	$9,318,547	
	CPA 2-year Target	720,000	

Figure 1 - Biennial Plan Summary

2024-2025 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 an independent third party. Applied Energy Group ("AEG") was the selected vendor who completed the CPA which was filed with the Washington Utility and Transportation Commission ("WUTC") on June 1, 2023. The CPA developed 30-year projections for technical, achievable, and economic savings potential.

Summary of Energy Savings, Selected Years	2024	2025	2026	2030	2035	2040	2050
Reference Baseline	86,056	85,329	84,624	82,162	79,092	76,123	70,733
Cumulative Savings (thousand therms)							
Achievable Economic TRC Potential	355	720	1,115	3,099	6,224	9,223	11,129
Achievable Economic UCT Potential	518	1,043	1,597	4,137	7,583	10,736	12,658
Achievable Technical Potential	585	1,180	1,807	4,686	8,526	11,940	13,950
Technical Potential	1,168	2,335	3,532	8,442	13,883	17,305	18,809
Cumulative Savings (% of Baseline)							
Achievable Economic TRC Potential	0.4%	0.8%	1.3%	3.8%	7.9%	12.1%	15.7%
Achievable Economic UCT Potential	0.6%	1.2%	1.9%	5.0%	9.6%	14.1%	17.9%
Achievable Technical Potential	0.7%	1.4%	2.1%	5.7%	10.8%	15.7%	19.7%
Technical Potential	1.4%	2.7%	4.2%	10.3%	17.6%	22.7%	26.6%

Figure 2 - CPA Summary

2024-2025 Cost Effectiveness

The Company continues to monitor its energy efficiency programs through cost-effectiveness tests and levelized costs. Benefit-cost ratios for incentive programs are screened by both the Utility Cost Test ("UCT") and Total Resource Cost ("TRC") tests. In recent years the levelized cost per therm saved has increased in response to the market and new program development.

Anticipated Program Performance	2024	2025	2024-25 (2-Year)
Incentive Program UCT	1.56	1.62	1.59
Incentive Program TRC	1.12	1.13	1.13

Figure 3 - Program Benefit Cost Ratios

Program Year	Levelized Cost
2022 – Approved Budget	$0.890
2022 – Actual	$0.636
2023 – Approved Budget	$0.873
2024 – Budgeted	$1.08
2025 – Budgeted	$1.06

Figure 4 - Portfolio Levelized Costs

Background

NW Natural began offering its current energy efficiency incentive 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 energy efficiency programs.

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.

History

Program Implementation

The Company began using Energy Trust of Oregon ("Energy Trust") as the delivery arm for its Oregon energy efficiency incentive programs 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 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.

Oversight

The EEAG includes representatives from NW Natural, WUTC Staff, Public Counsel, the Alliance of Western Energy Consumers ("AWEC") (formerly Northwest Industrial Gas Users), The Energy Project, and the NW Energy Coalition ("NWEC"). The Company hosts quarterly calls to report on program activity and collect feedback. Additional meetings are held on an ad hoc basis to consult the group on time sensitive issues. The Company provides drafts of all reports, conservation plans, and tariff adjustments to the EEAG for review prior to public filing.

Program Delivery

NW Natural'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 energy. The organization was formed in 2002 in response to Oregon legislation that restructured electric utilities[1] for multiple reasons. Energy Trust's mission is to provide clean affordable energy for all and actively works to expand their reach to engage with communities that have historically been underserved.

[1] 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.

The Washington Low Income program ("WA-LIEE") is delivered through local community action agencies. The agencies in NW Natural's Washington service territory include Clark County Community Action Agency and Washington Gorge Action Council of Lewis, Mason and Thurston Counties.

NW Natural also supports collaborative regional efforts for system planning and market transformation by funding and working with the RTF and NEEA. The RTF is a technical advisory committee that works to develop standards to verify and evaluate energy efficiency savings for the Northwest. NEEA is a regional organization funded by both investor-owned and publicly owned utilities committed to encouraging local markets to favor energy-efficient products and services.

Pilot offerings such as the BEE Program and the Industrial Audit Pilot, are delivered through third-party implementers selected by NW Natural through a competitive bid process. Bidgely is the chosen vendor for the BEE program; they specialize in artificial intelligence powered energy analytics and used by multiple utilities in the northwest. Energy 350 is the selected implementor for the Industrial Audit Pilot. Energy 350 is a local energy efficiency consulting firm with expertise in industrial energy performance.

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 the various programs and efforts that are included in NW Natural's 2024-2025 energy efficiency portfolio.

Incentive Programs

Residential Program Description

Residential programs in Southwest Washington acquire cost-effective gas savings by engaging with both builders and homeowners. There are four tracks within the Residential Incentive Program: Standard Home Retrofit, Standard Multifamily, Mid-stream (distributor), and new homes (EPS). The program coordinates with builders to increase energy efficiency of newly constructed, single-family homes through incentives, education, trade ally support and quality assurance. For existing single-family homes, small multifamily renters and landlords, incentives and services are available for the following energy saving efforts:

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

Specific measure offerings and details are listed in Appendix 3 and Appendix 4.

Residential Standard Track (Existing Home Retrofit)

Residential customers with gas heated homes are offered incentives for cost-effective weatherization measures and select 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. Online home energy reviews are also available wherein an energy use estimation tool identifies opportunities in the customers' home that could be installed to improve efficiency.

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 Commercial Program.

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 midstream efforts include smart thermostats, gas fireplaces, and gas tank water heaters. However, gas fireplaces are being transitioned from mid-stream to being retail and downstream.

Residential New Homes Track

The New Homes track consists of three different offerings: EPS New Homes, Code Credits, and stand-alone measures (smart thermostats and gas fireplaces). 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 5% better than Washington building code. EPS is a trademarked name 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 also offers a Code Credits pathway. 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.

With the launch of the newest WA energy code (2021 WSEC-R (WAC 51-11R)) the company has determined that there will no longer be a path for gas heated homes to receive incentives through the efficiency programs as the stringency of the code is now too great to offer cost effective measures. With this, the new homes program will be offered through 2024 to serve homes that were permitted under the previous 2018 WSEC-R code. However, in 2025 the company will likely no longer be providing services to new homes or rather will do so only through single stand-alone measures such as smart thermostats and gas fireplaces.

Community Partner Funding

Community Partner Funding ("CPF") is a pathway that provides increased incentive offers exclusively for community-based organizations to reach 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 3 and Appendix 4. The Washington Existing Buildings program has historically consisted of two tracks - custom and standard. The program recently launched a new offering of Strategic Energy Management in 2022.

Commercial Custom Track

The Commercial Custom Track acquires gas savings through incentivizing energy efficient capital projects and operations and maintenance upgrades that are complex or nonstandard upgrades. The Program Management Contractor ("PMC") account managers work with customers and engineering firms to identify and analyze customer opportunities. Once projects are completed the PMC ensures efficiency upgrades were installed and operating as anticipated. The custom track also pursues opportunities in retro-commissioning, which evaluates and incentivizes improvements related to controls or HVAC adjustments.

Commercial Standard Track

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

Commercial New Construction Track

The Commercial Program provides standard, prescriptive measure offerings for new commercial buildings. 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.

Commercial Strategic Energy Management ("SEM")

The Commercial Program launched an 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 was largely focused on initial outreach to participants as well as providing analysis of gas savings opportunities. Savings acquisition began in late 2022 and began being fully realized in 2023. In 2024 and 2025 the SEM offering is expected to see moderate participation and savings growth in part due to the Washington 2019 Clean Buildings Act and the Clean Buildings Performance Standard.

Low Income

Under NW Natural's Washington Low Income Energy Efficiency Program (WA-LIEE), agencies administering the program provide free weatherization services, equipment repairs, equipment upgrades, and funding for health and safety measures to income qualified households. Agencies fund their projects by leveraging both WA-LIEE dollars and other funding sources. Program details are available in the Company's Schedule I.

Market Transformation

The Company views the regional gas market transformation initiative led by NEEA a necessary investment in the future of gas demand side management ("DSM") and of regional power planning. NEEA helps accelerate the innovation and adoption of energy-efficient products into the market, then actively monitors previous initiatives to quantify energy savings and market impact. These market transformation efforts continue to deliver value to the region long after the initial investment.

NEEA's market transformation approach focuses on identifying energy efficiency opportunities along with associated barriers, then developing and implementing market intervention strategies to accelerate adoption and create lasting market change. Each technology falls into a stage within NEEA's sequencing:

1) Scanning & Concept Identification
2) Concept Opportunity Assessment
3) Market & Product Assessment
4) Strategy Testing & Finalization
5) Market Development
6) Long-Term Monitoring

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 refined. NEEA does not typically forecast savings associated with technology in the first four phases. Significant savings begin in the market development stage.

Pilot and Trial Programs

NW Natural investigates and initiates opportunities to further strengthen the suite of offerings through pilot projects and temporary 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 is briefed on all new initiatives and has the opportunity to provide feedback throughout the development process.

Behavioral Energy Efficiency

The Behavioral Energy Efficiency or BEE Pilot is a home energy report style program that provides energy breakdowns and tips for residential customers. Customers in the treatment group receive monthly digital reports that show their disaggregated natural gas usage for the previous month and show a weather normalized comparison to their own historical usage as well as similar homes. In addition to the digital reports, four paper reports are also sent throughout the year to drive behavioral changes.

Savings for this program are calculated by comparing the treatment group to a control group of customers that did not receive the home energy reports. This pilot is set to launch late in 2023 and run for three years. The program will be monitored closely in the first two pilot years to determine if the offering should become a permanent.

Industrial Audits to Incentive Program

In 2022, NW Natural started offering high-level energy audits to all industrial customers. The purpose of the Industrial Audit Pilot was to visit as many sites as possible and identify what savings opportunities are available at these sites. The information collected will be used to develop an incentive program for industrial customers. The offering will be available to customers through the end of 2023.

In 2024, NW Natural will use the audit information to develop an incentive program pilot offering to be available to customers in 2025.

Cost Effectiveness Standards

Cost effectiveness is measured by quantifying the benefits of an investment and comparing it to the costs associated with it. It is an important metric used to show that energy efficiency is a fiscally responsible use of rate-payer funding. NW Natural monitors and reports on energy efficiency programs using the Utility Cost Test ("UCT"), the Total Resource Cost Test ("TRC"), and levelized costs. The Company may investigate the options provided by the Nation Standard Practice Manual ("NSPM") for cost-effectiveness methodology. Any changes to cost-effectiveness reporting standards will be vetted through the EEAG process.

Utility Cost Test (UCT)

The UCT measures the present value of the energy savings over the lifetime of the measure in relation to the net costs incurred by the incentive program. This test excludes any net costs incurred by the participant and is used to set incentive level caps. The utility benefits and costs are defined as follows:

Utility Benefits:

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 Purchase and Transport Costs
- Supply and Distribution Capacity Infrastructure Costs
- Washington State Carbon Policy Adder (Social Cost of Carbon as direction by House Bill 1257)
- Risk Reduction Value

- 10% Northwest Power Act Credit

Utility Costs:

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

Total Resource Cost Test (TRC)

The TRC Test includes all quantifiable costs and benefits regardless of who accrues them. It is used within NW Natural's programs to evaluate if a measure should be offered. NW Natural's energy efficiency portfolio (excluding low-income programming) must maintain a TRC value equal or greater than 1.0. The total benefits and costs included are defined as follows:

Total Resource Benefits:

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 Purchase and Transport Costs
- Supply and Distribution Capacity Infrastructure Costs
- Washington State Carbon Policy Adder (Social Cost of Carbon as direction by House Bill 1257)
- Risk Reduction Value
- 10% Northwest Power Act Credit

Non-energy benefits as quantified by a reasonable and practical method. Examples non-energy benefits that may be included are:

- Electric Savings
- Water Savings
- Reduced maintenance costs

Total Resource Costs:

- Administrative and implementation costs
- Evaluation, verification, and monitoring
- The participant's remaining out-of-pocket costs for the installation of the measures after incentives and federal tax credits.

Levelized Cost

The levelized cost metric 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:

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

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.

Avoided Costs

Total avoided cost is an estimate of the cost to serve the marginal unit of demand with conventional supply-side resources. This incremental cost represents the cost that could be avoided if that unit of gas were not demanded due to energy efficiency or other supply side resources. Avoided costs are based on assumptions including the natural gas price and risk reduction value associated with offsetting gas purchases on the spot market. Supply capacity costs based on peak-day coincident factors, and distribution capacity costs based on peak-hour coincident factors are also included.

Avoided costs were updated in 2022 for use in the 2023 program year (see figure below). The most recent avoided costs will be used to retroactively review the cost-effectiveness of the previous program year because these values will best represent the current value of the 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.

30 Year Levelized Avoided Costs								
		Commodity Costs			Capacity Costs		10% Conservation Credit	**Total Avoided Costs**
		Natural Gas Commodity	Greenhouse Gas	Risk Reduction	Supply Capacity	Distribution System		
Washington	Residential Space Heating	$3.83	$6.26	$0.86	$0.64	$7.81	$1.23	**$20.64**
	Residential Hearths and Fireplaces	$3.83			$0.64	$3.93	$0.84	**$16.37**
	Commercial Space Heating	$3.83			$0.57	$9.42	$1.38	**$22.33**
	Water Heating	$3.50			$0.11	$1.77	$0.55	**$13.04**
	Cooking	$3.47			$0.12	$4.84	$0.85	**$16.40**
	Process Load	$3.47			$0.09	$0.78	$0.44	**$11.90**
	Interruptible Loads	$3.47			X	X	$0.36	**$10.95**

Figure 5 - Avoided Cost Summary by End Use (2021$/Dt)

Program Evaluation, Monitoring and Verification

Impact Evaluations

Annual savings reported by the Company are based on the assumed gross savings for each measure. The assumed savings are consistent with the most current impact studies performed. The Company or third parties perform impact studies to validate the engineering assumptions used for savings calculations. 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 or independent third parties 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 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"). Links to impact evaluations as well as a short summary of the results will be provided in the Annual Energy Efficiency Report ("AEER").

Process Evaluations

The Company or program delivery contractor may, as appropriate, contract with a third-party evaluation contractor to perform process evaluation on a subset or on all energy efficiency programs, pilots, and other efforts offered. The evaluation contractor studies the programs and reports on the processes employed for each program with recommendations for improved. A link or copy of the process evaluations completed in the year will be provided in the AEER.

Process for Program Changes

The Company reviews incentive levels and savings prior to filing its Biennial Energy Efficiency Plan. All standard offerings are listed in the Unit Energy Savings ("UES") Measure List (Appendix 3). If the UES Measure List needs an offering added, changed, or removed during the biennium, the Company will revise this Plan to make requested program modifications. This does not preclude the Company from filing to revise Schedule G, or the Plan and any of the appendices at any time during the year.

Tariff advice filings revising or adding offerings will include:

1) A measure-level BCR calculation as outlined in in the "Cost Effectiveness" section.
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 BEEP. The Plane 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 the EEAG members may intervene in that public proceeding.

The Company will give the EEAG thirty (30) days to review a draft filing.

Schedule for Program Planning

In accordance with RCW 80.28, NW Natural establishes an acquisition target every two years based on a conservation potential assessment that is prepared by an independent third party. In every odd year, NW Natural files a Biennial Energy Efficiency Plan that outlines planned program activities and budgets to achieve the two-year conservation target.

NW Natural hosts quarterly calls with the EEAG to discuss progress toward its goals, pilot/program development, tariff adjustments, or other topics related to the programs. Ad hoc meetings may be scheduled to address time sensitive matters.

An annual report will be due by the following June 15th after the end of the program year. Every even year, the annual report will be filed in conjunction with the Biennial Energy Efficiency Report ("BEER").

2024-2025 Reporting Schedule	
January 1st, 2024	Start of the 2024 program year
March 2024	First quarter check-in with EEAG
May 2024	Second quarter check-in with EEAG
June 15th, 2024	2022-2023 Biennial Report Filed with WUTC
August 2024	Third quarter check-in with EEAG
October	Fourth quarter check-in with EEAG
November 15th, 2024	File plan updates if required
January 1st, 2025	Start of the 2025 program year
March 2025	First quarter check-in with EEAG
May 2025	Second quarter check-in with EEAG
June 1st, 2025	CPA filed with WUTC
June 15th, 2025	2024 Annual Report Filed with WUTC
August	Third quarter check-in with EEAG
October	Fourth quarter check-in with EEAG
November 15th, 2025	File 2026-2027 Biennial EE Plan with WUTC
December 31st, 2025	End of the 2024-2025 program years.

Figure 6 - Reporting Schedule

Reporting Requirements

Reporting requirements are established in coordination with WUTC staff. All plans and reports must be posted on NW Natural's website. The following sections summarize reporting expectations outlined in UG-210831 Order 1.

Biennial Energy Efficiency Plan:

- On or before November 15th of every odd-numbered year, NW Natural must file with the Commission a biennial conservation plan.
- The plan must include a summary of public participation in the development.
- The ten-year conservation potential, biennial conservation target, and a description of how figures were developed must be included.
- Program descriptions and budgets must be outlined.
- Evaluation and verification plan that outlines the framework and budget is also required.

Annual Energy Efficiency Report:

- On or before June 15th of each year, NW Natural must file with the Commission, in the same docket as its current biennial energy efficiency plan, and annual conservation report regarding its progress in meeting its conservation target during the preceding year.
- The annual plan must include the biennial conservation target, budgeted and actual savings, budgeted and actual expenditures, and portfolio and program level cost-effectiveness.
- Descriptions are required for documenting key sources of variance between budgeted and actuals as well as key steps taken to adaptively manage the programs.

Biennial Energy Efficiency Report:

- Beginning in 2024, on or before June 15th of each even-numbered year, NW Natural must file with the Commission, in the same docket as its current biennial energy efficiency plan, a report regarding its progress in meeting its conservation target during the preceding two years.
- The report must include planned and claimed gas savings from conservation, budgeted and actual expenditures, and portfolio-level cost-effectiveness.
- A third-party evaluation of the portfolio-level savings achievement, and a summary of steps taken to adaptively manage programs is also required.
- The annual report may be filed together with the biennial report as a single report.

Program Budget Guidelines

The Company provides in this plan a total estimated budget for the 2024-2025 program years. The budget includes a breakdown of anticipated expenditures by program track. Program costs for the upcoming year are reviewed annually with the EEAG. Projections included in this Plan for 2025 are based on current expectations but may be subject to change. If major variances from the proposed 2025 budget are identified in 2024, the Company will file an update for the 2025 program year.

Program budgets are developed congruently with the Biennial Energy Efficiency Plan and materials are shared with the EEAG as available. 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.

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.

Cost Recovery

The incentive program, market transformation, evaluations, pilots, 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, which relates to low-income weatherization programming 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.

Biennial Energy Efficiency Plan

Current Program Drivers

NW Natural's programs continue to see lasting impact of the 2020 pandemic as the market continues to recover from shutdowns. Materials and equipment are now more readily available than in the previous biennium, but consumers are more cautious with investments due to high inflation and economic uncertainties. Changes in building codes also creates a barrier to achieving savings in new construction markets.

Residential

Participation among the single-family rental and small multifamily markets in Southwest Washington remain strong with steady year-over-year participation which is expected to continue into 2024. The EPS™ new construction program will be phased out by the end of 2024 due to the Washington Residential Energy Building code which is set to take effect in the next year.

Planned activities for the residential sector include:

- Increased engagement with single-family and rural customers through expanded trade ally recruitment, target marketing initiatives, and community events.
- Evaluate reintroducing bonus incentives for gas furnaces or other high-cost measures. Previous COVID-19 related bonuses in 2020 and 2021 generated high participation rates. Participation has dropped since the standard incentives were reinstated.
- Expand marketing investments and campaigns to both reengage past participants and acquire new customers.
- Expand engagement and recruitment of insulation installers into the trade ally network to increase insulation project and savings volumes.
- Explore collaborating with Calrk County's Planet Clark and Clark Public Utilities on trade ally education, recruitment, and community events.

Commercial

The commercial programs continue to navigate socioeconomic trends such as high labor turnover and shortages, equipment price increases, and long delivery timeframes. There are currently large bond capital new construction projects for a couple school districts which are nearing completion in the next twelve months. These projects are expected to drive program savings in the first year of the biennium. Due to building code restrictions the program does not expect many custom new construction projects to be introduced in 2024. Budget constraints continue to impact retrofit projects in certain sectors such as K-12 and large retail.

Planned activities for the commercial sector include:

- Increased outreach to local chambers, Vancouver Business Journal, Hispanic/Latino-owned businesses, the Downtown Business Association, and others to increase program awareness.
- Quarterly targeted outreach campaigns to active and new trade allies to review program updates and educate allies on the project submission process.
- Promote Building Operator Certification ("BOC") program participation to non-strategic energy management participants through specific customer contact.
- Deliver targeted marking campaigns to small business customers in rural areas that promote insulation and HVAC measures.
- Create and leverage a simple step-by-step help guide for participants to navigate the custom project submission process.
- Increase SEM program participation through the existing partnership with Clark Public Utilities and Energy Trust Southwest Washington customer sites.
- Expand lead generation and communications to support NW Natural's Major Account Services Managers.
- Meet with Clark Public Utilities Commercial Account Manager(s) quarterly to discuss customer trends, needs and leads for potential project acquisition and partnership.
- Conduct focused research on the impacts of expiring measures, small businesses support efforts, and market adaptation to code changes.
- Develop new ways of identifying savings opportunities with customers and explore the ability to develop packages of measures tailored to specific market segments.
- Apply findings from community engagement and past research efforts to adapt program approaches to better serve small businesses, rural areas, and businesses owned by people of the global majority, as well as to support workforce development.

Incentive Programs

The following tables summarize the forecasted budgets and savings for the 2024-2025 program years. Budgets are built from year-end forecasts, market intelligence gathering, and stakeholder feedback.

Energy Trust's Conservation Advisory Council ("CAC") and Diversity Advisory Council ("DAC") provided feedback for Energy Trust to take intentional steps to serve priority customers. This is reflected in the planned program activities that focus on culturally sensitive outreach and marketing to support workforce development within the energy industry.

Incentive Program Summary		2024	2025	Biennium Total
Residential Incentive Program	Budget	$ 2,117,068	$ 2,176,277	$ 4,293,345
	Savings (therms)	111,060	118,002	229,062
Commercial Incentive Program	Budget	$ 1,346,925	$ 1,515,212	$ 2,862,137
	Savings (therms)	133,179	153,413	286,592

Figure 7 - Incentive Program Summary

Therm Savings by Program

Incentive Program	Annual Therms Goal	2024	2025	2024-25
Commercial Programs	Existing Buildings - Standard	37,260	37,260	74,520
	Existing Buildings - Custom	46,500	46,500	93,000
	New Buildings - Standard	5,640	11,280	16,920
	New Buildings - Custom	-		-
	Strategic Energy Management	43,779	58,373	102,152
	Commercial Total	133,179	153,413	286,592
Residential Programs	Existing Homes Retrofit	107,584	117,561	225,145
	Mid-stream - Distributor	151	166	317
	New Home Construction	3,325	275	3,600
	Residential total	111,060	118,002	229,062
	Total savings	244,239	271,415	515,654
*Commercial Training added to EB-Standard				
** Residential Multifamily added to Existing Home Retrofit				

Figure 8 - Incentive Program Therm Savings

Expenses by Program

2024-25 Efficiency Program	Budgeted Expenditures	2024	2025	2024-25 Total
Commercial	Programs	$ 982,672	$ 1,074,930	$ 2,057,602
	Commercial administration	$ 451,227	$ 530,834	$ 982,061
	Commercial Total	$ 1,433,899	$ 1,605,764	$ 3,039,663
Residential	Programs	$ 1,564,297	$ 1,530,912	$ 3,095,209
	Residential Administration	$ 622,862	$ 707,719	$ 1,330,581
	Residential total	$ 2,187,159	$ 2,238,631	$ 4,425,790
	Total Expenditures	$ 3,621,058	$ 3,844,394	$ 7,465,452
Expenditures Include Incentives and Delivery				

Figure 9 - Incentive Program Expenses

Incentives by Program

2024-2025 Approved Budgets	Incentives Budget	2024	2025	2024/25 Total
Commercial Programs	Existing Buildings - Standard	$ 112,525	$ 112,525	$ 225,050
	Existing Buildings - Custom	$ 168,500	$ 168,500	$ 337,000
	New Buildings - Standard	$ 18,840	$ 37,680	$ 56,520
	New Buildings - Custom			$ -
	Strategic Energy Management	$ 109,078	$ 171,221	$ 280,299
	Commercial Total	$ 408,943	$ 489,926	$ 898,869
Residential Programs	Existing Homes Retrofit	$ 1,070,452	$ 1,195,353	$ 2,265,805
	Mid-stream: Distributor	$ 1,000	$ 1,100	$ 2,100
	New Home Construction	$ 99,805	$ 3,100	$ 102,905
	Residential total	$ 1,171,257	$ 1,199,553	$ 2,370,810
	Total Incentives	$ 1,580,200	$ 1,689,479	$ 3,269,679

Figure 10 - Incentive Budgets by Program

Low-Income Program

The WA-LIEE program will strive to weatherize 16 homes in the 2024-2025 program years. Our main weatherization partners are going through a transitional period, and they anticipate that this transition will impact the number of projects they can complete in 2024. A breakout of costs and therm savings estimates are reflected below.

Historically the WA-LIEE program has had a $1,000 cap on health and safety measures. In response to feedback from community partners and considering rising costs and inflation, NW Natural is proposing an additional $4,000 in flexible spending to be used for additional energy efficiency measures or health and safety measures. NW Natural is also exploring ways to make the program more visible with distinct types of enhanced outreach strategies like bill inserts for customers in Clark County and strategic outreach with community-based organizations in the area. NW Natural will begin seeking community-based partners to help reach more customers. Program details are available in the Company's Schedule I, "Washington Low Income Energy Efficiency Program (WA-LIEE)."

The targets below assume a standard $8,933 for energy efficiency measures and $1,000 on health and safety measures with an additional $4,000 in flexible spending to be distributed as needed between energy efficiency measures, health, and safety. Program providers may recover agency administrative costs up to 25% of project costs. The company is allowed up to 5% for processing administration.

Low Income Performance Targets

WA-LIEE	2023 Goal	2024 Goal	Biennial Goal
Number of Homes Weatherized	6	10	16
Therms Savings	3255	5425	8680

Figure 11 - WA-LIEE Program Goals

Low Income Budget

WA-LIEE			Budget
WA-LIEE	WA-LIEE Measures	$	142,928.0
	Health/Safety	$	16,000.0
	Flexible Funds for H/S/R or EE	$	64,000.0
	WA-LIEE Agency Administration (25%)	$	55,732.0
	WA-LIEE application processing admin (5% cap)	$	13,933.0
	WA-LIEE Total	**$**	**283,884.9**

Figure 12 - WA-LIEE Program Budget

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. NW Natural's goal is for these eligible households to reduce energy consumption, lower energy bills, and improve living conditions while also ensuring the durability and safety of their homes. For whole home efforts, WA-LIEE leverages funds provided by other state, federal, and local agencies. Those leveraged funds also utilize Total Resource Costs (TRC) tests or approved measures lists.

Gas Market Transformation

NW Natural will continue its participation with NEEA on regional natural gas market transformation. 2024 represents the final year of the current 5-year funding cycle.

The next funding cycle for NEEA is currently under development. Budget and savings values for 2025 are based on current drafts and will likely be refined in 2024. NEEA is currently anticipating a natural gas portfolio budget increase of approximately 87% over the previous funding cycle. The budget increase is driven by the expansion of the gas portfolio; multiple programs will be maturing into the market development stage and new programs will be added. In addition, costs have increased significantly in comparison to the previous budget cycle due to high inflation rates. NW Natural's direct funding share for its Washington service territory is also seeing a slight increase (from 3.1% to 3.4%) due to the Company's increased customer count.

During the 2024-2025 period, NEEA will focus its natural gas work on evaluating emerging technologies for inclusion into the portfolio while simultaneously advancing existing programs. Current areas of focus are efficient rooftop units, efficient gas water heaters, and high-performance windows. Another area of primary focus will be developing the gas heat pump market. NEEA has been critically influential in the product development and path to commercialization with manufactures and will continue to support the effort through participating in national collaborations and equipment testing.

NEEA savings are highly volatile. NW Natural uses the low end of the savings estimate range provided by NEEA to account for the uncertainty.

	2024	2025	Biennial Total
NEEA Funding	$88,149	$241,204	$329,353
Savings Estimate (therms)	20,000	40,000	60,000

Figure 13 - NEEA Summary

Pilots & Trial Programs

As the Company looks to acquire cost-effective savings, pilot or trial programs are offered to investigate the potential and initiate new offerings. Over the 2022-2023 Biennium, NW Natural further explored the potential by contracting for a residential home energy report pilot and launched an industrial audit program to gather more information on the industrial sector potential. Budgets are based on contracted amounts; actuals may vary based on program uptake and contractor billing.

Behavioral Energy Efficiency

NW Natural has been working to develop a behavioral energy efficiency program throughout 2023. The pilot program is set to run for 3 years. Anticipated program costs and saving goals are listed below. Platform costs for 2024 include a one-time set up fee for the delivery platform. Paper report costs are anticipated to decline in 2025 as participants opt-out of the program. Program savings will be reported by Bidgely and separately verified through a third-party evaluator.

BEE Program	2024	2025	Biennial Total
Platform Cost	$250,000	$100,000	$350,000
Treatment Cost	$123,840	$106,502	$230,342
Paper Report Cost	$86,829	$74,673	$161,502
Program Budget	$460,669	$281,175	$741,844
Program Savings Goal (therms)	93,024	112,684	205,708

Figure 14 - BEE Pilot Summary

Industrial Program Pilot

NW Natural is planning to launch an industrial incentive program in 2025. Given the lead time associated with starting programs NW Natural anticipates the first year of the program to be focused on customer recruitment and project lead generation. Budgets are expected to ramp up in the following year as projects are completed and incentives are paid out.

NW Natural will seek guidance from the EEAG on program development and provide a detailed program budget to the advisory group in 2024. Current estimates included in this plan are based on the industrial audit program activity that took place in the previous biennium.

Industrial Pilot	2024	2025	Biennial Total
Budget	N/A	$150,000	$150,000
Savings	N/A	-	-

Figure 15 - Industrial Pilot

Northwest Power and Conservation Council

The Company has agreed to support the work of the Northwest Power and Conservation Council's Regional Technical Forum. The Company is entering the last year of the 2020-2024 Business Plan and is currently working with the RTF to establish funding levels for the 2025-2029 Business Plan.

Regional Technical Forum	2024	2025	Biennial Total
Budget	$11,100	$15,000	$26,100

Figure 16 - RTF Funding

On-the-Bill Repayment Services

NW Natural 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. 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 2.

Evaluations

NW Natural has several evaluations planned for the 2024-2025 Biennium to evaluate both program activity and savings reporting. In 2024, NW Natural plans to conduct an independent third-party evaluation of portfolio-level biennial conservation savings achievement for inclusion in the 2022-2023 Biennial Energy Efficiency Report. In 2025, NW Natural plans to conduct an impact evaluation on the BEE pilot to validate reported savings.

The budgeted values are estimates based on previous evaluation work. NW Natural will hold a request for proposal process to ensure competitive pricing on evaluation. The EEAG will be kept apprised of the process and budget variances will be discussed with the advisory group prior to moving forward with evaluations.

Evaluations	2024	2025	Biennial Total
Budget	$60,000	$100,000	$160,000

Figure 17 - Evaluation Budget

Development Considerations

Targets for the 2024 and 2025 program years are based on the 2023 CPA provided by AEG. NW Natural initially selected AEG as the independent third-party contractor for the analysis through a competitive bid process for 2021 CPA. In early 2023, NW Natural contracted with AEG again to provide the 2023 CPA. The assessment uses standard industry and Northwest regional methodologies to develop reliable estimates of technical, achievable, and economic potentials. The work was performed in collaboration with NW Natural and Energy Trust of Oregon staff using information specific to NW Natural's customers and existing energy efficiency programs wherever possible.

NW Natural decided to include transportation rate customers in the assessment even though it was not required by statute. The impacts of the inclusion of transportation customers in energy efficiency programs will continue to be explored in the 2024-2025.

2023 Conservation Potential Assessment

To perform the CPA analysis, AEG used a bottom-up approach in which they characterized the current market using NW Natural usage and customer data, calibrated a baseline projection, created a list of measures, and estimated the technical, achievable, and economical energy savings. AEG also included an income-level analysis for the residential sector, which can be found in the "2023 NW Natural Washington Conservation Potential Assessment". The following tables summarize the potential and the top measures for the residential, commercial, and industrial sectors.

Rank	Measure / Technology	2024 Achievable Economic TRC Potential (thousand therms)	2050 Achievable Economic TRC Potential (thousand therms)	% of Total
1	ENERGY STAR - Connected Thermostat - Interactive/learning thermostat	69	2,110	28.1%
2	Water Heater (<= 55 gal) - UEF 0.87 (Instantaneous, ENERGY STAR 4.0)	11	1,690	22.5%
3	Furnace - AFUE 95% (ENERGY STAR 4.1)	23	1,330	17.7%
4	Fireplace - Tier 2 (>75% FE)	0	422	5.6%
5	Insulation - Ceiling, Installation - R-49 (Retro only)	3	306	4.1%
6	Water Heater - Low Flow Showerhead - 1.5 GPM showerhead	2	257	3.4%
7	Ducting - Repair and Sealing - 50% reduction in duct leakage	1	232	3.1%
8	ENERGY STAR Clothes Washers - ENERGY STAR unit	11	150	2.0%
9	Stove/Oven - High Efficiency (730 + 1660 IAEC)	0	138	1.8%
10	Water Heater - Pipe Insulation - Insulated 5' of pipe between unit and conditioned space	1	138	1.8%
11	Water Heater - Temperature Setback - Setback to 120° F	1	110	1.5%
12	Built Green homes - Built Green spec (NC Only)	0	103	1.4%
13	Insulation - Wall Cavity, Installation - R-11	1	102	1.4%
14	Insulation - Ducting - duct thermal losses reduced 50%	1	90	1.2%
15	Behavioral Programs - HER-style customer awareness program	63	88	1.2%
16	Water Heater - Faucet Aerator - 1.5 GPM aerator	1	76	1.0%
17	Intermittent Ignition System - Installed switch/remote on burner system	0	48	0.6%
18	Insulation - Basement Sidewall - R-15	0	42	0.6%
19	Insulation - Floor/Crawlspace - R-30	0	22	0.3%
20	Building Shell - Whole-Home Aerosol Sealing - 20% reduction in ACH50	0	15	0.2%
	Subtotal	**190**	**7,469**	**99.6%**
	Total Savings in Year	**191**	**7,500**	**100%**

Figure 18 - Residential Top Measures

Rank	Measure / Technology	2024 Achievable Economic TRC Potential (thousand therms)	2050 Achievable Economic TRC Potential (thousand therms)	% of Total
1	Water Heater - Tankless	4	781	23.1%
2	Insulation - Roof/Ceiling - R-38	49	703	20.8%
3	Broiler - Infrared Burners	3	270	8.0%
4	Insulation - Wall Cavity - R-21	21	255	7.5%
5	Boiler - TE 98%	5	178	5.3%
6	Gas Boiler - Insulate Hot Water Lines - Insulated water lines	9	132	3.9%
7	Range - High Efficiency	1	98	2.9%
8	ENERGY STAR Connected Thermostat - Wi-Fi/interactive thermostat installed	15	90	2.7%
9	Furnace - AFUE 96%	0	82	2.4%
10	Hydronic Heating Radiator Replacement - TBD	4	75	2.2%
11	Double Rack Oven - FTSC Qualified (>50% Cooking Efficiency)	1	71	2.1%
12	HVAC - Demand Controlled Ventilation - DCV enabled	1	65	1.9%
13	Thermostat - Programmable - Programmable thermostat installed	4	55	1.6%
14	Kitchen Hood - DCV/MUA - DCV/HUA vent hood	4	53	1.6%
15	Gas Boiler - Insulate Steam Lines/Condensate Tank - Lines and condensate tank insulated	4	52	1.5%
16	Oven - ENERGY STAR (3.0)	1	47	1.4%
17	Building Automation System - Automation system installed and programmed	0	46	1.4%
18	Strategic Energy Management - Energy management system installed and programmed	3	43	1.3%
19	Gas Boiler - Hot Water Reset - Reset control installed	2	43	1.3%
20	Thermostatic Radiator Valves - TBD	2	34	1.0%
	Subtotal	**131**	**3,172**	**93.7%**
	Total Savings in Year	**147**	**3,384**	**100.0%**

Figure 19 - Commercial Top Measures

Rank	Measure / Technology	2024 Achievable Economic TRC Potential (thousand therms)	2050 Achievable Economic TRC Potential (thousand therms)	% of Total
1	Strategic Energy Management - Energy management system installed and programmed	4.4	65	26.6%
2	Gas Boiler - Insulate Hot Water Lines - Insulated water lines	2.1	37	14.9%
3	Gas Boiler - Stack Economizer - Economizer installed	2.1	18	7.4%
4	Insulation - Roof/Ceiling - R-38	1.7	18	7.4%
5	Gas Boiler - Insulate Steam Lines/Condensate Tank - Lines and condensate tank insulated	1.0	18	7.2%
6	Gas Boiler - Hot Water Reset - Reset control installed	0.7	16	6.7%
7	Process - Insulate Heated Process Fluids - Insulated process fluid lines	1.9	16	6.4%
8	Building Automation System - Automation system installed and programmed	0.1	15	6.1%
9	Gas Boiler - Burner Control Optimization - Optimized burner controls	0.1	10	4.2%
10	Boiler - TE 98%	0.3	8	3.1%
	Subtotal	**14**	**221**	**90%**
	Total Savings in Year	**16**	**245**	**100%**

Figure 20 - Industrial Top Measures

Appendices

APPENDIX 1: List of Abbreviations

Abbreviation	Definition
AEER	Annual Energy Efficiency Report
AEG	Applied Energy Group
AFUE	Annual Fuel Utilization Efficiency
BEE	Behavioral Energy Efficiency
BEEP	Biennial Energy Efficiency Plan
BEER	Biennial Energy Efficiency Report
BOC	Building Operator Certification
CAC	Conservation Advisory Council
CDFI	Community Development Financial Institution
CPA	Conservation Potential Assessment
DAC	Diversity Advisory Council
DHW	Domestic Hot Water
DSM	Demand-Side Management
EEAG	Energy Efficiency Advisory Group
EPS	Trademarked name used for residential new homes program
ETO	Energy Trust of Oregon
EUI	Energy Usage Index
HER	Home Energy Report
HVAC	Heating Ventilation and Air Conditioning
IOU	Investor Owned Utility
IRP	Integrated Resource Plan
NEB	Non-Energy Benefit
NEEA	Northwest Energy Efficiency Alliance
O&M	Operations and Maintenance
PUD	Public Utility District
RTF	Regional Technical Forum
SEM	Strategic Energy Management
TRC	Total Resource Cost
UCT	Utility Cost Test
WAC	Washington Administrative Code
WA-LIEE	Washington Low-Income Energy Efficiency
WSEC	Washington State Energy Code
WUTC	Washington Utility and Transportation Commission

APPENDIX 2: On-The-Bill Repayment

The Company assists in marketing a low-interest financing offer to residential homeowners who heat their homes with natural gas. The program lender will originate loans granted for the purposes of installing conservation and energy efficiency measures incented by the existing homes program. 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.

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 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 Loan Fund to natural gas ratepayers in Southwest Washington.

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 that are incented under NW Natural's existing homes program.
- Loan amounts must be no less than $2,500 and no more than %15,000.
- The term of the loan can not exceed 7 years for loans up to $7,500. 15 years is the maximum term for loans between $7,500 and $15,000.
- 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, and there is no penalty for early repayment.
- 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 pay-offs, 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 3: UES Measure List

2024 Change	PROGRAM CODE	Measure Description	Incentive per Quantity	Incremental (TRC) Cost per Quantity	Savings (kWh) per Quantity	Savings (Therms) per Quantity	Estimated Max Incentive	Other NEB (Annual $)	UCT BCR at Anticipated Incentive Level (2022 v1 AC)	TRC BCR (2022 v1 AC)	MAD #
No change	Home Retrofit - Single Family Homes	Smart Thermostat - Gas Only Territory	80	189.99	0	32.07	$134.90	$4.80	1.69	0.71	153
No change	Home Retrofit - Small Multifamily	Smart Thermostat - Gas Only Territory	80.00	189.99	$0.00	32.07	$0.00	4.8	-	-	153
Incentive change	Home Retrofit - Single Family Homes	Smart Thermostat Contractor Installed - Gas Only Territory	250	250	0	30.63	$0.00	$5.18	-	-	153
No change	Home Retrofit - Small Multifamily	Smart Thermostat Contractor Installed - Gas Only Territory	100	250	0	14.12	#N/A	$2.51	N/A	N/A	153
No change	Home Retrofit - Single Family Homes	Direct Ship Smart Thermostat Gas Only - Zero Savings	189.99	189.99	0	0	#N/A	$0.00	N/A	N/A	153
No change	Home Retrofit - Small Multifamily	Direct Ship Smart Thermostat Gas Only - Zero Savings	189.99	189.99	0	0	#N/A	$0.00	N/A	N/A	153
No change	Home Retrofit - Small Multifamily	Community Partner DI SmartStat- Gas Furnace Gas Only	150	261.36	0	14.12	$261.36	$2.51	2.18	1.25	153
No change	Home Retrofit - Single Family Homes	Community Partner DI SmartStat- Gas Furnace Gas Only	150	564.62	0	30.63	$564.62	$5.18	4.72	1.25	153
No change	Home Retrofit - Single Family Homes	Smart Thermostat Instant Coupon - Gas Only Territory	80	189.99	0	32.07	$189.99	$4.80	9.27	3.90	153

No change	Home Retrofit - Small Multifamily	Direct Ship Smart Thermostat Gas Only	189.99	189.99	0	32.07	$189.99	$4.80	3.90	3.90	153
No change	Home Retrofit - Single Family Homes	Direct Ship Smart Thermostat Gas Only	189.99	189.99	0	32.07	$189.99	$4.80	1.71	1.74	153
No change	Home Retrofit - Small Multifamily	Smart Thermostat Instant Coupon - Gas Only Territory	80	189.99	0	32.07	$189.99	$4.80	15.46	6.51	153
No change	Home Retrofit - Single Family Homes	Windows - U-Value = 0.22 GOT	1.5	5.18	0	0.08	$3.08	$0.01	2.06	0.64	28
No change	Home Retrofit - Small Multifamily	Windows - U-Value = 0.22 GOT	1.5	5.18	0	0.08	$3.08	$0.01	2.06	0.64	28
No change	Home Retrofit - Single Family Homes	Windows - U-Value 0.23-0.27 GOT	1	3.31	0	0.05	$1.93	$0.01	1.93	0.71	28
No change	Home Retrofit - Small Multifamily	Windows - U-Value 0.23-0.27 GOT	1	3.31	0	0.05	$1.93	$0.01	1.93	0.71	28
New Incentive	Home Retrofit - Single Family Homes	Windows - Metal Double Pane to U-Value = 0.22 WA GOT	10	31.05	0	0.28	$10.80	$0.04	1.08	0.37	28
New Incentive	Home Retrofit - Small Multifamily	Windows - Metal Double Pane to U-Value = 0.22 WA GOT	10	31.05	0	0.28	$10.80	$0.04	1.08	0.37	28
New Incentive	Home Retrofit - Small Multifamily	Windows - Metal Double Pane to U-Value 0.23-0.27 WA GOT	8	29.18	0	0.25	$3.45	$0.04	0.43	1.38	28
New Incentive	Home Retrofit - Single Family Homes	Windows - Metal Double Pane to U-Value 0.23-0.27 WA GOT	8	29.18	0	0.25	$3.45	$0.04	0.43	1.38	28

New Incentive	Home Retrofit - Single Family Homes	Windows - Metal Double Pane to U-Value 0.28-0.30 WA GOT	6	27.05	0	0.22	$3.03	$0.03	0.51	1.48	28
New Incentive	Home Retrofit - Small Multifamily	Windows - Metal Double Pane to U-Value 0.28-0.30 WA GOT	6	27.05	0	0.22	$3.03	$0.03	0.51	1.48	28
New Incentive	Home Retrofit - Small Multifamily	Windows - Single Pane to U-Value = 0.22 WA GOT	10	31.05	0	0.44	$6.06	$0.06	0.61	1.38	28
New Incentive	Home Retrofit - Single Family Homes	Windows - Single Pane to U-Value = 0.22 WA GOT	10	31.05	0	0.44	$6.06	$0.06	0.61	1.38	28
New Incentive	Home Retrofit - Single Family Homes	Windows - Single Pane to U-Value 0.23-0.27 WA GOT	8	29.18	0	0.41	$0.59	$0.06	0.07	0.15	28
New Incentive	Home Retrofit - Small Multifamily	Windows - Single Pane to U-Value 0.23-0.27 WA GOT	8	29.18	0	0.41	$5.90	$0.06	0.74	0.20	28
New Incentive	Home Retrofit - Small Multifamily	Windows - Single Pane to U-Value 0.28-0.30 WA GOT	6	27.05	0	0.38	$0.54	$0.05	0.09	0.24	28
New Incentive	Home Retrofit - Single Family Homes	Windows - Single Pane to U-Value 0.28-0.30 WA GOT	6	27.05	0	0.38	$14.65	$0.05	2.44	0.57	28
No change	Home Retrofit - Single Family Homes	Resideo Annual Thermostat Optimization gFAF Gas Only	12	12	0	14.72	$12.00	$3.68	47.30	47.35	217
No change	Home Retrofit - Single Family Homes	Resideo Annual Thermostat Optimization gFAF + AC Gas Only	12	12	0	14.72	$12.00	$6.01	47.30	47.35	217

No change	Home Retrofit - Single Family Homes	Resideo Annual Thermostat Optimization gFAF Gas Only Cont Group	12	13.24	0	0	$0.00	$0.00	-	0.05	217
No change	Home Retrofit - Single Family Homes	Resideo Annual Thermostat Optimization gFAF + AC Gas Only C Grp	12	13.24	0	0	$0.00	$0.00	-	1.20	217
No change	Home Retrofit - Single Family Homes	Attic Insulation/SQFT, Gas Only Heat R0-R11	1.25	1.53	0	0.11	$1.52	$0.01	1.21	11.41	58
No change	Home Retrofit - Small Multifamily	Attic Insulation/SQFT, Gas Only Heat R0-R11	1.25	1.53	0	0.11	$0.16	$0.01	0.13	2.50	58
No change	Home Retrofit - Single Family Homes	Attic Insulation/SQFT, Gas Only Heat R12-R18	1.25	1.53	0	0.06	$1.39	$0.01	1.11	0.91	58
No change	Home Retrofit - Small Multifamily	Floor Insulation/SQFT, Gas Only Heat	1.25	2.01	0	0.09	$2.01	$0.02	1.67	1.04	58
No change	Home Retrofit - Single Family Homes	Floor Insulation/SQFT, Gas Only Heat	1.25	2.01	0	0.09	$2.01	$0.02	2.00	18.39	58
No change	Home Retrofit - Small Multifamily	Wall Insulation, Gas Heat, Gas Only	1.25	2.78	0	0.08	$2.22	$0.01	1.78	13.20	58
No change	Home Retrofit - Single Family Homes	Wall Insulation, Gas Heat, Gas Only	1.25	2.78	0	0.08	$2.22	$0.01	1.78	13.20	58
Incentive and savings change	Home Retrofit - Small Multifamily	Gas Furnace - Community Partner Funded	1600	1630	0	112.6	$1,630.00	$0.00	1.95	1.94	23

Savings change	Home Retrofit - Small Multifamily	Gas Furnace SW WA 95%+ AFUE	650	1630	0	112.6	$1,630.00	$0.00	4.81	1.94	23
Savings change	Home Retrofit - Single Family Homes	Gas Furnace SW WA 95%+ AFUE	650	1630	0	112.6	$1,630.00	$0.00	4.81	1.94	23
Incentive and savings change	Home Retrofit - Single Family Homes	Gas Furnace- WA Rentals	1600	1607.32	0	91.81	$1,607.32	$2.16	2.21	2.44	23
Incentive and savings change	Home Retrofit - Small Multifamily	Gas Furnace- WA Rentals	1600	1607.32	0	91.81	$1,265.47	$2.16	0.79	0.81	23
Savings change	Home Retrofit - Single Family Homes	Gas Hearth 75+ FE w/ ele ignition	250	0.01	0	23.22	$0.01	$0.00	1.28	34,042.38	29
Savings change	Home Retrofit - Small Multifamily	Gas Hearth 75+ FE w/ ele ignition	250	0.01	0	23.22	$0.01	$0.00	3.58	89,553.29	29
Savings change	Home Retrofit - Single Family Homes	Gas Hearth 70-74 FE w/ ele ignition	150	0.01	0	15.36	$0.01	$0.00	3.95	59,246.63	29
Savings change	Home Retrofit - Small Multifamily	Gas Hearth 70-74 FE w/ ele ignition	150	0.01	0	15.36	$0.01	$0.00	3.95	59,246.63	29
Discontinued	Retail	Gas hearth–electronic ignition $25, retailer/distributor incent	25	105	0	7.41	$105.00	$0.00	11.43	2.72	29
Discontinued	Retail	Gas hearth–electronic ignition $30, retailer/distributor incent	30	105	0	7.41	$105.00	$0.00	9.52	2.72	29

New Incentive (draft MAD)	Home Retrofit - Single Family Homes	TBD	0	0.01	0	15	$0.01	$0.52	N/A	57,858.54	197
New Incentive (draft MAD)	Home Retrofit - Small Multifamily	TBD	0	0.01	0	15	$0.01	$0.52	N/A	57,837.14	197
Savings change (draft MAD)	Home Retrofit - Small Multifamily	Gas Tankless Water Heater	400	1025.17	0	61	$1,025.17	-$1.84	5.88	2.29	197
Savings change (draft MAD)	Home Retrofit - Small Multifamily	Gas Tankless Water Heater w gas line upgrade	400	2225.17	0	61	$2,225.17	-$1.84	5.88	1.06	197
Savings change (draft MAD)	Home Retrofit - Single Family Homes	Gas Tankless Water Heater w gas line upgrade	400	1025.17	0	61	$1,025.17	-$1.84	5.88	2.29	197
Savings change (draft MAD)	Home Retrofit - Single Family Homes	Gas Tankless Water Heater	400	2225.17	0	61	$2,225.17	-$1.84	5.88	1.06	197
New Incentive (draft MAD)	Home Retrofit - Small Multifamily	Gas Tankless Water Heater - w/ cofunding	TBD	1402.98	0	66	$533.62	$243.90	N/A	0.68	197
New Incentive (draft MAD)	Home Retrofit - Small Multifamily	Gas Tankless Water Heater - w/ cofunding	TBD	1402.98	0	66	$533.62	$243.90	N/A	0.66	197
No change	Home Retrofit - Small Multifamily	Community Partner Funded Home Audit	250	0	0	0	$0.00	$0.00	-	N/A	0

No change	Home Retrofit - Single Family Homes	Community Partner Funded Home Audit	250	0	0	0	$0.00	$0.00	-	N/A		0
No change	Home Retrofit - Single Family Homes	Market Transformation Thermostat Optimization - Gas Heat	0	0	0	0	$0.00	$0.00	N/A	N/A		0
No change	EPS New Construction	New Homes Code Creds	1,103.50	1,104.00	0	34.28	$0.00		-	-		267
No change	EPS New Construction	New Homes gas fireplace	251.81	1.00	0	18.3	$0.00		-	-		267
No change	EPS New Construction	New Homes T-STATs	125.00	125.00	0	14.1	$0.00		-	-		267
No change	EPS New Construction	SW WA EPS Path 1 - 2018	$467.60	$ 949.00	0	79.9	$949.00	$13.18	5.79	1.85		145
No change	EPS New Construction	SW WA EPS Path 2 - 2018	$952.55	$ 2,463.00	0	142.1	$2,463.00	$14.88	5.41	1.27		145
No change	EPS New Construction	SW WA EPS Path 3 - 2018	$1,143.67	$ 6,437.00	0	258.2	$5,278.50	$52.36	8.47	0.99		145
No change	EPS New Construction	SW WA EPS Path 4 - 2018	$1,440.00	$ 8,519.00	0	293	$6,035.48	$53.90	7.71	0.84		145

Commercial Existing Buildings New Or Updated MADs for 2024 for Washinghton:

Data Taken From MADs in October 2023

MAD ID	Measure Application	Savings (therms/yr)	Max Incentive	Starts	Expires
201	Refrigeration Case w/ Door - remote condensing, vertical med temp - Gas Heat	66.40	$293.82	1/1/2024	12/31/2026
201	Refrigeration Case w/ Door - remote condensing, horizontal med temp - Gas Heat	25.68	$293.82	1/1/2024	12/31/2026
201	Refrigeration Case w/ Door - remote condensing, horizontal low temp - Gas Heat	15.91	$293.82	1/1/2024	12/31/2026
256	ARC-full gas heat - 500 to 1500 hrs	15.20	$425.70	1/1/2024	12/31/2026
256	ARC-full gas heat - 1500 to 2500 hrs	15.20	$425.70	1/1/2024	12/31/2026
256	ARC-full gas heat - 2500 to 3500 hrs	15.20	$425.70	1/1/2024	12/31/2026
256	ARC-full gas heat - 3500 to 4500 hrs	15.20	$425.70	1/1/2024	12/31/2026
256	ARC-full gas heat - 4500 to 5500 hrs	15.20	$425.70	1/1/2024	12/31/2026
256	ARC-full gas heat - 5500 to 6500 hrs	15.20	$425.70	1/1/2024	12/31/2026
256	ARC-full gas heat - 6500 to 7500 hrs	15.20	$425.70	1/1/2024	12/31/2026
256	ARC-full gas heat - 7500 to 8760 hrs	15.20	$425.70	1/1/2024	12/31/2026
265	Outdoor Pool Cover -Non-Condensing Gas Heater	2.77	$6.51	1/1/2024	12/31/2026
265	Outdoor Pool Cover - Condensing Gas Heater	2.37	$6.51	1/1/2024	12/31/2026
265	Indoor Pool Cover - Non-Condensing Gas Heater	2.09	$6.51	1/1/2024	12/31/2026
265	Indoor Pool Cover - Condensing Gas Heater	1.78	$6.51	1/1/2024	12/31/2026
212	CTWH - Restaurant <200 kBtu/h	8.18	$140.21	7/1/2023	12/31/2025
212	CTWH - Motel <200 kBtu/h	14.46	$140.21	7/1/2023	12/31/2025
212	CTWH - School <200 kBtu/h	19.33	$140.21	7/1/2023	12/31/2025
212	CTWH - Coin-op Laundry <200 kBtu/h	47.12	$140.21	7/1/2023	12/31/2025
212	CTWH - Gym <200 kBtu/h	21.90	$140.21	7/1/2023	12/31/2025
212	CTWH - All Commercial	15.51	$140.21	7/1/2023	12/31/2025
21	Office - Condensing Tank WH	0.94	$3.69	7/1/2023	12/31/2025
21	Schools- Condensing Tank WH	0.93	$3.75	7/1/2023	12/31/2025
21	Healthcare - Condensing Tank WH	0.63	$3.73	7/1/2023	12/31/2025
21	Hotel - Condensing Tank WH	1.90	$3.78	7/1/2023	12/31/2025
21	Restaurant - Condensing Tank WH	1.84	$3.68	7/1/2023	12/31/2025
21	Multifamily - Condensing Tank WH	1.44	$3.79	7/1/2023	12/31/2025

21	Gym/Fitness Center - Condensing Tank WH	0.43	$3.80	7/1/2023	12/31/2025
21	Coin-op Laundry - Condensing Tank WH	0.87	$3.81	7/1/2023	12/31/2025
21	All Commercial - Condensing Tank WH	1.11	$3.76	7/1/2023	12/31/2025
42	Steam Trap Replacement (all trap sizes) - Multifamily Space Heating- Operating Pressure <5 psig	116.68	$491.21	7/1/2023	12/31/2025
42	Steam Trap Replacement (all trap sizes) - Commercial Space Heating - Operating Pressure < 30 psig	331.79	$549.22	7/1/2023	12/31/2025
42	Steam Trap Replacement (all trap sizes) - Commercial Space Heating - Operating Pressure ≥ 30 psig and ≤ 50 psig	697.80	$576.96	7/1/2023	12/31/2025
42	Steam Trap Replacement (all trap sizes) - Dry Cleaners (no test report required) - Operating Pressure ≥ 75 psig and ≤ 125 psig	211.14	$376.96	7/1/2023	12/31/2025
42	Steam Trap Replacement (all trap sizes) - Commercial Space Heating (High Use) - Operating Pressure < 30 psig	654.86	$549.22	7/1/2023	12/31/2025
42	Steam Trap Replacement (all trap sizes) - Commercial Space Heating (High Use) - Operating Pressure ≥ 30 psig and ≤ 50 psig	1,377.23	$576.96	7/1/2023	12/31/2025
42	Steam Trap Repair (for trap size ≤ 1/2") - Multifamily Space Heating- Operating Pressure <5 psig	116.68	$491.21	7/1/2023	12/31/2025
42	Steam Trap Repair (for trap size ≤ 1/2") - Commercial Space Heating - Operating Pressure < 30 psig	331.79	$549.22	7/1/2023	12/31/2025
42	Steam Trap Repair (for trap size ≤ 1/2") - Commercial Space Heating - Operating Pressure ≥ 30 psig and ≤ 50 psig	697.80	$576.96	7/1/2023	12/31/2025
42	Steam Trap Repair (for trap size ≤ 1/2") - Commercial Space Heating (High Use) - Operating Pressure < 30 psig	654.86	$549.22	7/1/2023	12/31/2025
42	Steam Trap Repair (for trap size ≤ 1/2") - Commercial Space Heating (High Use) - Operating Pressure ≥ 30 psig and ≤ 50 psig	1,377.23	$576.96	7/1/2023	12/31/2025
42	Steam Trap Repair (for trap size ≥ 3/4") - Multifamily Space Heating- Operating Pressure <5 psig	116.68	$366.21	7/1/2023	12/31/2025
42	Steam Trap Repair (for trap size ≥ 3/4") - Commercial Space Heating - Operating Pressure < 30 psig	331.79	$424.22	7/1/2023	12/31/2025

42	Steam Trap Repair (for trap size ≥ 3/4") - Commercial Space Heating - Operating Pressure ≥ 30 psig and ≤ 50 psig	697.80	$451.96	7/1/2023	12/31/2025
42	Steam Trap Repair (for trap size ≥ 3/4") - Commercial Space Heating (High Use) - Operating Pressure < 30 psig	654.86	$424.22	7/1/2023	12/31/2025
42	Steam Trap Repair (for trap size ≥ 3/4") - Commercial Space Heating (High Use) - Operating Pressure ≥ 30 psig and ≤ 50 psig	1,377.23	$451.96	7/1/2023	12/31/2025
101	Rack Oven - Gas - Single	129.99	$2,273.15	7/1/2023	12/31/2025
101	Rack Oven – Gas - Double	218.44	$2,079.78	7/1/2023	12/31/2025
101	Convection Oven - Gas - Full-size	62.15	$798.04	7/1/2023	12/31/2025
101	Combination Oven – Gas	207.91	$3,425.02	7/1/2023	12/31/2025
101	Steam Cookers - Gas	555.32	$3,400.00	7/1/2023	12/31/2025
101	Conveyor Broilers with belt width < 20”	1,145.29	$2,523.03	7/1/2023	12/31/2025
101	Conveyor Broilers with belt width 20” - 26”	1,932.84	$3,145.87	7/1/2023	12/31/2025
101	Conveyor Broilers with belt width > 26”	3,161.26	$3,658.65	7/1/2023	12/31/2025
80	Ozone Laundry System - less than 75 lbs laundry capacity - Gas WH	2,232.29	$10,092.68	1/1/2024	12/31/2026
80	Ozone Laundry System - 75 to 125 lbs laundry capacity - Gas WH	4,464.57	$13,479.48	1/1/2024	12/31/2026
80	Ozone Laundry System - 126 to 400 lbs laundry capacity	11,719.50	$25,433.87	1/1/2024	12/31/2026
80	Ozone Laundry System - 401 to 600 lbs laundry capacity	22,322.85	$39,816.22	1/1/2024	12/31/2026
80	Ozone Laundry System - more than 600 lbs laundry capacity	31,251.99	$47,957.66	1/1/2024	12/31/2026
291	Two-stage Gas Valve on Clothes Dryers in Multifamily Buildings	24.67	$260.80	1/1/2024	12/31/2026
291	Two-stage Gas Valve on Clothes Dryers in Coin-Operated Laundromats	52.61	$556.11	1/1/2024	12/31/2026
291	Two-stage Gas Valve on Clothes Dryers in On-Premises Laundries	351.82	$875.00	1/1/2024	12/31/2026
235	Smart Thermostat Grocery - Gas Heat w/ Cooling (HZ1)	88.59	$599.00	5/25/2023	12/31/2025
235	Smart Thermostat Grocery - Gas Heat NO Cooling (HZ1)	88.59	$599.00	5/25/2023	12/31/2025

235	Smart Thermostat Non-Grocery - Gas Heat w/ Cooling (HZ1)	30.98	$599.00	5/25/2023	12/31/2025	
235	Smart Thermostat Non-Grocery - Gas Heat NO Cooling (HZ1)	30.98	$599.00	5/25/2023	12/31/2025	
235	Smart Thermostat Grocery - Gas Heat w/ Cooling (HZ2)	98.58	$599.00	5/25/2023	12/31/2025	
235	Smart Thermostat Grocery - Gas Heat NO Cooling (HZ2)	98.58	$599.00	5/25/2023	12/31/2025	
235	Smart Thermostat Non-Grocery - Gas Heat w/ Cooling (HZ2)	44.52	$599.00	5/25/2023	12/31/2025	
235	Smart Thermostat Non-Grocery - Gas Heat NO Cooling (HZ2)	44.52	$599.00	5/25/2023	12/31/2025	
89	MF Commercial Washer Ele Dryer Gas WH Tier 1	8.53	$98.09	1/1/2024	12/31/2026	
89	MF Commercial Washer Ele Dryer Gas WH Tier 2	12.10	$139.18	1/1/2024	12/31/2026	
89	MF Commercial Washer Gas Dryer Ele WH Tier 1	15.37	$176.73	1/1/2024	12/31/2026	
89	MF Commercial Washer Gas Dryer Ele WH Tier 2	20.71	$238.11	1/1/2024	12/31/2026	
89	MF Commercial Washer Gas Dryer Gas WH Tier 1	23.90	$274.82	1/1/2024	12/31/2026	
89	MF Commercial Washer Gas Dryer Gas WH Tier 2	32.81	$377.29	1/1/2024	12/31/2026	
89	Commercial Washer Ele Dryer Gas WH Tier 1	11.66	$89.24	1/1/2024	12/31/2026	
89	Commercial Washer Ele Dryer Gas WH Tier 2	16.55	$126.62	1/1/2024	12/31/2026	
89	Commercial Washer Gas Dryer Ele WH Tier 1	21.01	$160.79	1/1/2024	12/31/2026	
89	Commercial Washer Gas Dryer Ele WH Tier 2	28.31	$216.63	1/1/2024	12/31/2026	
89	Commercial Washer Gas Dryer Gas WH Tier 1	32.67	$250.03	1/1/2024	12/31/2026	
89	Commercial Washer Gas Dryer Gas WH Tier 2	44.86	$343.25	1/1/2024	12/31/2026	
29	Gas Hearth 70-74 FE w/ ele ignition	15.36	$150.00	1/1/2024	12/31/2026	These are Residential MADs with Commercial applicability
29	Gas Hearth 75+ FE w/ ele ignition	23.22	$250.00	1/1/2024	12/31/2026	These are Residential MADs with Commercial applicability
29	New Home Gas Hearth 70+ FE w/ ele ignition	16.68	$200.00	1/1/2024	12/31/2026	These are Residential MADs with Commercial applicability

All Other Commercial Existing Buildings Active MADs for Washinghton (neither new nor updated for 2024):

Data Taken From MADs in October 2023

MAD ID	Measure Application	Savings (therms/yr)	Max Incentive	Starts	Expires
28	Windows - U-Value ≤ 0.22 WA GOT	0.08	$3.58	1/1/2023	12/31/2025
28	Windows - U-Value 0.23-0.27 WA GOT	0.05	$2.27	1/1/2023	12/31/2025
28	Windows - U-Value 0.28-0.30 WA GOT	0.02	$0.80	1/1/2023	12/31/2025
28	Windows - Metal Double Pane to U-Value ≤ 0.22 WA GOT	0.28	$12.30	1/1/2023	12/31/2025
28	Windows - Metal Double Pane to U-Value 0.23-0.27 WA GOT	0.25	$10.99	1/1/2023	12/31/2025
28	Windows - Metal Double Pane to U-Value 0.28-0.30 WA GOT	0.22	$9.52	1/1/2023	12/31/2025
28	Windows - Single Pane to U-Value ≤ 0.22 WA GOT	0.44	$19.48	1/1/2023	12/31/2025
28	Windows - Single Pane to U-Value 0.23-0.27 WA GOT	0.41	$18.24	1/1/2023	12/31/2025
28	Windows - Single Pane to U-Value 0.28-0.30 WA GOT	0.38	$16.82	1/1/2023	12/31/2025
58	Wall Insulation R0-R4 Gas Heat SF/SMF	0.08	$2.78	1/1/2023	12/31/2025
58	Floor Insulation R0-R11 Gas Heat SF/SMF	0.09	$2.01	1/1/2023	12/31/2025
58	Attic Insulation R0-R11 Gas Heat SF/SMF	0.11	$1.53	1/1/2023	12/31/2025
58	Attic Insulation R12-R18 Gas Heat SF/SMF	0.06	$1.53	1/1/2023	12/31/2025
58	Floor Insulation R0-R11 Gas Heat XMH	0.04	$1.96	1/1/2023	12/31/2025
58	Attic Insulation R0-R11 Gas Heat XMH	0.04	$1.53	1/1/2023	12/31/2025
58	Attic Insulation R12-R18 Gas Heat XMH	0.02	$0.70	1/1/2023	12/31/2025
153	Smart Thermostat- SF & MH- Direct/ Contractor Install- gFAF	30.63	$250.00	1/1/2023	12/31/2025
153	Smart Thermostat- Multifamily- Direct/Contractor Install- gFAF	14.12	$239.12	1/1/2023	12/31/2025
153	Smart Thermostat- Retail/Online- gFAF	32.07	$189.99	1/1/2023	12/31/2025
153	Smart Thermostat- New Homes- gFAF	21.74	$250.00	1/1/2023	12/31/2025
153	Smart Thermostat- SF & MH- Direct/ Contractor Install- gFAF- with Co-Funding	30.63	$518.81	1/1/2023	12/31/2025
153	Smart Thermostat- Multifamily- Direct/ Contractor Install- gFAF- with Co-Funding	14.12	$239.12	1/1/2023	12/31/2025
153	Smart Thermostat- Retail/ Online- gFAF- with Co-Funding	32.07	$543.14	1/1/2023	12/31/2025

153	Smart Thermostat- New Homes- gFAF- with Co-Funding	21.74	$368.20	1/1/2023	12/31/2025
203	Furnace, 91%, Multifamily	1.34	$8.43	1/1/2023	12/31/2025
203	Furnace, 95%, Multifamily	1.83	11.35	1/1/2023	12/31/2025
203	Furnace, 98%, Multifamily	2.20	14.90	1/1/2023	12/31/2025
203	Incremental, 91% to 95%	0.49	2.92	1/1/2023	12/31/2025
203	Incremental, 91% to 98%	0.86	$6.47	1/1/2023	12/31/2025
203	Incremental, 95% to 98%	0.37	$3.55	1/1/2023	12/31/2025
171	Single Pane Window to 0.22 < U value ≤ 0.30 Window HZ1 Gas heating	1.15	$24.70	1/1/2023	12/31/2025
171	Single Pane Window to 0.22 < U value ≤ 0.30 Window HZ2 Gas heating	1.51	$24.70	1/1/2023	12/31/2025
171	Single Pane Window to U value ≤ 0.22 Window HZ1 Gas heating	1.27	$28.60	1/1/2023	12/31/2025
171	Single Pane Window to U value ≤ 0.22 Window HZ2 Gas heating	1.68	$28.60	1/1/2023	12/31/2025
171	Storm Window for Single Pane Window (Non-metal Frame) HZ1 Gas heating	0.92	$10.46	1/1/2023	12/31/2025
171	Storm Window for Single Pane Window (Non-metal Frame) HZ2 Gas heating	1.22	$10.46	1/1/2023	12/31/2025
171	Storm Window for Single Pane Window (Metal Frame) HZ1 Gas heating	1.18	$10.46	1/1/2023	12/31/2025
171	Storm Window for Single Pane Window (Metal Frame) HZ2 Gas heating	1.55	$10.46	1/1/2023	12/31/2025
171	Double Pane Window to 0.22 < U value ≤ 0.30 Window HZ1 Gas	0.62	$24.70	1/1/2023	12/31/2025
171	Double Pane Window to 0.22 < U value ≤ 0.30 Window HZ2 Gas	0.83	$24.70	1/1/2023	12/31/2025
171	Double Pane Window to U value ≤ 0.22 Window HZ1 Gas	0.75	$28.60	1/1/2023	12/31/2025
171	Double Pane Window to U value ≤ 0.22 Window HZ2 Gas	1.00	$28.60	1/1/2023	12/31/2025
171	Storm Window for Double Pane Window (Metal Frame) HZ1 Gas	0.60	$10.46	1/1/2023	12/31/2025
171	Storm Window for Double Pane Window (Metal Frame) HZ2 Gas	0.80	$10.46	1/1/2023	12/31/2025
110	MF Attic Insulation R11 or less - R49 HZ1 Gas Heat	0.05	$1.41	1/1/2023	12/31/2025

110	MF Floor Insulation R11 or less - R30 HZ1 Gas Heat	0.06	$1.90	1/1/2023	12/31/2025
110	MF Wall Insulation R6 or less - R11 HZ1 Gas Heat	0.10	$2.24	1/1/2023	12/31/2025
110	MF Attic Insulation R11 or less - R49 HZ2 Gas Heat	0.05	$1.41	1/1/2023	12/31/2025
110	MF Floor Insulation R11 or less - R30 HZ2 Gas Heat	0.08	$1.90	1/1/2023	12/31/2025
110	MF Wall Insulation R6 or less - R11 HZ2 Gas Heat	0.13	$2.24	1/1/2023	12/31/2025
104	IR Poly Film (per SF of film)	0.23	$0.08	1/1/2023	12/31/2025
104	Thermal Curtain (per SF floor space)	0.41	$1.15	1/1/2023	12/31/2025
104	Under Bench Heating (per SF floor space)	1.25	$2.19	1/1/2023	12/31/2025
68	HZ1 - Roof Insulation - R5 or less to R30 - gas heat - gas only	0.09	$2.85	1/1/2023	12/31/2025
68	HZ2/HZ3 - Roof Insulation - R5 or less to R30 - gas heat - gas only	0.15	$2.85	1/1/2023	12/31/2025
68	HZ1 - Roof Insulation - R0 to R15 - gas heat - gas only	0.43	$2.85	1/1/2023	12/31/2025
68	HZ2/HZ3 - Roof Insulation - R0 to R15 - gas heat - gas only	0.66	$2.85	1/1/2023	12/31/2025
68	HZ1 - Roof Insulation - R0 to R30 - gas heat - gas only	0.51	$2.85	1/1/2023	12/31/2025
68	HZ2/HZ3 - Roof Insulation - R0 to R30 - gas heat - gas only	0.76	$2.85	1/1/2023	12/31/2025
68	HZ1 - Attic Insulation - R9 or less to R25 - gas heat - gas only	0.14	$1.28	1/1/2023	12/31/2025
68	HZ2/HZ3 - Attic Insulation - R9 or less to R25 - gas heat - gas only	0.25	$1.28	1/1/2023	12/31/2025
68	HZ1 - Wall Insulation - R6 or less to R20 - gas heat - gas only	0.19	$1.61	1/1/2023	12/31/2025
68	HZ2/HZ3 - Wall Insulation - R6 or less to R20 - gas heat - gas only	0.31	$1.61	1/1/2023	12/31/2025
103	Greenhouse Controller Weighted Average Size/Schedule	0.29	$0.44	1/1/2023	12/31/2025
134	Condensing Unit Heater in Greenhouses	6.29	$13.90	1/1/2023	12/31/2025
91	Commercial DHW 1" pipe insulated to 1.5"	2.11	$18.41	1/1/2023	12/31/2025
91	Commercial DHW 2" pipe insulated to 2.0"	3.68	$25.49	1/1/2023	12/31/2025
91	Commercial DHW 3" pipe insulated to 2.0"	5.22	$31.47	1/1/2023	12/31/2025
91	Commercial DHW 4" pipe insulated to 2.0"	6.53	$37.46	1/1/2023	12/31/2025
91	Commercial HHW 1" pipe insulated to 1.5"	2.68	$33.48	1/1/2023	12/31/2025
91	Commercial HHW 2" pipe insulated to 2.0"	4.65	$40.56	1/1/2023	12/31/2025
91	Commercial HHW 3" pipe insulated to 2.0"	6.57	$46.54	1/1/2023	12/31/2025

91	Commercial HHW 4" pipe insulated to 2.0"	8.22	$52.53	1/1/2023	12/31/2025
91	Commercial LPS 1" pipe insulated to 1.5"	4.49	$33.48	1/1/2023	12/31/2025
91	Commercial LPS 2" pipe insulated to 2.0"	7.81	$40.56	1/1/2023	12/31/2025
91	Commercial LPS 3" pipe insulated to 2.0"	11.01	$46.54	1/1/2023	12/31/2025
91	Commercial LPS 4" pipe insulated to 2.0"	13.78	$52.53	1/1/2023	12/31/2025
91	Commercial MPS 1" pipe insulated to 2.0"	4.63	$33.48	1/1/2023	12/31/2025
91	Commercial MPS 2" pipe insulated to 2.5"	8.01	$40.56	1/1/2023	12/31/2025
91	Commercial MPS 3" pipe insulated to 2.5"	11.29	$46.54	1/1/2023	12/31/2025
91	Commercial MPS 4" pipe insulated to 2.5"	14.13	$52.53	1/1/2023	12/31/2025
91	Industrial LPS 0.5-1" pipe insulated to 1.5"	12.51	$33.03	1/1/2023	12/31/2025
91	Industrial LPS 1.25-1.5" pipe insulated to 1.5"	17.47	$35.72	1/1/2023	12/31/2025
91	Industrial LPS 2.0-2.5" pipe insulated to 2.0"	25.26	$42.05	1/1/2023	12/31/2025
91	Industrial LPS 2.5-3.5" pipe Insulated to 2.0"	34.68	$48.04	1/1/2023	12/31/2025
91	Industrial LPS 4-6" pipe Insulated to 2.0"	49.21	$58.51	1/1/2023	12/31/2025
91	Industrial LPS 8-10" pipe Insulated to 2.0"	80.56	$82.46	1/1/2023	12/31/2025
91	Industrial MPS 0.5-1" pipe insulated to 2.0"	21.14	$33.03	1/1/2023	12/31/2025
91	Industrial MPS 1.25-1.5" pipe insulated to 2.0"	29.54	$35.72	1/1/2023	12/31/2025
91	Industrial MPS 2.0-2.5" pipe insulated to 2.5"	42.34	$42.05	1/1/2023	12/31/2025
91	Industrial MPS 2.5-3.5" pipe insulated to 2.5"	58.14	$48.04	1/1/2023	12/31/2025
91	Industrial MPS 4-6" pipe insulated to 2.5"	82.56	$58.51	1/1/2023	12/31/2025
91	Industrial MPS 8-10" pipe insulated to 2.5"	135.22	$82.46	1/1/2023	12/31/2025
91	Industrial PHW 0.5-1" pipe insulated to 1.5"	7.36	$33.03	1/1/2023	12/31/2025
91	Industrial PHW 1.25-1.5" pipe insulated to 1.5"	10.20	$35.72	1/1/2023	12/31/2025
91	Industrial PHW 2.0-2.5" pipe insulated to 2.0"	14.72	$42.05	1/1/2023	12/31/2025
91	Industrial PHW 2.5-3.5" pipe insulated to 2.0"	20.24	$48.04	1/1/2023	12/31/2025
91	Industrial PHW 4-6" pipe insulated to 2.0"	28.76	$58.51	1/1/2023	12/31/2025
91	Industrial PHW 8-10" pipe insulated to 2.0"	47.40	$82.46	1/1/2023	12/31/2025
72	Large Office - CTWH ≥200 kBtu/h	0.44	$1.42	1/1/2023	12/31/2025
72	School - CTHW ≥200 kBtu/h	0.28	$1.42	1/1/2023	12/31/2025
72	Healthcare - CTWH ≥200 kBtu/h	0.14	$1.42	1/1/2023	12/31/2025
72	Hotel - CTWH ≥200 kBtu/h	0.21	$1.44	1/1/2023	12/31/2025
72	Restaurant - CTWH ≥200 kBtu/h	0.15	$1.43	1/1/2023	12/31/2025
72	Multifamily - CTWH ≥200 kBtu/h	0.42	$1.43	1/1/2023	12/31/2025
72	Commercial Gym - CTWH ≥200 kBtu/h	0.31	$1.42	1/1/2023	12/31/2025

72	Coin-op Laundry - CTWH ≥200 kBtu/h	0.67	$1.43	1/1/2023	12/31/2025
72	All Commercial - CTWH ≥200 kBtu/h	0.28	$1.43	1/1/2023	12/31/2025
196	Multifamily - Condensing Tankless Water Heater <200 kBtu/h	25.67	$140.21	1/1/2023	12/31/2025
238	Non-condensing heater – uncovered, indoor pool	0.21	$1.04	1/1/2023	12/31/2025
238	Non-condensing heater – uncovered, outdoor pool	0.38	$1.04	1/1/2023	12/31/2025
238	Non-condensing heater – covered, indoor pool	0.12	$0.98	1/1/2023	12/31/2025
238	Non-condensing heater - covered, outdoor pool	0.25	$1.04	1/1/2023	12/31/2025
238	Condensing heater – uncovered, indoor pool	0.70	$5.51	1/1/2023	12/31/2025
238	Condensing heater – uncovered, outdoor pool	1.29	$8.78	1/1/2023	12/31/2025
238	Condensing heater – covered, indoor pool	0.42	$3.27	1/1/2023	12/31/2025
238	Condensing heater – covered, outdoor pool	0.85	$6.69	1/1/2023	12/31/2025
111	3/4" DHW MF pipe insulated to 1.5"	2.27	$16.91	1/1/2023	12/31/2025
111	1" DHW MF pipe insulated to 1.5"	2.79	$18.41	1/1/2023	12/31/2025
111	2" DHW MF pipe insulated to 2"	4.87	$25.49	1/1/2023	12/31/2025
111	3" DHW MF pipe insulated to 2"	6.88	$31.47	1/1/2023	12/31/2025
111	4" DHW MF pipe insulated to 2"	8.61	$37.46	1/1/2023	12/31/2025
111	3/4" LPS (<15 psig) MF pipe insulated to 1.5"	1.73	$31.98	1/1/2023	12/31/2025
111	1" LPS (<15 psig) MF pipe insulated to 1.5"	2.12	$33.48	1/1/2023	12/31/2025
111	2" LPS (<15 psig) MF pipe insulated to 2"	3.69	$40.56	1/1/2023	12/31/2025
111	3" LPS (<15 psig) MF pipe insulated to 2"	5.19	$46.54	1/1/2023	12/31/2025
111	4" LPS (<15 psig) MF pipe insulated to 2"	6.49	$52.53	1/1/2023	12/31/2025
111	3/4" HHW MF pipe insulated to 1.5"	1.05	$22.84	1/1/2023	12/31/2025
111	1" HHW MF pipe insulated to 1.5"	1.28	$27.98	1/1/2023	12/31/2025
111	2" HHW MF pipe insulated to 2"	2.22	$40.56	1/1/2023	12/31/2025
111	3" HHW MF pipe insulated to 2"	3.13	$46.54	1/1/2023	12/31/2025
111	4" HHW MF pipe insulated to 2"	3.91	$52.53	1/1/2023	12/31/2025
66	GAS TEMP 1 1/4 HP Gas-Only	91.74	$897.17	1/1/2023	12/31/2025
66	GAS TEMP 1 3/4 HP Gas-Only	91.74	$1,112.46	1/1/2023	12/31/2025
66	GAS TEMP 1/2 HP Gas-Only	91.74	$944.09	1/1/2023	12/31/2025
66	GAS TEMP 1/4 HP Gas-Only	76.45	$927.05	1/1/2023	12/31/2025
66	GAS TEMP 1/6 HP Gas-Only	60.36	$731.86	1/1/2023	12/31/2025
66	GAS TEMP 1/8 HP Gas-Only	30.18	$224.80	1/1/2023	12/31/2025
66	GAS TEMP 2 HP Gas-Only	91.74	$1,112.46	1/1/2023	12/31/2025

66	GAS TEMP 3 1/2 HP Gas-Only	91.74	$1,112.46	1/1/2023	12/31/2025
66	GAS TEMP 3/4 HP Gas-Only	91.74	$920.63	1/1/2023	12/31/2025
66	GAS TEMP 4 1/2 HP Gas-Only	91.74	$1,112.46	1/1/2023	12/31/2025
66	GAS TEMP 5 HP Gas-Only	91.74	$1,112.46	1/1/2023	12/31/2025
66	GAS COMB 1 1/4 HP Gas-Only	430.04	$2,017.00	1/1/2023	12/31/2025
66	GAS COMB 1 3/4 HP Gas-Only	430.04	$2,619.47	1/1/2023	12/31/2025
66	GAS COMB 1/2 HP Gas-Only	430.04	$2,063.91	1/1/2023	12/31/2025
66	GAS COMB 1/4 HP Gas-Only	358.36	$2,087.37	1/1/2023	12/31/2025
66	GAS COMB 1/6 HP Gas-Only	282.91	$2,095.19	1/1/2023	12/31/2025
66	GAS COMB 1/8 HP Gas-Only	141.46	$455.49	1/1/2023	12/31/2025
66	GAS COMB 2 HP Gas-Only	430.04	$3,221.95	1/1/2023	12/31/2025
66	GAS COMB 3 1/2 HP Gas-Only	430.04	$4,426.90	1/1/2023	12/31/2025
66	GAS COMB 3/4 HP Gas-Only	430.04	$2,040.46	1/1/2023	12/31/2025
66	GAS COMB 4 1/2 HP Gas-Only	430.04	$5,214.56	1/1/2023	12/31/2025
66	GAS COMB 5 HP Gas-Only	430.04	$5,214.56	1/1/2023	12/31/2025
66	GAS LRN 1 1/4 HP Gas-Only	260.89	$897.17	1/1/2023	12/31/2025
66	GAS LRN 1 3/4 HP Gas-Only	260.89	$1,219.69	1/1/2023	12/31/2025
66	GAS LRN 1/2 HP Gas-Only	260.89	$944.09	1/1/2023	12/31/2025
66	GAS LRN 1/4 HP Gas-Only	217.41	$967.55	1/1/2023	12/31/2025
66	GAS LRN 1/6 HP Gas-Only	171.63	$975.37	1/1/2023	12/31/2025
66	GAS LRN 1/8 HP Gas-Only	85.82	$334.55	1/1/2023	12/31/2025
66	GAS LRN 2 HP Gas-Only	260.89	$1,542.21	1/1/2023	12/31/2025
66	GAS LRN 3 1/2 HP Gas-Only	260.89	$2,187.25	1/1/2023	12/31/2025
66	GAS LRN 3/4 HP Gas-Only	260.89	$920.63	1/1/2023	12/31/2025
66	GAS LRN 4 1/2 HP Gas-Only	260.89	$2,832.29	1/1/2023	12/31/2025
66	GAS LRN 5 HP Gas-Only	260.89	$3,163.51	1/1/2023	12/31/2025
122	DCKV – gas heat -gas only	142.00	$2,187.50	1/1/2023	12/31/2025
88	Condensing Boiler - Multifamily	1.16	$6.64	1/1/2023	12/31/2025
88	Condensing Boiler - Healthcare	2.67	$6.64	1/1/2023	12/31/2025
88	Condensing Boiler - Office	0.80	$6.64	1/1/2023	12/31/2025
88	Condensing Boiler - Restaurant	1.33	$6.64	1/1/2023	12/31/2025
88	Condensing Boiler - Retail	1.19	$6.64	1/1/2023	12/31/2025
88	Condensing Boiler - School	0.93	$6.64	1/1/2023	12/31/2025
88	Condensing Boiler - Hotel	1.78	$6.64	1/1/2023	12/31/2025

88	Condensing Boiler - Warehouse	1.44	$6.64	1/1/2023	12/31/2025
184	Outputs from the tool may be used through custom or semi-custom program tracks, when cost effective.			1/1/2023	12/31/2025
137	BOC in Existing Buildings	1,592.80	$1,895.00	1/1/2023	12/31/2025
137	BOC in Multifamily	626.04	$1,895.00	1/1/2023	12/31/2025
152	MF WA Clothes Washer - Gas DHW	5.53	$51.96	1/1/2022	12/31/2024
152	MF WA Laundry Center Washer/Dryer - Gas DHW	5.46	$45.10	1/1/2022	12/31/2024
200	<0.5 inch Orifice, Low Pressure Steam Trap	343.49	$500.00	1/1/2022	12/31/2024
200	0.5 to <1 inch Orifice, Low Pressure Steam Trap	2,421.62	$550.00	1/1/2022	12/31/2024
200	1 to 1.5 inch Orifice, Low Pressure Steam Trap	6,984.35	$600.00	1/1/2022	12/31/2024
200	<0.5 inch Orifice, Medium Pressure Steam Trap	1,768.91	$500.00	1/1/2022	12/31/2024
200	0.5 to <1 inch Orifice, Medium Pressure Steam Trap	13,487.97	$550.00	1/1/2022	12/31/2024
197	SW WA Gas ESTAR Tankless WH	60.69	$449.77	1/1/2022	12/31/2023
197	SW WA Gas ESTAR Tankless WH - w/ Gas Upgrade	60.69	$873.52	1/1/2022	12/31/2023
270	Furnace >=95% AFUE in existing commercial buildings	0.82	$8.44	1/1/2022	12/31/2024
270	Furnace >=95% AFUE in new commercial buildings	0.51	$8.44	1/1/2022	12/31/2024
117	Infrared Radiant Heaters, low intensity, non-modulating, non-condensing	2.93	$1.31	1/1/2022	12/31/2024
117	Infrared Radiant Heaters, low intensity, modulating, non-condensing	3.80	$2.44	1/1/2022	12/31/2024
253	PRSV - 0.81 to 1.00 gpm, gas water heat – Standard measure - EB	25.00	$30	8/1/2020	12/31/2023
253	PRSV - 0.61 to 0.80 gpm, gas water heat – Standard measure - EB	39.00	$30.00	8/1/2020	12/31/2023
253	PRSV - 0.81 to 1.00 gpm, gas water heat – Direct Install - EB	25.00	$84.00	8/1/2020	12/31/2023
253	PRSV - 0.61 to 0.80 gpm, gas water heat – Direct Install - EB	39.00	$132.00	8/1/2020	12/31/2023
253	PRSV - 0.81_to_1.00_gpm - gas water heat – Standard measure - MF	30.00	$30.00	8/1/2020	12/31/2023
253	PRSV - 0.61_to_0.80_gpm - gas water heat – Standard measure - MF	47.00	$30.00	8/1/2020	12/31/2023
253	PRSV - 0.81_to_1.00_gpm - gas water heat - Direct Install - MF	30.00	$100.00	8/1/2020	12/31/2023
253	PRSV - 0.61_to_0.80_gpm - gas water heat - Direct Install - MF	47.00	$159.00	8/1/2020	12/31/2023

47	Door Retrofit - vertical med temp - Gas Heat	56.48	$420.92	1/1/2023	12/31/2025
47	Door Retrofit - horizontal low temp - Gas Heat	11.96	$235.71	1/1/2023	12/31/2025
47	Door Retrofit - horizontal med temp - Gas Heat	19.39	$382.05	1/1/2023	12/31/2025
195	DCV, New gas heat RTU	21.46	$38.28	1/1/2024	12/31/2024
45	Multifamily Buildings - Thermostatic Radiator Valve	42.01	215.00	1/1/2022	12/31/2024
280	This tool is used to calculate savings for custom projects or "special measures" that are tested individually for cost-effectiveness.			8/9/2023	12/31/2025
142	Modulating Boiler Burner - 5:1 turndown or higher	0.87	$13.03	1/1/2023	12/31/2025
102	Gas Storage WH - ESTAR non-power non-cond	15.10	$100.00	1/1/2022	12/31/2023

APPENDIX 4: Measure Approval Documents

Measure Approval Document for Gas Furnaces in SW Washington

Valid Dates
January 1, 2024 - December 31, 2026

End Use or Description
95%+ AFUE gas furnace

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
  - Single family homes
  - Manufactured homes
- Multifamily homes, 2-4 units and side by side structures

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

- Replacement

Purpose of Re-Evaluating Measure
MAD 22.4 Savings methodology updated to align with RTF, Efficiency requirement, gas savings, measure life, and incremental cost are updated.
MAD 22.5 Clarifies existing fuel requirements

Cost Effectiveness
Cost effectiveness is demonstrated for Washington in Table 1. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2024-v1.2. The Washington gas avoided cost year is 2024. The values in these tables are per unit.

Table 1 Cost Effectiveness Calculator Washington, per unit.

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Ele	% Gas
1	95%+ AFUE Gas Furnace	22	112.6	$1,630	$1,630	2.4	2.4	0%	100%

Requirements
- Installed in Washington state.
- Furnace must have Annual Fuel Utilization Efficiency (AFUE) of 95% or higher.

Existing Fuel Requirements
- This replacement measure may replace heating systems of any fuel.

Baseline
This measure uses code baseline of 80% AFUE. Guidance from the NW Natural Energy Efficiency Advisory Group (EEAG) in their Q2 Meeting (May 23, 2023) indicated the use of an 80% AFUE code baseline aligns with other Washington natural gas utilities.

Measure Analysis and Savings
Savings estimates are taken directly from the Regional Technical Forum's (RTF) Residential Gas Furnaces analysis. The energy calculations in the workbook were updated and the Residential Gas Furnaces v1.1 workbook was approved in the RTF meeting held in July 2021. The RTF analysis was subsequently updated with the 2021 Plan cost effectiveness methodology. These updates were approved in the Residential Gas Furnaces v2.0 workbook in April 2022.

The RTF's method is to use calibrated SEEM runs to estimate heat load for a set of homes that were characterized in the two Residential Building Stock Assessment (RBSA) studies. SEEM runs produce heating load estimates in terms of electric energy (kWh) for single family homes in each heating zone (HZ). These heating load values are then converted to therms. Therm values are adjusted for specific AFUE values.

Review of the Oregon gas furnace sale data collected by NEEA for Energy Trust found that nearly all furnaces are either AFUE 80% or AFUE 95% or greater as shown in Table 2. In the previous MAD, two measures were defined to require at least 90% efficiency and incremental cost was calculated based on the observed mix of furnace efficiencies. Since the market share of furnaces with efficiency between 90% and 94% has been shrinking and was only 1% in 2021, the measure is updated to require of AFUE 95% or higher.

Table 2 Market Share of Gas Furnaces Sold in Oregon By Heating Efficiency Level (AFUE)

Heating Efficiency	2016	2017	2018	2019	2020	2021
80% up to 89.99% AFUE	21%	24%	25%	27%	30%	28%
90% up to 94.99% AFUE	14%	14%	8%	6%	2%	1%
95% AFUE or greater	64%	62%	67%	67%	68%	70%

An examination of the AFUE of furnaces installed in Washington through the program and specifically furnaces with AFUE of 95% or higher found that the average efficiency of such systems is 95.7%. This analysis of PT attribute data is shown in Table 3.

Table 3 Average Efficiency of Furnaces Installed in Washington with AFUE of 95% or higher

Year Installed	Average AFUE	Quantity
2021	95.7	731
2022	95.7	588
2023	95.7	157
Total	**95.7**	**1,476**

Savings are calculated as the difference between the baseline and the efficient case as shown in Table 4. Per Energy Trust's Technical Guidelines, measures developed specifically for Washington may be developed using assumptions for HZ1.

Table 4 Annual Heating Energy Consumption and Savings Calculation for Single Family Homes

Description	Single Family, Heating Zone 1 (therms)
Energy Consumption with an 80.0% AFUE Furnace	685.8
Energy Consumption with a 95.7% AFUE Furnace	573.1
Savings (Difference in energy consumption)	**112.6**

Comparison to RTF or other programs

As noted above, energy consumption values for these measures are taken directly from the RTF's Residential Gas Furnaces workbook. Savings values here are higher since the RTF measures use a full market baseline rather than the code minimum AFUE 80% baseline used for these niche markets.

For measure cost, the RTF used values from Department of Energy (DoE) Technical Support Document (TSD). Since the TSD is dated 2015, more current costs were obtained through a survey of Oregon contractors that is described below.

Energy Trust's furnace offering in Oregon, which is approved in MAD 22 uses the same sources for savings and costs.

In a presentation from the Q2 EEAG meeting, NW Natural noted that the current furnace incentive in Washington is $650 and other utilities were offering $700 for a similar measure.

Measure Life

Measure life of 22 years is taken directly from the RTF analysis. The RTF found this value from DoE TSD documentation.

Load Profile

These measures use the Gas Load Profile *Res Heating*. Since no electric savings are expected, an Electric Load Profile is none.

Cost

Detailed records for gas furnace measures installed in Washington are included in the Project Tracker and summarized in Table 5. Average cost is shown in the table but the same cost trends were present for median cost as well: costs decreased in 2021 and rose in 2022.

Table 5 Average Gas Furnace Installation Cost and Quantities from PT

	2020		2021		2022	
Description	**Install Cost**	**Quantity**	**Install Cost**	**Quantity**	**Install Cost**	**Quantity**
Gas Furnace SW WA 95%+ AFUE	$ 7,057	393	$ 5,972	733	$ 6,854	577

Since PT only includes data for efficient measures and also because costs rose sharply in 2022, updated cost estimates were sought from program contractors. The installers were separated into three tiers by volume:

- Tier 1 includes the 18 highest volume contractors that represent 50% of program volume
- Tier 2 is the 55 contractors that represent an additional 35% of program volume
- Tier 3 is the 188 contractors that represent the remaining 15% of measure volume

The data collection objective was to obtain at least four bids from Tier 1 contractors and four bids from Tier 2 contractors. Actual results included nine total sets of estimates: two from Tier 1, six from Tier 2, and one from Tier 3. The contractors were given the following list of installation conditions in order to have the estimates be as uniform as possible.

Bids were asked to be made assuming all of the conditions listed below.

- Gas line in place
- Push Pull – simple removal and installation using as many existing connection points as possible
- Assume standard (~$200) fabrications for new plenum connections
- No duct modifications
- On the 95%+ AFUE furnace, include any costs to vent intake and exhaust to outside
- Assume no modifications to abandoned venting system
- Standard filtration system
- Permit costs excluded
- Within 25 miles of contractor location
- Unit in typical location: basement, garage, mechanical room
- New installation heating capacity of 60,000 btus
- No asbestos abatement required
- Cash Customer

To summarize the contractor bids, maximum, minimum, and average values are provided in Table 6. The difference between the straight average of 80% AFUE bids and 95%+ AFUE bids is $1,630. This value is used for the incremental cost of the measure.

Table 6 Contractor Bids Collected in 2023

Description	80% AFUE	95%+ AFUE	Incremental Cost
Minimum	$4,100	$4,607	$409
Maximum	$5,899	$7,500	$2,700
Average	**$4,537**	**$6,167**	**$1,630**

This is the third time that contractor bids have been collected to inform incremental cost for efficient furnace measures. Results for AFUE 80% and AFUE 95%+ are summarized in Table 7.

Table 7 Incremental Cost Trend

Description	2014	2020	2023
AFUE 80%	$2,607	$4,330	$4,537
AFUE 95%+	$3,682	$6,238	$6,167
Incremental Cost	**$1,075**	**$1,908**	**$1,630**
Number of Contractors	9	4	9

Incentive Structure

The maximum incentive listed in Table 1 is for reference only and is not a suggested incentive. Incentives will be per furnace and may be paid to homeowners, property owners, or through contractor instant discounts.

Follow-Up

- The assumption that a code minimum AFUE 80% furnace is an appropriate baseline should be checked given the growing market share of AFUE 95%+ furnaces
- Cost data for the measure has varied significantly over short periods, frequent cost updates are recommended.
- Increased federal efficiency requirements are expected in 2029. This schedule should be considered in work on future updates.

Supporting Documents

The cost effectiveness screening for these measures is number 23.5.3. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Residential\Res HVAC\furnace\nwn WA furnaces

23.5.3 OR WA CEC
2024 v1.2 res furnac

Version History and Related Measures

Energy Trust has been offering furnace measures for many years. These predate our measure approval documentation process and record retention requirements. Table 8 may be incomplete, particularly for measures approved prior to 2013.

Table 8 Version History

Date	Version	Reason for revision
1/01/2009	23.x	Approve 90%+ AFUE furnaces in SW WA.
9/04/2014	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.
7/07/2023	23.4	Update efficiency requirement, gas savings, measure life, and incremental cost.
7/12/23	23.5	Clarifies existing fuel requirements

Table 9 Related Measures

Measures	MAD ID
Residential Gas Furnaces in Niche Markets in Oregon	22

Approved & Reviewed by

Jackie Goss, PE
Sr. Engineer – Planning & Evaluation

Disclaimer

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Energy Trust of Oregon

Measure Approval Document for Residential Windows

Valid Dates
January 1, 2023 through December 31, 2025

End Use or Description
Replacement and Retrofit installations of efficient framed windows.

Retrofit measures requiring co-funding. RBSA II characteristic data of the single family housing stock indicate 33% of windows would meet requirements for retrofit projects, with up to 50% of manufactured home windows.

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
- Existing Manufactured Homes
- Existing Buildings
  - Small Multifamily (2-4/side by side)

Within these programs, applicability to the following customer qualifications, delivery methods, building types or market segments or program tracks are expected or required:

- Income Qualified
- Rentals
- Self-Install
- Direct Install
- Contractor Install
- Community Partner co-funded and/or Installed

Within these programs, the measures are applicable to the following classes:

- Retrofit
- Replacement

Purpose of Re-Evaluating Measure
- New U-value tiers
- Savings, Costs and NEBs have been updated
- Addition of retrofit measures with sufficient co-funding

Cost Effectiveness
Cost effectiveness of replacement windows is demonstrated for Oregon in Table 1 and retrofit windows in Table 2. Cost effectiveness in Washington is demonstrated in Table 3. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2023-v1.0. In Oregon the electric avoided cost year is 2023 and the gas avoided cost year is 2023. In Washington the gas avoided cost year is 2023. The values in these tables are per square foot of window glazing.

Table 1 Cost Effectiveness Calculator Oregon, Replacement Windows, 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	% Ele Alloc.	% Gas Alloc.
1	Windows - U-Value ≤ 0.22 Ele	45	0.74	0.00	$5.18	$0.00	$1.52	1.1	0.3	100%	0%
2	Windows - U-Value ≤ 0.22 Gas	45	0.14	0.08	$5.18	$0.00	$2.63	1.1	0.5	9%	91%
3	Windows - U-Value ≤ 0.22 GOT	45	0.00	0.08	$5.18	$0.02	$2.41	1.1	0.6	0%	100%
4	Windows - U-Value 0.23-0.27 Ele	45	0.49	0.00	$3.31	$0.00	$1.01	1.1	0.3	100%	0%
5	Windows - U-Value 0.23-0.27 Gas	45	0.09	0.05	$3.31	$0.00	$1.67	1.1	0.5	9%	91%
6	Windows - U-Value 0.23-0.27 GOT	45	0.00	0.05	$3.31	$0.01	$1.53	1.1	0.6	0%	100%

Energy Trust has received guidance from the OPUC that complimentary funding may be subtracted from the incremental cost of a measure, and the remaining cost used in the cost effectiveness calculations. The *Max Remaining Cost* column shown in Table 2 describes the maximum remaining cost that results in a cost-effective retrofit measure configuration, and is calculated as follows:

Total Cost = Customer Payment + Complimentary Funding + Energy Trust Incentive

Remaining Cost = Total Cost - Complimentary Funding = Customer Payment + Energy Trust Incentive

Approved complementary funding sources are those that originate from outside of Energy Trust's public purpose utility funding arrangements, which includes community partner funding contributions, state and federal tax credits & incentives, and additional utility funding such as SB 838 marketing dollars.

Table 2 Cost Effectiveness Calculator Oregon, Retrofit Windows Co-funded, Per Square Foot

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Max Remaining Cost ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Ele Alloc.	% Gas Alloc.
7	Windows - Metal Double Pane to U-Value ≤ 0.22 Co-Funded Ele	45	3.28	0.00	$7.49	$0.00	$7.49	1.0	1.0	100%	0%
8	Windows - Metal Double Pane to U-Value ≤ 0.22 Co-Funded Gas	45	0.48	0.28	$9.75	$0.00	$9.75	1.0	1.0	9%	91%
9	Windows - Metal Double Pane to U-Value ≤ 0.22 Co-Funded GOT	45	0.00	0.28	$9.92	$0.06	$8.85	1.0	1.0	0%	100%
10	Windows - Metal Double Pane to U-Value 0.23-0.27 Co-Funded Ele	45	3.03	0.00	$6.92	$0.00	$6.92	1.0	1.0	100%	0%
11	Windows - Metal Double Pane to U-Value 0.23-0.27 Co-Funded Gas	45	0.43	0.25	$8.72	$0.00	$8.72	1.0	1.0	9%	91%
12	Windows - Metal Double Pane to U-Value 0.23-0.27 Co-Funded GOT	45	0.00	0.25	$8.87	$0.05	$7.90	1.0	1.0	0%	100%
13	Windows - Metal Double Pane to U-Value 0.28-0.30 Co-Funded Ele	45	2.68	0.00	$6.12	$0.00	$6.12	1.0	1.0	100%	0%
14	Windows - Metal Double Pane to U-Value 0.28-0.30 Co-Funded Gas	45	0.38	0.22	$7.55	$0.00	$7.55	1.0	1.0	9%	91%
15	Windows - Metal Double Pane to U-Value 0.28-0.30 Co-Funded GOT	45	0.00	0.22	$7.68	$0.04	$6.84	1.0	1.0	0%	100%
16	Windows - Single Pane to U-Value ≤ 0.22 Co-Funded Ele	45	4.67	0.00	$10.65	$0.00	$10.65	1.0	1.0	100%	0%
17	Windows - Single Pane to U-Value ≤ 0.22 Co-Funded Gas	45	0.75	0.44	$15.42	$0.00	$15.42	1.0	1.0	9%	91%
18	Windows - Single Pane to U-Value ≤ 0.22 Co-Funded GOT	45	0.00	0.44	$15.68	$0.09	$14.00	1.0	1.0	0%	100%
19	Windows - Single Pane to U-Value 0.23-0.27 Co-Funded Ele	45	4.44	0.00	$10.13	$0.00	$10.13	1.0	1.0	100%	0%
20	Windows - Single Pane to U-Value 0.23-0.27 Co-Funded Gas	45	0.71	0.41	$14.44	$0.00	$14.44	1.0	1.0	9%	91%
21	Windows - Single Pane to U-Value 0.23-0.27 Co-Funded GOT	45	0.00	0.41	$14.69	$0.08	$13.11	1.0	1.0	0%	100%
22	Windows - Single Pane to U-Value 0.28-0.30 Co-Funded Ele	45	4.09	0.00	$9.32	$0.00	$9.32	1.0	1.0	100%	0%
23	Windows - Single Pane to U-Value 0.28-0.30 Co-Funded Gas	45	0.66	0.38	$13.32	$0.00	$13.32	1.0	1.0	9%	91%
24	Windows - Single Pane to U-Value 0.28-0.30 Co-Funded GOT	45	0.00	0.38	$13.55	$0.08	$12.09	1.0	1.0	0%	100%

Washington measures have no co-funding or maximum remaining project cost requirements.

Table 3 Cost Effectiveness Calculator Washington, Per Square Foot

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Ele Alloc	% Gas Alloc
1	Windows - U-Value ≤ 0.22 WA GOT	45	0.08	$5.18	$0.01	$3.58	1.0	0.7	0%	100%
2	Windows - U-Value 0.23-0.27 WA GOT	45	0.05	$3.31	$0.01	$2.27	1.0	0.7	0%	100%
3	Windows - U-Value 0.28-0.30 WA GOT	45	0.02	$1.18	$0.00	$0.80	1.0	0.7	0%	100%
4	Windows - Metal Double Pane to U-Value ≤ 0.22 WA GOT	45	0.28	$31.05	$0.04	$12.30	1.0	0.4	0%	100%
5	Windows - Metal Double Pane to U-Value 0.23-0.27 WA GOT	45	0.25	$29.18	$0.04	$10.99	1.0	0.4	0%	100%
6	Windows - Metal Double Pane to U-Value 0.28-0.30 WA GOT	45	0.22	$27.05	$0.03	$9.52	1.0	0.4	0%	100%
7	Windows - Single Pane to U-Value ≤ 0.22 WA GOT	45	0.44	$31.05	$0.06	$19.48	1.0	0.7	0%	100%
8	Windows - Single Pane to U-Value 0.23-0.27 WA GOT	45	0.41	$29.18	$0.06	$18.24	1.0	0.7	0%	100%
9	Windows - Single Pane to U-Value 0.28-0.30 WA GOT	45	0.38	$27.05	$0.05	$16.82	1.0	0.7	0%	100%

Exceptions

On December 13, 2022 the OPUC granted cost effectiveness exceptions (Order 22-482) for the windows replacement measures shown in Table 1 under UM 551 criteria A and C. The OPUC agrees that higher efficiency windows provide non-quantifiable non-energy benefits in the form of increased thermal comfort, reduce drafts, and have higher sound mitigation properties, reducing the amount of outdoor noise entering a home. Additionally, these offers will be aligned with regional and national policies (ENERGY STAR Version 7.0's U-value) to create demand and encourage manufacturers to support the production of more efficient windows.[1] The exception is effective until March 31, 2026.

Requirements

- Windows and sliding glass doors must be rated according to NFRC:
  - Tier 1: NFRC U-factor rating of 0.28 to 0.30
  - Tier 2: NFRC U-factor rating of 0.23 to 0.27
  - Tier 3: NFRC U-factor of 0.22 or less
- Window and sliding doors must be installed between a conditioned and unconditioned space

Retrofit Requirements

Retrofit measures in Table 2 and Table 3 rows 4-9 require existing window construction of either:

- Metal framed double pane
- Single pane with any framing material

Oregon retrofit measures in Table 2 require co-funding and PMC will ensure each prospective partner serves one or more of the target populations listed below.

- Low-to-moderate income (LMI) customers
- Renters
- Communities of color

[1] ENERGY STAR Residential Windows, Doors and Skylights Version 7.0.

- Rural customers
- Veterans
- People with disabilities
- Other ratepayer groups underrepresented in program participation and/or at the direction of Energy Trust or OPUC policy

Washington retrofit measures in Table 3 rows 4-9 are applicable to all audiences who meet existing condition requirements.

Additional requirements for Oregon complementary funded retrofit measures

- Remaining cost in Oregon must not exceed those shown in Table 2
- Program must track co-funding amounts and sources
- Partner funders must meet requirements outlined in OPUC guidance on complementary funding regarding sources of funds and reporting of savings
- Verification that co-funding meets requirement must be done by internal Energy Trust staff

Baseline

These measures use two baselines depending on application:

- Retrofit - Existing Condition Baseline
- Replacement - Full Market Baseline

Retrofit Measures - Existing Condition Baseline

Existing conditions definitions are based on RTF analysis of Regional Building Stock Assessment, RBSA, data on window framing and estimated U-value ranges associated with those products, as shown in Table 4. RTF analysis did not model any additional pane or framing material existing condition combinations beyond those listed below.

Table 4 RTF Efficiency Ranges and Associated Existing Condition Window Framing Material

Housing Type	RTF Baseline Possible Values	RTF Measure Identifiers	RTF Specified Framing Material
Single Family/Small Multifamily	U > 0.84	Retrofit Single Pane	Any Framing
Single Family/Small Multifamily	0.84 ≥ U > 0.58	Retrofit Double Pane	Metal Framing
Manufactured Home	U-value > 0.90	Retrofit Single Pane	Any Framing
Manufactured Home	0.90 ≥ U-value > 0.60	Retrofit Double Pane	Metal Framing

Replacement Measures - Full Market Baseline

Energy Trust's 2018 Market Research conducted by Apex Analytics[2] forecast 2022 Oregon window market share by U-value bins. Forecasted market shares were combined with Energy Trust Project Tracker data determine the replacement market baseline by removing new construction's market share. While Apex's research only considered the Oregon market results are applied to Energy Trust's southwest Washington territory which assumes that installers and suppliers in these markets overlap to a degree.

Table 5 Oregon 2022 U-Value Range Forecasted Market Shares from 2018 Market Research

U-Value Range	2022 Forecasted Total Market Share
> 0.35	4%
0.31 - 0.35	24%
0.28 - 0.30	40%
0.25 - 0.27	24%
0.20 -0.24	6%
< 0.20	2%

The market share values shown in Table 5 represent the total windows market in Oregon for new construction, retrofit/remodel and replacement market segments. The portions of the market belonging to new construction and/or Energy Trust programs were removed from the overall market shares to calculate market 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 most 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 new construction market share is distributed across U-value bins proportionate to 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. A 6% existing homes program market share assumption has been carried over from prior MAD analyses. The distribution of Existing Homes program windows across U-value bins is taken from 2017 Energy Trust projects, the most recent year where individual window project U-values were recorded in Energy Trust's Project Tracker. 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 6. The final weighted baseline used for all housing types is U-0.311.

Table 6 Final Oregon 2022 U-Value Range Forecasted Average U-Values and Weighted Baseline

U-Value Range	2022 Forecasted Existing Construction Market Share	Average U-Value
> 0.35	9%	0.35
0.31 - 0.35	55%	0.33
0.28 - 0.30	21%	0.29
0.25 - 0.27	11%	0.26
0.20 -0.24	2%	0.22
< 0.20	1%	0.20
Weighted Average U-value		**0.311**

Measure Analysis

RTF single family and manufactured home weatherization Simplified Energy Enthalpy Model, SEEM, runs[3] underpin this savings analysis. Within each RTF SEEM workbook are inputs and outputs for insulation, air sealing, storm and framed windows improvements and corresponding 'baseline' home models. RTF savings estimated are calculated via subtraction of total estimated energy

[2] Energy Trust of Oregon 2018 Windows Market Research Report – Apex Analytics
[3] SEEM description: https://rtf.nwcouncil.org/simplified-energy-enthalpy-model-seem/

consumption between baseline and efficient case models. Weights are used for baseline and efficient models to account for variation in climate zones, structure size and other characteristics influencing energy use.

Original RTF SEEM and UES workbooks for the windows portion of the savings analysis were adjusted to more closely align with Energy Trust's service territory, such as: distribution of incented activity by climate zone, market baseline and participating housing types. Non-windows weatherization savings and models were preserved in SEEM runs to act as a verification mechanism for comparison of original RTF and modified SEEM runs to ensure no unintentional alterations were introduced in the modeling process.

- Original, unaltered RTF SEEM workbook efficient case models' window U-value and SHGC inputs were adjusted to reflect windows data specific to Energy Trust projects. Itemized window data was collected from a sample of over 150 Energy Trust 2021 window projects including over 1,100 individual windows with a combined area upwards of 130,000 square feet.
- Each original RTF SEEM workbook 'SEEMoutput' tab contains all inputs used by the RTF in the original analysis (columns AS:DW) and are inserted into SEEM's input template after efficient case U-value/SHGC adjustments – found in SEEMoutput tab columns CI and CJ.
- All other RTF inputs, window baseline U-values, model weighting and heat pump model calibration, where applicable, were not altered.
    - The original four SEEM modeling workbooks for single family/manufactured homes and gas/electric heat, were duplicated and each was used to model two U-value bins for a total of eight SEEM workbooks.
        - This approach reduces the chance for errors in weighting and heat pump calibration that could occur from introducing additional rows of model inputs, outputs and RTF saving calculations formulas and formatting – which would also significantly increase SEEM modeling run times.
        - All eight SEEM modeling workbooks were run in parallel rather than sequentially.
- Existing condition savings estimates were used 'as is' with the exception of heat pump related savings, which were calibrated using the RTF's approved methodology to account for real world data and assumptions that deviate from modeled 'optimal' heat pump performance in SEEM.
- Incremental savings for a market baseline used the RTF's approach of subtracting the existing condition savings for efficient cases from the estimated baseline savings from the same existing condition baseline (calculated using double pane metal existing condition).
- Unaltered RTF UES workbook formulas were used for final adjustments and formatting. Accommodating two additional U-value tiers for each housing and heating fuel type for Energy Trust analysis involved duplicating the original two RTF UES workbooks. This allowed the modified SEEM outputs to be incorporated into RTF UES workbooks without altering formulas or formatting.
- Energy Trust sourced program data was then used to weight the RTF suite of measures together by housing type, climate zone and heating system type for use as final savings estimates.

The following sections and Table 7 through Table 13 describe the data sources, input calculations and modeling adjustment steps in more detail.

SEEM Modeling Process, Details, Sources and Calculations

Original RTF analysis inputs for UES modeling are shown in Table 7. Pre-conditions are based on the RBSA II's sampled data for the northwest's regional housing stock of existing window types. The RTF then associated typical U-values for these framing types to facilitate SEEM energy consumption and savings.

Single pane glazing in Oregon single family homes represented 22% of all windows while double pane metal framed construction accounted for 11%.[4] RBSA II data on manufactured homes indicate 50% of pre-1990 construction have had replacement windows of some kind installed, but the estimated average U-value across the sample was nearly 0.8.[5]

Table 7 Original RTF Window UES Measure Baseline and Efficient Case SEEM Inputs

Housing Type	RTF Baseline Type	Tier	Baseline Possible Values	Efficient Case Possible Values
SF/SMF	Pre-Conditions	Single pane any framing window to U30	U > 0.84	U: 0.29; SHGC: 0.30
		Double pane metal window to U30	0.84 ≥ U > 0.58	U: 0.29; SHGC: 0.30
		Single pane any framing window to U22	U > 0.84	U: 0.22; SHGC: 0.26
		Double pane window to U22	0.84 ≥ U > 0.58	U: 0.22; SHGC: 0.26
	Current Practice	Upgrade window U30 - U22	U: 0.29; SHGC: 0.30	U: 0.22; SHGC: 0.26
MH	Pre-Conditions	Single pane any framing window to U30	U-value > 0.90	U: 0.29; SHGC: 0.30
		Double pane metal window to U30	0.90 ≥ U-value > 0.60	U: 0.29; SHGC: 0.30
		Single pane any framing window to U22	U-value > 0.90	U: 0.22; SHGC: 0.26
		Double pane window to U22	0.90 ≥ U-value > 0.60	U: 0.22; SHGC: 0.26
	Current Practice	Upgrade window U30 - U22	U: 0.29; SHGC: 0.30	U: 0.22; SHGC: 0.26

Modified SEEM Inputs – SHGC and U value tiers

Program staff reviewed 173 randomly selected 2021 completed windows projects, containing 1,114 windows, stratified by installer project volume. Large installers were those representing a target of 80% of total project activity. The sampling aimed for a 66/33% split between large and small contractors to create a more diverse representation of overall program activity. Project volume rather than area of windows installed was used for sampling as an additional means to diversify the data collection as large contractors typically have larger projects and tend to be clustered in urban areas. Once reviews began a number of project exclusion screens were added to reduce review time (projects with >12 windows, community partner funded) that shifted the eligible population between contractor category of projects slightly (79/21%) but was not deemed an issue.

Each project's individual windows' area, U-value, SHGC among other attributes were captured in the data collection. Sample weights were applied to window area, rather than project volume, to arrive at program wide averages for U-value and SHGC presented in Table 9. Sampling weights from Table 8 were applied to determine final U-values by tier and an overall SHGC for use in SEEM. A single value was used for SHGC across all tiers as program data does not specify the orientation of window installation making accurate modeling of winter/summer heat gains impractical. Variation in weighted average SHGC between U-value tiers was small, ranging from 0.25-0.27.

[4] NEEA 2016-2017 RBSA II Single Family Report, Table 31
[5] NEEA 2016-2017 RBSA II Manufactured Homes Report, Tables 22-23

Table 8 Sampled Project Average U-Value by Efficiency Tier and Contractor Volume, Weighted/Un-Weighted

U-Value	Installer	Un-Weighted Average U-Value	Weighted Average U-Value	Un-Weighted Average SHGC	Weighted Average SHGC	Overall Weighted Average SHGC
U-Value ≤ 0.22	Small Contractor	0.211	0.214	0.282	0.26	0.26
	Large Contractor	0.216		0.244		
U-Value 0.23 to 0.27	Small Contractor	0.255	0.249	0.288	0.27	
	Large Contractor	0.247		0.266		
U-Value 0.28 to 0.30	Small Contractor	0.290	0.289	0.280	0.25	
	Large Contractor	0.288		0.239		

Final inputs used in Energy Trust's modified SEEM runs by efficiency tiers are shown in Table 9.

Table 9 Energy Trust Efficient Case SEEM Inputs Based on 2021 Energy Trust Window Project Reviews

Installation Type	Tier	Modified Efficient Values
Retrofit	Metal Double Pane to U-Value ≤ 0.22	U: 0.214; SHGC: 0.26
	Metal Double Pane to U-Value 0.23 to 0.27	U: 0.249; SHGC: 0.26
	Metal Double Pane to U-Value 0.28 to 0.30	U: 0.289; SHGC: 0.26
	Single Pane to U-Value ≤ 0.22	U: 0.214; SHGC: 0.26
	Single Pane to U-Value 0.23 to 0.27	U: 0.249; SHGC: 0.26
	Single Pane to U-Value 0.28 to 0.30	U: 0.289; SHGC: 0.26
Replacement	Market to U-Value ≤ 0.22	U: 0.214; SHGC: 0.26
	Market to U-Value 0.23 to 0.27	U: 0.249; SHGC: 0.26

Weightings

A number of weights were created to condense multiple housing types, climate zones and heating systems into a more compact suite of measures. These weighting factors were applied after the 126 SEEM generated unit energy consumption and savings, using inputs described in Table 9, calculations were performed.

Housing Type

Residential installed window area from 2021 was used to weight housing type , with the distribution shown in Table 10. Small multifamily housing is qualified for these windows offers but use single family analysis assumptions and are therefore not represented in the housing weights.

Table 10 Housing Weights Using 2021 Installed Window Area by Program

Housing Type	Total Window Area	Final Housing Weights
Single Family	766,703	97.8%
Manufactured Home	17,005	2.2%

Heating Zones

Energy Trust's 2022 Technical Guidelines were used to source Energy Trust's customer population by heating zones. Cooling savings are estimated within the SEEM modeling based on RTF's weighting of cooling zones within heating zones and presence of cooling equipment.

Table 11 Energy Trust 2022 Technical Guideline Heating Zone Weights

Heating Zone	Energy Trust Population Weighting
Zone 1	92%
Zone 2/3	8%

Heating Systems

RBSA II Single Family and Manufactured Homes data for Oregon was used to estimate electric heating system weights. Single Family electric 'Heating System Share' do not add to 100% as non-eligible systems (e.g., boilers/wood/gas furnaces) were excluded, these values were re-weighted to 100%. Gas Furnace RTF modeling came in three flavors: condensing, non-condensing and any, based on furnace type shares in the RBSA II. RTF's 'Any' gas furnace default regional AFUE average of 86% sourced from the RBSA II.

Table 12 Oregon RBSA II Heating System Weighting

Housing Type	Heating System	Heating System Share	Heating System re-weighted to 100%
Single Family	Electric Furnace	3%	9.6%
	Heat Pump	16%	47.9%
	Zonal Electric	14%	42.5%
Manufactured Home	Electric Furnace	57%	70.5%
	Heat Pump	24%	29.5%
Single Family	Gas Furnace	100%	100%
Manufactured Home			

Savings Calculation

Weighting SEEM savings outputs by housing type, heating zone and system give us final estimates of retrofit savings. All weighted efficiency tiers, baselines and associated savings by fuel type can be found in Table 13.

Replacement measures' saving calculations use the RTF's calculation:

(Double Pane Ex. Cond. UEC - 0.311 UEC) – (Double Pane Ex. UEC - Efficient Case UEC) = Replacement Savings

Table 13 Final Weighted Window kWh and Therm Savings Per Square Foot by Baseline and Efficiency Tier

Heating Fuel	Installation Type	Tier	Savings (kWh)	Savings (therms)
Electric	Replacement – Full Market Baseline	Market to U-Value ≤ 0.22	0.74	0
		Market to U-Value 0.23 to 0.27	0.49	0
		Market to U-Value 0.28 to 0.30	0.14	0
	Retrofit – Existing Condition	Metal Double Pane to U-Value ≤ 0.22	3.28	0
		Metal Double Pane to U-Value 0.23 to 0.27	3.03	0
		Metal Double Pane to U-Value 0.28 to 0.30	2.68	0
		Single Pane to U-Value ≤ 0.22	4.67	0
		Single Pane to U-Value 0.23 to 0.27	4.44	0
		Single Pane to U-Value 0.28 to 0.30	4.09	0
Gas	Replacement – Full Market Baseline	Market to U-Value ≤ 0.22	0.14	0.08
		Market to U-Value 0.23 to 0.27	0.09	0.05
		Market to U-Value 0.28 to 0.30	0.03	0.02
	Retrofit – Existing Condition	Metal Double Pane to U-Value ≤ 0.22	0.48	0.28
		Metal Double Pane to U-Value 0.23 to 0.27	0.43	0.25
		Metal Double Pane to U-Value 0.28 to 0.30	0.38	0.22
		Single Pane to U-Value ≤ 0.22	0.75	0.44
		Single Pane to U-Value 0.23 to 0.27	0.71	0.41
		Single Pane to U-Value 0.28 to 0.30	0.66	0.38

Comparison to RTF or other programs

The RTF uses a calibrated SEEM modelling approach to estimate energy savings for both retrofit existing condition and replacement upgrade (roughly U-values 0.30 and 0.22) measures for single family/manufactured homes with gas or electric heating. This analysis departs from the RTF by using custom U-values associated with recent project activity within newly defined Energy Trust tiers.

Energy Trust's Existing Buildings window measures for large multifamily buildings use different analysis inputs to reflect differences in market characteristics including purchasing decisions and building construction. Those measures are retrofits.

Measure Life

Framed windows use 45-year measure lives for all housing types in line with previous weatherization MADs and the RTF's single and multifamily framed window assumption.

RTF manufactured home windows UES uses 25 years, whereas 45 years are used for these Energy Trust measures. Prior analysis, discussions and stakeholder feedback (input collected and used in the development of Energy Trust's Manufactured Homes Early Retirement MAD[6]) on manufactured homes in poor condition continuing to be occupied for long periods of time led to this assumption.

Load Profile

Table 14 Load Profile Selection by Measure Type

Measure	Electric Load Profile	Gas Load Profile
Electric Measures	Res Air Source HP	None - gas
Gas Measures	Res Ele Resistance Heat	Res Heating
Gas Only Territory Measures	None - ele	Res Heating

Electric Measures: Air source heat pumps made up nearly 50% of heating systems weighted single and manufactured home HVAC baselines in the savings modeling. Heat pump and AC compressor usage combined with cooling related fan savings represent over two percent of total electric savings.

Gas Measures: Measures with electric savings the electric resistance load profile is used as air conditioning compressor and fan savings averaged one percent of total electric savings, reflecting a heating only load shape.

Cost

All costs are sourced from the RTF's standard information workbook version 4.6 which contains 2017 program data from a number of northwest utilities and program administrators including Energy Trust.[7] Like savings, costs are unitized to dollars per square foot of window glazing.

RTF estimation of a specific U-value's retrofit or upgrade cost utilizes installed costs from known U-value installations with high volumes (0.27 and 0.30 in the dataset) and interpolates/extrapolates the cost associated with a given U-value delta. Energy Trust specific average U-values within each efficiency tier are then inserted into the RTF's equation for determining costs (see CEC 28.5 tab 'RTF SF Window Cost' and SIW v4.6 tab 'SF Window' for calculations). Finally, the 25th percentile of cost per square foot is used assuming features unrelated to energy efficiency such as exotic framing, non-standard dimensions and/or difficult to itemize invoices could inflate project costs relative to other measures of central tendency.

This analysis uses SIW version 4.6 which shares underlying cost data in version 4.1 cited by the RTF window UES workbooks. The difference between them is the adjusted dollar year used for the RTF's UES analysis.

Retrofit Measures

Using the RTF's interpolation/extrapolation method described above, the 25th percentile of total installed cost by U-value bin was estimated based on the weighted average U-value with each efficiency tier.

Replacement Measures

Replacement measure incremental cost estimation per square foot uses the following RTF approach:

Efficient cost - U-0.311 cost = Incremental cost

[6] Energy Trust MAD 199.6 - Manufactured Homes Early Retirement.
[7] RTF Standard Information Workbooks: https://rtf.nwcouncil.org/standard-information-workbook/

Final Costs

RTF sourced window costs were from 2017 and are converted to 2022 dollars (1.0847 multiplier) using the GDP deflator found in the RTF's Standard Information Workbook version 4.6.[8] Baseline cost is $23.85/sq ft. in 2017$s before adjustment in the final costs for all measure types in Table 15.

Table 15 Energy Trust Modified RTF Cost Analysis by Baseline Type and Efficiency Tier

Measure Tiers	Energy Trust Baseline Identifier	Efficient Full Cost (2017$s)	Efficient Full Cost (2022$s)	Baseline Cost (2022$s)	Incremental Cost (Efficient less Baseline Cost 2022$s)	Existing Condition Full Cost (2022$s)
U-Value ≤ 0.22	Existing Condition	$28.63	$31.05	$0.00		$31.05
U-Value 0.23 to 0.27		$26.90	$29.18			$29.18
U-Value 0.28 to 0.30		$24.93	$27.05			$27.05
U-Value ≤ 0.22	Full Market Baseline	$28.63	$31.05	$25.87	$5.18	
U-Value 0.23 to 0.27		$26.90	$29.18		$3.31	
U-Value 0.28 to 0.30 Washington		$24.93	$27.05		$1.18	

Non-Energy Benefits

Fan and cooling savings for gas heated homes outside of Energy Trust electric service territories are valued as a non-energy benefit based on average residential electric retail rates of $0.116/kWh in Oregon and $0.082/kWh in Washington.

Windows measures, especially retrofits, have extensive non-quantifiable non-energy benefits including improved comfort, noise mitigation and potentially health related benefits.

Incentive Structure

The maximum incentives listed in Table 1, Table 2 and Table 3 are for reference only and are not suggested incentives. Incentives are structured per square foot of glazing.

Under the cost effectiveness exception, the max incentives for Oregon replacement windows have been set to the limit outlined in the order, the cost-effective limit less two years of bill savings.

Follow-Up

- Baseline revision ought to be considered with next revision, current analysis relies on 2022 forecasts of U-value distribution based on market conditions in 2017.
  - Depending on the state of window market research in the region a baseline update could require a study similar to the 2018 Apex Analytics report cited in this MAD.
- Costs in this analysis are inflation adjusted from 2017, newer costs at next update could better reflect the emergence of new products such as thin triple pane windows.
- Revisit new and existing construction market shares and U-value distribution's in full market baseline estimation. Current analysis backs out new and existing construction market share estimates using 2014 data.
  - Oregon's EPS MAD 181.5 baseline window U-value is 0.27 and Washington's EPS MAD 145.5 uses a code baseline of U-0.25 for medium sized new residential construction. New residential construction has larger glazing areas, as shown in Table 16, compared to existing homes likely to need window replacements or retrofits. Current market research identifies windows market by number of windows sold, but not window area. Accounting for new construction codes for window U-value and identifying window area could result in a more accurate representation of the existing construction market baseline U-value.

Table 16 Average Sq ft. of Window Area by Home Vintage

RBSA II Single Family Vintage	Average Sq ft. of Windows			
	ID sq ft.	MT	OR	WA
Post-2010	281	178	304	303
2001-2010	245	255	264	273
1991-2000	241	230	268	268
1981-1990	190	166	227	261
Pre 1981	181	169	223	211

Supporting Documents

The cost effectiveness screening for these measures is number 28.5.4 It is attached and can be found along with supporting documentation at: \\Etoo.org\home\Groups\Planning\Measure Development\Residential\Res Weatherization\windows

28.5.4 OR WA CEC
2023_v_1_0 Res Win

References

All original RTF workbooks used in the analysis for inputs or as the basis for Energy Trust specific modifications:

- UES Measure Workbooks:
  - ResMHWeatherization_v5_5 https://rtf.nwcouncil.org/measure/manufactured-home-weatherization/
  - ResSFWx_v4_4 https://rtf.nwcouncil.org/measure/single-family/
- RTF SEEM modeling workbooks for UES workbooks:
  - Single Family:
    - SEEM Run Workbook - February 2020 Electric Homes
    - SEEM Run Workbook-May 2020 Gas Homes
  - Manufactured Homes:
    - SEEM Run Workbook - March 2020 Electric Homes

[8] While the RTF windows workbooks used in this analysis for single and manufactured homes cite version 4.1 of the RTF's standard information workbook (released June 3rd, 2019) both 4.1 and 4.6 use the same underlying costs, as does the more recent version 4.7.

    - [SEEM Run Workbook - May 2020 Gas Homes]
- RTF Standard Information Workbook, SIW:
    - [RTFStandardInformationWorkbook_4_6]

Version History and Related Measures

Energy Trust has been offering residential windows for many years. These predate our measure approval documentation process and record retention requirements. Table 17 may be incomplete, particularly for measures approved prior to 2013.

Table 17 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
12/20/22	28.5	Update baseline. Update tiers to 0.27 and 0.22. Retrofit co-funded measures added.

Table 18 Related Measures

Measures	MAD ID
Multifamily windows	171

Approved & Reviewed by

Jackie Goss, PE
Sr. Engineer – Planning & Evaluation

Disclaimer

Measure Approval Document for Efficient Gas Fireplaces

Valid Dates
January 1, 2024 to December 31, 2026

End Use or Description
Installation of thermally efficient gas fireplaces new and existing construction based on the Canadian EnerGuide Fireplace Efficiency (FE) metric. Efficient units must be equipped with ignition mechanisms other than continuous pilot lights.

Additional background can be found in the Regional Technical Forum's (RTF) thorough presentation on residential gas fireplaces from their September 20, 2022 monthly meeting.[1]

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
- Existing Manufactured Homes
- Washington New Residential Construction
- Existing Buildings - Multifamily

Within these programs, these measures are applicable to the following:
- TLM/GeoTEE Qualified
- Rentals
- Self-Install
- Contractor Install
- Small Multifamily

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

Purpose of Re-Evaluating Measure
General Updates:
- Incorporation of Washington new residential construction MAD 275 into consolidated analysis.
- Savings, baseline and dwelling type weighting updated.
- Analysis changes:
  - Adoption of the RTF's unit energy savings (UES) approach. Significant changes from previous MADs include:
    - Incorporation of a btu/h output turndown ratio (80%) in savings calculations rather than maximum output.
    - Using unit btu/h output based on burner efficiency rather than input btu/h.
    - Discontinuation of electronic ignition savings as a separate calculation.

Program design changes:
- Discontinuation of electronic ignitions as a standalone measure at midstream. Market data indicates a high saturation of models qualifying for Energy Trust FE tiers and those that don't are equipped with efficient electronic ignitions indicating a successful market transition toward a feature that considerably reduces gas consumption in these products.

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 2024-v1.0. The Oregon electric avoided cost year is 2024 and the Oregon gas avoided cost year is 2024. The Washington gas avoided cost year is 2023. The values in these tables are per unit.

Table 1 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	Gas Hearth 70-74 FE w/ ele ignition	16	0.00	15.36	$0.01	$0.00	$150	2.2	32,482.5	0%	100%
2	Gas Hearth 75+ FE w/ ele ignition	16	0.00	23.22	$0.01	$0.00	$250	2.0	49,100.6	0%	100%

Table 2 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	Gas Hearth 70-74 FE w/ ele ignition	16	15.36	$0.01	$0.00	$150	2.3	33,756.0	0%	100%
2	Gas Hearth 75+ FE w/ ele ignition	16	23.22	$0.01	$0.00	$250	2.0	51,025.6	0%	100%
3	New Home Gas Hearth 70+ FE w/ ele ignition	16	16.68	$0.01	$0.00	$200	1.8	36,655.3	0%	100%

Exceptions
Incentives are higher than the calculated incremental cost. This is usually not allowed by the OPUC, but they are aware that we are paying incentives above incremental cost.

Requirements
- Existing construction:
  - Model listed on the Canadian EnerGuide list with natural gas specific FE rating or efficiency percentage.[2]
  - 70 or greater fireplace efficiency rating with ignition system identified as "non-continuous" only.

[1] RTF Residential Gas Fireplace Presentation.
[2] Natural Resources Canada gas fireplace energy efficiency ratings search.

- Additional Washington New Home Requirements:
  - 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.

Implementation Details

- Existing single family, manufactured homes and multifamily may use measures 1-2 in Table 1 and Table 2.
- Washington New homes may use measure 3 in Table 2.

Baseline

This measure uses a Full Market Baseline.

Baseline was determined using Energy Trust 2018-2021 fireplace sales via midstream incentives. The RTF used this to calculated Average FE by FE bins, shown in Table 3. Baseline analysis for Oregon and Washington are identical in the RTF workbook.[3]

Table 3 Average FE by FE Tier

Category	Average FE	n	WA New Home 70+ FE Tier Weighted Efficient FE	
All	58%	30,080		
New Homes	54%	8,670		
0-49.9 FE	45%	304		
50-64.9 FE	54%	23,321		
65-69.9 FE	67%	2,054		
70-74.9 FE	71.4%	3,717	70+ FE	72.1%
75+ FE	76%	684		

Measure Analysis and Savings

The RTF Savings calculations are based on the following formulas:

$$\frac{\Delta Therm}{year} = Efficiency\ kBtu\ Savings x \frac{therm}{kBtu}$$

$$Efficiency\ kBtu\ Savings = \frac{Hours}{year} x \frac{kBtu}{hour} x \left(\frac{1}{Baseline} FE - \frac{1}{Efficient} FE\right)$$

In addition to the baseline calculations above in Table 3, the following detail the remaining variables for therm savings calculations.

Hours of Use

Analysis by the RTF was based on extrapolations of Energy Trust's existing homes fireplace metering study and new home usage surveys.[4,5] Hours of use from the studies (Table 4) were extrapolated by heating degree days to estimate total annual hours of use by heating zone (Table 5).

Table 4 Energy Trust Study Hours of Use Results by Existing/New Construction

	Existing Homes	New Homes (Survey)	New/Existing Ratio
Hours/ week	14	5	39%

Table 5 Annual Hours of Use by Heating Zone Using HDD Extrapolation

Heating Zone	Average HDD	Existing Homes Hours/Year	New Homes Hours/Year
HZ1	4846	534	208
HZ2	6674	736	287
HZ3	8191	903	352

Unit Capacity and Output Turndown

Unit output capacities and an assumed output turndown rate are shown in Table 6. Given the lack of information on actual user preference for modulation, the RTF approved UES uses a modulation assumption of 80%.

Table 6 RTF Sourced EnerGuide Unit Capacities for Savings Calculation – All Housing and Construction Types

FE Bin	n	Average Max Input (BTU/hr)	Average Max Output (BTU/hr)	Average Min Output (BTU/hr)	Min/Max Ratio	**80% of Max Output (BTU/hr)**
All	1,465	37,049	21,633	13,447	62%	**17,306**

Regarding turndown ratios the RTF notes:

- ~92% of gas fireplace models can modulate their output.
  - ~45% of ETO mid-stream data (that included data on modulation) were able to modulate.
- CAT located no sources that provide insight into the use of modulation by gas fireplace owners.
- CAT is proposing to Firestone this one.
  - 20% turndown ratio.
    - 0% turndown would be no modulation.
    - 40% turndown (average maximum turndown in available units) would be 100% modulation.

[3] RTF Workbook: Residential Gas Fireplace v1.1.
[4] Energy Trust Gas Fireplace Market Research & Metering Study.
[5] Energy Trust New Homes Gas Fireplace Study.

Final Savings Calculations

Therm saving weighting by construction type, housing type and heating zone along with final savings by FE tier are shown below in Table 7. FE tier weighting by housing type (single family – SF, manufactured home – MH, multifamily – MF) is based on Energy Trust Project Tracker data from 2021 – May 2023 for MAD eligible existing construction programs. Energy Trust population weights are sourced from the 2023 Measure Development Technical Guidelines table 14-5.[6]

Table 7 Savings Weighting for New and Existing Construction in Washington and Oregon

Construction Type	Home Type	Heating Zone	FE Bin	RTF Therm, Savings	Energy Trust Program Data FE tier Weighting	Energy Trust Heating Zone Weighting	Housing, FE Tier, HZ Weighted Therm Savings	Final Weighted Therm Savings by FE Tier
New	SF	HZ1	70+	16.68	100%			**16.68**
Existing	SF	HZ1	70-74.9	15.19	97.41%	93.10%	13.78	**15.36**
	SF	HZ2	70-74.9	20.92	97.41%	6.60%	1.35	
	SF	HZ3	70-74.9	25.68	97.41%	0.40%	0.10	
	MH	HZ1	70-74.9	13.52	0.08%	93.10%	0.01	
	MH	HZ2	70-74.9	18.62	0.08%	6.60%	0.00	
	MH	HZ3	70-74.9	22.86	0.08%	0.40%	0.00	
	MF	HZ1	70-74.9	5.10	2.51%	93.10%	0.12	
	MF	HZ2	70-74.9	7.02	2.51%	6.60%	0.01	
	MF	HZ3	70-74.9	8.62	2.51%	0.40%	0.00	
	SF	HZ1	≥75	23.19	95.71%	93.10%	20.67	**23.22**
	SF	HZ2	≥75	31.94	95.71%	6.60%	2.02	
	SF	HZ3	≥75	39.21	95.71%	0.40%	0.15	
	MH	HZ1	≥75	20.64	0.36%	93.10%	0.07	
	MH	HZ2	≥75	28.43	0.36%	6.60%	0.01	
	MH	HZ3	≥75	34.89	0.36%	0.40%	0.00	
	MF	HZ1	≥75	7.78	3.93%	93.10%	0.28	
	MF	HZ2	≥75	10.72	3.93%	6.60%	0.03	
	MF	HZ3	≥75	13.15	3.93%	0.40%	0.00	

Comparison to RTF or other programs

This Energy Trust MAD aligns with the RTF analysis with a few key differences:

- RTF savings estimates by existing construction types have been blended.
- RTF savings by heating zone are blended.
- RTF only calculated savings for FE tiers 70-74.9 and 75+, this MAD uses a single 70+ FE tier for Washington new residential construction, the savings are based on the RTF weighting for tier distribution and average FE within the tiers.
- For purposes of calculating benefit cost ratios this analysis uses $0.01 for incremental cost rather than the RTF's UES workbook's $0.00 incremental cost.

Measure Life

16 years – the RTF estimated this from US department of energy analysis but indicate medium uncertainty in the estimate due to an inability to verify sources for this effective useful life estimate.

Load Profile

Oregon – Uses 'Res Heating' load profile, no current load profile specific for fireplaces/hearths is available for Oregon measure development.

Washington – Uses the measure specific 'hearth' load profile.

Cost

Incremental costs for efficient gas fireplaces is $0, in line with past MAD versions examining midstream cost data. Previous studies have indicated that aesthetic considerations often rank higher than efficiency in consumer choice making isolation of the cost of efficiency difficult if not impossible.

The RTF further elaborates notes:

> "The contract analyst team is proposing $0 incremental cost for this measure due to the inability to isolate the incremental cost (+/-) of the efficiency gain and manufacturer assertion that aesthetics is the primary driver of cost."

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.

Follow-Up

- Following RTF's updated analysis when their UES measure sunsets September 30, 2025.
  - Components of the RTF's workplan can be incorporated into future updates of this MAD:
    - More accurate hours of use through metering sample.
    - Updated distributor data for baselines and costs.
    - Potential data on user modulation or turndown of unit btu/h output.

[6] Energy Trust Technical Guidelines for Energy Efficiency Measures.

Supporting Documents

The cost effectiveness screening for these measures is number 29.5.4. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Residential\Res HVAC\fireplace

29_5-4_OR_WA_CEC
_2024_v_1_2_Res_Ga

Version History and Related Measures

Energy Trust has been offering an efficient fireplace measure for many years. These predate our measure approval documentation process and record retention requirements. Table 8 may be incomplete, particularly for measures approved prior to 2013.

Table 8 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.
9/14/2023	29.4	Updated FE baseline and savings for FE improvement (costs unchanged). Discontinued standalone midstream electronic ignition measure. Incorporated Washington new residential construction MAD 275 into a single MAD, 29.
10/18/2023	29.5	Correct typo in reqirements

Table 9 Related Measures

Measures	MAD ID
New Homes EPS	181

Approved & Reviewed by

Kenji Spielman
Planning Engineer

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Measure Approval Document for Existing Single Family and Small Multifamily Insulation Retrofit

Valid Dates
January 1, 2023 – December 31, 2025

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.

Ceiling and attic insulation serve the same purposes and are used interchangeably in this document.

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
- Existing Manufactured Homes
- Existing Buildings
    - Small Multifamily (2-4/side by side)

Within these programs, applicability to the following customer qualifications, delivery methods, building types, or program tracks are expected:

- Income Qualified
- Rentals
- Self Install
- Direct Install
- Contractor Install
- Community Partner Funding

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

- Retrofit

Purpose of Re-Evaluating Measure
Savings, costs, and NEBs have been updated. Measures consolidated by heating zone. Manufactured home measures added. Re-introduction of an additional tier of attic insulation for homes with a low amount of existing insulation.

This update also combines separate MADs for standard retrofit measures (MAD 58) and direct install or co-funded measures (MAD 252) into a single document.

Cost Effectiveness
Cost effectiveness is demonstrated for Oregon in Table 1 and Table 2. Cost effectiveness is demonstrated for Washington in Table 3. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2023-v1.0. In Oregon the electric avoided cost year is 2023 and the gas avoided cost year is 2023. In Washington the gas avoided cost year is 2023. The values in these tables are per square foot (SF) of insulation.

Table 1 Cost Effectiveness Calculator Oregon, for standard measures, per SF

#	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	Wall Insulation R0-R4 Electric Heat SF/SMF	45	0.82	-	$2.78	$0.00	$1.86	1.0	0.7	100%	0%
2	Wall Insulation R0-R4 Gas Heat SF/SMF	45	0.13	0.08	$2.78	$0.00	$2.78	1.1	1.1	10%	90%
3	Wall Insulation R0-R4 Gas Heat GOT SF/SMF	45	-	0.08	$2.78	$0.02	$2.64	1.0	1.1	0%	100%
4	Floor Insulation R0-R11 Electric Heat SF/SMF	45	0.38	-	$2.01	$0.00	$0.88	1.0	0.4	100%	0%
5	Floor Insulation R0-R11 Gas Heat SF/SMF	45	0.19	0.09	$2.01	$0.00	$2.01	1.7	1.7	13%	87%
6	Floor Insulation R0-R11 Gas Heat GOT SF/SMF	45	-	0.09	$2.01	$0.02	$2.01	1.5	1.7	0%	100%
7	Attic Insulation R0-R11 Electric Heat SF/SMF	45	1.49	-	$1.53	$0.00	$1.53	2.2	2.2	100%	0%
8	Attic Insulation R0-R11 Gas Heat SF/SMF	45	0.14	0.11	$1.53	$0.00	$1.53	2.6	2.6	8%	92%
9	Attic Insulation R0-R11 Gas Heat GOT SF/SMF	45	-	0.11	$1.53	$0.02	$1.53	2.4	2.6	0%	100%
10	Attic Insulation R12-R18 Electric Heat SF/SMF	45	1.03	-	$1.53	$0.00	$1.53	1.5	1.5	100%	0%
11	Attic Insulation R12-R18 Gas Heat SF/SMF	45	0.10	0.06	$1.53	$0.00	$1.53	1.5	1.5	10%	90%
12	Attic Insulation R12-R18 Gas Heat GOT SF/SMF	45	-	0.06	$1.53	$0.01	$1.53	1.3	1.5	0%	100%
13	Floor Insulation R0-R11 Electric Heat XMH	45	0.51	-	$2.71	$0.00	$1.16	1.0	0.4	100%	0%
14	Floor Insulation R0-R11 Gas Heat XMH	45	0.06	0.04	$2.71	$0.00	$1.54	1.0	0.6	9%	91%
15	Floor Insulation R0-R11 Gas Heat GOT XMH	45	-	0.04	$2.71	$0.01	$1.41	1.0	0.6	0%	100%
16	Attic Insulation R0-R11 Electric Heat XMH	45	0.75	-	$1.53	$0.00	$1.53	1.1	1.1	100%	0%
17	Attic Insulation R0-R11 Gas Heat XMH	45	0.06	0.04	$1.53	$0.00	$1.53	1.0	1.0	9%	91%
18	Attic Insulation R0-R11 Gas Heat GOT XMH	45	-	0.04	$1.53	$0.01	$1.39	1.0	1.0	0%	100%
19	Attic Insulation R12-R18 Electric Heat XMH	45	0.25	-	$1.53	$0.00	$0.56	1.0	0.4	100%	0%
20	Attic Insulation R12-R18 Gas Heat XMH	45	0.02	0.02	$1.53	$0.00	$0.55	1.0	0.4	9%	91%
21	Attic Insulation R12-R18 Gas Heat GOT XMH	45	-	0.02	$1.53	$0.00	$0.50	1.0	0.4	0%	100%

Table 2 Cost Effectiveness Calculator Oregon, for community partner qualified, Low and Moderate Income (LMI) customers and customers experiencing energy burdens per SF

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
22	Qualified Wall Insulation R0-R4 Electric Heat SF/SMF	45	0.82	-	$2.78	$0.00	$2.32	0.8	0.7	100%	0%
23	Qualified Wall Insulation R0-R4 Gas Heat SF/SMF	45	0.13	0.08	$2.78	$0.00	$3.67	0.8	1.1	10%	90%
24	Qualified Wall Insulation R0-R4 Gas Heat GOT SF/SMF	45	-	0.08	$2.78	$0.02	$3.30	0.8	1.1	0%	100%
25	Qualified Floor Insulation R0-R11 Electric Heat SF/SMF	45	0.38	-	$2.01	$0.00	$1.09	0.8	0.4	100%	0%
26	Qualified Floor Insulation R0-R11 Gas Heat SF/SMF	45	0.19	0.09	$2.01	$0.00	$4.20	0.8	1.7	13%	87%
27	Qualified Floor Insulation R0-R11 Gas Heat GOT SF/SMF	45	-	0.09	$2.01	$0.02	$3.65	0.8	1.7	0%	100%
28	Qualified Attic Insulation R0-R11 Electric Heat SF/SMF	45	1.49	-	$1.53	$0.00	$4.25	0.8	2.2	100%	0%
29	Qualified Attic Insulation R0-R11 Gas Heat SF/SMF	45	0.14	0.11	$1.53	$0.00	$4.93	0.8	2.6	8%	92%
30	Qualified Attic Insulation R0-R11 Gas Heat GOT SF/SMF	45	-	0.11	$1.53	$0.02	$4.53	0.8	2.6	0%	100%
31	Qualified Attic Insulation R12-R18 Electric Heat SF/SMF	45	1.03	-	$1.53	$0.00	$2.94	0.8	1.5	100%	0%
32	Qualified Attic Insulation R12-R18 Gas Heat SF/SMF	45	0.10	0.06	$1.53	$0.00	$2.77	0.8	1.5	10%	90%
33	Qualified Attic Insulation R12-R18 Gas Heat GOT SF/SMF	45	-	0.06	$1.53	$0.01	$2.49	0.8	1.5	0%	100%
34	Qualified Floor Insulation R0-R11 Electric Heat XMH	45	0.51	-	$2.71	$0.00	$1.45	0.8	0.4	100%	0%
35	Qualified Floor Insulation R0-R11 Gas Heat XMH	45	0.06	0.04	$2.71	$0.00	$1.92	0.8	0.6	9%	91%
36	Qualified Floor Insulation R0-R11 Gas Heat GOT XMH	45	-	0.04	$2.71	$0.01	$1.76	0.8	0.6	0%	100%
37	Qualified Attic Insulation R0-R11 Electric Heat XMH	45	0.75	-	$1.53	$0.00	$2.13	0.8	1.1	100%	0%
38	Qualified Attic Insulation R0-R11 Gas Heat XMH	45	0.06	0.04	$1.53	$0.00	$1.91	0.8	1.0	9%	91%
39	Qualified Attic Insulation R0-R11 Gas Heat GOT XMH	45	-	0.04	$1.53	$0.01	$1.74	0.8	1.0	0%	100%
40	Qualified Attic Insulation R12-R18 Electric Heat XMH	45	0.25	-	$1.53	$0.00	$0.70	0.8	0.4	100%	0%
41	Qualified Attic Insulation R12-R18 Gas Heat XMH	45	0.02	0.02	$1.53	$0.00	$0.68	0.8	0.4	9%	91%
42	Qualified Attic Insulation R12-R18 Gas Heat GOT XMH	45	-	0.02	$1.53	$0.00	$0.62	0.8	0.4	0%	100%

Table 3 Cost Effectiveness Calculator Washington for standard measures, per SF

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Wall Insulation R0-R4 Gas Heat SF/SMF	45	0.08	$2.78	$0.01	$2.78	1.3	1.4	0%	100%
2	Floor Insulation R0-R11 Gas Heat SF/SMF	45	0.09	$2.01	$0.02	$2.01	2.0	2.2	0%	100%
3	Attic Insulation R0-R11 Gas Heat SF/SMF	45	0.11	$1.53	$0.01	$1.53	3.3	3.5	0%	100%
4	Attic Insulation R12-R18 Gas Heat SF/SMF	45	0.06	$1.53	$0.01	$1.53	1.8	1.9	0%	100%
5	Floor Insulation R0-R11 Gas Heat XMH	45	0.04	$2.71	$0.00	$1.96	1.0	0.8	0%	100%
6	Attic Insulation R0-R11 Gas Heat XMH	45	0.04	$1.53	$0.00	$1.53	1.3	1.3	0%	100%
7	Attic Insulation R12-R18 Gas Heat XMH	45	0.02	$1.53	$0.00	$0.70	1.0	0.5	0%	100%

Exceptions

A major cost effectiveness exception (Order 22-482) was granted by the Oregon Public Utility Commission on December 13, 2022 for all home insulation as follows:

1) All insulation measures be exempted from TRC cost-effectiveness requirements (TRC exceptions); and
2) All insulation measure offers for income-qualified and energy-burdened households are exempted from UCT cost-effectiveness requirements up to a score of 0.8.

The exception was granted based on Exception Criteria C: The measure is included for consistency with other demand side management (DSM) programs in the region; Exception Criteria D: Measure helps to increase participation in a cost effective program; 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.

OPUC argues that this strategy is an ideal opportunity to pursue a “no regrets” strategy that would be beneficial for the energy systems, the ratepayer, and the participant. The risks of future cost increases related to compliance with Oregon’s clean energy goals have not been fully quantified yet, as there are many decisions about resource options and policy still to be made. As energy systems transition to lower carbon intensities, it is unknown how much of the cost of these transitions will be paid by ratepayers in the future. Investing now protects both participating customers and the general ratepayer regardless of what policy decisions happen in the future.

The exception is granted through March 31, 2028 or until the incentives from the measures exceeding UCT of 1.0 (up to 0.8) exceed 5% of the program’s incentives.

Requirements

General Requirements:

- Program must verify that incentives do not exceed actual project costs.

Ceiling and Attic Insulation Requirements:

- Measures designated as SF/SMF R0-R11 or XMH R0-R11, existing insulation must be R-11 or less.
- Measures designated as SF/SMF R12-R18 or XMH R12-R18, existing insulation must be between R-12 and R-18 inclusive.
- SF/SMF, must insulate to R-38 or greater or fill cavity.
- XMH, must insulate to R-30 or greater or fill cavity.

Wall Insulation Requirements:

- 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 for knee wall insulation to be eligible.

Floor Insulation Requirements

- Existing insulation must be R-11 or less. For SF/SMF, must insulate to R-30 or greater or fill cavity. For XMH, must insulate to R-22 or greater or fill cavity.

Community Partner or Income *Qualified Projects:*

- The measure applications identified in Table 2 the PMC will ensure each prospective partner or offering serves one or more of the target populations listed below.
  - Low-to-moderate income (LMI) customers.
  - Customers experiencing energy burden
  - Renters
  - Communities of color
  - Rural customers
  - Veterans
  - People with disabilities

Baseline

This measure uses an Existing Condition Baseline.

The baseline is a dwelling with little to no insulation.

Savings and Measure Analysis

The cost effectiveness tables present energy savings estimates for each insulation measure application by heating fuel type and for any heating zone. Two types of sources were used for these values: Recurve analyses and Regional Technical Forum (RTF) workbooks. The specification of measures in this way reflects the available data from the Recurve studies. The RTF workbooks include specific values for various electric heat types and for two heating zones. These RTF values were blended to simplify administration of insulation measures and to match the specification of Recurve-based measures.

Single family and small multifamily measures

Small multifamily buildings are expected to have similar heating and cooling characteristics to single family and measures based on single family analysis are also applicable to small multifamily homes. For single family and small multifamily homes, energy savings estimates are available from multiple sources. Potential sources include the following, in order of preference:

- Analysis of Energy Trust Residential Insulation Impacts 2013-2018[1]. This analysis was also completed by Recurve.
- Recurve Ceiling Insulation Impact Analysis 2013-2017[2].
- RTF Residential Single Family Weatherization workbook v5.0[3].

The Recurve analyses were ultimately used for all insulation measures in gas heated homes and all ceiling insulation measures while the RTF was ultimately used for floor and wall measures in electrically heated homes.

The Recurve Ceiling analysis does not provide heating zone-specific values. The Recurve residential study only reported savings for gas-heated homes for heating zone 1. Heating zone 1 values are used for homes located anywhere in Energy Trust territory since this represents more than 90% of expected projects and is considered a conservative estimate because savings from heating zone 2 or heating zone 3 are generally larger than heating zone 1.

For ceiling insulation in a gas-heated home where the starting condition is R0-R10 and the end condition is for at least R38, both Recurve analyses provide savings estimates. The Recurve Residential values are used because the Residential study has a larger sample size (n=1,070) for this measure than the Recurve Ceiling analysis (n=477) and the Residential study provides savings values for floor and wall insulation based on the same dataset.

In cases where Recurve estimates are not available or reliable (wall and floor insulation in electrically heated homes), savings are analyzed based on the RTF weatherization workbook. Since RTF savings estimates for insulation are based on SEEM simulations, they include a measure for each heating zone and heating system type. For homes with electric heat, the RTF workbook provides savings for three heating system types:

- Electric forced air furnace (FAF),
- Zonal or DHP, and
- Heat pump

Participant data for 2,086 projects completed between 2020-2022 was used to weight the various electric heating types. The electric heat system weights are shown in Table 4.

Table 4 Electric heat system weights based on MAD 58.2 participation

Electric Heat Type	Square Feet Installed	Share of Total
Electric FAF	534,860	21%
Zonal or DHP	936,589	36%
Heat Pump	1,109,677	43%
Total	**2,581,126**	**100%**

[1] https://energytrust.org/documents/analysis-of-energy-trust-residential-insulation-impacts-2013-2018/
[2] https://energytrust.org/documents/recurve-ceiling-insulation-impact-analysis-2013-2017/
[3] https://rtf.nwcouncil.org/measure/single-family/

In the RTF workbook, both gas and electric savings are provided for heating zone 1 and a blended heating zone 2/3. These separate estimates are combined using the heating zone distribution provided in Table 14-6 of the 2022 Measure Development Technical Guidelines and shown in Table 5.

Table 5 Simplified Heating Zone Weightings

Heating Zone	Energy Trust Population Weighting
1	92.0%
2/3	8.0%

The total weighting of the RTF measures is shown in Table 6.

Table 6 Weighted savings for single family and small multifamily floor and wall insulation measures

Measure	Heating System Type	Heating Zone	Savings (kWh)	Heating Zone Distribution	Heating System Distribution	Weighted Savings
Floor:R0-R30	Electric FAF	1	0.340	92%	21%	0.385
		2/3	0.574	8%	21%	
	Zonal or DHP	1	0.623	92%	36%	
		2/3	0.939	8%	36%	
	Heat Pump	1	0.184	92%	43%	
		2/3	0.072	8%	43%	
Wall:R0-R11	Electric FAF	1	1.043	92%	21%	0.816
		2/3	1.629	8%	21%	
	Zonal or DHP	1	0.843	92%	36%	
		2/3	1.490	8%	36%	
	Heat Pump	1	0.595	92%	43%	
		2/3	0.875	8%	43%	

The available values from these three sources are presented in Table 7**Error! Reference source not found.**. The savings estimate(s) used for each measure is/are shown in **bold** font. The Recurve confidence results are indicated by the key located below the table. These ratings are based on relative precision and sample size. The Recurve billing analysis-based values were preferred over the RTF values produced by Simplified Energy Enthalpy Model (SEEM) simulations.

Table 7 Savings estimates for single family and small multifamily homes from three sources

			RTF SF 4.4		Recurve Residential		Recurve Ceiling	
Type	Fuel	Heat Zone	kWh	therms	kWh	therms	kWh	therms
Ceiling R0-R38	Gas	Any	0.168	0.092	**0.140**	**0.114**	0.146	0.090
	Electric	Any	1.408				**1.491**	
Ceiling R11-R38	Gas	Any	0.057	0.031			**0.101**	**0.063**
	Electric	Any	0.392				**1.032**	
Floor	Gas	Any	0.070	0.035	**0.190**	**0.092**		
	Electric	Any	**0.385**					
Wall	Gas	Any	0.131	0.067	**0.130**	**0.083**		
	Electric	Any	**0.816**					

Reliability of Recurve results

Reliability of Recurve results
Very high or high
Moderate
Very low or low

Manufactured Home measures

For existing manufactured homes, savings are based on the RTF Manufactured Home Weatherization workbook v6.0.

Similar to the RTF analysis for single family homes, the SEEM-generated savings values are provided for homes with gas furnaces in heating zone 1 and heating zone 2/3. The electric and gas savings for gas-heated homes in each heating zone were weighted to produce “Any” heating zone savings using the heating zone distribution in Table 5.

For electrically heated homes savings are provided for three heating system types in both heating zone 1 and heating zone 2/3. These values were weighted with the electric system distribution in Table 4. The generalized savings values for homes with gas heat and homes with electric heat are shown in Table 8.

Table 8 Savings for Existing Manufactured Homes based on RTF manufactured home weatherization workbook v6.0

Type	Fuel	Heat Zone	kWh	therms
Ceiling R0-R30	Gas	Any	0.059	0.044
	Electric	Any	0.749	
Ceiling R11-R30	Gas	Any	0.020	0.016
	Electric	Any	0.246	
Floor R0-R22	Gas	Any	0.058	0.044
	Electric	Any	0.508	

Cooling

Cooling savings are not shown separately in this document. It should be noted however that all sources used here do include cooling savings in their estimates of energy savings resulting from insulation measures.

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. Overall energy savings estimates include both heating season and cooling season reductions.

Comparison to RTF or other programs

Energy Trust engaged Recurve to conduct billing analyses that estimated energy savings for measures installed in actual homes in the service territory. When the Recurve billing-based values are compared to the RTF simulation-based values shown in Table 7**Error! Reference source not found.**, it is apparent that the billing analysis often found greater savings.

Measure Life

Insulation measures carry a 45-year measure life, in line with previous Energy Trust analysis and RTF regional estimates.

Load Profile

For measures in Oregon, the *Res Air Source HP* electric load profile is used for all measures. As noted in the Measure Development Technical Guidelines, this profile assumes most savings in the winter and some savings in the summer. It is a useful profile for other measures that save both electric heating and cooling energy, such as eFAF/AC combinations and weatherization measures. For homes with gas heat, the *Res Heating* gas profile is used.

Cost

The average and median values shown in Table 9 are based on over 5,300 participants between January 2020 until April of 2022. Incremental cost compared to an existing condition baseline is the full project cost. In this case, the total project cost in Project Tracker was divided by the total area of the project in square feet. Since there is wide variability in insulation installation project costs, the median value was used to ensure that a small number of very high cost projects did not inflate the incremental cost used in cost effectiveness testing.

Table 9 Average and median cost by insulation type and fuel based on single family and small multifamily participants

Home Type	Measure	Average per sq ft	Median per sq ft
Single family / Small Multifamily	Wall:R0-R11	$3.18	$2.78
	Floor:R0-R30	$2.03	$2.01
	Attic:R0-R38	$1.78	$1.53
Manufactured Home	Floor R0 - R22	$2.71	$2.71

Supplemental attic insulation (R11-R38) was not offered between 2020 and 2022. In the absence of data for this measure, attic insulation costs for single family and small multifamily homes are used. No attic insulation in manufactured home projects are recorded during this time except for six direct installation projects. In the absence of data for this measure and home type, attic insulation costs for single family and small multifamily homes are used.

Non Energy Benefits

For gas measures installed outside Energy Trust's electric service territory, fan and cooling electric savings are converted to a NEB at the blended residential utility rate of $0.116/kWh in Oregon. These are identified as gas only territory or "GOT" in the Oregon CEC tables. Since all of SW Washington is gas only territory, the Washington measures do not include the GOT designation. Electric savings are converted to a NEB at the Clark County rate of $0.082/kWh.

In addition to the quantified NEBs, insulation provides a number of non-quantifiable benefits to home occupants including increased comfort and noise reduction.

Incentive Structure

The maximum incentives for the standard measures are listed in Table 1 and Table 3 and for qualified measures in Table 2. These maximum values are for reference only and are not suggested incentives.

Incentives will be structured per square foot of insulation installed.

Follow-Up

The savings based on RTF workbooks are weighted by the distribution of HVAC system types and efficiencies for participants during the period from 2020 to 2022. This distribution should be updated using more recent participant data.

Project costs should be updated at the time of the next update.

Supporting Documents

The cost effective screening for these measures is number 58.3.2. It is attached and can be found along with supporting documentation at: \\Etoo.org\home\Groups\Planning\Measure Development\Residential\Res Weatherization\insulation\existing homes and small mf

58.3.2 OR WA
CEC_2023_v_1_0 Res

Version History and Related Measures

Energy Trust has been offering residential insulation measure for many years. These predate our measure approval documentation process and record retention requirements. Table 10 may be incomplete, particularly for measures approved prior to 2013.

Table 10 Version History

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.
7/3/2020	252.1	Introduce direct install ceiling insulation
12/19/2022	58.3	Update savings, costs, and NEBs. Combine MADs 252 and 58.

Table 11 Related Measures

Measures	MAD ID
Multifamily insulation	110

Approved & Reviewed by

Jackie Goss, PE
Sr. Engineer – Planning & Evaluation

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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 1 and in Washington Table 2.**Error! Reference source not found.** 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 1 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 2 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.

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[1]. ENERGY STAR specifications have been updated to reflect Uniform Energy Factor, UEF, product rating which are now used throughout the industry. Table 3 is a comparison of ENERGY STAR Product Criteria eligibility details between versions.

Table 3 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[2].

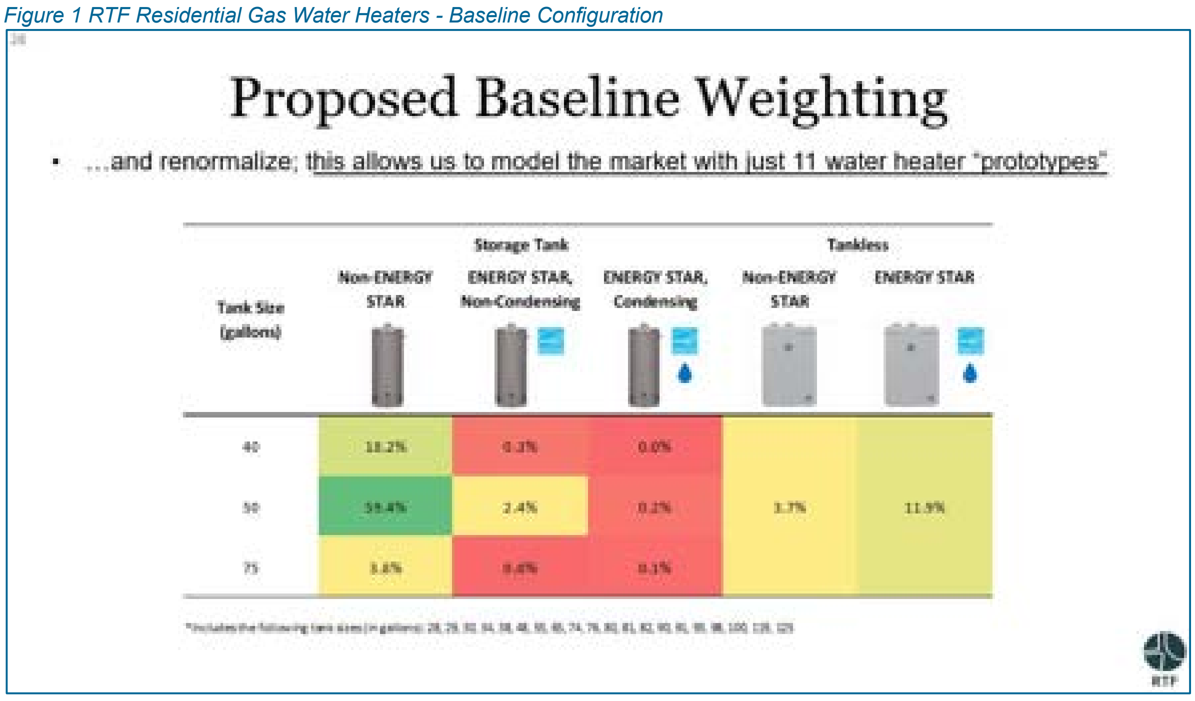
Baseline

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 1 and Table 4 from the RTF Residential Gas Water Heaters: New Measure Proposal presentation from 4/14/2021[3] and RTF measure analysis.

Figure 1 RTF Residential Gas Water Heaters - Baseline Configuration



[1] 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
[2] Regional Technical Forum, Residential Gas Water Heaters measures: https://rtf.nwcouncil.org/measure/residential-gas-water-heaters-0
[3] RTF Residential Gas Water Heaters Presentation, April 14, 2021: https://nwcouncil.app.box.com/v/20210414GasWaterHeaterPres

Table 4 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)[4]. 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 1 and Equation 2, respectively.

Equation 1 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 2 Tankless Water Heater WHAM

The resulting equation is:

$$Q_{in} = \frac{vol \times den \times C_p \times (T_{tank} - T_{in})}{RE \times (1 + PA_{twh})} \times \left(1 - \frac{Q_p}{P_{ON}}\right) + 24 \times Q_p \times (T_{Tank} - T_{amb})$$

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_{twh} = 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

[4] https://www.regulations.gov/document?D=EERE-2006-STD-0129-0149

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[5] data as follows in Table 5, market share is noted in Table 4.

Table 5 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 6, 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 6 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*[6] 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 7 is a summary of installations costs, Table 8 is the combined install and equipment costs, and Table 9 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*[7], Sept. 6, 2019 and reflect plumbing, electrical, venting, condensate, gas line upgrades as needed by equipment type.

[5] 2016-2017 Regional Building Stock Assessment (RBSA) II https://neea.org/resources/rbsa-ii-combined-database
[6] RTF Residential Gas Water Heaters Workbook v1.0: https://nwcouncil.box.com/v/ResGasWaterHeaterv1-0
[7] NEEA Lab Testing of Tankless Water Heater System, Sept. 6, 2019: https://neea.org/resources/lab-testing-of-tankless-water-heater-systems

Table 7 RTF Residential Gas Water Heaters - Installation Cost by Water Heater Type ($2020)

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 8 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 9 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 1 and Table 2 ***Error! Reference source not found.****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-CE
C_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 10 may be incomplete, particularly for measures approved prior to 2013.

Table 10 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 11 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

Measure Approval Document for New Manufactured Homes ENERGY STAR and NEEM+

Valid Dates
January 1, 2024 – December 31, 2026 or 6 months after the new code is implemented.

End Use or Description
New Manufactured Homes

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

- Residential New Manufactured Homes

Within these programs, applicability to the following customer qualifications, delivery methods, building types or market segments or program tracks are expected or required:

- Retailer incentives
- Customer incentives

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

- New

Purpose of Re-Evaluating Measure
Federal Housing and Urban Development, HUD, building code for manufactured homes and specifications for ENERGY STAR® and Northwest Energy Efficiency Manufactured Housing Program, NEEM, certifications were expected to be updated in 2023. However, legal challenges to proposed federal HUD code have delayed the adoption and implementation of new HUD Code[1] and the development of new NEEM specifications. ENERGY STAR v3.0 specifications begin January 1, 2026 but are not significantly different than v2.0 specifications seen in the Northwest. We anticipate updating the new manufactured homes configurations within 6 months of when the new ENERGY STAR and NEEM specifications are implemented. This MAD continues approval of the measures until new code and improved specifications are finalized and implemented.

This MAD includes updated measure costs and weightings. Baseline and required specifications are unchanged though savings are updated due to updated weightings.

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 2024-v1.2. The Oregon electric avoided cost year is 2024 and the Oregon gas avoided cost year is 2024. The Washington gas avoided cost year is 2024. The zones in the measure application descriptions refer to heating zones. The values in these tables are per home.

Table 1 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	% Elec	% Gas
1	ENERGY STAR Electric Zone 1	45	2,068.40	0.00	4,013.89	0.00	4,013.89	1.0	1.0	100%	0%
2	ENERGY STAR Electric Zone 2	45	3,153.18	0.00	4,013.89	0.00	4,013.89	1.6	1.6	100%	0%
7	NEEM+PLUS Electric Zone 1	45	2,609.33	0.00	6,642.63	0.00	5,226.73	1.0	0.8	100%	0%
8	NEEM+PLUS Electric Zone 2	45	3,890.91	0.00	6,642.63	0.00	6,642.63	1.2	1.2	100%	0%
14	Energy Star or NEEM+Plus Gas any zone	45	26.98	118.23	4,049.42	0.00	4,049.42	1.2	1.2	1%	99%
15	Energy Star or NEEM+Plus Gas any zone Gas only	45	0.00	118.23	4,049.42	3.33	4,049.42	1.2	1.2	0%	100%

Table 2 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	ENERGY STAR Gas Zone 1	45	105.91	$4,013.89	$1.99	$4,013.89	1.5	1.5	0%	100%
2	NEEM+PLUS Gas Zone 1	45	123.77	$6,642.63	$17.98	$6,642.63	1.0	1.1	0%	100%
3	ENERGY STAR or NEEM+ Gas Zone 1	45	106.15	$4,049.42	$2.20	$4,049.42	1.4	1.5	0%	100%

Exceptions
Energy Trust was granted an exception from the Oregon Public Utilities Commission (PUC) on 9/19/23 to continue to offer incentives for manufactured homes meeting NEEM+ Electric in Heating Zone 1 specifications. The exception used the minor exception process. The PUC staff acknowledges the volume and savings of this measure is 1% of the new manufacture homes program which is well within the 5% program requirements. The exception was granted under UM551 exception criteria:

C. Measure is included for consistency with other programs in the region. On March 21,2023 in Docket UM 1710(6) the PUC approved a cost-effectiveness exception for Idaho Power to offer new manufactured homes measures including NEEM+ electric homes in HZ1. Many regional consumer owned utilities also offer similar measures. In total, 28 have been identified in Oregon. Additionally, manufactured homes are an efficiency measure of focus for NEEA, which is supported by the region's utilities.

D. Measure helps to increase participation in a cost effective program. Overall, Energy Trust's new manufactured home program is cost-effective, of which NEEM+ homes represent a small share. The NEEM+ option is important for its role as the most efficient in the new manufactured home program. Energy Trust pays retailers a per-unit incentive to encourage their promotion of energy efficient models, and eliminating incentives for the most efficient option could complicate the buying and selling market.

[1] Federal Register. Energy Conservation Program: Energy Conservation Standards for Manufactured Housing; Extension of Compliance Date. Effective 5/30/2023. Docket Number 2023-11043. _ 2023-11043 Federal Register Extension of MH Code.pdf

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 12/31/2026, when the measure become >5% of the Program's savings, or when a new MAD is produced with a TRC drop. Energy Trust shall notify PUC Staff if the measure increases to 25% of incented new manufactured homes. Energy Trust will monitor the development of the new building code from Federal agencies, the Department of Energy and Housing and Urban Development, and update the measure within 6 months of this code update.

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+.

Implementation Details

- In Oregon Measure # 15 is for use in gas heated buildings in gas only territory
- If offered in Washington, the program may decide to either offer either option a) or b) but cannot offer both at the same time:
  a) Washington Measures 1: ENERGY STAR Gas Zone 1 and Measure 2: NEEM+PLUS Gas Zone 1
  b) Washington Measure 3: ENERGY STAR or NEEM+Plus Gas Zone 1
- In Oregon, where gas heated homes are blended by efficiency tier and heating zone, tier and zone information must continue to be collected.

Details

Manufactured Homes built to ENERGY STAR and NEEM+ specifications[2] save electricity and natural gas through built-in efficiency upgrades across various home components. Home certification and verification is performed by NW Energy Works. The Regional Technical Forum, RTF, SEEM modeling assumptions for baseline and improved cases are listed in Table 3. Note that these are the modeled components and may not align directly with the specifications.

Table 3 RTF SEEM modeled components for baseline and improved cases

Component	Baseline (average non-NEEM house)	ENERGY STAR	NEEM +PLUS
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 84.4% 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 assumes the average components of non-NEEM homes, referred to as "HUD Code", with a few improvements from the actual code, including:

- 50% LED lighting in all homes
- 84.4 AFUE gas furnace efficiency in gas heated homes
- Blend of 60% electric forced air furnaces and 40% 7.7 HSPF heat pumps in electric heated homes

Measure Analysis

Energy savings are based on Regional Technical Forum, RTF, SEEM modeling of three manufactured home prototypes of 924, 1568 and 2352 square feet. Each efficiency level: baseline, ENERGY STAR, and NEEM+ were modeled with specifications listed in Table 3 for each of three heating system types: gas furnace, electric furnace and heat pumps. 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). Total savings per prototype were converted to savings per square foot and then rolled up to reflect whole home saving for an average 1,572 square foot manufactured home, based on average conditioned floor area of new manufactured homes from NEEM as described in the RTF New Manufactured Homes and HVAC v5.1 measure analysis 'Parameters' from June 2023[3].

Heating and Cooling Savings

The majority of 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 Ecotope field studies, NEEM input and RTF staff review and consultations, full SEEM modeling details sourced from RTF MHNewCosntructionSEEMWorkBookv10[4]. 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*

[2] Northwest Energy Efficient Manufactured Housing Program, Technical Specification Comparison published 02/04/2019: https://static1.squarespace.com/static/5b10a91989c172d4391ab016/t/5c58dbc28165f5be9d9e8503/1549327298845/NEEM_Spec_Comparison_020419.pdf
[3] RTF Residential New Manufactured Homes analysis ResMHNewHomesandHVAC_v5_1 published 6/29/2023: https://rtf.nwcouncil.org/measure/new-manufactured-homes/
[4] RTF SEEM modeling details, assumptions and analysis of New Manufactured Homes v10: https://nwcouncil.box.com/v/20200519NewMHSEEM

Billing Analysis[5] prepared by Ecotope for Northwest Energy Efficiency Alliance, NEEA. These years are used for baseline reference as 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.

Lighting Saving

The baseline is based on the RTF Residential Lighting tool ResLighting_v8.2[6], weighted to the Regional Building Stock Assessment II, 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 36.6 lamps per house and 2.1 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, they are calculated at 130.4 kWh.

Appliances

Appliance savings are based on RTF analysis and are 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. Both ENERGY STAR and NEEM+ homes include 24.3 kWh savings for efficient refrigerators while the NEEM+ homes include an additional 65.7 kWh savings for efficient mechanical ventilation.

Electric Homes Weighting

Heat pump home savings from the RTF analysis distinguished savings by heating and cooling zone. To simplify the measure offers the program is not offering cooling zone specific measures. Each of these heat pump configurations was rolled into a single savings value per heating zone, based on program distribution of cooling zones across all new manufactured homes, see Table 4.

Table 4 Heat pump savings per heating zone, weighted by cooling zone distribution of all new manufactured homes from 2020-July 2023 per program data

ENERGY STAR HOMES	RTF ENERGY STAR Whole Home Savings (kWh)	RTF NEEM + Whole Home Savings kWh	Cooling Zone Distribution of All New Manufactured Homes	ENERGY STAR Heat Pump Home Savings per Heating Zone	NEEM + Heat Pump Home Savings per Heating Zone
HP HZ1 CZ1	1199.2	1593.2	21%	1,204.7	1,600.3
HP HZ1 CZ2	1203.8	1599.3	52%		
HP HZ1 CZ3	1210.7	1607.9	27%		
HP HZ2 CZ1	1930.4	2453.0	21%	1,935.8	2,460.2
HP HZ2 CZ2	1935.0	2459.1	52%		
HP HZ2 CZ3	1941.8	2467.8	27%		
HP HZ3 CZ1	2603.2	3247.3	21%	2,608.6	3,254.4
HP HZ3 CZ2	2607.8	3253.4	52%		
HP HZ3 CZ3	2614.6	3262.0	27%		

To calculate one savings value for any electrically heated homes, electric forced air furnaces and heat pumps were combined assuming 60% of electrically heated homes have an electric furnace while 40% have a heat pump installed. This is based on RBSA heating system prevalence, NEEM studies, and RTF review and discussion as noted in the RTF New Manufactured Homes measure analysis v5.1 and is applied to baseline and improved cases. Electric heated homes were weighted to reflect savings for Heating Zone 1 and a combined Heating Zone 2 & 3, based on program distribution of electric heated new manufactured homes, see Table 5.

Table 5 Heating zone distribution and savings of electrically heated new manufactured homes from 2020 – July 2023 program data

Efficiency Level	Heating Zone	Savings eFAF Heated Homes (kwh)	Savings Heat Pump Heated Homes (kWh)	Savings Any Electric Heat (kWh)	HZ Distribution of Electrically Heated Homes	Savings (kWh)
ENERGY STAR	HZ 1	2644.2	1204.7	2068.4	89%	2068.4
	HZ 2	3746.9	1935.8	3022.5	9%	3153.2
	HZ 3	4629.8	2608.6	3821.3	2%	
NEEM +	HZ 1	3282.0	1600.3	2609.3	89%	2609.3
	HZ 2	4586.7	2460.2	3736.1	9%	3890.9
	HZ 3	5634.1	3254.4	4682.2	2%	

Gas Homes Weighting

Gas homes were weighted to single ENERGY STAR or NEEM+ Any Heating Zone measure per 2020 Oregon Public Utility Commission, OPUC, guidance 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."*

Gas homes were weighted based on program distribution of gas heated new manufactured homes per heating zone, see Table 6, resulting in 24.3 kWh and 118 therms for ENERGY STAR homes and 220.4 kWh and 138 therms for NEEM+ homes in any heating zone. To determine a single gas heated manufactured home savings to reflect both ENERGY STAR and NEEM+ homes, savings were further weighted by program participation of each efficiency level from 2020 to July 2023, 98.6% ENERGY STAR and 1.4% NEEM+, resulting in a total weighted savings of 27.0 kWh and 118.2 therms for any efficient gas heated manufactured home in any heating zone. For the Washington measure, only heating zone 1 savings are used.

Table 6 Heating zone distribution of gas heated new manufactured homes from 2020 – July 2023 program data

Heating Zone	Gas Heated New Manufactured Homes	ENERGY STAR		NEEM+	
		Savings (kWh)	Savings (therms)	Savings (kWh)	Savings (therms)
1	73%	24.3	105.9	220.4	123.8
2	27%	24.3	150.5	220.4	176.5
3	0%	24.3	186.2	220.4	218.8
Gas Manufactured Home Savings, Any Heating Zone		**24.3**	**118.0**	**220.4**	**138.0**

[5] Ecotope. Summary of 2006 NEEM Manufactured Homes: Field Data and Billing Analysis, March 2009. https://www.ecotope.com/ecotope-publications-database/
[6] RTF Residential Lighting Workbook v8.2, April 2020: https://rtf.nwcouncil.org/measure/residential-lighting/

Comparison to RTF or other programs
This analysis is drawn directly from RTF savings and baseline calculations. RTF has more measure identifiers than Energy Trust. For programmatic efficiency, we combine similar measures and weight them based on program prevalence rather than RTF prevalence.

RTF has also extended this measure, with price updates only, to address HUD code and efficient case specification delays.

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.

Load Profile
Electric Load Profiles:
- Ele Resistance – all electric heat measures
- Res Refrigerator - gas heat measures

Gas Load Profiles:
- No gas profile is used/needed for electric heated measures as there are no gas savings
- Res Heating – all gas heated measures

Cost
Costs used in this MAD are based on the RTF New Manufactured Homes v5.1 workbook from June 2023. RTF costs are based on conversation with NW Energy Works staff in 2017 and additional conversations with NEEA staff which include the following process and costs adjustments:
- Incremental cost from HUD code to ENERGY STAR and NEEM+ components are summarized in Table 7 and are summed as Incremental Whole Home Costs. Insulation component costs were increased 110% in May 2020 reflecting NW Energy Works and manufacturer feedback.
- Wholesaler to retailer markup of 185% has been in place since 2017 and has not been adjusted
- Additional costs for upgraded lighting, ENERGY STAR refrigerators and mechanical ventilation fans are added.
- Whole home costs were increased 150% over pre-COVID costs, based on conversations with Northwest Energy Works in April 2022, reflecting material and labor cost increases. This 150% is applied to RTF 2016$ values and is meant to reflect cost changes and inflation costs simultaneously, additional GDP adjustments were not applied. The 150% cost increase explained in the RTF Manufactured Home Replacement Savings and Costs v2.1 analysis, published in August 2022[7], were not included in the New Manufactured Homes v5.1 workbook published in 2023, so are applied within this analysis.

The final incremental costs of $4,014 for ENERGY STAR and $6,643 for NEEM+. For the gas measures blending ENERGY STAR and NEEM+, the incremental costs are blended at the same gas program participation rates of 98.6% and 1.4%, respectively, for a weighted incremental cost of $4,049.

Table 7 Incremental component costs from RTF

Incremental Component Cost (2016$)	**ENERGY STAR**	**NEEM+**
Ceiling	$300	$654
Window	$247	$470
Ducts	$158	$158
Floors	$327	$327
Walls	$383	$722
Incremental Whole Home Cost	**$1,416**	**$2,332**
185% Wholesaler to retail mark up		
Retailer Cost to Customer (2016$)	**$2,619**	**$4,314**
Additional Incremental Component Cost (2016$)		
Lighting Upgrade	$0	$31
ENERGY STAR Refrigerator	$56	$56
Mechanical Ventilation Fan Upgrade	$0	$27
Pre-COVID costs with appliance upgrades	**$2,676**	**$4,428**
150% cost and inflation adjustment		
2023 Incremental Cost to Customer (2023$)	**$4,014**	**$6,643**

Heating equipment costs are not included in the incremental costs as the baseline and improved cases use the same equipment at the same market prevalence within the RTF savings analysis. For gas furnaces the market baseline efficiency is 84.4 AFUE based on input from NW Energy Works indicating 60% of gas furnaces are 80 AFUE and 40% are 92 AFUE. For electric homes, the electric furnace and an 8.2 HSPF heat pump savings are blended based on the assumption that 40% of new electric heated manufactured homes will have a heat pump.

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.

Incentive Structure
The maximum incentives listed in Table 1 and Table 2 *are for reference only and are not suggested incentives.* Incentives will be paid to retailers per qualifying home, additional incentives may be paid to the end-customers; total combined retailer and customer incentives are not to exceed the maximum. Incentives will be structured per manufactured home.

Follow-Up
- Federal HUD code, ENERGY STAR and NEEM specifications are expected to be updated and implemented at the end of-2025, these new specifications should be reviewed for next updates.
- The RTF New Manufactured Homes measure is expected to be updated, including a new modeling tool, the program should review and incorporate RTF updates as appropriate.
- Weighting of homes by program participation for efficiency rating and heating and cooling zones should continue to be reviewed and updated.
- Lighting baselines should be updated to reflect federal and state standards as well as market conditions.

[7] RTF Manufactured Home Replacement Savings and Cost v2.1 published 8/1/2022: https://rtf.nwcouncil.org/measure/manufactured-home-replacement/

Supporting Documents

The cost effectiveness screening for these measures is number 109.5.3. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Residential\Manufactured homes\new manufactured homes

109.5.3 OR-WA-CE Calculator_2024_v_1

Version History and Related Measures

Energy Trust has been offering manufactured home measures for many years. These predate our measure approval documentation process and record retention requirements. Table 8 may be incomplete, particularly for measures approved prior to 2013.

Table 8 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
10/17/2023	109.5	Update to cost and program participation weights; extends measure until next code update expected in 2024.

Table 9 Related Measures

Measures	MAD ID
Manufactured homes early retirement	199

Approved & Reviewed by

Jackie Goss, PE
Sr. Engineer – Planning & Evaluation

Disclaimer

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Measure Approval Document for Connected Smart Thermostats

Valid Dates
January 1, 2023 to December 31, 2025

End Use or Description
Web-enabled smart thermostats with occupancy detection provide energy savings through reduced run time of heating and cooling systems and/or changes in auxiliary heat control when paired with heat pumps. Some models also provide additional energy savings through opt-in Thermostat Optimization services.

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
- Products
- Existing Buildings (Multifamily)
- Existing Manufactured Homes
- New Homes

Within these programs, applicability to the following delivery channels and program tracks are expected:
- Retail delivery (midstream)
- Direct Ship
- Contractor Install
- Self-Install
- Community Partner Funding
- Income Qualified

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

Purpose of Re-Evaluating Measure
- Version 153.8: removes co-funded project costs from contractor installed cost calculations as these did not reflect pre-co-funding project totals, corrects error in gas-only install rates. Clarification of co-funding rules for Washington.
- Version 153.7: corrects error in optimization savings calculation.
- Version 153.6: residential thermostat MADs #148, #153, #222, #250 and #274 have been combined. Sources, assumptions and methods aligned between applications.

Cost Effectiveness
Cost effectiveness is demonstrated in Table 1 through Table 4. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2023-v1.0. In Oregon the electric avoided cost year is 2023 and the gas avoided cost year is 2023. In Washington the gas avoided cost year is 2023. The values in these tables are per unit.

Energy Trust has received guidance 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 complementary funded measures, we anticipate remaining cost will be most often understood as the customer payment plus Energy Trust incentive. Table 2 and Table 4 show measure applications for complementary funded projects. In these tables the maximum allowable remaining cost after co-funding is shown instead of incremental cost.

Table 1 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	% Ele	% Gas
1	Smart Thermostat- SF & MH- Direct/ Contractor Install- Heat Pump	11	963.71	0.00	$250.00	0	$250.00	3.5	3.5	100%	0%
2	Smart Thermostat- SF & MH- Direct/ Contractor Install- gFAF	11	63.46	30.63	$250.00	0	$250.00	2.2	2.2	29%	71%
3	Smart Thermostat- SF & MH- Direct/ Contractor Install- eFAF	11	399.24	0.00	$250.00	0	$250.00	1.5	1.5	100%	0%
4	Smart Thermostat- Multifamily- Direct/Contractor Install- Heat Pump	11	573.20	0.00	$250.00	$0.00	$250.00	2.1	2.1	100%	0%
5	Smart Thermostat- Multifamily- Direct/Contractor Install- gFAF	11	30.82	14.12	$250.00	$0.00	$250.00	1.0	1.0	30%	70%
11	Smart Thermostat- Retail/ Online- Heat Pump	11	902.54	0.00	$189.99	$0.00	$189.99	4.4	4.4	100%	0%
12	Smart Thermostat- Retail/ Online- gFAF	11	58.79	32.07	$189.99	$0.00	$189.99	2.9	2.9	26%	74%
13	Smart Thermostat- Retail/ Online- eFAF	11	412.71	0.00	$189.99	$0.00	$189.99	2.0	2.0	100%	0%
14	Smart Thermostat- Retail/ Online- Any Electric	11	755.61	0.00	$189.99	$0.00	$189.99	3.7	3.7	100%	0%
15	Smart Thermostat- SF & MH- Direct/ Contractor Install- gFAF GOT	11	0.00	30.63	$250.00	$7.36	$250.00	1.6	1.8	0%	100%
17	Smart Thermostat- Retail/ Online- gFAF GOT	11	0.00	32.07	$189.99	$6.82	$189.99	2.1	2.4	0%	100%
33	Smart Thermostat- New Homes- Heat Pump	11	588.40	0.00	$250.00	$0.00	$250.00	2.2	2.2	100%	0%
34	Smart Thermostat- New Homes- gFAF	11	70.26	21.74	$250.00	$0.00	$250.00	1.8	1.8	39%	61%
37	Smart Thermostat- New Homes- gFAF GOT	11	0.00	21.74	$250.00	$8.15	$250.00	1.1	1.4	0%	100%

Table 2 Cost Effectiveness Calculator Oregon, Co-Funded Measure Configurations, per unit

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Max Remaining Cost ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Ele	% Gas
19	Smart Thermostat- SF & MH- Direct/ Contractor Install- Heat Pump- with Co-funding	11	963.71	0.00	$886.54	0	$886.54	1.0	1.0	100%	0%
20	Smart Thermostat- SF & MH- Direct/ Contractor Install- gFAF- with Co-funding	11	63.46	30.63	$543.86	0	$543.86	1.0	1.0	29%	71%
21	Smart Thermostat- SF & MH- Direct /Contractor Install- eFAF- with Co-funding	11	399.24	0.00	$367.27	0	$367.27	1.0	1.0	100%	0%
22	Smart Thermostat- Multifamily- Direct/ Contractor Install- Heat Pump- with Co-funding	11	573.20	0.00	$527.30	0	$527.30	1.0	1.0	100%	0%
23	Smart Thermostat- Multifamily- Direct/ Contractor Install- gFAF- with Co-funding	11	30.82	14.12	$254.53	0	$254.53	1.0	1.0	30%	70%
24	Smart Thermostat- Multifamily- Direct/ Contractor Install- eFAF- with Co-funding	11	207.89	0.00	$191.24	0	$191.24	1.0	1.0	100%	0%
25	Smart Thermostat- Retail/ Online- Heat Pump- with Co-funding	11	902.54	0.00	$830.27	$0.00	$830.27	1.0	1.0	100%	0%
26	Smart Thermostat- Retail/ Online- gFAF- with Co-funding	11	58.79	32.07	$550.60	$0.00	$550.60	1.0	1.0	26%	74%
27	Smart Thermostat- Retail/ Online- eFAF- with Co-funding	11	412.71	0.00	$379.66	$0.00	$379.66	1.0	1.0	100%	0%
28	Smart Thermostat- Retail/ Online- Any Electric- with Co-funding	11	755.61	0.00	$695.10	$0.00	$695.10	1.0	1.0	100%	0%
29	Smart Thermostat- SF & MH- Direct/ Contractor Install- gFAF GOT- with Co-funding	11	0.00	30.63	$450.72	$7.36	$387.95	1.0	1.0	0%	100%
30	Smart Thermostat- Multifamily- Direct/ Contractor Install- gFAF GOT- with Co-funding	11	0.00	14.12	$209.29	$3.57	$178.80	1.0	1.0	0%	100%
31	Smart Thermostat- Retail/ Online- gFAF GOT- with Co-funding	11	0.00	32.07	$464.30	$6.82	$406.14	1.0	1.0	0%	100%
35	Smart Thermostat- New Homes- Heat Pump- with Co-funding	11	588.40	0.00	$541.28	$0.00	$541.28	1.0	1.0	100%	0%
36	Smart Thermostat- New Homes- gFAF- with Co-funding	11	70.26	21.74	$447.96	$0.00	$447.96	1.0	1.0	39%	61%
38	Smart Thermostat- New Homes- gFAF GOT- with Co-funding	11	0.00	21.74	$344.83	$8.15	$275.33	1.0	1.0	0%	100%

Table 3 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	% Ele	% Gas
1	Smart Thermostat- SF & MH- Direct/ Contractor Install- gFAF	11	30.63	$250.00	$5.18	$250.00	2.1	2.3	0%	100%
2	Smart Thermostat- Multifamily- Direct/Contractor Install- gFAF	11	14.12	$250.00	$2.51	$239.12	1.0	1.0	0%	100%
3	Smart Thermostat- Retail/Online- gFAF	11	32.07	$189.99	$4.80	$189.99	2.9	3.1	0%	100%
7	Smart Thermostat- New Homes- gFAF	11	21.74	$250.00	$5.73	$250.00	1.5	1.7	0%	100%

Table 4 Cost Effectiveness Calculator Washington, Co-Funded Measure Configurations, per unit

#	Measure	Measure Life (years)	Savings (therms)	Max Remaining Cost ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Ele	% Gas
4	Smart Thermostat- SF & MH- Direct/ Contractor Install- gFAF- with Co-Funding	11	30.63	$564.62	$5.18	$518.81	1.0	1.0	0%	100%
5	Smart Thermostat- Multifamily- Direct/ Contractor Install- gFAF- with Co-Funding	11	14.12	$284.22	$2.51	$239.12	1.0	1.0	0%	100%
6	Smart Thermostat- Retail/ Online- gFAF- with Co-Funding	11	32.07	$585.58	$4.80	$543.14	1.0	1.0	0%	100%
8	Smart Thermostat- New Homes- gFAF- with Co-Funding	11	21.74	$418.92	$5.73	$368.20	1.0	1.0	0%	100%

Requirements

- Thermostats must be on Energy Trust's Qualified Products List
- Home must be heated with fuel provided by a participating Energy Trust utility.
- Orders for online (i.e., Direct Ship) delivery channels will be limited to one thermostat per central HVAC system, up to two per residence.
- Incentives for Retail and Online delivery channels cannot exceed total product cost.

Additional requirements for Contractor Installed Thermostats on Heat Pumps

- Ducted heat pump must be the primary heating source
- Participants in measures for heat pump conversions in manufactured or single-family homes are not eligible, as those heat pumps are expected to have lock out controls.
- Thermostats must be installed to lock out supplemental/auxiliary electric furnace heat based on outdoor air temperature. The outdoor air temperature shall be determined either by a locally installed outdoor temperature sensor or by online weather data.
- If the thermostat uses online weather data, the unit must be connected to the Wi-Fi network in the home in which it is installed and configured with the location of the home
- Thermostats must be configured to lock out electric auxiliary heat at 35°F as specified in the Heat Pump Controls section of the Existing Homes Specifications Manual2 or meet one of the following exceptions:
  - Nest thermostat set to use the "Max Savings" Heat Pump Balance setting in lieu of the 35°F lockout temperature setting
  - Completion of PTCS or CheckMe! protocols that include the setting of an auxiliary heat lockout.
  - A waiver request submitted to the program for pre-approval

Additional requirements for complementary funded measures

- Remaining cost in Oregon must not exceed those shown in Table 2
- The remaining costs in Table 4 for Washington are recommended, however our treatment of complementary funding is only sanctioned by the OPUC for use in Oregon. In Washington there is not a measure-level TRC requirement so co-funding is not required.
- Program must track co-funding amounts and sources

Baseline

This measure uses an Existing Condition Baseline.
In new homes this measure uses a Market Baseline.

The baseline assumes a standard programmable thermostat, that is not enrolled in a thermostat optimization service, in a home with typical HVAC loads. Baseline heating and cooling load estimates are shown in Table 5.

For electrically heated single family and manufactured homes are baseline loads are sourced from the RTF's v2.1 Connected Thermostats UES Measure analysis1. Baseline existing single family and manufactured home gas furnace heating loads which are taken from RBSA 2's gas space heat usage estimate for Oregon. RBSA gas space heat usage estimates are used instead of RTF estimates since the RTF's baseline gas space heat usage values are not intuitive and appear to represent supplemental heat use, particularly in heating zones 2 and 3. RTF's baseline heating loads for eFAF homes also appear low. We assume this is related to smaller home sizes with eFAF compared to HP or gFAF.

Baseline heating load estimates for existing multifamily are also taken from the RTF's v2.1 Connected Thermostats Measure analysis. However, since the RTF's estimates cooling loads for multifamily appear to be unrealistically high, this analysis instead calculates multifamily cooling loads by applying the ratio of multifamily to single family heating loads (approximately 50% depending on heating system type), to estimated single family cooling loads.

RTF baseline heating and cooling load values for HZ1 and HZ2 in existing single family and manufactured homes are combined into statewide weighted average values using climate zone weights from Energy Trust's 2022 Measure Development Technical Guidelines (92% HZ1, 8% HZ2). RTF baseline heating and cooling load values for existing multifamily are not estimated separately by heating zone, and so no weighting by heating zone is necessary.

Baseline heating and cooling load estimates for new homes are based on modeled energy use estimates for single-family dwellings built to the 2021 ORSC.

Table 5 Statewide Weighted Average Baseline Heating and Cooling Loads

Housing Type	Heating System	Electric Heating (kWh)	Electric Cooling (kWh)	Gas Heating (therms)
Single Family & Manufactured Homes	Heat Pump	7,158	600	0
	gFAF	0	600	571.5
	eFAF	7,016	444	0
Existing Multifamily	Heat Pump	4,155	348	0
	gFAF	0	246	234.4
	eFAF	3,311	209	0
New Homes	Heat Pump	4,088	542	0.0
	gFAF	301	591	390

Measure Analysis

Energy Savings calculations in this analysis are divided into two parts; 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, auxiliary heat lockout, and an engaging user interface.

Optimization savings refer to the incremental energy 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

Thermostat device savings are calculated for each of the three main HVAC system types that connected smart thermostats are compatible with; heat pumps, gas furnaces and electric furnaces.

Device savings are calculated as a percentage of baseline heating and cooling loads. Percent savings assumptions are derived from the results of Energy Trust's 2020 Recurve Smart Thermostats Impact Analysis2 in the case of gas furnace and electric furnace homes and from Energy Trust's 2015 Nest Heat Pump Control Pilot Analysis3 in the case of heat pump homes. The 2020 Recurve analysis did not produce a statistically significant savings estimate for electric furnace homes or heat pump homes due to small sample size constraints and so Recurve's gas furnace savings estimate is applied to electric furnace homes. The 2015 Nest Heat Pump Control Pilot Analysis is used to estimate savings in Heat Pump homes since that is the most recent and applicable study specific to thermostat savings in heat pump homes in our region.

Table 6 Thermostat Device Savings Assumptions

Heating System	Savings as a % of Heating/Cooling Load	Source
Heat Pump	12.0%	Energy Trust 2015 Nest Heat Pump Control Pilot Billing Analysis
gFAF	4.9%	Energy Trust 2020 Recurve Smart Thermostats Impact Analysis
eFAF	4.9%	Energy Trust 2020 Recurve Smart Thermostats Impact Analysis

Percent savings assumptions are then multiplied by baseline heating and cooling loads to arrive at device savings by housing type and heating system type, shown in Table 7.

1 https://nwcouncil.app.box.com/v/ResConTstats-v2-1
2 https://energytrust.org/wp-content/uploads/2020/02/Recurve-Smart-Thermostat-Impact-Analysis-Reports-2015-2017.pdf
3 https://www.energytrust.org/wp-content/uploads/2016/12/nest_heat_pump_control_pilot_follow-up_billing_analysis.pdf

Table 7 Thermostat Device Savings Components

Housing Type	Heating System	% Savings	Electric Heating Savings (kWh)	Electric Cooling Savings (kWh)	Gas Heating Savings (therms)
Single Family & Manufactured Homes	Heat Pump	12.0%	859	72	0
	gFAF	4.9%	0	29	28.0
	eFAF	4.9%	344	22	0
Existing Multifamily	Heat Pump	12.0%	499	42	0
	gFAF	4.9%	0	12	11.5
	eFAF	4.9%	162	10	0
New Homes	Heat Pump	12.0%	490.56	65.04	0.00
	gFAF	4.9%	14.75	28.96	19.11

The last component of thermostat device savings is fan savings in gas heated homes. 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:

$$Fan\ kWh\ savings = (therm\ savings * 100{,}000 Btu/therm) input\ Btu/h * fan\ input$$

The resulting fan savings for gas heated homes are 24 kWh for single family/manufactured homes and 10 kWh for multifamily.

Measure analysis was also completed for smart thermostats in new multifamily units, but the baseload in new buildings is much lower leading to much lower savings and the measure was not cost effective or approved.

Device savings for smart thermostats are applied also to contractor installed advanced controls for heat pumps, despite that measure having a wider allowable QPL. While the these savings are based on Nest and ecobee in particular, which have savings features beyond lock-out heat control, it is the most recent source of residential lock out savings available.

Optimization Savings

Thermostat optimization savings are calculated separately for Nest and ecobee devices using evaluation results specific to each thermostat brand. Average optimization savings across both brands are then calculated and applied to each measure configuration according to relative volume of Nest versus ecobee devices in the program.

Optimization savings for Nest thermostats are based on the results of Energy Trust's 2017 Nest Seasonal Savings Pilot Evaluation4. Average Nest heating season optimization savings by heating system type, per opt-in device, are shown in Table 8. The 2017 Nest Seasonal Savings Pilot evaluation also found 4.1 kWh of cooling savings per opt-in device, which is applied to heat pump homes as well as the share of gFAF and eFAF homes that are estimated to have central cooling, according to RBSA 2 data. HVAC system weights and weighted average Nest optimization cooling savings for the three primary heating system types are shown in Table 9.

Table 8 Nest Optimization Heating Season Savings, per opt-in device

HVAC System	Savings Source	Savings per Opt In (therm or kWh)
Heat Pump	Heating Energy	121.00
Gas Furnace	Heating Energy	17.80
	Fan Energy	15.34
Electric Furnace	Heating Energy	195.89
	Fan Energy	15.34

Table 9 Nest Optimization Cooling Savings and RBSA Weights, per opt-in device

Housing Type	HVAC System	RBSA weight of cooling system	Nest Cooling Savings (kWh)	Weighted Average Savings (kWh)
Single Family & Manufactured Homes	Heat Pump	100%	4.1	4.10
	Gas Furnace w/CAC	55%	4.1	2.26
	Gas Furnace wo/CAC	45%	-	
	Electric Furnace w/CAC	17%	4.1	0.69
	Electric Furnace wo/CAC	83%	-	
Existing Multifamily	Heat Pump	100%	4.1	4.10
	Gas Furnace w/CAC	46%	4.1	1.88
	Gas Furnace wo/CAC	54%	-	
	Electric Furnace w/CAC	28%	4.1	1.15
	Electric Furnace wo/CAC	72%	-	

Optimization opt-in rates for Nest devices were provided by Nest staff in Fall 2021 and are 52% for the winter season and 41% for summer season. Opt-in rates for Nest's optimization service are also applied to the heating and cooling season savings shown in Table 8 and Table 9 to arrive at the final Nest optimization savings values shown in Table 12.

Optimization savings for ecobee devices are based on a pilot study of the eco+ optimization service in summer 2019, which found average cooling season savings of 39.24 kWh per device in our region. Results from eco+ pilot study reflect average savings across all ecobee users who each choose to participate in the eco+ optimization service at their desired level along a sliding scale, which means that an opt-in rate deduction does not need to be applied to ecobee optimization savings in the same way as Nest optimization savings. Ecobee optimization cooling savings are applied only to heat pump homes and to the portion of gFAF and eFAF homes that are estimated to have central cooling, as shown in Table 10.

4 https://www.energytrust.org/wp-content/uploads/2017/12/Energy-Trust-of-Oregon-Nest-Seasonal-Savers-Pilot-Evaluation-FINAL-wSR.pdf

Table 10 ecobee Optimization Cooling Savings and HVAC system weights

Housing Type	HVAC System	RBSA Weight of cooling system	Ecobee Cooling Savings (kWh)	Weighted Average Savings (kWh)
Single Family & Manufactured Homes	Heat Pump	100%	39.1	39.12
	Gas Furnace w/CAC	55%	39.1	21.56
	Gas Furnace wo/CAC	45%	-	
	Electric Furnace w/CAC	17%	39.1	6.63
	Electric Furnace wo/CAC	83%	-	
Existing Multifamily	Heat Pump	100%	39.1	39.12
	Gas Furnace w/CAC	46%	39.1	17.90
	Gas Furnace wo/CAC	54%	-	
	Electric Furnace w/CAC	28%	39.1	10.93
	Electric Furnace wo/CAC	72%	-	

Average optimization savings for all program delivered thermostats are calculated by combining the optimization savings components described above for Nest and ecobee according to each brand's prevalence in the 2020-2021 program years within the delivery channel categories represented in this analysis. Brand prevalence for new homes is assumed to be equal to brand prevalence in the direct/ contractor installed delivery channel.

Table 11 Nest vs ecobee Prevalence, 2020-2021

Delivery Channel Category	Nest Prevalence	ecoboee Prevalence	Other Brand Prevalence
Direct/Contractor Installed	28%	37%	35%
Retail/Online	78%	22%	0%

Final thermostat optimization savings for each measure configuration, shown in Table 12, are then calculated as:

$$Savings\ per\ Device * Opt\ in\ Rate\ (where\ applicable) * Brand\ Prevalence$$

Table 12 Combined Optimization Savings by Delivery Channel and Housing Type, including Opt-In rate adjustments

Delivery Channel	Housing Type	Heating System	Nest Heating Savings Gas (therms)	Nest Heating Savings Electric (kWh)	Nest Cooling Savings (kWh)	ecobee Cooling Savings (kWh)	Total Electric Savings (kWh)
Direct/ Contractor Installed	Single Family & Manufactured Homes	Heat Pump	0.00	17.89	0.48	14.47	32.84
		gFAF	2.63	2.27	0.26	7.98	10.51
		eFAF	0.00	31.23	0.08	2.45	33.76
	Existing Multifamily	Heat Pump	0.00	17.89	0.48	14.47	32.84
		gFAF	2.63	2.27	0.22	6.62	9.11
		eFAF	0.00	31.23	0.13	4.04	35.41
	New Homes	Heat Pump	0.00	17.89	0.48	14.43	32.80
		gFAF	2.63	2.27	0.26	7.95	10.48
Retail/ Online	Single Family & Manufactured Homes	Heat Pump	0.00	49.17	1.31	8.58	59.03
		gFAF	7.23	6.23	0.72	4.73	11.67
		eFAF	0.00	85.83	0.22	1.45	87.50
	Existing Multifamily	Heat Pump	0.00	49.17	1.31	8.58	59.03
		gFAF	7.23	6.23	0.60	3.92	10.76
		eFAF	0.00	85.83	0.37	2.40	88.60

Install Rate

A 92% install rate assumption is applied to thermostats delivered within the Retail/Online channels, which is based on the rate of returned devices from the 2014 gas thermostat pilot which depended on self-installation. 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.

Housing Type Blending

Measure configurations for the Retail/Online delivery channel category reflect a blending of Single Family & Manufactured Homes (SF & MH) and Existing Multifamily savings values since housing type cannot always be reliably determined within these delivery channels. Housing type weights are determined using RBSA 2 data for Oregon and are shown in Table 13.

Table 13 RBSA Housing Type Weights for OR

Building Category	RBSA 2 Weight
Manufactured	11%
Large Multifamily (5 or more units)	2%
Single Family and Small Multifamily (4 or fewer units)	87%

Similarly, an "Any Electric System" measure configuration is also included in this analysis for Retail/Online delivery channels, which can be used in situations where the specific electric heating system type (heat pump or eFAF) cannot be reliably determined. RBSA 2 data on primary heating systems is used to determine the relative prevalence of heat pump and electric furnace homes in Oregon.

Table 14 RBSA 2 Electric Primary Heating System Weights for OR

Primary Heating System	RBSA 2 weight
Air Source Heat Pump	70%
Electric Furnace	30%

Final Electric and Gas savings for thermostats, including both device savings and optimization savings, and taking into account all applicable housing type weights, heating system weights, and opt in rates, are shown in Table 15.

Table 15 Final Thermostat Savings by Delivery Channel, Heating System and Housing Type

Measure Configuration	Device Savings		Optimization Savings				
	Electric (kWh)	**Gas (Therms)**	**Electric (kWh)**	**Gas (Therms)**	**Install Rate**	**Final Electric Savings Total (kWh)**	**Final Gas Savings Total (Therms)**
SF & MH- Direct/Contractor Install- Heat Pump	930.91	0.00	32.80	0.00	100%	963.71	0.00
SF & MH- Direct/Contractor Install- gFAF	52.97	28.00	10.48	2.63	100%	63.46	30.63
SF & MH- Direct/Contractor Install- eFAF	365.48	0.00	33.76	0.00	100%	399.24	0.00
Existing MF- Direct/Contractor Install- Heat Pump	540.40	0.00	32.80	0.00	100%	573.20	0.00
Existing MF- Direct/Contractor Install- gFAF	21.73	11.49	9.09	2.63	100%	30.82	14.12
Existing MF- Direct/Contractor Install- eFAF	172.49	0.00	35.40	0.00	100%	207.89	0.00
Retail/Online- Heat Pump	921.99	0.00	59.03	0.00	92%	902.54	0.00
Retail/Online- gFAF	52.26	27.62	11.65	7.23	92%	58.79	32.07
Retail/Online- eFAF	361.07	0.00	87.53	0.00	92%	412.71	0.00
Retail/Online- Any Electric	753.73	0.00	67.58	0.00	92%	755.61	0.00
New Homes- Contractor Install- Heat Pump	555.60	0.00	32.80	0.00	100%	588.40	0.00
New Homes- Contractor Install- gFAF	59.78	19.11	10.48	2.63	100%	70.26	21.74

Measure Life
The estimated measure life for programmable thermostats is 11 years according to the California Database for Energy Efficiency Resources (DEER).

Load Profile
The electric load profile "Res Air Source HP", which assigns 10% of annual savings to the cooling season, is used for Heat Pump and eFAF measure configurations since cooling savings are estimated to between 2% to 29% for those applications.

The electric load profile "Res Central AC", which assigns 50% of annual savings to the cooling season, is used for the electric fan and cooling savings in gas furnace (gFAF) measure applications, since cooling savings are estimated to be between 30-74% of total electric savings for gas furnace measure configurations.

The gas load profile "Res Heating" is applied to all gas-saving measures.

Cost
Incremental cost for retail and online thermostats was determined by looking at the lowest cost qualifying thermostat model for both Nest and Ecobee (MSRP $129.99 and $189.99). The greater of these two costs is then used in for cost-effectiveness screening to represent a potential scenario where the full cost of a thermostat is paid for by Energy Trust Incentive, and where customer retains their preferred choice of thermostat brand. The program is not expected to cover the full cost of a thermostat in all or most situations, but this approach to incremental costs maintains the flexibility to do so in certain targeted situations.

Incremental costs for Contractor Installed and Direct Install Thermostats are calculated as median installed cost for Energy Trust incentivized thermostats within those delivery channels from 2020-2021, excluding co-funded projects where PT data is not complete. Median cost excluding outlier project costs (>$1,000) is $250 per unit for single family, manufactured homes, and existing multifamily installations.

Costs for complementary funded thermostats will vary based on the details of each complementary funding agreement partnership. Energy Trust has received guidance 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 complementary funded measures, 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:

Max Remaining Cost ≥ Energy Trust Incentive + Customer Payment
Max Remaining Cost ≥ Total Cost – Co-funding

Non Energy Benefits
In both Oregon and Washington, unclaimed electric savings are included as non-energy benefits valued at the residential retail rate of electricity for those territories ($0.116/kWh OR, $0.082/kWh SW WA).

Comparison to RTF or other programs
This measure analysis uses baseline heating and cooling loads from the RTF's connected thermostats analysis but employs different percent savings assumptions for thermostat device savings that are based on Energy Trust's own evaluations. Energy Trust uses a longer measure life than the RTF and includes distinct savings assumptions for thermostat optimization that are not included in the RTF's measure analysis.

Incentive Structure
The maximum incentives listed in Table 1 through Table 4 are for reference only and are not suggested incentives. Incentives will be structured per unit.

Some of the max incentives for co-funded measures well exceed reasonable costs for this measure. Program should select incentives with care to ensure not over-paying.

Follow-Up
Install rate assumptions for retail and direct ship delivery channels should be re-examined and updated if needed in the next measure update.

At the next update baseline heating and cooling loads should be verified and updated, if necessary, as the RTF source includes several unintuitive values.

Supporting Documents

The cost effectiveness screening for these measures is number 153.8.6 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

153.8.6 or wa CEC
2023 v1.0 Smart The

Version History and Related Measures

Energy Trust has been offering thermostat and other HVAC controls and commissioning measure for many years. These predate our measure approval documentation processes and our record retention limits. Table 16 may be incomplete, especially for measures approved or implemented prior to 2013.

Table 16 Version History

Date	Version	Reason for revision
3/21/2006	x	Heat pump tune up approvals
8/6/2006	x	Minor corrections to heat pump Checkme! Commissioning approval
8/8/2006	x	Approval for heat pump Checkme! commissioning
8/30/2006	x	Approval for heat pump Checkme! commissioning using summer protocols
2007	x	Approval for commissioning of new and existing heat pumps
2007	x	Approval for heat pump commissioning for new and existing heat pumps.
11/22/2010	148.x	Pilot approval for contractor installed heat pump controls on existing heat pumps
9/12/2013	x	Nest heat pump pilot
9/6/2014	19.1	Approval for contractor installed advanced heat pump controls on new heat pumps
10/9/2014	132.x	Web-enabled thermostat gas heated homes pilot
12/3/2014	148.x	Web-enabled thermostats and soft lockout added to measures for existing heat pumps
8/17/2015	138.x	Retail and contractor installed web-enabled thermostats, electric and gas. Replaced MAD 132
10/22/2015	148.1	Updated savings for contractor installed thermostats on HP based on pilot results, updated costs
4/1/2016	153.1	Retail-only web-enabled thermostat measure, electric and gas. Update avoided costs. Replaced MAD 138.
5/15/2017	153.2	Adds measure identifiers for multifamily. Fan savings added. Contractor install included, may be offered concurrently with MAD 148.
10/5/2017	19.2	Updated costs, added web thermostats, clarified language & applicability for new heat pumps
10/5/2017	148.2	Cost update, correction to outdoor lockout savings for existing heat pumps
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 direct install. Corrected load profiles. Added gas only service territory measures.
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.
4/20/2020	250.1	New offer for direct ship
8/27/2020	148.3	Updated savings for all thermostat types to be based on web-enabled thermostat savings. Updated costs. Merge MAD 148 and 19 into a single document. MAD 19 will be retired.
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.
10/13/2020	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
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.
3/12/2021	153.5	Add contractor purchase as approved delivery channel.
10/6/2021	274.1	New Homes Washington thermostats approved
8/24/2022	153.6	Merge MADs 153, 250, 222, 274 and 148. Align savings methods and assumptions. Savings updated based on evaluation
09/26/2022	153.7	Correct error in optimization savings for retail/online applications
11/23/2022	153.8	Correct errors in contractor installed costs, GOT install rates and typos.

Table 17 Related Measures

Measures	MAD ID
Resideo Thermostat Optimization	217
Small Commercial Thermostat Pilot	235
New Homes Washington Thermostat	274
Contractor Installed Thermostats on Heat Pumps (inactive)	148
DI Smart Thermostats with Funding Partners (inactive)	222
Direct Ship Web Enabled Thermostats (inactive)	250

Approved & Reviewed by

Jackie Goss, PE
Sr. Engineer – Planning & Evaluation

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[1]. 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 1. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2021-v1.1. In Washington, the gas avoided cost year is 2020.

Table 1 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[2]. ENERGY STAR specifications have been updated to reflect Uniform Energy Factor, UEF, product rating which are now used throughout the industry. See Table 2 for a comparison of ENERGY STAR Product Criteria eligibility details between versions.

[1] Regional Technical Forum, Residential Gas Water Heaters measures: https://rtf.nwcouncil.org/measure/residential-gas-water-heaters-0
[2] 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

Table 2 ENERGY STAR Product Criteria Version 3.0 Compared to Version 4.0

	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 1 and Table 3 from the RTF Residential Gas Water Heaters: New Measure Proposal presentation from 4/14/2021[3] and RTF measure analysis.

Figure 1 RTF Residential Gas Water Heaters - Baseline Configuration

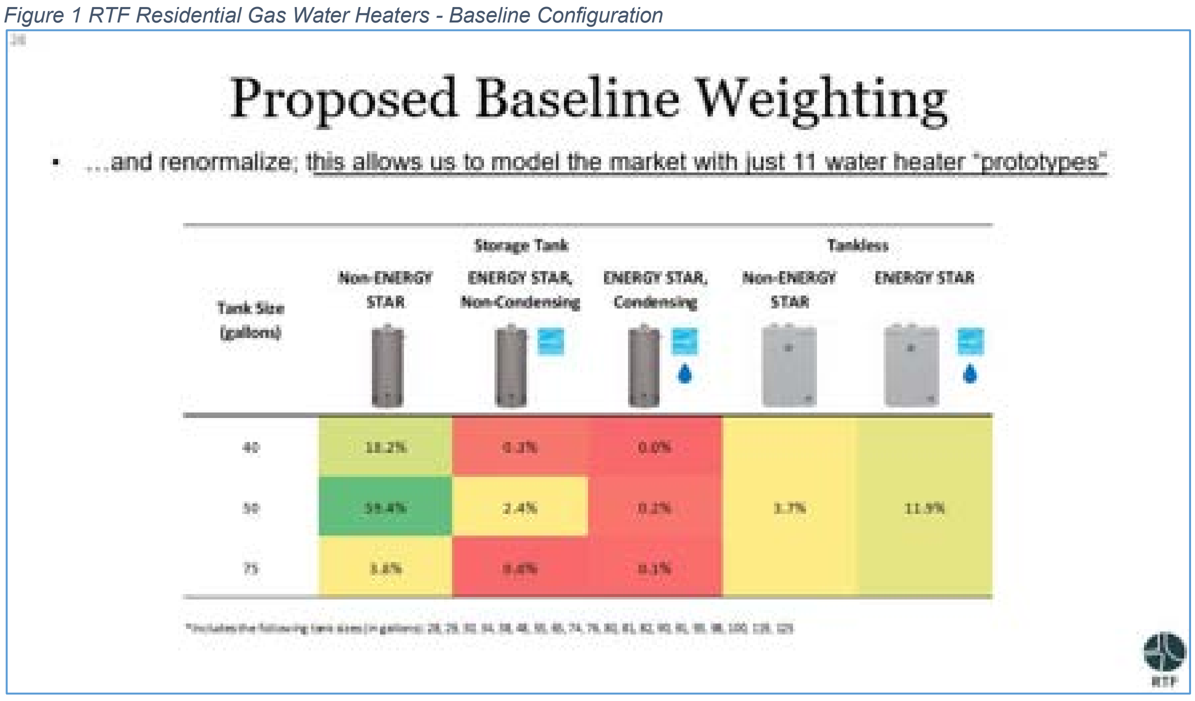

Table 3 RTF Residential Gas Water Heaters – Market Share Equipment Distribution

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)[4]. 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 1 and Equation 2, respectively.

[3] RTF Residential Gas Water Heaters Presentation, April 14, 2021: https://nwcouncil.app.box.com/v/20210414GasWaterHeaterPres
[4] https://www.regulations.gov/document?D=EERE-2006-STD-0129-0149

Equation 1 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.

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 2 Tankless Water Heater WHAM

The resulting equation is:

$$Q_{in} = \frac{vol \times den \times C_p \times (T_{tank} - T_{in})}{RE \times (1 + PA_{twh})} \times \left(1 - \frac{Q_P}{P_{ON}}\right) + 24 \times Q_p \times (T_{Tank} - T_{amb})$$

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_{twh} = 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[5] data as follows in Table 4, market share is noted above in Table 3.

5 2016-2017 Regional Building Stock Assessment (RBSA) II https://neea.org/resources/rbsa-ii-combined-database

Table 4 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 5, 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 5 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*[6] 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 6 is a summary of installations costs based on DOE LCCs and RTF CAT judgment, Table 7 shows the combined install and equipment costs, and Table 8 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*[7], Sept. 6, 2019 and reflect plumbing, electrical, venting, condensate, gas line upgrades as needed by equipment type.

Table 6 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

[6] RTF Residential Gas Water Heaters Workbook v1.0: https://nwcouncil.box.com/v/ResGasWaterHeaterv1-0
[7] NEEA Lab Testing of Tankless Water Heater System, Sept. 6, 2019: https://neea.org/resources/lab-testing-of-tankless-water-heater-systems

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 7 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 8 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 1 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/

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 9 may be incomplete, particularly for measures approved prior to 2013.

Table 9 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 10 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

Measure Approval Document for Resideo Thermostat Optimization

Valid Dates
January 1, 2023 through December 31, 2025

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 to be applied continuously for one year to households with eligible devices.

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
- Existing Manufactured Homes

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

Purpose of Re-Evaluating Measure
- Opt-out rates have been updated.
- Gas only territory measures created (site level participation is identified).
- Control group fraction of total participants updated for cost effectiveness screening.

Cost Effectiveness
Cost effectiveness is demonstrated for Oregon in Table 1 and Table 2, Washington in Table 3 and Table 4. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2023-v1.0. In Oregon the electric avoided cost year is 2023 and the gas avoided cost year is 2023. In Washington the gas avoided cost year is 2023. The values in these tables are per unit.

Table 1 and Table 3**Error! Reference source not found.** show the approved measures with treatment group cost per enrollment only. Roughly ten percent of enrolled participants will be allocated to the control group. Table 2 and Table 4Table 3 demonstrate cost effectiveness when the cost of the control group is incorporated.

Table 1 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	Resideo Tstat Optimization - Annual - gFAF	1	45.08	14.72	$12.00	$0.00	$12.00	2.1	2.1	25%	75%
2	Resideo Tstat Optimization - Annual - gFAF GOT	1	0.00	14.72	$12.00	$5.68	$12.00	1.6	2.0	0%	100%
3	Resideo Tstat Optimization - Annual - gFAF + AC	1	73.60	14.72	$12.00	$0.00	$12.00	2.5	2.5	36%	64%
4	Resideo Tstat Optimization - Annual - gFAF + AC GOT	1	0.00	14.72	$12.00	$9.28	$12.00	1.6	2.3	0%	100%
5	Resideo Tstat Optimization - Annual - eFAF	1	425.96	0.00	$12.00	$0.00	$12.00	2.4	2.4	100%	0%
6	Resideo Tstat Optimization - Annual - eFAF + AC	1	454.48	0.00	$12.00	$0.00	$12.00	3.3	3.3	100%	0%
7	Resideo Tstat Optimization - Annual - Heat Pump	1	191.36	0.00	$12.00	$0.00	$12.00	1.4	1.4	100%	0%

Table 2 Cost Effectiveness Calculator Oregon with Control Group Cost, 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
8	Resideo Tstat Optimization - Annual - gFAF w/Control Group	1	45.08	14.72	$13.24	$0.00	$13.24	1.9	1.9	25%	75%
9	Resideo Tstat Optimization - Annual - gFAF GOT w/Control Group Cost	1	0.00	14.72	$13.24	$5.68	$13.24	1.4	1.9	0%	100%
10	Resideo Tstat Optimization - Annual - gFAF + AC w/Control Group Cost	1	73.60	14.72	$13.24	$0.00	$13.24	2.2	2.2	36%	64%
11	Resideo Tstat Optimization - Annual - gFAF + AC GOT w/Control Group Cost	1	0.00	14.72	$13.24	$9.28	$13.24	1.4	2.1	0%	100%
12	Resideo Tstat Optimization - Annual - eFAF w/Control Group Cost	1	425.96	0.00	$13.24	$0.00	$13.24	2.2	2.2	100%	0%
13	Resideo Tstat Optimization - Annual - eFAF + AC w/Control Group Cost	1	454.48	0.00	$13.24	$0.00	$13.24	3.0	3.0	100%	0%
14	Resideo Tstat Optimization - Annual - Heat Pump w/Control Group Cost	1	191.36	0.00	$13.24	$0.00	$13.24	1.3	1.3	100%	0%

Table 3 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	Resideo Tstat Optimization - Annual - gFAF WA	1	14.72	$12.00	$3.68	$12.00	2.1	2.4	0%	100%
2	Resideo Tstat Optimization - Annual - gFAF + AC WA	1	14.72	$12.00	$6.01	$12.00	2.1	2.6	0%	100%

Table 4 Cost Effectiveness Calculator Washington with Control Group Cost, per unit

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
3	Resideo Tstat Optimization - Annual - gFAF WA w/Control Group	1	14.72	$13.24	$3.68	$13.24	1.9	2.2	0%	100%
4	Resideo Tstat Optimization - Annual - gFAF + AC WA w/Control Group	1	14.72	$13.24	$6.01	$13.24	1.9	2.4	0%	100%

Requirements

- Household must have an eligible internet-connected thermostat compatible with Resideo's 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 site address or zip code.

Details

Resideo is paid for each device that enrolled in the optimization program and provides data about each enrolled device including street address, zip code, heating (gas or electric forced air furnace, or heat pump) and cooling systems (central air, heat pump, none). The optimization algorithm will be applied throughout the year

Participants are notified of their enrollment and can opt-out of the service once enrolled. Energy Trust 2021 full year attrition was calculated at eight percent and are applied to the savings estimates. Participant attrition reasons include customer opt-outs, disconnected service, move-outs and disqualification.

Baseline

This measure uses an Existing Condition Baseline.

Baseline conditions are the existing settings of internet-connected qualifying thermostats not enrolled in the Resideo offering.

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[1] for energy savings and participant attrition values.

Key evaluation findings:

- 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 5.

Table 5 Combined Per-Thermostat Energy Savings for the Connected Savings Pilot, by System and Fuel Type

System	Season	Fuel Savings	TMY Savings	90% CI	Relative Precision	Savings as % Heating or Cooling Load
Gas Furnace	Winter	Therms	16	±7	±44%	3.2%
Electric Furnace		kWh	414	±170	±41%	3.2%
Furnace Fan		kWh	49	±22	±45%	5.1%
Heat Pump		kWh	177	±146	±82%	4.0%
Air Conditioner	Summer	kWh	31	±26	±84%	3.9%

Apex calculated the Electric furnace values calculated using Gas Furnace values converted to kWh. Furnace fan savings were calculated from the weather-dependent electricity consumption of homes with gas furnaces.

The per-thermostat savings apply to homes participating for the entire calendar year. Since some participants stop participating during each season, attrition rates were applied. Attrition factors and rate are shown in Table 6 and were applied to estimated savings.

Table 6 Summary of 2021 Program Year Treatment Group Attrition

Total 2021 Treatment Participants	500
2021 Treatment Cancellations	40
Treatment Cancelation Rate	**8.0%**

Comparison to RTF or other programs

- Currently, this is the only Energy Trust approved standalone thermostat optimization service.
  - Nest and ecobee devices have integrated their optimization algorithms into their thermostats and savings estimates are captured in those devices' MADs.
- No current RTF approved UES for thermostat optimization services.

Measure Life

A one-year measure life is used in this analysis based on participating devices requiring an initial and annual reenrollment fee. Persistence of savings beyond this period may exist but has not been studied.

Load Profile

The load profile is Res Ele Resistance Heat for all forced air furnace measures without central cooling. 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.

[1] 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

Table 7 Load Profile Selection

Measure	Electric Load Profile	Gas Load Profile	Total Savings (kWh)	Cooling Savings (kWh)	Percent Cooling
Resideo Tstat Optimization gFAF	Res Ele Resistance Heat	Res Heating	45.08		
Resideo Tstat Optimization gFAF GOT	None - ele	Res Heating	0.00		
Resideo Tstat Optimization gFAF + AC	Res Space Conditioning	Res Heating	73.60	28.52	39%
Resideo Tstat Optimization gFAF + AC GOT	None - ele	Res Heating	0.00		
Resideo Tstat Optimization eFAF	Res Ele Resistance Heat	None - gas	425.96		
Resideo Tstat Optimization eFAF + AC	Res Air Source HP	None - gas	454.48	28.52	6%
Resideo Tstat Optimization Heat Pump	Res Air Source HP	None - gas	191.36	28.52	15%

Cost
Resideo's optimization algorithm deployment is $12 per household for one full year. This fee is charged to Energy Trust and payment is via incentives with no cost to the end user.

Control group payment accounting
A target of ten percent of enrollees are designated as 'control' sites and do not receive thermostat optimization. The most recent full year (2021) of program activity resulted in 10.3% of total sites as enrolled in the control group at year's end resulting in a calculated control group site cost of $1.24 per participating site's base cost of $12 for a total of $13.24. Cost effectiveness including control sites is demonstrated in Table 2 and Table 4 , all measures are cost effective.

Non-Energy Benefits
Electric bill savings for Energy Trust gas only customers are incorporated as a non-energy benefit:
- In Oregon, electric savings for gas sites out of Energy Trust electric territory are converted to a customer bill savings NEB at a blended electric rate of $0.116/kWh.
- In Washington, electric savings for all sites are converted to a customer bill savings NEB based on Clark County PUD's electric rate of $0.082/kWh.

Incentive Structure
The maximum incentives listed in Table 1 and Table 3 are for reference only and are not suggested incentives. Incentives will be structured per enrolled thermostat unit and are paid directly to the servicer.

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 central cooling equipment have high uncertainty. If future evaluations find more conclusive results those should be incorporated.
- Opt-out rates and proportion of participants in the control group can be updated with the most recent data as appropriate in future updates.

Supporting Documents
The cost effectiveness screening for these measures is number 217.4.4. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Residential\Res HVAC\thermostat\web enabled thermostat\optimization\Resideo

217.4.4 OR_WA CE
Calcuator v1.0 Resid

Version History and Related Measures

Table 8 Version History

Date	Version	Reason for revision
6/12/2018	217.1	Approval for Whisker Labs (now Resideo) pilot
10/23/2019	217.2	Transition to standard measure. Winter only.
5/1/2020	217.3	Expansion to include annual savings.
8/18/2022	217.4	Update to opt-out rate savings adjustment, gas only territory measures.

Table 9 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

Approved & Reviewed by

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EnergyTrust of Oregon

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 1Table 1. 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 1 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[1]
- 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 homes[2].

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 2 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 as in existing homes.

Table 2 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**

[1] Natural Resources Canada gas fireplace energy efficiency ratings search
[2] 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 3 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 3 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 1 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 4 Version History

Date	Version	Reason for revision
10/8/2021	275.1	Introduce standalone fireplace offering for new homes in WA

Table 5 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

Approved & Reviewed by

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Measure Approval Document for Commercial Condensing Tank Water Heaters

Valid Dates
July 1, 2023 – December 31, 2025

End Use or Description
High efficiency, condensing, storage-type water heater installed in commercial facilities. Energy savings are produced from reduced natural gas usage.

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, the measure is applicable to the following classes:
- New
- Replacement

Purpose of Re-Evaluating Measure
Savings analysis and costs were updated, where annual hot water demand was aligned with the sources and methodology used in MAD 72.4- Condensing Tankless Water Heaters ≥ 200 kBtu/h.

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 2024-v1.2. In Oregon the electric avoided cost year is 2024 and the gas avoided cost year is 2024. In Washington the gas avoided cost year is 2024. The values in these tables are per kBtu/h of input capacity.

Table 1 Cost Effectiveness Calculator Oregon, per kBtu/h input capacity

#	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	0.00	0.94	3.69	0.00	$3.69	3.8	3.8	0%	100%
2	Schools- Condensing Tank WH	15	0.00	0.93	3.75	0.00	$3.75	3.7	3.7	0%	100%
3	Healthcare - Condensing Tank WH	15	0.00	0.63	3.73	0.00	$3.73	2.5	2.5	0%	100%
4	Hotel - Condensing Tank WH	15	0.00	1.90	3.78	0.00	$3.78	7.5	7.5	0%	100%
5	Restaurant - Condensing Tank WH	15	0.00	1.84	3.68	0.00	$3.68	7.5	7.5	0%	100%
6	Multifamily - Condensing Tank WH	15	0.00	1.44	3.79	0.00	$3.79	5.7	5.7	0%	100%
7	Gym/Fitness Center - Condensing Tank WH	15	0.00	0.43	3.80	0.00	$3.80	1.7	1.7	0%	100%
8	Coin-op Laundry - Condensing Tank WH	15	0.00	0.87	3.81	0.00	$3.81	3.4	3.4	0%	100%
9	All Commercial - Condensing Tank WH	15	0.00	1.11	3.76	0.00	$3.76	4.4	4.4	0%	100%

Table 2 Cost Effectiveness Calculator Washington, per kBtu/h input capacity

#	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	0.94	3.69	0.00	$3.69	4.3	4.3	0%	100%
2	Schools- Condensing Tank WH	15	0.93	3.75	0.00	$3.75	4.1	4.1	0%	100%
3	Healthcare - Condensing Tank WH	15	0.63	3.73	0.00	$3.73	2.8	2.8	0%	100%
4	Hotel - Condensing Tank WH	15	1.90	3.78	0.00	$3.78	8.4	8.4	0%	100%
5	Restaurant - Condensing Tank WH	15	1.84	3.68	0.00	$3.68	8.4	8.4	0%	100%
6	Multifamily - Condensing Tank WH	15	1.44	3.79	0.00	$3.79	6.3	6.3	0%	100%
7	Gym/Fitness Center - Condensing Tank WH	15	0.43	3.80	0.00	$3.80	1.9	1.9	0%	100%
8	Coin-op Laundry - Condensing Tank WH	15	0.87	3.81	0.00	$3.81	3.8	3.8	0%	100%
9	All Commercial - Condensing Tank WH	15	1.11	3.76	0.00	$3.76	5.0	5.0	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.
  - 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 program choose to use the All Commercial savings option,
  - Building type and/or served hot water loads must be recorded
  - 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 & Entertainment (casino, arts and convention centers etc.), Jail/Reformatory/Penitentiary, and campus living).
- If programs choose to apply the measure by specific building type (i.e., not use 'All commercial'),

- The water heater units must serve the primary water heating loads of the portion of the building indicated (ie: shower rooms for gyms, kitchens for restaurants, multiple motel rooms for motels)
- The measures can applied to areas of multi-use sites for hot water systems that provide dedicated service to that area type with the requirements listed in **Error! Reference source not found.**. 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.
- Installations must follow the requirements in Table 3

Use in multifamily is limited to shared central DHW systems.

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

Existing Condition Requirements

- These measures are intended as replacement at/near burn out, or new. There are no existing fuel requirements.

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 kBtu/h 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 the Department of Energy Technical Support Document (DoE TSD) for Commercial Water Heating Equipment, 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 (Btu)
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

[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

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×(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:

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

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 annual hot water usage for all buildings (except gym and coin-op laundries) was estimated using the daily hot water load schedules and normalized peak demand listed in Appendix 7B of the US DOE's Technical Support Document (DoE TSD) for Commercial Water Heating Equipment.[3] The product of the normalized peak and hourly ratios yielded the hourly demand in a 24-hour period. The daily demands were multiplied by 365.25 days to determine the annual hot water consumptions. This methodology for estimating annual hot water usage aligns with MAD 72.4 – Commercial and Multifamily Condensing Tankless Water Heaters ≥ 200 kBtu/h, which was approved in 2022.

The gym annual hot water demand was similarly determined using daily hot water schedules and normalized peak demands, but the information was sourced from Table 11 of the DOE's U.S. Commercial Reference Building Models of the National Building Stock[4] report.

Because the DOE's TSD does not cover coin-op laundries, annual hot water demand was estimated based on typical number of machines per laundromat, loads per day per machine, and gallons of hot water per load.[5,6,7,8] Table 4 summarizes the daily and annual hot water demands for all building sub-sectors.

The hot water demand for various market segments that was determined from multiple sources are detailed in Table 4.

Table 4 Hot Water Demand per Market Segment

Market Segment	Sub-sector	Annual Hot Water Demand (Gal)
Office	Medium Office	71,285
	Large Office	599,187
Healthcare	Outpatient Health Care	126,391
	Hospital	1,196,544
Hotel	Small Hotel	855,512
	Large Hotel	1,629,104
Restaurant	Quick-service	206,179
	Full-service	581,622
Multifamily	-	1,263,215
Schools	Primary School	228,986
	Secondary School	942,467
Gym	-	401,816
Coin-op Laundry	-	1,421,418

Heat Load Input Assumptions

The heat load calculations are based on density of water, specific heat capacity of water, annual hot water consumption, 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.

[3] https://www.regulations.gov/document/EERE-2014-BT-STD-0042-0016
[4] http://www.nrel.gov/docs/fy11osti/46861.pdf
[5] Washer capacity values: http://toolbox.calwep.org/wiki/Clothes_Washers_-_Coin-Operated
[6] Water factors: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=08fdbac2df2f7ef118bf97844a8f7453&r=PART&n=10y3.0.1.4.19#se10.3.431_1156
[7] Usage per washer: https://downloads.regulations.gov/EERE-2012-BT-STD-0020-0036/attachment_8.pdf
[8] Wash per cycle: https://www.allianceforwaterefficiency.org/sites/www.allianceforwaterefficiency.org/files/assets/ws-commercial-water-sense-at-work-ci.pdf

The physical constants for water (density and specific heat capacity) were found using the Properties of water values from 2010 DOE TSD. Table 5 shows the assumptions for these inputs:

Table 5 Heat Load Inputs

Input	Value
Water Heater Inlet Temperature (°F)	54.21[9]
Water Heater Outlet Temperature (°F)	140[10]
Temperature Rise (°F)	85.79
Density of Water (lb/gal)	8.29[11]
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 6 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%	

Proposed case:

Minimum efficiency of 94% selected to align with the Energy Star criteria[12] 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**Error! Reference source not found.**.

The number (counts) of schools in Oregon was found using the Oregon Department of Education data[13]. 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[14]. 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[15]. 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[16] (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[17]. 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	77%
	Secondary School	23%
Healthcare	Outpatient Health Care	90%
	Hospitals	10%
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.

[9] Regional Technical Forum. 2020. “RTFStandardInformationWorkbook_v4_2.xlsx.” https://rtf.nwcouncil.org/standard-information-workbook
[10] Regional Technical Forum. 2020. “ComHPWH_v1_3.xlsm.” , GPD Guide tab, Rows 45-65, Column O. https://nwcouncil.app.box.com/v/CommercialHPWHv1-3
[11] Properties of water (values from 2010 DOE TSD)
[12] https://www.energystar.gov/products/water_heaters/commercial_water_heaters/key_product_criteria
[13] Oregon Department of Education : https://www.oregon.gov/ode/reports-and-data/students/Pages/Student-Enrollment-Reports.aspx
[14]US Bureau of Labor Statistics – Quarterly Census of Employment and Wages. 2019 Dataset: https://www.bls.gov/cew/downloadable-data-files.htm
[15]Census of Service Industries: Subject Series, Hotels, Motels, and Other Lodging Places: https://www.census.gov/library/publications/1996/econ/sc92-s-3.html
[16] https://neea.org/data/commercial-building-stock-assessments
[17] 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

All Commercial Weighting Methodology

A weighted average was determined using installed water heater input capacity (kBtu/h) to cover all commercial building types based on project data for this measure in the Existing and New Building programs from 2020-2023. The weightings are shown in Table 8 below.

Table 8 Weightage averaging across all commercial building types

Market Segment	Weighting (based on installed input capacity kBtu/h)
Office	0%
Schools (K-12 School, College/University)	71%
Healthcare	4%
Hotel (Lodging/Hotel/Motel)	18%
Restaurant (Food service)	3%
Coin-op Laundry	2%
Gym	1%

Savings

Savings are summarized in Table 9.

Table 9 Summary of gas savings in Therms per market segment

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	71,285	0.72	69%	0%	0.94
	Large Office	599,187	1.40	31%		
Schools	Primary School	126,391	0.88	77%	71%	0.92
	Secondary School	767,010	1.08	23%		
Healthcare	Outpatient Health Care	126,391	0.55	90%	4%	0.68
	Hospital	1,196,544	1.36	10%		
Hotel	Small Hotel	855,512	1.96	48%	29%	1.90
	Large Hotel	1,629,104	1.84	52%		
Restaurant	Quick Service Restaurant	1,263,215	1.58	43%	3%	1.84
	Full-Service Restaurant	228,986	2.03	57%		
Multifamily	-	942,467	1.44	N/A	N/A	1.44
Commercial Gym	-	401,816	0.43	N/A	2%	0.43
Coin-op Laundry	-	1,421,418	0.87	N/A	1%	0.87
All Commercial	-					1.30

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 are aligned with previous MAD version 21.3. The costs were adopted from a California Codes and Standards Enhancement (CASE) report for high efficiency water heaters[18].

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, Table 10, this includes costs of steel venting materials which are required for the hotter exhaust gases. For condensing water heaters, Table 11, 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

[18] 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

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 based on 2021 data was calculated by adding up the equipment, labor, and ancillary costs per category. Then the RTF's Standard Information Workbook v4.8 was used to determine inflation factors to update 2021 costs to 2023. Final incremental costs are shown in Table 12.

Table 12 Final incremental costs

Building Type	Capacity (kBtuh)	Non-Condensing Total ($/kBtuh)	All Condensing Total ($/kBtuh)	Condensing - HE Total ($/kBtuh)	Weighted Average Baseline Cost ($/kBtuh)	Efficient Case Cost ($/kBtuh)	2021 Incremental Cost ($/kBtuh)	2023 Incremental Cost ($/kBtuh)
Office (weighted average)	163	$39.15	$44.89	$45.07	$41.77	$45.07	$3.30	$3.69
Schools (weighted average)	286	$37.85	$43.69	$43.87	$40.51	$43.87	$3.36	$3.75
Healthcare (weighted average)	265	$38.21	$44.02	$44.20	$40.86	$44.20	$3.34	$3.74
Hotel (weighted average)	456	$37.25	$43.14	$43.32	$39.94	$43.32	$3.38	$3.78
Restaurant (weighted average)	157	$39.26	$44.99	$45.17	$41.87	$45.17	$3.29	$3.68
High-Rise Apartment	600	$37.00	$42.90	$43.09	$39.69	$43.09	$3.39	$3.79
Gym	727	$36.85	$42.78	$42.96	$39.56	$42.96	$3.40	$3.80
Coin-op Laundry	958	$36.69	$42.63	$42.81	$39.40	$42.81	$3.41	$3.81
All Commercial	-	-	-	-	-	-	$3.36	$3.75

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 of water heater and will not exceed 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.

Supporting Documents

The cost effectiveness screening for these measures is number 21.4.3. 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_6_5_OR_WA_CEC_2024_v_1_2_Com_

Version History and Related Measures

Energy Trust has been offering this 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.
7/21/2023	21.4	Aligned annual hot water consumption with MAD 72.4 and adjusted costs to 2023
10/5/2023	21.5	Corrected an error in the CEC
10/12/2023	21.6	Corrected an error in the CEC

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

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Disclaimer

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Measure Approval Document for Commercial and Multifamily Steam Trap Replacement and Repair

Valid Dates
7/1/2023 – 12/31/2025

End Use or Description
Steam traps are mechanical components of central steam systems in space heating and process applications such as dry cleaning. 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 into open atmosphere or into a condensate recovery 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. This measure aims to replace or repair steam traps that have failed in the open position.

Since it is common practice for dry cleaners to replace traps regardless of failure state and that traps are not commonly repaired; no steam trap repair measures are offered for dry cleaners.

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 (includes 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
Steam trap repairs were re-introduced, and costs were 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 2024-v1.2. In Oregon the electric avoided cost year is 2024 and the gas avoided cost year is 2024. In Washington the gas avoided cost year is 2024. The values in these tables are per steam trap.

Table 1 Cost Effectiveness Calculator for Oregon

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Ele	% Gas
1	Steam Trap Replacement (all trap sizes) - Multifamily Space Heating- Operating Pressure <5 psig	6	116.68	491.21	$491.21	2.2	2.2	0%	100%
2	Steam Trap Replacement (all trap sizes) - Commercial Space Heating - Operating Pressure < 30 psig	6	331.79	549.22	$549.22	5.5	5.5	0%	100%
3	Steam Trap Replacement (all trap sizes) - Commercial Space Heating - Operating Pressure ≥ 30 psig and ≤ 50 psig	6	697.80	576.96	$576.96	11.0	11.0	0%	100%
4	Steam Trap Replacement (all trap sizes) - Dry Cleaners (no test report required) - Operating Pressure ≥ 75 psig and ≤ 125 psig	6	211.14	376.96	$376.96	3.6	3.6	0%	100%
5	Steam Trap Replacement (all trap sizes) - Commercial Space Heating (High Use) - Operating Pressure < 30 psig	6	654.86	549.22	$549.22	10.8	10.8	0%	100%
6	Steam Trap Replacement (all trap sizes) - Commercial Space Heating (High Use) - Operating Pressure ≥ 30 psig and ≤ 50 psig	6	1,377.23	576.96	$576.96	21.7	21.7	0%	100%
7	Steam Trap Repair (for trap size ≤ 1/2") - Multifamily Space Heating- Operating Pressure <5 psig	6	116.68	491.21	$491.21	2.2	2.2	0%	100%
8	Steam Trap Repair (for trap size ≤ 1/2") - Commercial Space Heating - Operating Pressure < 30 psig	6	331.79	549.22	$549.22	5.5	5.5	0%	100%
9	Steam Trap Repair (for trap size ≤ 1/2") - Commercial Space Heating - Operating Pressure ≥ 30 psig and ≤ 50 psig	6	697.80	576.96	$576.96	11.0	11.0	0%	100%
11	Steam Trap Repair (for trap size ≤ 1/2") - Commercial Space Heating (High Use) - Operating Pressure < 30 psig	6	654.86	549.22	$549.22	10.8	10.8	0%	100%
12	Steam Trap Repair (for trap size ≤ 1/2") - Commercial Space Heating (High Use) - Operating Pressure ≥ 30 psig and ≤ 50 psig	6	1,377.23	576.96	$576.96	21.7	21.7	0%	100%
13	Steam Trap Repair (for trap size ≥ 3/4") - Multifamily Space Heating- Operating Pressure <5 psig	6	116.68	366.21	$366.21	2.9	2.9	0%	100%
14	Steam Trap Repair (for trap size ≥ 3/4") - Commercial Space Heating - Operating Pressure < 30 psig	6	331.79	424.22	$424.22	7.1	7.1	0%	100%
15	Steam Trap Repair (for trap size ≥ 3/4") - Commercial Space Heating - Operating Pressure ≥ 30 psig and ≤ 50 psig	6	697.80	451.96	$451.96	14.0	14.0	0%	100%
17	Steam Trap Repair (for trap size ≥ 3/4") - Commercial Space Heating (High Use) - Operating Pressure < 30 psig	6	654.86	424.22	$424.22	14.0	14.0	0%	100%
18	Steam Trap Repair (for trap size ≥ 3/4") - Commercial Space Heating (High Use) - Operating Pressure ≥ 30 psig and ≤ 50 psig	6	1,377.23	451.96	$451.96	27.7	27.7	0%	100%

Table 2 Cost Effectiveness Calculator for Washington

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Steam Trap Replacement (all trap sizes) - Multifamily Space Heating- Operating Pressure <5 psig	6	116.68	491.21	$491.21	2.8	2.8	0%	100%
2	Steam Trap Replacement (all trap sizes) - Commercial Space Heating - Operating Pressure < 30 psig	6	331.79	549.22	$549.22	7.8	7.8	0%	100%
3	Steam Trap Replacement (all trap sizes) - Commercial Space Heating - Operating Pressure ≥ 30 psig and ≤ 50 psig	6	697.80	576.96	$576.96	15.6	15.6	0%	100%
4	Steam Trap Replacement (all trap sizes) - Dry Cleaners (no test report required) - Operating Pressure ≥ 75 psig and ≤ 125 psig	6	211.14	376.96	$376.96	3.8	3.8	0%	100%
5	Steam Trap Replacement (all trap sizes) - Commercial Space Heating (High Use) - Operating Pressure < 30 psig	6	654.86	549.22	$549.22	15.3	15.3	0%	100%
6	Steam Trap Replacement (all trap sizes) - Commercial Space Heating (High Use) - Operating Pressure ≥ 30 psig and ≤ 50 psig	6	1,377.23	576.96	$576.96	30.7	30.7	0%	100%
7	Steam Trap Repair (for trap size ≤ 1/2") - Multifamily Space Heating- Operating Pressure <5 psig	6	116.68	491.21	$491.21	2.8	2.8	0%	100%
8	Steam Trap Repair (for trap size ≤ 1/2") - Commercial Space Heating - Operating Pressure < 30 psig	6	331.79	549.22	$549.22	7.8	7.8	0%	100%
9	Steam Trap Repair (for trap size ≤ 1/2") - Commercial Space Heating - Operating Pressure ≥ 30 psig and ≤ 50 psig	6	697.80	576.96	$576.96	15.6	15.6	0%	100%
11	Steam Trap Repair (for trap size ≤ 1/2") - Commercial Space Heating (High Use) - Operating Pressure < 30 psig	6	654.86	549.22	$549.22	15.3	15.3	0%	100%
12	Steam Trap Repair (for trap size ≤ 1/2") - Commercial Space Heating (High Use) - Operating Pressure ≥ 30 psig and ≤ 50 psig	6	1,377.23	576.96	$576.96	30.7	30.7	0%	100%
13	Steam Trap Repair (for trap size ≥ 3/4") - Multifamily Space Heating- Operating Pressure <5 psig	6	116.68	366.21	$366.21	3.8	3.8	0%	100%
14	Steam Trap Repair (for trap size ≥ 3/4") - Commercial Space Heating - Operating Pressure < 30 psig	6	331.79	424.22	$424.22	10.1	10.1	0%	100%
15	Steam Trap Repair (for trap size ≥ 3/4") - Commercial Space Heating - Operating Pressure ≥ 30 psig and ≤ 50 psig	6	697.80	451.96	$451.96	19.9	19.9	0%	100%
17	Steam Trap Repair (for trap size ≥ 3/4") - Commercial Space Heating (High Use) - Operating Pressure < 30 psig	6	654.86	424.22	$424.22	19.9	19.9	0%	100%
18	Steam Trap Repair (for trap size ≥ 3/4") - Commercial Space Heating (High Use) - Operating Pressure ≥ 30 psig and ≤ 50 psig	6	1,377.23	451.96	$451.96	39.2	39.2	0%	100%

Requirements

- Must replace or repair 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.
- Washington participation is limited to multifamily and commercial properties that qualify for services through the Existing Buildings program on a commercial gas rate.
- 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/repair 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.
- 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.
- Dry cleaners are only eligible for replacement, not repair measures.

Documentation requirements

- All projects must document connection size (trap size) and project costs in the Project Tracker for use in future measure updates.

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. This baseline assumes steam traps would not be replaced or repaired in a timely manner without the program.

Baseline equipment in dry cleaners is a mix of failed and not failed steam traps. The reason for considering a mix of failed 27% and 73% 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[1,2,3]. 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[4] 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 [5].
- 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:
- 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 by replacing a trap failed in open position is calculated using the equation below.

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[1] 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
[2] 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
[3] Steam Traps Workpaper for PY 2006-08, SoCal Gas Company, https://www.sdge.com/sites/default/files/SteamTrap%2520Workpaper%2520%252811Dec06%2529_0.doc
[4] Massachusetts Steam Trap Evaluation Phase 2, March 2017, https://ma-eeac.org/wp-content/uploads/Steam-Trap-Evaluation-Phase-II.pdf
[5] Inspect and Repair Steam Traps, U.S DoE Advanced Manufacturing Office, https://www.energy.gov/sites/prod/files/2014/05/f16/steam1_traps.pdf
[6] Federal Technology Alert- Steam Trap Performance Assessment, https://invenoeng.com/wp-content/uploads/2017/08/Steam-Trap-Performance-Assessment.pdf

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

Where,

- Boiler efficiency is assumed to be 80% based on the 'Oregon Commercial and Industrial Boilers Market Characterization' Study by Cadeo in December 2020[7] (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 2022 Illinois Statewide Technical Reference Manual for Energy Efficiency (version 10.0)[8]. 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 10)[9]. 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 3.

Table 3 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 4. Table 5 shows simple averages (no weighting included) calculated from results in Table 4 for each case defined by facility type and pressure range:

[7] EnergyTrust_CIGasBoilerMarketResearch-Memo_FINAL.pdf
[8] 2022 Illinois Statewide Technical Reference Manual for Energy Efficiency (version 10.0), Sep 2021, https://www.icc.illinois.gov/downloads/public/2022%20IL-TRM%20Version%2010.0%20Volume%202%20Commercial%20and%20Industrial%20Measures%20(Final).pdf
[9] New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs, Version 10, Dec 2022, c1e1783c-c3d3-48a4-8647-a5923c39553c.pdf (ny.gov)

Table 4 Energy savings calculated for each individual case

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 5 Energy savings averaged by facility type and operating pressure (using results from Table 4)

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 10), the 2022

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

Replacement Costs

Cost estimates for replacement were obtained from research data shared by Energy Trust as summarized in Table 6 (based on 2021 dollars). Costs for new traps range between approximately $100 - $300 per steam trap for commercial and multifamily applications (for typical sizes up to 1/2") and generally increase with increase in design pressure and 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 6 Steam Traps Cost Data (in 2021 dollars)

Energy Trust Cost Research							
Hourly Install Fee:		$150.00 **per trap**		**Labor Hours:**		1.5 **hrs per trap**	
Orifice Size	**Δ P**	**SCG 2007 Workpaper (inflated to 2021)**	**Proctor Sales**	**Trade Allies**	**Armstrong**	**McKinstry**	**Pyramid Heating**
1/8"	2 or 15	$97.71	$130.00	$70.00	-	-	-
1/8"	50 or 100	$97.71	$173.00	$70.00	-	-	-
5/16"	2 or 15	$104.06	$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
ket	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 6 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- $97.71
  b. Orifice size 5/16" and pressure <15 psig- $104.06
  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)

To estimate total cost for replacement, it was assumed that labor cost for installation per trap is $225 (1.5 hrs. at $150/hr. labor rate) and cost for testing traps was also included (estimated at $56 per trap). Therefore, total cost for replacement per trap was estimated as the total of new trap cost, installation labor cost, and cost for testing traps. After the total was calculated in 2021 dollars, the total replacement cost values were inflated to 2023 dollars using a 2021 to 2023 inflation factor obtained from the RTF's Standard Information Workbook v4.8[10]. The average resulting costs for trap replacement are shown in Table 7.

Repair Costs

Feedback on costs for repairs was collected from Trade Allies. One trade ally indicated that repairs are not common for trap sizes up to 1/2", and if done are likely cost the same as replacement. Therefore, cost estimates for repairs of traps up to 1/2" size are assumed to be same as and replacement costs.

Feedback from two more Trade Allies indicated: (i) For traps 3/4" size, repair costs are generally $100-$150 less than replacement (this includes cost of repair kit and labor to repair); and (ii) Repairs save about 1/4th cost on total labor (which comes to $56 lesser per trap on total labor of $225 used in the analysis). Feedback from Existing Buildings program staff experienced with steam traps specified that repairs can save more than $100-$150 over replacement on larger traps (≥ 1"). Since data on cost savings from repairs for larger traps was not available, a more conservative estimate of $125 was used (average of $100 and $150) as the average amount by which repairs are cheaper than replacement for traps 3/4" and larger.

Average trap repair costs by size are summarized in Table 7

[10] RTF Standard Information Workbook v4.8, RTFStandardInformationWorkbook_v4_8.xlsx | Powered by Box

Table 7 Summary of Average Steam Trap Replacement and Repair Costs

Facility Type	Pressure	Avg. Replacement Cost (all sizes)	Avg. Repair Cost Traps ≤ 1/2"	Avg. Repair Cost Traps ≥ 3/4"
Multifamily	≤ 5 psig	$491.21	$491.21	$366.21
Commercial	< 30 psig	$549.22	$549.22	$424.22
Commercial	≥ 30 psig and ≤ 50 psig	$576.96	$576.96	$451.96
Commercial (High Use)	< 30 psig	$549.22	$549.22	$424.22
Commercial (High Use)	≥ 30 psig and ≤ 50 psig	$576.96	$576.96	$451.96

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 2 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:

- Trap size data collected from projects should be considered for cost estimation and weightings.

Supporting Documents

The cost effectiveness screening for these measures is number 42.4.3. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Commercial and Industrial\Process Equipment\steam traps\commercial steam traps

42.4.3 OR-WA CEC_2024_v_1.2 Stea

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 8 may be incomplete, particularly for measures approved prior to 2013.

Table 8 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.
6/21/23	42.4	Trap repairs were reintroduced, costs updated to 2023 dollars

Table 9 Related Measures

Measures	MAD ID
Multifamily Thermostatic Radiator valves	45
Industrial Steam Traps	200
Industrial Direct Install Steam Traps	249

Approved & Reviewed by

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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 **Error! Reference source not found.** and Washington in **Error! Reference source not found.**. 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 1 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 2 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[1]. 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[2],[3] which have attempted to investigate energy savings and benefits of installing TRVs.

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[4] and this resulted in 0.008524 Therms savings/HDD per TRV installed.

[1] Thermostatic Radiator Valve (TRV) Demonstration Project, NYSERDA, September 1995, https://www.osti.gov/servlets/purl/119941
[2] Thermostatic Radiator Valve Evaluation, Jan 2015, NREL / U.S. DoE, https://www.nrel.gov/docs/fy15osti/63388.pdf
[3] 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
[4] 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

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 3 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 3 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 **Error! Reference source not found.** and **Error! Reference source not found.** 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 v1.0

Version History and Related Measures

Error! Reference source not found.

Table 4 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 5 Related Measures

Measures	MAD ID
Commercial & Multifamily Steam Traps	42

Approved & Reviewed by

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Measure Approval Document for Domestic Hot Water Recirculation Controls

Valid Dates
January 1, 2023 – December 31, 2025

End Use or Description
Domestic hot water recirculation controls aim to reduce water heating energy use and recirculation pump energy by turning off the recirculation pump during periods of low usage. The acceptable control types are temperature, learning, and combined temperature and timer control. Both add-on and integral controls are eligible. These systems are applicable on multifamily buildings with central water heating.

The control techniques function by determining the demand for domestic hot water and turning off the recirculation pump during periods of low demand. The Temperature technique monitors the temperature in the DHW distribution piping, learning monitors usage and develops usage patterns, and combined controls uses a timer and temperature sensor to control the DHW pump.

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

Within these programs, applicability to the following building types or market segments or program tracks are expected:
- Multifamily buildings (must be stacked with ≥ 5 units)
- Dormitories

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

Purpose of Re-Evaluating Measure:
The methodology was updated to reflect changes in the RTF measure cost, savings and methodology.

As part of this update Aquastat controls were renamed to be Temperature Control to better include other temperature control type manufacturers.

The on-demand control type was removed as RTF determined it was not viable in commercial facility types.

Cost Effectiveness
Cost effectiveness is demonstrated for Oregon in Table 1 for systems with electric resistance water heaters in dual fuel territory, Table 2 summarizes measure applications for systems with gas fueled water heaters in dual fuel territory, Table 3 summarizes measure applications for systems with gas fueled water heaters in gas-only territory, Table 4 summarizes measure applications for systems with electric resistance water heaters in electric-only territory, Table 5 summarizes measure applications for systems with gas or other fuel (such as propane) water heaters in electric-only territory, and Table 6 summarizes measure applications cost effectiveness for systems with gas water heaters in Washington.

Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2023-v1.0. In Oregon, the electric avoided cost year is 2023 and the gas avoided cost year is 2023. In Washington the gas avoided cost year is 2023. The values in these tables are controller. For measure application names, the following abbreviations are used, along with pump motor HP:
- GAS – Gas water heat
- ELE RS– Electric Resistance Water Heat
- TEMP - Temperature Control
- LRN – Learning Control
- COMB – Combined Temperature and Timer Control

Table 1 Cost Effectiveness Calculator Oregon, Electric Water Heat, dual fuel territory

#	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	ELE RS TEMP 1 1/4 HP	12	3,788.78	(6.06)	$897.17	$0.00	$897.17	2.8	2.8	100%	0%
2	ELE RS TEMP 1 3/4 HP	12	4,598.41	(6.06)	$1,219.69	$0.00	$1,219.69	2.5	2.5	100%	0%
3	ELE RS TEMP 1/2 HP	12	3,104.25	(6.06)	$944.09	$0.00	$944.09	2.2	2.2	100%	0%
4	ELE RS TEMP 1/4 HP	12	2,400.39	(5.05)	$967.55	$0.00	$967.55	1.7	1.7	100%	0%
5	ELE RS TEMP 1/6 HP	12	1,905.64	(3.98)	$975.37	$0.00	$975.37	1.3	1.3	100%	0%
6	ELE RS TEMP 1/8 HP	12	1,026.81	(1.99)	$224.80	$0.00	$224.80	3.1	3.1	100%	0%
7	ELE RS TEMP 2 HP	12	5,408.04	(6.06)	$1,542.21	$0.00	$1,542.21	2.4	2.4	100%	0%
8	ELE RS TEMP 3 1/2 HP	12	7,027.30	(6.06)	$2,187.25	$0.00	$2,187.25	2.2	2.2	100%	0%
9	ELE RS TEMP 3/4 HP	12	3,446.51	(6.06)	$920.63	$0.00	$920.63	2.5	2.5	100%	0%
10	ELE RS TEMP 4 1/2 HP	12	8,646.56	(6.06)	$2,832.29	$0.00	$2,832.29	2.1	2.1	100%	0%
11	ELE RS TEMP 5 HP	12	10,265.81	(6.06)	$3,477.33	$0.00	$3,477.33	2.0	2.0	100%	0%
12	ELE RS COMB 1 1/4 HP	12	12,762.95	(24.69)	$2,017.00	$0.00	$2,017.00	4.2	4.2	100%	0%
13	ELE RS COMB 1 3/4 HP	12	14,055.38	(24.69)	$2,619.47	$0.00	$2,619.47	3.6	3.6	100%	0%
14	ELE RS COMB 1/2 HP	12	11,649.90	(24.69)	$2,063.91	$0.00	$2,063.91	3.8	3.8	100%	0%
15	ELE RS COMB 1/4 HP	12	9,397.04	(20.57)	$2,087.37	$0.00	$2,087.37	3.0	3.0	100%	0%
16	ELE RS COMB 1/6 HP	12	7,425.71	(16.24)	$2,095.19	$0.00	$2,095.19	2.4	2.4	100%	0%
17	ELE RS COMB 1/8 HP	12	3,805.31	(8.12)	$455.49	$0.00	$455.49	5.6	5.6	100%	0%
18	ELE RS COMB 2 HP	12	15,347.80	(24.69)	$3,221.95	$0.00	$3,221.95	3.2	3.2	100%	0%
19	ELE RS COMB 3 1/2 HP	12	17,932.66	(24.69)	$4,426.90	$0.00	$4,426.90	2.7	2.7	100%	0%
20	ELE RS COMB 3/4 HP	12	12,206.43	(24.69)	$2,040.46	$0.00	$2,040.46	4.0	4.0	100%	0%
21	ELE RS COMB 4 1/2 HP	12	20,517.52	(24.69)	$5,631.85	$0.00	$5,631.85	2.5	2.5	100%	0%
22	ELE RS COMB 5 HP	12	23,102.38	(24.69)	$6,836.80	$0.00	$6,836.80	2.3	2.3	100%	0%
23	ELE RS LRN 1 1/4 HP	12	7,867.34	(15.37)	$897.17	$0.00	$897.17	5.9	5.9	100%	0%
24	ELE RS LRN 1 3/4 HP	12	8,714.11	(15.37)	$1,219.69	$0.00	$1,219.69	4.8	4.8	100%	0%
25	ELE RS LRN 1/2 HP	12	7,149.84	(15.37)	$944.09	$0.00	$944.09	5.1	5.1	100%	0%
26	ELE RS LRN 1/4 HP	12	5,762.12	(12.81)	$967.55	$0.00	$967.55	4.0	4.0	100%	0%
27	ELE RS LRN 1/6 HP	12	4,559.31	(10.11)	$975.37	$0.00	$975.37	3.1	3.1	100%	0%
28	ELE RS LRN 1/8 HP	12	2,355.06	(5.06)	$334.55	$0.00	$334.55	4.7	4.7	100%	0%
29	ELE RS LRN 2 HP	12	9,560.88	(15.37)	$1,542.21	$0.00	$1,542.21	4.2	4.2	100%	0%
30	ELE RS LRN 3 1/2 HP	12	11,254.41	(15.37)	$2,187.25	$0.00	$2,187.25	3.5	3.5	100%	0%
31	ELE RS LRN 3/4 HP	12	7,508.59	(15.37)	$920.63	$0.00	$920.63	5.5	5.5	100%	0%
32	ELE RS LRN 4 1/2 HP	12	12,947.94	(15.37)	$2,832.29	$0.00	$2,832.29	3.1	3.1	100%	0%
33	ELE RS LRN 5 HP	12	14,641.48	(15.37)	$3,477.33	$0.00	$3,477.33	2.9	2.9	100%	0%

Table 2 Cost Effectiveness Calculator Oregon - Gas water heat, dual fuel territory

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
34	GAS TEMP 1 1/4 HP	12	1,650.64	91.74	$897.17	$0.00	$897.17	2.2	2.2	56%	44%
35	GAS TEMP 1 3/4 HP	12	2,460.27	91.74	$1,219.69	$0.00	$1,219.69	2.1	2.1	66%	34%
36	GAS TEMP 1/2 HP	12	966.10	91.74	$944.09	$0.00	$944.09	1.6	1.6	43%	57%
37	GAS TEMP 1/4 HP	12	618.60	76.45	$967.55	$0.00	$967.55	1.2	1.2	37%	63%
39	GAS TEMP 1/8 HP	12	323.49	30.18	$224.80	$0.00	$224.80	2.3	2.3	44%	56%
40	GAS TEMP 2 HP	12	3,269.90	91.74	$1,542.21	$0.00	$1,542.21	2.0	2.0	72%	28%
41	GAS TEMP 3 1/2 HP	12	4,889.16	91.74	$2,187.25	$0.00	$2,187.25	1.9	1.9	79%	21%
42	GAS TEMP 3/4 HP	12	1,308.37	91.74	$920.63	$0.00	$920.63	1.9	1.9	51%	49%
43	GAS TEMP 4 1/2 HP	12	6,508.41	91.74	$2,832.29	$0.00	$2,832.29	1.9	1.9	84%	16%
44	GAS TEMP 5 HP	12	8,127.67	91.74	$3,477.33	$0.00	$3,477.33	1.9	1.9	86%	14%
45	GAS COMB 1 1/4 HP	12	2,815.14	430.04	$2,017.00	$0.00	$2,017.00	3.0	3.0	32%	68%
46	GAS COMB 1 3/4 HP	12	4,107.56	430.04	$2,619.47	$0.00	$2,619.47	2.6	2.6	41%	59%
47	GAS COMB 1/2 HP	12	1,702.09	430.04	$2,063.91	$0.00	$2,063.91	2.6	2.6	22%	78%
48	GAS COMB 1/4 HP	12	1,107.19	358.36	$2,087.37	$0.00	$2,087.37	2.0	2.0	18%	82%
49	GAS COMB 1/6 HP	12	881.28	282.91	$2,095.19	$0.00	$2,095.19	1.6	1.6	18%	82%
50	GAS COMB 1/8 HP	12	533.09	141.46	$455.49	$0.00	$455.49	3.8	3.8	21%	79%
51	GAS COMB 2 HP	12	5,399.99	430.04	$3,221.95	$0.00	$3,221.95	2.4	2.4	48%	52%
52	GAS COMB 3 1/2 HP	12	7,984.85	430.04	$4,426.90	$0.00	$4,426.90	2.2	2.2	57%	43%
53	GAS COMB 3/4 HP	12	2,258.62	430.04	$2,040.46	$0.00	$2,040.46	2.8	2.8	27%	73%
54	GAS COMB 4 1/2 HP	12	10,569.71	430.04	$5,631.85	$0.00	$5,631.85	2.0	2.0	64%	36%
55	GAS COMB 5 HP	12	13,154.57	430.04	$6,836.80	$0.00	$6,836.80	1.9	1.9	69%	31%
56	GAS LRN 1 1/4 HP	12	1,824.37	260.89	$897.17	$0.00	$897.17	4.2	4.2	34%	66%
57	GAS LRN 1 3/4 HP	12	2,671.13	260.89	$1,219.69	$0.00	$1,219.69	3.5	3.5	42%	58%
58	GAS LRN 1/2 HP	12	1,106.87	260.89	$944.09	$0.00	$944.09	3.4	3.4	23%	77%
59	GAS LRN 1/4 HP	12	726.31	217.41	$967.55	$0.00	$967.55	2.7	2.7	19%	81%
60	GAS LRN 1/6 HP	12	583.77	171.63	$975.37	$0.00	$975.37	2.1	2.1	20%	80%
61	GAS LRN 1/8 HP	12	367.30	85.82	$334.55	$0.00	$334.55	3.2	3.2	24%	76%
62	GAS LRN 2 HP	12	3,517.90	260.89	$1,542.21	$0.00	$1,542.21	3.2	3.2	49%	51%
63	GAS LRN 3 1/2 HP	12	5,211.43	260.89	$2,187.25	$0.00	$2,187.25	2.8	2.8	59%	41%
64	GAS LRN 3/4 HP	12	1,465.62	260.89	$920.63	$0.00	$920.63	3.8	3.8	29%	71%
65	GAS LRN 4 1/2 HP	12	6,904.97	260.89	$2,832.29	$0.00	$2,832.29	2.6	2.6	66%	34%
66	GAS LRN 5 HP	12	8,598.50	260.89	$3,477.33	$0.00	$3,477.33	2.4	2.4	70%	30%

Table 3 Cost Effectiveness Calculator Oregon - Gas water heat, gas-only territory

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
68	GAS TEMP 1 1/4 HP Gas-Only	12	0.00	91.74	$897.17	$191.44	$875.36	1.0	2.9	0%	100%
69	GAS TEMP 1 3/4 HP Gas-Only	12	0.00	91.74	$1,219.69	$285.34	$875.36	1.0	2.9	0%	100%
70	GAS TEMP 1/2 HP Gas-Only	12	0.00	91.74	$944.09	$112.05	$875.36	1.0	2.0	0%	100%
71	GAS TEMP 1/4 HP Gas-Only	12	0.00	76.45	$967.55	$71.75	$729.46	1.0	1.4	0%	100%
72	GAS TEMP 1/6 HP Gas-Only	12	0.00	60.36	$975.37	$57.87	$575.88	1.0	1.1	0%	100%
73	GAS TEMP 1/8 HP Gas-Only	12	0.00	30.18	$224.80	$37.52	$224.80	1.3	2.8	0%	100%
74	GAS TEMP 2 HP Gas-Only	12	0.00	91.74	$1,542.21	$379.24	$875.36	1.0	2.8	0%	100%
75	GAS TEMP 3 1/2 HP Gas-Only	12	0.00	91.74	$2,187.25	$567.04	$875.36	1.0	2.8	0%	100%
76	GAS TEMP 3/4 HP Gas-Only	12	0.00	91.74	$920.63	$151.74	$875.36	1.0	2.5	0%	100%
77	GAS TEMP 4 1/2 HP Gas-Only	12	0.00	91.74	$2,832.29	$754.84	$875.36	1.0	2.7	0%	100%
78	GAS TEMP 5 HP Gas-Only	12	0.00	91.74	$3,477.33	$942.64	$875.36	1.0	2.7	0%	100%
79	GAS COMB 1 1/4 HP Gas-Only	12	0.00	430.04	$2,017.00	$326.50	$2,017.00	2.0	3.5	0%	100%
80	GAS COMB 1 3/4 HP Gas-Only	12	0.00	430.04	$2,619.47	$476.39	$2,619.47	1.6	3.2	0%	100%
81	GAS COMB 1/2 HP Gas-Only	12	0.00	430.04	$2,063.91	$197.41	$2,063.91	2.0	2.9	0%	100%
82	GAS COMB 1/4 HP Gas-Only	12	0.00	358.36	$2,087.37	$128.41	$2,087.37	1.6	2.2	0%	100%
83	GAS COMB 1/6 HP Gas-Only	12	0.00	282.91	$2,095.19	$102.21	$2,095.19	1.3	1.7	0%	100%
84	GAS COMB 1/8 HP Gas-Only	12	0.00	141.46	$455.49	$61.83	$455.49	3.0	4.2	0%	100%
85	GAS COMB 2 HP Gas-Only	12	0.00	430.04	$3,221.95	$626.29	$3,221.95	1.3	3.0	0%	100%
86	GAS COMB 3 1/2 HP Gas-Only	12	0.00	430.04	$4,426.90	$926.08	$4,103.15	1.0	2.8	0%	100%
87	GAS COMB 3/4 HP Gas-Only	12	0.00	430.04	$2,040.46	$261.95	$2,040.46	2.0	3.2	0%	100%
88	GAS COMB 4 1/2 HP Gas-Only	12	0.00	430.04	$5,631.85	$1,225.87	$4,103.15	1.0	2.7	0%	100%
89	GAS COMB 5 HP Gas-Only	12	0.00	430.04	$6,836.80	$1,525.66	$4,103.15	1.0	2.6	0%	100%
90	GAS LRN 1 1/4 HP Gas-Only	12	0.00	260.89	$897.17	$211.59	$897.17	2.8	4.9	0%	100%
91	GAS LRN 1 3/4 HP Gas-Only	12	0.00	260.89	$1,219.69	$309.80	$1,219.69	2.0	4.4	0%	100%
92	GAS LRN 1/2 HP Gas-Only	12	0.00	260.89	$944.09	$128.37	$944.09	2.6	3.9	0%	100%
93	GAS LRN 1/4 HP Gas-Only	12	0.00	217.41	$967.55	$84.24	$967.55	2.1	2.9	0%	100%
94	GAS LRN 1/6 HP Gas-Only	12	0.00	171.63	$975.37	$67.71	$975.37	1.7	2.3	0%	100%
95	GAS LRN 1/8 HP Gas-Only	12	0.00	85.82	$334.55	$42.60	$334.55	2.4	3.6	0%	100%
96	GAS LRN 2 HP Gas-Only	12	0.00	260.89	$1,542.21	$408.00	$1,542.21	1.6	4.0	0%	100%
97	GAS LRN 3 1/2 HP Gas-Only	12	0.00	260.89	$2,187.25	$604.42	$2,187.25	1.1	3.7	0%	100%
98	GAS LRN 3/4 HP Gas-Only	12	0.00	260.89	$920.63	$169.98	$920.63	2.7	4.4	0%	100%
99	GAS LRN 4 1/2 HP Gas-Only	12	0.00	260.89	$2,832.29	$800.84	$2,489.25	1.0	3.5	0%	100%
100	GAS LRN 5 HP Gas-Only	13	0.00	260.89	$3,477.33	$997.25	$2,665.21	1.0	3.5	0%	100%

Table 4 Cost Effectiveness Calculator Oregon – Electric water heat, electric-only customers

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
102	ELE RS TEMP 1 1/4 HP Ele-Only	12	3,788.78	0.00	$897.17	-$6.28	$897.17	2.9	2.8	100%	0%
103	ELE RS TEMP 1 3/4 HP Ele-Only	12	4,598.41	0.00	$1,219.69	-$6.28	$1,219.69	2.6	2.5	100%	0%
104	ELE RS TEMP 1/2 HP Ele-Only	12	3,104.25	0.00	$944.09	-$6.28	$944.09	2.3	2.2	100%	0%
105	ELE RS TEMP 1/4 HP Ele-Only	12	2,400.39	0.00	$967.55	-$5.24	$967.55	1.7	1.7	100%	0%
106	ELE RS TEMP 1/6 HP Ele-Only	12	1,905.64	0.00	$975.37	-$4.13	$975.37	1.3	1.3	100%	0%
107	ELE RS TEMP 1/8 HP Ele-Only	12	1,026.81	0.00	$224.80	-$2.07	$224.80	3.1	3.1	100%	0%
108	ELE RS TEMP 2 HP Ele-Only	12	5,408.04	0.00	$1,542.21	-$6.28	$1,542.21	2.4	2.4	100%	0%
109	ELE RS TEMP 3 1/2 HP Ele-Only	12	7,027.30	0.00	$2,187.25	-$6.28	$2,187.25	2.2	2.2	100%	0%
110	ELE RS TEMP 3/4 HP Ele-Only	12	3,446.51	0.00	$920.63	-$6.28	$920.63	2.6	2.5	100%	0%
111	ELE RS TEMP 4 1/2 HP Ele-Only	12	8,646.56	0.00	$2,832.29	-$6.28	$2,832.29	2.1	2.1	100%	0%
112	ELE RS TEMP 5 HP Ele-Only	12	10,265.81	0.00	$3,477.33	-$6.28	$3,477.33	2.0	2.0	100%	0%
113	ELE RS COMB 1 1/4 HP Ele-Only	12	12,762.95	0.00	$2,017.00	-$25.62	$2,017.00	4.4	4.2	100%	0%
114	ELE RS COMB 1 3/4 HP Ele-Only	12	14,055.38	0.00	$2,619.47	-$25.62	$2,619.47	3.7	3.6	100%	0%
115	ELE RS COMB 1/2 HP Ele-Only	12	11,649.90	0.00	$2,063.91	-$25.62	$2,063.91	3.9	3.8	100%	0%
116	ELE RS COMB 1/4 HP Ele-Only	12	9,397.04	0.00	$2,087.37	-$21.35	$2,087.37	3.1	3.0	100%	0%
117	ELE RS COMB 1/6 HP Ele-Only	12	7,425.71	0.00	$2,095.19	-$16.85	$2,095.19	2.4	2.4	100%	0%
118	ELE RS COMB 1/8 HP Ele-Only	12	3,805.31	0.00	$455.49	-$8.43	$455.49	5.8	5.6	100%	0%
119	ELE RS COMB 2 HP Ele-Only	12	15,347.80	0.00	$3,221.95	-$25.62	$3,221.95	3.3	3.2	100%	0%
120	ELE RS COMB 3 1/2 HP Ele-Only	12	17,932.66	0.00	$4,426.90	-$25.62	$4,426.90	2.8	2.7	100%	0%
121	ELE RS COMB 3/4 HP Ele-Only	12	12,206.43	0.00	$2,040.46	-$25.62	$2,040.46	4.1	4.0	100%	0%
122	ELE RS COMB 4 1/2 HP Ele-Only	12	20,517.52	0.00	$5,631.85	-$25.62	$5,631.85	2.5	2.5	100%	0%
123	ELE RS COMB 5 HP Ele-Only	12	23,102.38	0.00	$6,836.80	-$25.62	$6,836.80	2.3	2.3	100%	0%
124	ELE RS LRN 1 1/4 HP Ele-Only	12	7,867.34	0.00	$897.17	-$15.95	$897.17	6.0	5.9	100%	0%
125	ELE RS LRN 1 3/4 HP Ele-Only	12	8,714.11	0.00	$1,219.69	-$15.95	$1,219.69	4.9	4.8	100%	0%
126	ELE RS LRN 1/2 HP Ele-Only	12	7,149.84	0.00	$944.09	-$15.95	$944.09	5.2	5.1	100%	0%
127	ELE RS LRN 1/4 HP Ele-Only	12	5,762.12	0.00	$967.55	-$13.29	$967.55	4.1	4.0	100%	0%
128	ELE RS LRN 1/6 HP Ele-Only	12	4,559.31	0.00	$975.37	-$10.49	$975.37	3.2	3.1	100%	0%
129	ELE RS LRN 1/8 HP Ele-Only	12	2,355.06	0.00	$334.55	-$5.25	$334.55	4.8	4.7	100%	0%
130	ELE RS LRN 2 HP Ele-Only	12	9,560.88	0.00	$1,542.21	-$15.95	$1,542.21	4.3	4.2	100%	0%
131	ELE RS LRN 3 1/2 HP Ele-Only	12	11,254.41	0.00	$2,187.25	-$15.95	$2,187.25	3.5	3.5	100%	0%
132	ELE RS LRN 3/4 HP Ele-Only	12	7,508.59	0.00	$920.63	-$15.95	$920.63	5.6	5.5	100%	0%
133	ELE RS LRN 4 1/2 HP Ele-Only	12	12,947.94	0.00	$2,832.29	-$15.95	$2,832.29	3.1	3.1	100%	0%
134	ELE RS LRN 5 HP Ele-Only	12	14,641.48	0.00	$3,477.33	-$15.95	$3,477.33	2.9	2.9	100%	0%

Table 5 Cost Effectiveness Calculator Oregon - Gas or other fuel water heat, electric-only customers

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
135	GAS TEMP 1 1/4 HP Ele-Only	12	1,650.64	0.00	$897.17	$95.20	$897.17	1.3	2.2	100%	0%
136	GAS TEMP 1 3/4 HP Ele-Only	12	2,460.27	0.00	$1,219.69	$95.20	$1,219.69	1.4	2.1	100%	0%
137	GAS TEMP 1/2 HP Ele-Only	12	966.10	0.00	$944.09	$95.20	$665.11	1.0	1.6	100%	0%
138	GAS TEMP 1/4 HP Ele-Only	12	618.60	0.00	$967.55	$79.33	$425.88	1.0	1.2	100%	0%
140	GAS TEMP 1/8 HP Ele-Only	12	323.49	0.00	$224.80	$31.32	$222.71	1.0	2.3	100%	0%
141	GAS TEMP 2 HP Ele-Only	12	3,269.90	0.00	$1,542.21	$95.20	$1,542.21	1.5	2.0	100%	0%
142	GAS TEMP 3 1/2 HP Ele-Only	12	4,889.16	0.00	$2,187.25	$95.20	$2,187.25	1.5	1.9	100%	0%
143	GAS TEMP 3/4 HP Ele-Only	12	1,308.37	0.00	$920.63	$95.20	$900.75	1.0	1.9	100%	0%
144	GAS TEMP 4 1/2 HP Ele-Only	12	6,508.41	0.00	$2,832.29	$95.20	$2,832.29	1.6	1.9	100%	0%
145	GAS TEMP 5 HP Ele-Only	12	8,127.67	0.00	$3,477.33	$95.20	$3,477.33	1.6	1.9	100%	0%
146	GAS COMB 1 1/4 HP Ele-Only	12	2,815.14	0.00	$2,017.00	$446.24	$1,938.08	1.0	3.0	100%	0%
147	GAS COMB 1 3/4 HP Ele-Only	12	4,107.56	0.00	$2,619.47	$446.24	$2,619.47	1.1	2.6	100%	0%
148	GAS COMB 1/2 HP Ele-Only	12	1,702.09	0.00	$2,063.91	$446.24	$1,171.81	1.0	2.5	100%	0%
149	GAS COMB 1/4 HP Ele-Only	12	1,107.19	0.00	$2,087.37	$371.87	$762.25	1.0	2.0	100%	0%
150	GAS COMB 1/6 HP Ele-Only	12	881.28	0.00	$2,095.19	$293.57	$606.72	1.0	1.6	100%	0%
151	GAS COMB 1/8 HP Ele-Only	12	533.09	0.00	$455.49	$146.79	$367.01	1.0	3.7	100%	0%
152	GAS COMB 2 HP Ele-Only	12	5,399.99	0.00	$3,221.95	$446.24	$3,221.95	1.2	2.4	100%	0%
153	GAS COMB 3 1/2 HP Ele-Only	12	7,984.85	0.00	$4,426.90	$446.24	$4,426.90	1.2	2.2	100%	0%
154	GAS COMB 3/4 HP Ele-Only	12	2,258.62	0.00	$2,040.46	$446.24	$1,554.95	1.0	2.8	100%	0%
155	GAS COMB 4 1/2 HP Ele-Only	12	10,569.71	0.00	$5,631.85	$446.24	$5,631.85	1.3	2.0	100%	0%
156	GAS COMB 5 HP Ele-Only	12	13,154.57	0.00	$6,836.80	$446.24	$6,836.80	1.3	1.9	100%	0%
157	GAS LRN 1 1/4 HP Ele-Only	12	1,824.37	0.00	$897.17	$270.72	$897.17	1.4	4.2	100%	0%
158	GAS LRN 1 3/4 HP Ele-Only	12	2,671.13	0.00	$1,219.69	$270.72	$1,219.69	1.5	3.5	100%	0%
159	GAS LRN 1/2 HP Ele-Only	12	1,106.87	0.00	$944.09	$270.72	$762.02	1.0	3.4	100%	0%
160	GAS LRN 1/4 HP Ele-Only	12	726.31	0.00	$967.55	$225.60	$500.03	1.0	2.6	100%	0%
161	GAS LRN 1/6 HP Ele-Only	12	583.77	0.00	$975.37	$178.10	$401.90	1.0	2.1	100%	0%
162	GAS LRN 1/8 HP Ele-Only	12	367.30	0.00	$334.55	$89.05	$252.87	1.0	3.2	100%	0%
163	GAS LRN 2 HP Ele-Only	12	3,517.90	0.00	$1,542.21	$270.72	$1,542.21	1.6	3.2	100%	0%
164	GAS LRN 3 1/2 HP Ele-Only	12	5,211.43	0.00	$2,187.25	$270.72	$2,187.25	1.6	2.8	100%	0%
165	GAS LRN 3/4 HP Ele-Only	12	1,465.62	0.00	$920.63	$270.72	$920.63	1.1	3.8	100%	0%
166	GAS LRN 4 1/2 HP Ele-Only	12	6,904.97	0.00	$2,832.29	$270.72	$2,832.29	1.7	2.5	100%	0%
167	GAS LRN 5 HP Ele-Only	12	8,598.50	0.00	$3,477.33	$270.72	$3,477.33	1.7	2.4	100%	0%

Table 6 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	GAS TEMP 1 1/4 HP Gas-Only	12	91.74	$897.17	$191.44	$897.17	1.2	3.3	0%	100%
2	GAS TEMP 1 3/4 HP Gas-Only	12	91.74	$1,219.69	$285.34	$1,112.46	1.0	3.1	0%	100%
3	GAS TEMP 1/2 HP Gas-Only	12	91.74	$944.09	$112.05	$944.09	1.2	2.3	0%	100%
4	GAS TEMP 1/4 HP Gas-Only	12	76.45	$967.55	$71.75	$927.05	1.0	1.7	0%	100%
5	GAS TEMP 1/6 HP Gas-Only	12	60.36	$975.37	$57.87	$731.86	1.0	1.3	0%	100%
6	GAS TEMP 1/8 HP Gas-Only	12	30.18	$224.80	$37.52	$224.80	1.6	3.2	0%	100%
7	GAS TEMP 2 HP Gas-Only	12	91.74	$1,542.21	$379.24	$1,112.46	1.0	3.1	0%	100%
8	GAS TEMP 3 1/2 HP Gas-Only	12	91.74	$2,187.25	$567.04	$1,112.46	1.0	3.0	0%	100%
9	GAS TEMP 3/4 HP Gas-Only	12	91.74	$920.63	$151.74	$920.63	1.2	2.8	0%	100%
10	GAS TEMP 4 1/2 HP Gas-Only	12	91.74	$2,832.29	$754.84	$1,112.46	1.0	2.9	0%	100%
11	GAS TEMP 5 HP Gas-Only	12	91.74	$3,477.33	$942.64	$1,112.46	1.0	2.9	0%	100%
12	GAS COMB 1 1/4 HP Gas-Only	12	430.04	$2,017.00	$326.50	$2,017.00	2.6	4.1	0%	100%
13	GAS COMB 1 3/4 HP Gas-Only	12	430.04	$2,619.47	$476.39	$2,619.47	2.0	3.7	0%	100%
14	GAS COMB 1/2 HP Gas-Only	12	430.04	$2,063.91	$197.41	$2,063.91	2.5	3.4	0%	100%
15	GAS COMB 1/4 HP Gas-Only	12	358.36	$2,087.37	$128.41	$2,087.37	2.1	2.7	0%	100%
16	GAS COMB 1/6 HP Gas-Only	12	282.91	$2,095.19	$102.21	$2,095.19	1.6	2.1	0%	100%
17	GAS COMB 1/8 HP Gas-Only	12	141.46	$455.49	$61.83	$455.49	3.8	5.1	0%	100%
18	GAS COMB 2 HP Gas-Only	12	430.04	$3,221.95	$626.29	$3,221.95	1.6	3.5	0%	100%
19	GAS COMB 3 1/2 HP Gas-Only	12	430.04	$4,426.90	$926.08	$4,426.90	1.2	3.2	0%	100%
20	GAS COMB 3/4 HP Gas-Only	12	430.04	$2,040.46	$261.95	$2,040.46	2.6	3.8	0%	100%
21	GAS COMB 4 1/2 HP Gas-Only	12	430.04	$5,631.85	$1,225.87	$5,214.56	1.0	3.0	0%	100%
22	GAS COMB 5 HP Gas-Only	12	430.04	$6,836.80	$1,525.66	$5,214.56	1.0	2.9	0%	100%
23	GAS LRN 1 1/4 HP Gas-Only	12	260.89	$897.17	$211.59	$897.17	3.5	5.8	0%	100%
24	GAS LRN 1 3/4 HP Gas-Only	12	260.89	$1,219.69	$309.80	$1,219.69	2.6	5.0	0%	100%
25	GAS LRN 1/2 HP Gas-Only	12	260.89	$944.09	$128.37	$944.09	3.4	4.6	0%	100%
26	GAS LRN 1/4 HP Gas-Only	12	217.41	$967.55	$84.24	$967.55	2.7	3.6	0%	100%
27	GAS LRN 1/6 HP Gas-Only	12	171.63	$975.37	$67.71	$975.37	2.1	2.8	0%	100%
28	GAS LRN 1/8 HP Gas-Only	12	85.82	$334.55	$42.60	$334.55	3.1	4.3	0%	100%
29	GAS LRN 2 HP Gas-Only	12	260.89	$1,542.21	$408.00	$1,542.21	2.1	4.6	0%	100%
30	GAS LRN 3 1/2 HP Gas-Only	12	260.89	$2,187.25	$604.42	$2,187.25	1.4	4.1	0%	100%
31	GAS LRN 3/4 HP Gas-Only	12	260.89	$920.63	$169.98	$920.63	3.4	5.2	0%	100%
32	GAS LRN 4 1/2 HP Gas-Only	12	260.89	$2,832.29	$800.84	$2,832.29	1.12	3.80	0%	100%
33	GAS LRN 5 HP Gas-Only	12	260.89	$3,477.33	$997.25	$3,163.51	1.00	3.63	0%	100%

Requirements

- Retrofitted controls or integral controls are eligible
- Systems must follow all applicable codes and regulations.
- Only approved for multifamily buildings. Other buildings - including lodging - don't qualify for this measure.

Baseline

This measure uses a full market baseline.

The baseline was determined by DOE estimates of consumer control types shown in Table 7.

Table 7 Control Types Hours of Use

Control Type	Fraction of Consumers	Hours Per Year	Notes
None	50%	8,200	Constant Operation Based on NEEA Research
Timer or Learning	25%	3,700	Combine timer and learning because learning is just determining the timer settings based on use
Temperature	20%	3,900	Assumes that Temperature controls in NEEA research included timers.
Combined Temperature and Timer	5%	1,300	If the pumps did not have a timer, the Temperature control would run the pump during the hours of little or no use.

Measure Analysis

This measure analysis is largely based on the RTF's work[1].

The savings are composed of the following factors, pump savings, water heating savings and HVAC interactive effects:

$$\Delta E = \Delta E_{Pump} + \Delta E_{Water\ Heating} + \Delta E_{HVAC}$$

Where:

$$\Delta E = Energy\ Savings$$
$$\Delta E_{Pump} = Pump\ Energy\ Savings$$
$$\Delta E_{Water\ Heating} = Water\ Heater\ Energy\ Savings$$
$$\Delta E_{HVAC} = HVAC\ Energy\ Savings$$

[1] Circulator Pumps (nwcouncil.org)

Pump Savings

Pumps savings come as a result in runtime reduction resulting from the improving the controls strategy to better align with hot water demand. The analysis takes the pump efficiency rating (PER) in watts and multiplies it by the difference in runtime from no controls to the efficient controls strategy.

$$\Delta E_{Pump} = PER(t_{baseline} - t_{efficient})$$

Where:

$$PER = Pump\ Efficiency\ Rating\ (watts)$$
$$t_{baseline} = Runtime\ Baseline\ Case$$
$$t_{efficient} = Runtime\ Efficient\ Case$$

Although pumps with integral demand controls are included in this analysis, Pump Efficiency Rating (PER) is held constant between the baseline and efficient case to only capture savings from the controls. To determine PER, the Regional Technical Forum (RTF) used Department of Energy (DOE) working group estimates of circulator efficiency levels (EL's) by nominal horsepower bin. The EL's are listed below:

- EL0 – Single speed induction motor
- EL1 – Single speed induction motor with improved efficiency
- EL2 – Single speed EC motor
- EL3 – Variable speed EC motor with proportional pressure controls
- EL4 – Variable speed EC motor with differential temperature or reference curve controls

The RTF modified the DOE estimates upward, to represent a higher prevalence of efficient technologies, thereby reducing baseline energy usage. PER for each EL was determined by the DOE working group by performing an engineering analysis on representative units from manufacturers' products. Below is a summary of the PER analysis:

Table 8 Pump Efficiency Rating by HP Bin

HP Bin	1/40	1/25	1/12	1/6	1/4	1/2	3/4	1	1 1/2	2	2 1/2	3	3 1/2	4	4 1/2	5
PER	62	116	173	283	353	564	775	986	1479	1972	2464	2957	3450	3943	4436	4929

Water Heating Savings

Savings for water heating are a result of not losing as much heat to the recirculating loop. When the pump is not running the water heater is only maintaining the tank temperature and not the heat loss from the loop piping. Savings for water heating were calculated using the methodology below.

$$Eelctric\ Fuel: \Delta kWh_{DHW} = kWh_{DHWbaseline} - kWh_{DHWefficient}$$

$$Gas\ Fuel: \Delta therm_{DHW} = therm_{DHWbaseline} - therm_{DHWefficient}$$

Where:

$$\Delta kWh = Electricity\ Savings$$
$$\Delta therm = therm\ savings$$

Temperature and learning control type savings were determined using estimate of on-demand water heating savings. The on-demand savings are based on an NREL field study, which found savings of 15,800 kWh per 1/6 HP pump. The analysis assumes that savings will scale linearly with pump horsepower. It is assumed that Temperature and learning control types will generate 1/3 of the savings of on-demand control type, based on estimates by the RTF.

Water heating efficiencies shown in Table 9 were used to determine corresponding gas savings when study savings were expressed in kWh.

Table 9 Water Heating System Efficiencies

System Type	COP
Electric Resistance	1
Gas	0.75

The RTF analysis was modified so that all electric water heating systems are assumed to be electric resistance, since heat pump water heaters are very uncommon in large central systems.

HVAC Interactive Effects

With the reduction in heat loss from the recirculation loop discussed in the Water Heating Savings calculation, there is less heat being added to the space. This results in an increased heating load during the heating season and reduced cooling load during the cooling season. This is known as the HVAC interactive effect for this measure. This interactive effect was calculated using the equations below.

$$\Delta kWh_{cooling} = \Delta kWh_{DHW} * CoolingInteraction_{electric}$$

$$\Delta kWh_{heating} = \Delta kWh_{DHW} * HeatingInteraction_{electric}$$

$$\Delta therm_{heating} = \frac{\Delta kWh_{DHW} * HeatingInteraction_{gas}}{100}$$

Where:

$$CoolingInteraction = Cooling\ Interactive\ Effect\ Factor$$
$$HeatingInteraction = Heating\ Interactive\ Effect\ Factor$$

HVAC interactive effects were determined by using the interactive factor shown in Table 10 and the system efficiencies shown in Table 11. This data was referenced from the Standard Information Workbook V4_2 as part of the RTF analysis.

Table 10 Interactive Effect Factors

HVAC	System	Interactive Effect
Heating	Electric Resistance	-0.25
	Electric Heat Pump	-0.12
	Gas	-0.012
Cooling	Electric	0.15

Table 11 Heating System and Efficiencies

System	COP
Gas	0.6375
Zonal Electric	1
Forced Air Furnace	0.85
Heat Pump	2.5

Comparison to RTF or other programs

This measure differs from the RTF measure in the measure types that were included. This measure only looks at multifamily applications for DHW Recirculation control and excludes heat pump hot water heaters due to the lack of prevalence in the target market.

Measure Life

The measure life is 12 years which is based on a weighted average of typical circulator pumps useful life based on RTFs market analysis shown below:

Table 12 Circulator Lifetime and Prevalence

Circulator Variety	Description	Average Lifetime	CP Weights
CP1	Wet rotor	10	80%
CP2	Dry rotor, close-coupled	15	10%
CP3	Dry rotor, mechanically-coupled	20	10%

Cost

Costs are based on the RTF workbook which uses DOE estimates and retail costs for the different measure types and motors including the equipment and labor costs. The RTF costs were based on 2016 dollars, as part of this analysis the costs were adjusted to 2023 dollars to better represent current costs.

Table 13 Incremental Measure Cost for Controls

Horsepower (HP) Class	Temperature	Timer or Learning	Combined Temperature and Timer
≤1/30 HP	$76	$186	$262
>1/30 - ≤1/16 HP	$76	$186	$262
>1/16 - ≤1/8 HP	$121	$231	$352
>1/8 - ≤1/6 HP	$1,120	$1,120	$2,240
>1/6 - ≤1/4 HP	$1,120	$1,120	$2,240
>1/4 - ≤1/2 HP	$1,120	$1,120	$2,240
>1/2 - ≤3/4 HP	$1,120	$1,120	$2,240
>3/4 - ≤1.25 HP	$1,120	$1,120	$2,240
>1.25 - ≤1.75 HP	$1,400	$1,400	$2,800
>1.75 - ≤2.5 HP	$1,680	$1,680	$3,359
>2.5 - ≤3.5 HP	$2,240	$2,240	$4,479
>3.5 - ≤4.5 HP	$2,800	$2,800	$5,599
>4.5 - ≤5 HP	$3,359	$3,359	$6,719

Table 14 Total Installed Cost for Motors

Name	EL0	EL1	EL2	EL3	EL4
≤1/30 HP	$601	$601	$737	$910	$975
>1/30 - ≤1/16 HP	$594	$594	$792	$837	$885
>1/16 - ≤1/8 HP	$820	$820	$1,032	$1,139	$1,205
>1/8 - ≤1/6 HP	$755	$755	$1,240	$1,324	$1,381
>1/6 - ≤1/4 HP	$918	$918	$1,394	$1,482	$1,538
>1/4 - ≤1/2 HP	$1,409	$1,409	$1,860	$1,956	$2,004
>1/2 - ≤3/4 HP	$1,899	$1,899	$2,326	$2,431	$2,473
>3/4 - ≤1.25 HP	$2,390	$2,390	$2,792	$2,905	$2,940
>1.25 - ≤1.75 HP	$3,585	$3,585	$4,188	$4,358	$4,410
>1.75 - ≤2.5 HP	$4,779	$4,779	$5,583	$5,811	$5,879
2.5 HP	$5,974	$5,974	$6,980	$7,263	$7,349
>2.5 - ≤3.5 HP	$7,169	$7,169	$8,375	$8,716	$8,819
3.5 HP	$8,364	$8,364	$9,772	$10,168	$10,289
>3.5 - ≤4.5 HP	$9,559	$9,559	$11,167	$11,622	$11,758
4.5 HP	$10,754	$10,754	$12,563	$13,074	$13,228
>4.5 - ≤5 HP	$11,949	$11,949	$13,959	$14,526	$14,698

Non-Energy Benefits

In single fuel territories (electric-only or gas-only), unclaimed savings for out of territory fuel are considered as non-energy benefits. Their value is calculated as a product of the unclaimed fuel savings (electricity, natural gas, or propane) and the blended residential utility rate in Oregon for electricity or natural gas depending on the fuel.

For measures where propane is an eligible fuel, NEB was valued as the product of unclaimed natural gas savings and appropriate rate for propane.

Load Profile

- Electric savings use the profile Lodging Hot Water
- Gas savings use the profile DHW

Incentive Structure

The maximum incentives listed in Table 1 through Table 6 *are for reference only and are not suggested incentives.* Note that maximum incentives are lower in single fuel territory than in dual fuel territory for some equipment. Incentives will be structured per pump controlled.

Follow-Up

The latest version of RTF's Circulator Pump UES should be reviewed in the next update.

Further investigation should be done to create a measure for DHW recirculation controls in commercial applications.

This measure uses a load profile based on water use in lodging. It does not accurately reflect the savings profile. At next update consider if any available profile better represents time of savings.

Supporting Documents

The cost effectiveness screening for these measures is number 66.3.2. It is attached and can be found along with supporting documentation at: I:\Groups\ Planning\Measure Development\Residential\Multifamily\HVAC\recirculation control

66.3.2 OR WA CEC
2023 v1.0 MF DHW I

Version History and Related Measures

Energy Trust has been offering recirculation controls measures for many years. These measures predate our measure approval documentation process and our record retention polices. Table 15 may be incomplete, particularly for measures approved prior to 2013.

Table 15 Version History

Date	Version	Reason for revision
5/1/2012	66.X	First release as calculator
3/9/2015	66.1	Update costs and avoided costs
4/5/2019	66.2	New calculation methodology, multiple control strategies, no longer a calculated measure
9/1/2022	66.3	Updated costs, savings, and measure applications based on RTF updates.

Table 16 Related Measures

Measures	MAD ID
Commercial Condensing Tank Water Heaters	21
Commercial Condensing Tankless	72
Commercial Pipe Insulation	91
Multifamily Pipe Insulation	111
Multifamily 199 kBtu Condensing Tankless WH	192
Multifamily hydronic heating controls	TBD

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Measure Approval Document for Commercial Insulation

Valid Dates
1/1/2023 – 12/31/2025

End Use or Description
Installation of insulation for flat roofs, attics, and walls in commercial buildings/facilities where there was none previously or only a negligible amount is present. Increased insulation reduces heat transfer that happens through the building envelope. This leads to reduced heating and cooling loads and that produces electricity and 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
- Production Efficiency

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

Purpose of Re-Evaluating Measure
Measure costs have been updated. Cooling zone is no longer a measure identifier. Updated requirements.

Cost Effectiveness
Cost effectiveness is demonstrated for Oregon in Table 1 through Table 4 and for Washington in Table 5. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2023-v1.0. In Oregon the electric avoided cost year is 2023 and the gas avoided cost year is 2023. In Washington the gas avoided cost year is 2023. The values in these tables are per square feet (SF) of insulation.

Table 1 includes buildings that use either electric resistance or heat pump as the primary energy source for space heating in Energy Trust's dual-fuel or electric only territory. Table 2 includes gas-heated buildings in Energy Trust's dual-fuel territory. Table 3 includes gas-heated buildings in Energy Trust's gas-only territory. Table 4 includes buildings with gas or other fuels in Energy Trust's electric-only territory, these are expected to be rare and would include customers on non-qualified gas rate schedules, transport gas customers, or customers that heat with propane, wood or other biomass and have participating electric provider. Table 5 includes buildings that heat with gas in Washington, which is gas-only territory.

Table 1 Cost Effectiveness Calculator Oregon, electric heating, per SF

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
3	HZ1 - Roof Insulation - R5 or less to R30 - heat pump	25	2.53	0.00	2.85	$0.00	$2.85	1.2	1.2	100%	0%
4	HZ2/HZ3 - Roof Insulation - R5 or less to R30 - heat pump	25	3.52	0.00	2.85	$0.00	$2.85	1.6	1.6	100%	0%
5	HZ1 - Roof Insulation - R5 or less to R30 - elec resistance	25	4.33	0.00	2.85	$0.00	$2.85	2.3	2.3	100%	0%
6	HZ2/HZ3 - Roof Insulation - R5 or less to R30 - elec resistance	25	6.66	0.00	2.85	$0.00	$2.85	3.5	3.5	100%	0%
9	HZ1 - Roof Insulation - R0 to R15 - heat pump	25	12.00	0.00	2.85	$0.00	$2.85	5.5	5.5	100%	0%
10	HZ2/HZ3 - Roof Insulation - R0 to R15 - heat pump	25	15.45	0.00	2.85	$0.00	$2.85	7.1	7.1	100%	0%
11	HZ1 - Roof Insulation - R0 to R15 - elec resistance	25	20.75	0.00	2.85	$0.00	$2.85	10.8	10.8	100%	0%
12	HZ2/HZ3 - Roof Insulation - R0 to R15 - elec resistance	25	28.87	0.00	2.85	$0.00	$2.85	15.1	15.1	100%	0%
15	HZ1 - Roof Insulation - R0 to R30 - heat pump	25	13.76	0.00	2.85	$0.00	$2.85	6.3	6.3	100%	0%
16	HZ2/HZ3 - Roof Insulation - R0 to R30 - heat pump	25	17.55	0.00	2.85	$0.00	$2.85	8.1	8.1	100%	0%
17	HZ1 - Roof Insulation - R0 to R30 - elec resistance	25	24.22	0.00	2.85	$0.00	$2.85	12.6	12.6	100%	0%
18	HZ2/HZ3 - Roof Insulation - R0 to R30 - elec resistance	25	33.15	0.00	2.85	$0.00	$2.85	17.3	17.3	100%	0%
21	HZ1 - Attic Insulation – R9 or less to R25 - heat pump	30	5.10	0.00	1.28	$0.00	$1.28	5.8	5.8	100%	0%
22	HZ2/HZ3 - Attic Insulation - R9 or less to R25 - heat pump	30	6.81	0.00	1.28	$0.00	$1.28	7.8	7.8	100%	0%
23	HZ1 - Attic Insulation - R9 or less to R25 - elec resistance	30	7.93	0.00	1.28	$0.00	$1.28	10.3	10.3	100%	0%
24	HZ2/HZ3 - Attic Insulation - R9 or less to R25 - elec resistance	30	9.98	0.00	1.28	$0.00	$1.28	12.9	12.9	100%	0%
27	HZ1 - Wall Insulation – R6 or less to R20 - heat pump	30	5.70	0.00	1.61	$0.00	$1.61	5.2	5.2	100%	0%
28	HZ2/HZ3 - Wall Insulation - R6 or less to R20 - heat pump	30	7.64	0.00	1.61	$0.00	$1.61	6.9	6.9	100%	0%
29	HZ1 - Wall Insulation - R6 or less to R20 - elec resistance	30	9.54	0.00	1.61	$0.00	$1.61	9.8	9.8	100%	0%
30	HZ2/HZ3 - Wall Insulation - R6 or less to R20 - elec resistance	30	14.03	0.00	1.61	$0.00	$1.61	14.5	14.5	100%	0%

Table 2 Cost Effectiveness Calculator Oregon, natural gas heating in dual-fuel territory, per SF

#	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	HZ1 - Roof Insulation - R5 or less to R30 - gas heat	25	1.09	0.09	2.85	$0.00	$2.85	1.4	1.4	48%	52%
2	HZ2/HZ3 - Roof Insulation - R5 or less to R30 - gas heat	25	1.03	0.15	2.85	$0.00	$2.85	1.9	1.9	33%	67%
7	HZ1 - Roof Insulation - R0 to R15 - gas heat	25	5.04	0.43	2.85	$0.00	$2.85	6.5	6.5	46%	54%
8	HZ2/HZ3 - Roof Insulation - R0 to R15 - gas heat	25	4.76	0.66	2.85	$0.00	$2.85	8.3	8.3	35%	65%
13	HZ1 - Roof Insulation - R0 to R30 - gas heat	25	5.43	0.51	2.85	$0.00	$2.85	7.5	7.5	44%	56%
14	HZ2/HZ3 - Roof Insulation - R0 to R30 - gas heat	25	5.14	0.76	2.85	$0.00	$2.85	9.3	9.3	33%	67%
19	HZ1 - Attic Insulation - R9 or less to R25 - gas heat	30	2.84	0.14	1.28	$0.00	$1.28	7.1	7.1	60%	40%
20	HZ2/HZ3 - Attic Insulation - R9 or less to R25 - gas heat	30	2.74	0.25	1.28	$0.00	$1.28	9.2	9.2	45%	55%
25	HZ1 - Wall Insulation - R6 or less to R20 - gas heat	30	2.65	0.19	1.61	$0.00	$1.61	6.2	6.2	51%	49%
26	HZ2/HZ3 - Wall Insulation - R6 or less to R20 - gas heat	30	2.56	0.31	1.61	$0.00	$1.61	8.1	8.1	38%	62%

Table 3 Cost Effectiveness Calculator Oregon, natural gas heating in gas-only territory, per SF

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
32	HZ1 - Roof Insulation - R5 or less to R30 - gas heat - gas only	25	0.00	0.09	2.85	$0.08	$2.06	1.0	1.2	0%	100%
33	HZ2/HZ3 - Roof Insulation - R5 or less to R30 - gas heat - gas only	25	0.00	0.15	2.85	$0.08	$2.85	1.3	1.7	0%	100%
34	HZ1 - Roof Insulation - R0 to R15 - gas heat - gas only	25	0.00	0.43	2.85	$0.39	$2.85	3.5	5.5	0%	100%
35	HZ2/HZ3 - Roof Insulation - R0 to R15 - gas heat - gas only	25	0.00	0.66	2.85	$0.37	$2.85	5.4	7.3	0%	100%
36	HZ1 - Roof Insulation - R0 to R30 - gas heat - gas only	25	0.00	0.51	2.85	$0.42	$2.85	4.2	6.4	0%	100%
37	HZ2/HZ3 - Roof Insulation - R0 to R30 - gas heat - gas only	25	0.00	0.76	2.85	$0.40	$2.85	6.2	8.3	0%	100%
38	HZ1 - Attic Insulation - R9 or less to R25 - gas heat - gas only	30	0.00	0.14	1.28	$0.22	$1.28	2.8	5.7	0%	100%
39	HZ2/HZ3 - Attic Insulation - R9 or less to R25 - gas heat - gas only	30	0.00	0.25	1.28	$0.21	$1.28	5.1	7.8	0%	100%
40	HZ1 - Wall Insulation - R6 or less to R20 - gas heat - gas only	30	0.00	0.19	1.61	$0.21	$1.61	3.0	5.1	0%	100%
41	HZ2/HZ3 - Wall Insulation - R6 or less to R20 - gas heat - gas only	30	0.00	0.31	1.61	$0.20	$1.61	5.1	7.1	0%	100%

Table 4 Cost Effectiveness Calculator Oregon, natural gas or other fuel heating in electric-only territory, per SF

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
43	HZ1 - Roof Insulation - R5 or less to R30 - gas or other heat - elec only	25	1.09	0.00	2.85	$0.26	$1.88	1.0	2.0	100%	0%
44	HZ2/HZ3 - Roof Insulation - R5 or less to R30 - gas or other heat - elec only	25	1.03	0.00	2.85	$0.45	$1.77	1.0	3.0	100%	0%
45	HZ1 - Roof Insulation - R0 to R15 - gas or other heat - elec only	25	5.04	0.00	2.85	$1.27	$2.85	3.0	9.6	100%	0%
46	HZ2/HZ3 - Roof Insulation - R0 to R15 - gas or other heat - elec only	25	4.76	0.00	2.85	$1.94	$2.85	2.9	13.0	100%	0%
47	HZ1 - Roof Insulation - R0 to R30 - gas or other heat - elec only	25	5.43	0.00	2.85	$1.51	$2.85	3.3	11.1	100%	0%
48	HZ2/HZ3 - Roof Insulation - R0 to R30 - gas or other heat - elec only	25	5.14	0.00	2.85	$2.26	$2.85	3.1	14.8	100%	0%
49	HZ1 - Attic Insulation - R9 or less to R25 - gas or other heat - elec only	30	2.84	0.00	1.28	$0.41	$1.28	4.3	9.5	100%	0%
50	HZ2/HZ3 - Attic Insulation - R9 or less to R25 - gas or other heat - elec only	30	2.74	0.00	1.28	$0.74	$1.28	4.1	13.5	100%	0%
51	HZ1 - Wall Insulation - R6 or less to R20 - gas or other heat - elec only	30	2.65	0.00	1.61	$0.55	$1.61	3.2	8.8	100%	0%
52	HZ2/HZ3 - Wall Insulation - R6 or less to R20 - gas or other heat - elec only	30	2.56	0.00	1.61	$0.92	$1.61	3.0	12.4	100%	0%

Table 5 Cost Effectiveness Calculator Washington, natural gas heat in gas-only territory, per SF

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	HZ1 - Roof Insulation - R5 or less to R30 - gas heat - gas only	25	0.09	2.85	$0.08	$2.85	1.1	1.5	0%	100%
2	HZ2/HZ3 - Roof Insulation - R5 or less to R30 - gas heat - gas only	25	0.15	2.85	$0.08	$2.85	1.9	2.3	0%	100%
3	HZ1 - Roof Insulation - R0 to R15 - gas heat - gas only	25	0.43	2.85	$0.39	$2.85	5.2	7.3	0%	100%
4	HZ2/HZ3 - Roof Insulation - R0 to R15 - gas heat - gas only	25	0.66	2.85	$0.37	$2.85	7.9	10.0	0%	100%
5	HZ1 - Roof Insulation - R0 to R30 - gas heat - gas only	25	0.51	2.85	$0.42	$2.85	6.2	8.5	0%	100%
6	HZ2/HZ3 - Roof Insulation - R0 to R30 - gas heat - gas only	25	0.76	2.85	$0.40	$2.85	9.2	11.4	0%	100%
7	HZ1 - Attic Insulation - R9 or less to R25 - gas heat - gas only	30	0.14	1.28	$0.22	$1.28	4.2	7.2	0%	100%
8	HZ2/HZ3 - Attic Insulation - R9 or less to R25 - gas heat - gas only	30	0.25	1.28	$0.21	$1.28	7.6	10.5	0%	100%
9	HZ1 - Wall Insulation - R6 or less to R20 - gas heat - gas only	30	0.19	1.61	$0.20	$1.61	4.5	6.8	0%	100%
10	HZ2/HZ3 - Wall Insulation - R6 or less to R20 - gas heat - gas only	30	0.31	1.61	$0.20	$1.61	7.5	9.7	0%	100%

Requirements

- All insulation must be installed in areas of the building envelope that separate conditioned space and unconditioned space. Insulation installed between conditioned spaces does not qualify.
- Damaged or missing insulation claimed as providing no insulating value (R-0) for purposes of claiming the 'no existing insulation' baseline condition must be prequalified and documented by the installation contractor
- Roof insulation
  - If existing insulation is R5 or less, must retrofit to at least R30 or fill cavity
  - If existing insulation is R0, must retrofit to at least R15 or fill cavity to use the measures designed for R0 to R15.
  - If existing insulation is R0, must retrofit to at least R30 or fill cavity beyond R15 to use the measures designated for R0 to R30.
- Attic insulation
  - Existing insulation must be R9 or less (including R0)
  - Must retrofit to at least R25 or fill cavity
- Wall insulation
  - Existing insulation must be R6 or less (including R0)
  - Must retrofit to at least R20 or fill cavity

Fuel/utility territory details

- Customers with electric space heating (electric resistance or heat pump) in dual-fuel territory must use the measures listed in Table 1.
- Customers with gas-based space heating in dual-fuel territory must use the measures listed in Table 2.
- Customers with gas-based space heating in gas-only territory must use the measures listed in Table 3.
- Customers with gas in electric-only territory must use the measures listed in Table 4.
- Customers with other fuel-based space heating (propane, wood, biomass etc.) must have a participating electric provider and use the measures listed in Table 4
- Washington customers must have natural gas-based space heating and must use measures listed in Table 5.

Baseline

This measure uses an existing condition baseline.

The baseline conditions for these measures are assumed to fall into one of three categories:

- The existing insulation is effective, but barely. When originally installed, the insulation was effective, but is now compressed or damaged resulting in effectiveness of R-5 or less.
- The insulation is compressed or damaged and not effective; essentially R-0
- There is no existing insulation; R-0

Savings and Measure Analysis

Estimated annual savings are the result of whole building simulations performed using EnergyPlus v8.8.0. Simulations were performed using DOE models constructed to represent existing commercial reference buildings constructed in or after 1980. 15 building types were simulated for insulation of commercial roofs, attics, and walls. Models were simulated using TMY3 weather files in seven cities across Oregon and include: Baker City, Medford, North Bend, Pendleton, Portland, Redmond, and Salem.

Table 6 lists the reference building models and associated measures expected for them, but this does not imply that only these insulation types are applicable to a certain building. All buildings are eligible to participate for all three types of insulation.

Table 6 Reference Models and Associated Measures

Building Type	Floor Area (ft^2)	Roof	Attic	Wall
Full Service Restaurant	5,500		x	x
Hospital	241,351	x		
Large Hotel	122,120	x		x
Large Office	498,588	x		x
Medium Office	53,628	x		x
Primary School	73,960	x		x
Quick Service Restaurant	2,500		x	x
Secondary School	210,887	x		x
Small Hotel	43,200		x	
Small Office	5,500		x	
Stand-alone Retail	24,962	x		x
Strip Mall	22,500	x		x
Supermarket	45,000	x		x
Warehouse	52,045	x		x

Savings were grouped by city according to Energy Trust's heating zones to determine average annual savings estimates for heating zones 1 and 2. Model locations are shown in Table 7. Measures in heating zone 3 can use measures developed for heating zone 2 as population in heating zone 3 is only 0.4% of Oregon's total population per Table 14-5 of the 2022 Technical Guidelines.

Table 7 Modeled locations and their climate zones

City	Heating Zone
Baker City	2
Medford	1
North Bend	1
Pendleton	1
Portland	1
Redmond	2
Salem	1

For electrically heated buildings, projected gas savings were converted to electric savings to represent both heat pump and electric resistance primary heating systems. For electric resistance heating, gas savings in therms per square foot were converted directly to kWh savings per square foot. For electrically heated buildings using heat pumps, therms savings per square foot were converted to kWh saving per square foot using air-source heat pump HSPF of 7.7, sourced from the RTF standard information workbook v4.7[1].

Measure Life

Insulation measure life will follow per SB1149 measure life guidelines[2]

- Roof insulation will use 25 years
- Attic insulation will use 30 years
- Wall insulation will use 30 years

Load Profile

Per the 2022 Technical Guidelines, measures that save both heating and cooling energy, such as weatherization measures, are usually best described by the ventilation profile, which includes all-season savings during typical business hours unless either heating or cooling represents more than 80% of savings. Therefore, for heat pump heating, Commercial Other Ventilation electric load profile was chosen.

Table 8 Electric and natural gas load profile

	Electric Load Profile	Natural Gas Load Profile
Gas heating in dual-fuel territory	Commercial Other Cooling	Com Heating
Heat pump heating in dual-fuel territory	Commercial Other Ventilation	None - gas
Electric heating in dual-fuel territory	Commercial Other Heating	None - gas
Gas heating in gas-only territory	None – ele	Com Heating
Gas or other fuel heating in electric-only territory	Commercial Other Cooling	None- gas

Cost

Costs were estimated on a $/SF basis using median values from PT data for attic, flat roof, and wall projects from 2019 up to latest data available in 2022. Median costs for each type of insulation are shown in Table 9.

Table 9 Insulation median costs

Type	Median cost
Roof insulation	$2.85/ SF
Attic insulation	$1.28/ SF
Wall insulation	$1.61/ SF

Non Energy Benefits

Out of territory energy savings are included as non-energy benefits using Energy Trust's blended commercial rates. Propane costs are assumed for other fuel savings.

Incentive Structure

The maximum incentives listed in Table 1 to Table 5 are for reference only and are not suggested incentives. Incentives will be structured per SF in insulation.

[1] https://nwcouncil.box.com/v/RTF-SIW-v4-7
[2] https://www.oregon.gov/energy/energy-oregon/Documents/SB1149_Schools_Program_Guidelines.pdf

Follow-Up

In the next MAD update:

- Latest ASHRAE 90.1 standard should be referred to update the measure case insulation levels if required.
- Costs
- Weighting by building type

Supporting Documents

The cost effectiveness screening for these measures is number 68.4.3. It is attached and can be found along with supporting documentation at: \\Etoo.org\home\Groups\Planning\Measure Development\Commercial and Industrial\Commercial Weatherization\insulation

68.4.3 OR WA CEC 2023 v1.0 Comm Insu

Version History and Related Measures

Energy Trust has been offering commercial insulation measures for many years. These predate our measure approval documentation process and record retention requirements. Table 10 may be incomplete, particularly for measures approved prior to 2013.

Table 10 Version History

Date	Version	Reason for revision
2003	x	Introduce commercial insulation measures for gas heated buildings
9/24/2008	x	Add measures for electric heated buildings
4/4/2012	68.x	Update savings and costs for Wall, Attic and Roof insulation.
9/9/2014	68.x	Add measures for roof and attic insulation with pre-existing insulation.
9/11/2014	68.1	Add Washington attic insulation
7/11/2019	68.2	Revise savings and costs. Differentiate by heating zones only. Change minimum insulation levels
9/26/2019	68.3	Corrects copy/paste errors in Tables 1-4. No change to actual measure definitions.
9/28/2022	68.4	Costs updated. Measures no longer separated by cooling zone

Table 11 Related Measures

Measures	MAD ID
Multifamily Insulation	110

Approved & Reviewed by

Jackie Goss, PE
Sr. Engineer – Planning & Evaluation

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

Valid Dates
January 1, 2023 – December 31, 2025

End Use or Description
This measure covers installation of high efficiency condensing tankless water heaters (CTWH) and supply boilers 200 kBtu/h or greater used in commercial and multifamily 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
- Production Efficiency

Within these programs, applicability to the following building types is expected:
- Office
- Schools (primary and secondary)
- Healthcare (outpatient and hospitals)
- Hotels
- Restaurants
- Multifamily
- Gyms
- Coin-operated laundry

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

Purpose of Re-Evaluating Measure
Changes to align sources and assumptions with other commercial tankless measures. Healthcare, restaurant, and multifamily applications are now cost effective and 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 2023-v1.0. In Oregon the electric avoided cost year is 2023 and the gas avoided cost year is 2023. In Washington the gas avoided cost year is 2023. The values in these tables are per kBtu/h input capacity.

Table 1 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	0.00	0.44	$1.42	$0.00	$1.42	4.5	4.5	0%	100%
2	School - CTHW ≥200 kBtu/h	20	0.00	0.28	$1.42	$0.00	$1.42	2.8	2.8	0%	100%
3	Healthcare - CTWH ≥200 kBtu/h	20	0.00	0.14	$1.42	$0.00	$1.42	1.4	1.4	0%	100%
4	Hotel - CTWH ≥200 kBtu/h	20	0.00	0.21	$1.44	$0.00	$1.44	2.1	2.1	0%	100%
5	Restaurant - CTWH ≥200 kBtu/h	20	0.00	0.15	$1.43	$0.00	$1.43	1.5	1.5	0%	100%
6	Multifamily - CTWH ≥200 kBtu/h	20	0.00	0.42	$1.43	$0.00	$1.43	4.2	4.2	0%	100%
7	Commercial Gym - CTWH ≥200 kBtu/h	20	0.00	0.31	$1.42	$0.00	$1.42	3.2	3.2	0%	100%
8	Coin-op Laundry - CTWH ≥200 kBtu/h	20	0.00	0.67	$1.43	$0.00	$1.43	6.8	6.8	0%	100%
9	All Commercial - CTWH ≥200 kBtu/h	20	0.00	0.28	$1.43	$0.00	$1.43	2.8	2.8	0%	100%

Table 2 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	0.44	$1.42	$0.00	$1.42	5.7	5.7	0%	100%
2	School - CTHW ≥200 kBtu/h	20	0.28	$1.42	$0.00	$1.42	3.6	3.6	0%	100%
3	Healthcare - CTWH ≥200 kBtu/h	20	0.14	$1.42	$0.00	$1.42	1.8	1.8	0%	100%
4	Hotel - CTWH ≥200 kBtu/h	20	0.21	$1.44	$0.00	$1.44	2.7	2.7	0%	100%
5	Restaurant - CTWH ≥200 kBtu/h	20	0.15	$1.43	$0.00	$1.43	1.9	1.9	0%	100%
6	Multifamily - CTWH ≥200 kBtu/h	20	0.42	$1.43	$0.00	$1.43	5.4	5.4	0%	100%
7	Commercial Gym - CTWH ≥200 kBtu/h	20	0.31	$1.42	$0.00	$1.42	4.0	4.0	0%	100%
8	Coin-op Laundry - CTWH ≥200 kBtu/h	20	0.67	$1.43	$0.00	$1.43	8.6	8.6	0%	100%
9	All Commercial - CTWH ≥200 kBtu/h	20	0.28	$1.43	$0.00	$1.43	3.6	3.6	0%	100%

Requirements
- Condensing, tankless water heater and supply boiler units must serve a central service water heating system.
  - Installed equipment must not provide building space heating.
- Integral tank volume must be <10 gallons.
- CTWHs must have a thermal efficiency rating of 94.0% or greater.
- CTWHs capacities must be 200 kBtu/h or greater.
- Installed equipment must be on the AHRI certified products list.

Existing Condition Requirements

The measures in Table 1 and Table 2 are intended as replacement at/near burn out or new. There are no existing fuel requirements.

Measure Selection

- Programs may choose the All Commercial measure application, which is a weighted average of savings and costs **or** the building-specific measures.
- Programs may not use the All Commercial measure 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 tankless water heaters. It is assumed that these customers would not be considering new storage tank water heaters. The full market baseline is based on an analysis of tankless water heater product lists and efficiencies from the AHRI database.

The AHRI database was used to determine the share and average thermal efficiencies for non-condensing and condensing tankless water heaters with capacities of 200 kBtu/h or greater. The average efficiency was weighted by database share and used for the baseline energy consumption calculations. Table 4 summarizes the AHRI product counts, average efficiencies, and the weighted average baseline thermal efficiency.

Table 4: AHRI Product Counts, Average Efficiencies, and Full Market Baseline Efficiency

Type	Count	Share	Average Thermal Efficiency	Baseline Thermal Efficiency
Condensing	107	42%	96%	**88.4%**
Non-Condensing	145	58%	83%	

Measure Analysis

Savings were based on spreadsheet calculations, whose primary inputs are annual hot water demand, peak hot water demand (to establish total TWH capacity), and water temperature rise. The main input sources are from the Department of Energy's (DOE) Technical Support Document (TSD): Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment.[1] The site-level assumptions for calculating annual hot water and CTWH capacity requirements are based on the DOE's prototype building characterizations.

Hot Water Demand – WHAM Energy Consumption Equation

The DOE's Water Heater Analysis Model[2] (WHAM) for tankless water heaters was used to calculate the total water heater input energy. The equation uses the estimated total annual hot water demand in gallons, estimated temperature rise, the specific heat capacity of water, the average density of water, the thermal efficiency, and an adjustment factor to account for actual observed performance.

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

Where:

Q_{in}	=	total water heater energy consumption, Btu
vol	=	annual water use, gal
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, %
PAi_{wh}	=	performance adjustment factor

The total heat input required by the water heaters is converted to therms. The total savings are the difference between the baseline and proposed measure case total input therms.

$$\text{Annual Savings}_{\text{therms}} = Q_{\text{in Baseline}} - Q_{\text{in Measure}}$$

Annual Hot Water Demand

The annual hot water demand for most building types was determined using the daily hot water load schedules and normalized peak demand listed in Appendix 7B of the US DOE's TSD prototype buildings. The product of the normalized peak and hourly ratios yielded the hourly demand in a 24-hour period. The daily demands were multiplied by 365.25 days to determine the annual hot water consumptions.

[1] https://downloads.regulations.gov/EERE-2014-BT-STD-0042-0016/attachment_1.pdf
[2] https://downloads.regulations.gov/EERE-2006-STD-0129-0149/attachment_1.pdf

The gym annual hot water demand was similarly determined using daily hot water schedules and normalized peak demands, but the information was sourced from Table 11 of the DOE's U.S. Commercial Reference Building Models of the National Building Stock[3] report.

Because the DOE's TSD does not cover coin-op laundries, annual hot water demand was estimated based on typical number of machines per laundromat, loads per day per machine, and gallons of hot water per load.[4,5,6,7] Table 5 summarizes the daily and annual hot water demands for all building sub-sectors.

Table 5: Daily and Annual Hot Water Demand

Building sub-sector	Daily DHW [gal]	Annual DHW [gal]
Large Office	1,640	599,187
Primary School	627	228,986
Secondary School	2,580	942,467
Outpatient Healthcare	346	126,391
Hospital	3,276	1,196,544
Small Hotel	2,342	855,512
Large Hotel	4,460	1,629,104
Full-Service Restaurant	1,592	581,622
High-Rise Apartment	3,458	1,263,215
Commercial Gym	1,100	401,816
Coin-op Laundry	3,892	1,421,418

Peak Hot Water Demand – Total Tankless Water Heater Capacity Requirements

The annual savings were normalized per input capacity, which required calculating the tankless water heater capacity necessary to meet the peak hot water demand. Rather than estimating the peak flow demand, the tank-type hot water heater storage and heating capacities listed in Table 2.2 of the DOE's Enhancement to ASHRAE 90.1 Prototype Buildings Models[8] were converted to tankless capacity using the methodology in section 7.7 of the DOE's TDS. The method established the equivalent total tankless water heater capacity required to meet the peak hot water demand.

$$\mathrm{Q_{tankless}} = \left(\mathrm{Q_{tank}} + \mathrm{dT} * \mathrm{C_p} * \mathrm{y} * \mathrm{Vol} * \mathrm{Tank_u}/t_{load}\right) * \mathrm{Adj_{tankelss}}$$

Where:

- $Q_{tankless}$ = adjusted tankless capacity, Btu/h
- Q_{tank} = tank water heater capacity, Btu/h
- dT = temperature rise, °F
- C_p = specific heat of water, 1.000743 Btu/lb·°F
- y = specific weight of water, 8.29 lb/gal
- Vol = tank volume, gallons
- $Tank_u$ = fraction of hot water in the tank that is usable
- $Adj_{tankless}$ = tankless adjustment factor
- t_{load} = maximum load duration, hr

The DOE's sources do not cover water heater capacities for the coin-op and gym sub-sector. The total required tankless water heater capacities were determined using estimates of hot water fixtures and the equivalent fixture units, which were used with the modified Hunter curve to estimate peak hot water demand. The peak hot water demand was used to calculate the total CTWH capacities based on the measure case thermal efficiency.

Temperature Rise Input Assumptions

The inlet water temperature was determined by using the Regional Technical Forum's (RTF) Standard Information Workbook's (SIW)[9] ground water temperatures by heating zone. The temperatures were averaged, weighted by their share of project uptake using Project Tracker (PT) data. The water heater outlet temperature is assumed to be 140°F, which is adopted from the RTF's commercial heat-pump water heater measure.[10]

The average inlet temperature and zone weightings by project uptake between 2016 and 2021 are listed in Table 6.

Table 6: Heating Zone Weighted Average Inlet Temperature

Heating Zone	Projects by Zone	Temperature by Zone [°F]	Weighted Average Temperature [°F]
1	89%	55.3	**55.0**
2	11%	51.7	
3	0%	49.1	

Building Sub-Sector Weighting

Savings for the schools, healthcare, and hotel market segments were weighted by sub-sectors, which are summarized in Table 7.

Oregon Department of Education data[11] was used to determine the share of primary versus secondary schools and estimate the weightage for the school market segment. Healthcare sub-sector weightage was found using CBSA-4 2019[12] data to determine counts of outpatient vs hospitals. The hotel sub-sector weightage was found using statistics from the 1992 Census of Service Industries: Subject Series, Hotels, Motels, and other Lodging Places.[13]

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[3] http://www.nrel.gov/docs/fy11osti/46861.pdf
[4] Washer capacity values: http://toolbox.calwep.org/wiki/Clothes_Washers_-_Coin-Operated
[5] Water factors: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=08fdbac2df2f7ef118bf97844a8f7453&r=PART&n=10y3.0.1.4.19#se10.3.431_1156
[6] Usage per washer: https://downloads.regulations.gov/EERE-2012-BT-STD-0020-0036/attachment_8.pdf
[7] Wash per cycle: https://www.allianceforwaterefficiency.org/sites/www.allianceforwaterefficiency.org/files/assets/ws-commercial-water-sense-at-work-ci.pdf
[8] https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-23269.pdf
[9] https://nwcouncil.box.com/v/RTFSIW--v4-5
[10] https://nwcouncil.box.com/v/ComHPWH-v3-0
[11] Oregon Department of Education (https://www.oregon.gov/ode/reports-and-data/students/Pages/Student-Enrollment-Reports.aspx)
[12] https://neea.org/resources/cbsa-4-data-files
[13] https://www.census.gov/library/publications/1996/econ/sc92-s-3.html

Table 7: Sub-Sector Weight Per Market Segment

Market Segment	Sub-sector	Weighting
Schools	Primary School	77%
	Secondary School	23%
Healthcare	Outpatient Health Care	90%
	Hospitals	10%
Hotel	Small Hotel	48%
	Large Hotel	52%

All Commercial Weighting

The all-commercial measure application is the average of all other market segments savings weighted by historical project uptake of this measure. PT data reported 49 commercial projects between 2016 and 2021. Market type counts were aggregated where appropriate – such as k-12 Schools and College/University – into market segment weights, which are summarized in Table 8.

Table 8: Market Segment Weights for All-Commercial Measure Applications Savings

Type	Project Count	Weight %
Large Office (Office)	2	6.7%
Schools (K-12 School, College/University)	8	26.7%
Healthcare	2	6.7%
Hotel (Lodging/Hotel/Motel)	8	26.7%
Restaurant (Food service)	5	16.7%
Gym	2	6.7%
Coin-op Laundry	3	10.0%

Savings

Table 9 summarizes savings per kBtu/h and the following characteristics: CTWH input capacity, annual hot water demand, baseline and measure case energy uses, and total annual savings. The annual savings are based on the DOE's prototypical buildings characterized in the TSD.

The annual hot water consumption for primary schools, secondary schools, hospitals, and large hotels includes the dishwashing water demand, which is assumed to be a load on the main water heating system. The hospital, small hotel and large hotel sub-sectors further include laundry demands in the total annual hot water consumption. The total annual savings in therms were divided by the total CTWH capacities to establish savings per input kBtu/h.

Table 9: Summary of Energy Use and Savings by Subsector and Market Segment

Building Sub-Sector	CTHW input Capacity [kBtu/h]	Hot Water Demand [gal/yr]	Baseline Energy Use [kBtu/yr]	Measure Energy Use [kBtu/yr]	Annual Savings [kBtu]	Total Annual Savings [therm]	Sub-Sector Savings [therm/ kBtuh]	Sub-Sector Weight	Measure Savings [therm/ kBtuh]
Large Office	708	599,187	524,492	493,162	31,330	313	0.44	100%	0.44
Primary School	472	228,986	200,440	188,467	11,973	120	0.25	77%	0.28
Secondary School	1,416	942,467	824,978	775,698	49,280	493	0.35	23%	
Outpatient Healthcare	472	126,391	110,635	104,026	6,609	66	0.14	90%	0.14
Hospital	4,692	1,196,544	1,047,382	984,817	62,565	626	0.13	10%	
Small Hotel	2,176	855,512	748,863	704,130	44,733	447	0.21	48%	0.21
Large Hotel	3,917	1,629,104	1,426,019	1,340,836	85,183	852	0.22	52%	
Full Service Restaurant	2,085	581,622	509,117	478,705	30,412	304	0.15	100%	0.15
High-Rise Apartment	1,572	1,263,215	1,105,742	1,039,690	66,051	661	0.42	100%	0.42
Commercial Gym	676	401,816	351,725	330,715	21,010	210	0.31	100%	0.31
Coin-op Laundry	1,111	1,421,418	1,244,223	1,169,900	74,324	743	0.67	100%	0.67
All Commercial - CTWH ≥200 kBtu/h									0.28

Comparison to RTF or other programs

The RTF has a residential gas water heater workbook[14], which includes storage tank and tankless water heater savings. The workbook uses the WHAM methodology to calculate tankless water heater energy consumption, which is also used by this measure's analysis. However, annual hot water demand is determined using SEEM runs, which differs from this analysis' use of the DOE's TSD water use schedules and normalized peak hot water demand.

Energy Trust also *Commercial Condensing Tankless Water Heaters <200 kBtu/h*, and *Multifamily Condensing Tankless Water Heaters <200 kBtu/h*, via MADs 212 and 196 which assumes the typical CTWH size is 199 kBtu/h. While the measures overlap some of the same market segments those measures is intended to cover smaller projects requiring lower installed CTWH capacities.

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

- Electric: None – ele
- Gas: DHW

Cost

Equipment costs

Online retail costs for CTWHs ≥200 kBtu/h were used to determine the average cost per burner capacity. The water heaters were categorized into different efficiency tiers as follows:

- Non-condensing (≤86% TE)

[14] https://rtf.nwcouncil.org/measure/residential-gas-water-heaters-0/

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

Each TWH was allocated under one of the above categories and its costs was normalized per kBtu/h. The costs for the non-condensing units and the average of all condensing units were used to establish the full market baseline costs. The costs for high efficiency condensing units were used for the proposed measure case costs.

Labor and Ancillary Costs

Labor and ancillary material costs leveraged estimates from the California Codes and Standards Enhancement (CASE) report for high efficiency water heaters.[15] Because the report is dated from 2013, the costs were adjusted to 2023 dollars using the RTF's Standard Information Workbook inflation factors.[16]

The labor and ancillary estimates are specific to the TWH type, which for non-condensing water heaters include costs of steel venting materials required for the higher temperature exhaust. For condensing water heaters, the costs include PVC venting materials, condensate drain connection, condensate neutralizer, and condensate pump.

Table 10 summarizes the baseline, measure, and incremental costs by market segment. Baseline costs were weighted by share of condensing and non-condensing TWH weights summarized in Table 4.

Table 10: Baseline, Measure, and Incremental Costs

Building Type	Baseline Cost [$/kBtuh]	Measure Cost [$/kBtuh]	Incremental Cost [$/kBtuh]
Large Office - CTWH ≥200 kBtu/h	$19.57	$20.99	$1.42
School - CTHW ≥200 kBtu/h	$19.60	$21.01	$1.42
Healthcare - CTWH ≥200 kBtu/h	$19.42	$20.84	$1.42
Hotel - CTWH ≥200 kBtu/h	$18.99	$20.43	$1.44
Restaurant - CTWH ≥200 kBtu/h	$19.07	$20.51	$1.43
Multifamily - CTWH ≥200 kBtu/h	$19.16	$20.59	$1.43
Commercial Gym - CTWH ≥200 kBtu/h	$19.61	$21.03	$1.42
Coin-op Laundry - CTWH ≥200 kBtu/h	$19.30	$20.72	$1.43
All Commercial - CTWH ≥200 kBtu/h	-	-	$1.43

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 of input capacity.

Follow-Up

- The market baseline should be reevaluated at the next update to comprehend the share of condensing vs non-condensing THW sales.
- Annual hot water demand should be reevaluated using the latest DOE's prototype building model hot water load schedule if available and consideration what building types this technology and equipment size is suited to.
- Costs should be updated with current pricing or actual project costs. The 2013 CASE source in particular is becoming dated.

Supporting Documents

The cost-effective screening for these measures is number 72.4.3. 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

72.4.3OR-WA-CE Calculator_2023_v_1

Version History and Related Measures

Energy Trust has been offering tankless water heater measure for many years. These predate our measure approval documentation process and record retention requirements. Table 12 Related Measures may be incomplete, particularly for measures approved prior to 2013.

Table 11 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%
9/19/2022	72.4	Savings were updated using alternate annual hot water demand data and calculation methodology. Cost per input kBtu/h were updated due to CTWH capacity adjustments.

Table 12 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

[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
[16] https://nwcouncil.box.com/v/RTF-SIW-v4-6

Approved & Reviewed by

Jackie Goss, PE
Sr. Engineer – Planning & Evaluation

Disclaimer

Measure Approval Document for Ozone Laundry Systems

Valid Dates
1/1/2024 – 12/31/2026

End Use or Description
Ozone laundry systems generate ozone gas (O_3), which is a powerful oxidant, is introduced in the washer and it dissolves readily in cold water. The ozone and dissolved hydroxyl ions open fibers, remove stains/soils, and remove odors with using less hot water or without using any hot water, and less detergent/fabric softener, and chemical use. This technology has also demonstrated that less water is required to wash clothes.

An ozone generator creates ozone gas from ambient air using either high-voltage corona discharge or ultraviolet light. This ozone gas is injected into the washer's cold water supply where it readily dissolves. Ozone gas dissolved in cold water also generates hydroxyl ions (OH-). Both ozone and hydroxyl ions are powerful oxidizing agents which open fibers, remove stains and remove odors without using hot water. The ozone gas and hydroxyl ions then combine back into oxygen molecules within a few minutes and are released into the ambient air. There are no other byproducts other than oxygen.

Energy savings are realized at the water heater/boiler using less fuel due to reduced hot water usage since ozone dissolves in cold water.

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 market segments is expected:
- Lodging and hospitality facilities including hotels, motels, resorts, spas
- Gym/fitness centers
- Healthcare facilities including hospitals and clinics
- Nursing homes, assisted living
- Correctional facilities
- Laundry services

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

Purpose of Re-Evaluating Measure
All new analysis of a previously discontinued measure.

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 2024-v1.2. In Oregon the electric avoided cost year is 2024 and the gas avoided cost year is 2024. In Washington the gas avoided cost year is 2024. The values in these tables are per project.

Table 1 Cost Effectiveness Calculator Oregon, per unit, binned by total laundry capacity connected to installed ozone generator system(s)

#	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	Ozone Laundry System - less than 75 lbs laundry capacity - Gas WH- Dual Fuel	10	513.18	2,232.29	$10,092.68	$2,748.06	$10,092.68	2.3	4.5	1%	99%
2	Ozone Laundry System - 75 to 125 lbs laundry capacity - Gas WH- Dual Fuel	10	1,026.35	4,464.57	$13,479.48	$5,496.12	$13,479.48	3.5	6.7	1%	99%
3	Ozone Laundry System - 126 to 400 lbs laundry capacity - Gas WH- Dual Fuel	10	2,694.18	11,719.50	$25,433.87	$14,427.32	$25,433.87	4.9	9.4	1%	99%
4	Ozone Laundry System - 401 to 600 lbs laundry capacity - Gas WH- Dual Fuel	10	5,131.77	22,322.85	$39,816.22	$27,480.60	$39,816.22	5.9	11.4	1%	99%
5	Ozone Laundry System - more than 600 lbs laundry capacity - Gas WH- Dual Fuel	10	7,184.48	31,251.99	47,957.66	$38,472.84	$47,957.66	6.9	13.2	1%	99%
7	Ozone Laundry System - less than 75 lbs laundry capacity - Gas WH- Gas Only Territory	10	0.00	2,232.29	$10,092.68	$2,851.71	$10,092.68	2.3	4.5	0%	100%
8	Ozone Laundry System - 75 to 125 lbs laundry capacity - Gas WH- Gas Only Territory	10	0.00	4,464.57	$13,479.48	$5,703.43	$13,479.48	3.5	6.8	0%	100%
9	Ozone Laundry System - 126 to 400 lbs laundry capacity - Gas WH- Gas Only Territory	10	0.00	11,719.50	$25,433.87	$14,971.50	$25,433.87	4.8	9.5	0%	100%
10	Ozone Laundry System - 401 to 600 lbs laundry capacity - Gas WH- Gas Only Territory	10	0.00	22,322.85	$39,816.22	$28,517.15	$39,816.22	5.9	11.5	0%	100%
11	Ozone Laundry System - more than 600 lbs laundry capacity - Gas WH- Gas Only Territory	10	0.00	31,251.99	$47,957.66	$39,924.01	$47,957.66	6.8	13.4	0%	100%
13	Ozone Laundry System - less than 75 lbs laundry capacity - Gas WH- non-qualified gas rate	10	513.18	0.00	$10,092.68	$5,380.80	$320.47	1.0	4.3	100%	0%
14	Ozone Laundry System - 75 to 125 lbs laundry capacity - Gas WH- non-qualified gas rate	10	1,026.35	0.00	$13,479.48	$10,761.61	$640.94	1.0	6.4	100%	0%
15	Ozone Laundry System - 126 to 400 lbs laundry capacity - Gas WH- non-qualified gas rate	10	2,694.18	0.00	$25,433.87	$28,249.22	$1,682.47	1.0	8.9	100%	0%
16	Ozone Laundry System - 401 to 600 lbs laundry capacity - Gas WH- non-qualified gas rate	10	5,131.77	0.00	$39,816.22	$53,808.04	$3,204.70	1.0	10.8	100%	0%
17	Ozone Laundry System - more than 600 lbs laundry capacity - Gas WH- non-qualified gas rate	10	7,184.48	0.00	47,957.66	$75,331.26	$4,486.58	1.0	12.5	100%	0%
19	Ozone Laundry System - less than 75 lbs laundry capacity - Elec. WH	10	51,803.91	0.00	$10,092.68	$2,748.06	$10,092.68	3.2	5.4	100%	0%
20	Ozone Laundry System - 75 to 125 lbs laundry capacity - Elec. WH	10	103,607.82	0.00	$13,479.48	$5,496.12	$13,479.48	4.8	8.0	100%	0%
21	Ozone Laundry System - 126 to 400 lbs laundry capacity - Elec. WH	10	271,970.52	0.00	$25,433.87	$14,427.32	$25,433.87	6.7	11.2	100%	0%
22	Ozone Laundry System - 401 to 600 lbs laundry capacity - Elec. WH	10	518,039.09	0.00	$39,816.22	$27,480.60	$39,816.22	8.1	13.6	100%	0%
23	Ozone Laundry System - more than 600 lbs laundry capacity - Elec. WHy	10	725,254.73	0.00	47,957.66	$38,472.84	$47,957.66	9.4	15.8	100%	0%

Table 2 Cost Effectiveness Calculator Washington, per unit, binned by total laundry capacity connected to installed ozone generator system(s)

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Ozone Laundry System - less than 75 lbs laundry capacity - Gas WH	10	2,232.29	$10,092.68	$1,719.13	$10,092.68	2.3	3.8	0%	100%
2	Ozone Laundry System - 75 to 125 lbs laundry capacity - Gas WH	10	4,464.57	$13,479.48	$3,438.26	$13,479.48	3.5	5.6	0%	100%
3	Ozone Laundry System - 126 to 400 lbs laundry capacity	10	11,719.50	$25,433.87	$9,025.44	$25,433.87	4.9	7.8	0%	100%
4	Ozone Laundry System - 401 to 600 lbs laundry capacity	10	22,322.85	$39,816.22	$17,191.32	$39,816.22	5.9	9.5	0%	100%
5	Ozone Laundry System - more than 600 lbs laundry capacity	10	31,251.99	$47,957.66	$24,067.85	$47,957.66	6.9	11.1	0%	100%

Requirements

- The ozone laundry system(s) must be a newly purchased product and installed on new or existing commercial washing machine(s).
- Each ozone generator may serve one or more washers.
- All existing/new washers at a facility must be reprogrammed and connected to work with the new ozone laundry system. Partial conversions are not eligible.
- Water heating for clothes washing must be from natural gas-fired or electric water heaters or boilers.
- The ozone laundry system(s) must transfer ozone into the water with either the venturi injection or bubble diffusion process.
- Multifamily laundromats are not eligible.

Implementation

- Sites with electric water heating must be served by PGE or Pacific Corp. These project use measures 19-23 in Table 1.
- Sites with gas heat in dual fuel territory use measures 1-5 in Table 1.
- Sites with gas heat in gas-only territory in Oregon use measures 7-11 in Table 1 and in Washington use the measures in Table 2.
- Sites with gas heat on non-qualifying gas rate must have electric service from PGE or Pacific Corp. These use measures 13-17 in Table 1.
    - Note the maximum incentives for this configuration are significantly lower than the others and may not be high enough to credibly support Energy Trust's claims of influence on customer decisions.
- Measures are binned by total connected washer capacity for the whole project.

Baseline

This measure uses an Existing Condition Baseline.

The baseline equipment is a conventional commercial clothes washer system(s) without an ozone generator, which uses hot water from a natural gas-fired or electric resistance-based water heater/boiler.

Savings Analysis

The majority of this analysis is based on PG&E's2017 Ozone Laundry Workpaper[1] which contains field data from based on 15 projects at hotels, jails, and nursing facilities that participated in PG&E's Nonresidential-Demand Response (NRR-DR) program.

Energy savings are realized from reduced hot water usage since ozone works with cold water. Electric savings are also produced as embedded electric savings from reduced water usage.

Reduced hot water usage

$$Annual\ savings\ =\ Annual\ baseline\ usage\ -\ Annual\ measure\ case\ usage$$

$$Annual\ baseline\ usage\ =\ Water\ Heating\ Energy\ x\ \frac{laundry\ washed}{year}\ x\ hot\ water\ use\ factor$$

$$Annual\ Measure\ case\ usage\ =\ Annual\ baseline\ usage\ x\ (1 - hot\ water\ reduction\ factor)$$

$$Water\ Heating\ Energy\ =Density\ of\ water\left(\frac{lb}{gal}\right) \times Change\ in\ Enthalpy\ \left(\frac{Btu}{lb\ of\ water}\right) \times \frac{1}{Boiler\ Efficiency}$$

Where:

- Density of water = 8.34 lb per gallon of water
- City supply water temperature = 55.1oF2
- Hot water temperature = 140oF3
- Enthalpy of city supply water (55.1oF) = 23.16 Btu/lb water
- Enthalpy of hot water for washing machine (140 oF) = 108.00 Btu/lb water
- Change in Enthalpy = 108.00 – 23.16 = 84.85 Btu/lb water
- Water Heater/Boiler Efficiency = 80%

The calculated water heating energy is 884.51 Btu per gallon of water or 0.00885 therms per gallon of water for gas water heaters. In electric resistance-based water heater/boiler, the gas savings estimate converted to kWh. It was assumed that the electric resistance-based water heater or boiler is 98% efficient and using the conversion factor of 1 kWh = 3412.14 Btu.

Laundry washed per year estimate is based on 13 projects in PG&E's workpaper. Table 3 shows the 13 projects and their details. The median annual quantity is 4,380 lbs. of laundry washed per lb. of laundry capacity assuming all loads are full loads.

Table 3 Estimated Laundry Washed per Year

NRR-DR Project Number	Washer Capacity	Washer Use Rate			Washer Utilization Factor
Units:	[lbs/Cycle]	[Cycles/day]	[Cycles/year]	[lbs/year]	[lbs/lbs-capacity]
Source:	DATA	DATA	Calculation	Calculation	Calculation
Project #3	170	7	2,373	403,325	2,373
Project #4	325	12	4,380	1,423,500	4,380
Project #5	115	11	4,015	461,725	4,015
Project #6	100	8	2,920	292,000	2,920
Project #7	625	8	2,920	1,825,000	2,920
Project #8	280	21	7,665	2,146,200	7,665
Project #9	180	30	10,950	1,971,000	10,950
Project #10	1040	8	2,920	3,036,800	2,920
Project #11	190	13	4,745	901,550	4,745
Project #12	220	13	4,745	1,043,900	4,745
Project #13	200	9	3,103	620,500	3,103
Project #14	305	35	12775	3896375	12775
Project #15	250	17	6,205	1,551,250	6,205
Project #1	190	No Washer Use Data Available			N/A
Project #2	147	No Washer Use Data Available			N/A

Median:	4,380

[1] Pacific Gas & Electric (PG&E) Company, 2017, Work Paper PGECOAPP123 Revision #6, Ozone Laundry Nonresidential
[2] RTF's Standard Information Workbook (SIW) v4.8, https://nwcouncil.app.box.com/v/RTF-SIW-v4-8
[3] RTF's Heat Pump Water Heater UES Measure, https://rtf.nwcouncil.org/measure/commercial-unitary-heat-pump-water-heaters/

Hot water use factor represents how efficiently a typical conventional washing machine utilized hot water per unit of clothes washed. It is estimated based on 10 projects listed in PG&E's Ozone Laundry workpaper. Table 4 shows the 10 projects. The average volume of hot water used per lb. of laundry washed is 1.34 gallons.

Table 4 Hot Water Usage

NRR-DR Project Number	Washer Use Rate	Annual Hot Water	Hot Water Use Factor
Units:	[lbs/year]	[Gal/year]	[Gal/lb]
Source:	Table 3	DATA	Calculated
Project #3	403,325	723,138	1.79
Project #4	1,423,500	1,482,816	1.04
Project #5	461,725	88,878	0.19
Project #6	292,000	513,920	1.76
Project #7	1,825,000	2,539,670	1.39
Project #8	2,146,200	2,090,246	0.97
Project #9	1,971,000	2,837,145	1.44
Project #10	3,036,800	4,010,182	1.32
Project #11	901,550	1,894,350	2.10
Project #12	1,043,900	1,414,011	1.35
Project #1	N/A	1,456,387	N/A
Project #2	N/A	469,025	N/A
Project #13	620,500	No Water Data Available	
Project #14	3,896,375	No Water Data Available	
Project #15	1,551,250	No Water Data Available	

Mean	1.34

Hot Water Reduction Factor represents how less hot water a washing machine connected to an ozone generator system uses when compared to a conventional washing machine without an ozone generator system. It is estimated based on 12 projects listed in PG&E's Ozone Laundry workpaper. Table 5 shows the 12 projects. The average reduction in hot water usage is 86%.

Table 5 Estimated Hot Water Reduction

NRR-DR Project Number	Annual Hot Water (Base Case)	Annual Hot Water (Ozone)	Hot Water Savings	% Reduction
Units:	[Gal]	[Gal]	[Gal]	[%]
Source:	DATA	DATA	Calculated	Calculated
Project #1	**1,456,387**	**127,020**	1,329,367	91%
Project #2	**469,025**	**39,563**	429,462	92%
Project #3	**723,138**	**-**	723,138	100%
Project #4	**1,482,816**	**-**	1,482,816	100%
Project #5	**88,878**	**69,259**	19,619	22%
Project #6	**513,920**	**90,520**	423,400	82%
Project #7	**2,539,670**	**317,915**	2,221,755	87%
Project #8	**2,090,246**	**-**	2,090,246	100%
Project #9	**2,837,145**	**1,248,300**	1,588,845	56%
Project #10	**4,010,182**	**-**	4,010,182	100%
Project #11	**1,894,350**	**-**	1,894,350	100%
Project #12	**1,414,011**	**-**	1,414,011	100%
Project #13	No Water Data Available			N/A
Project #14	No Water Data Available			N/A
Project #15	No Water Data Available			N/A

Mean:	86%

Reduced water consumption

$$Total\ water\ savings\ (gal) = \ water\ usefactor\ x\ lbs.laundry\ x\ water\ savings\ factor\ .$$

Water Usage Factor is a measure of how much water a machine uses in base case. The water savings factor is the reduction in water use resulted in measure case. These are estimated based on 8 projects listed in PG&E's Ozone Laundry workpaper. Table 6 shows the 8 projects. The average water usage factor is 2.10 gal./lb. and reduction in hot water usage is 30%.

Table 6 Estimated Water Usage

NRR-DR Project Number	Washer Use Rate	Annual Water (Base Case)	Annual Water (Ozone)	Annual Water Savings	% Reduction	Water Usage Factor
Units:	[lbs/year]	[Gal]	[Gal]	[Gal]	[%]	[Gal/lb]
Source:	Table 3	DATA	DATA	Calculated	Calculated	Calculated
Project #3	403,325	979,368	680,433	298,935	31%	2.43
Project #4	1,423,500	2,844,328	1,650,720	1,193,608	42%	2.00
Project #5	461,725	387,265	343,100	44,165	11%	0.84
Project #6	292,000	770,880	513,920	256,960	33%	2.64
Project #7	1,825,000	3,295,950	2,746,260	549,690	17%	1.81
Project #8	2,146,200	4,332,258	3,200,904	1,131,354	26%	2.02
Project #9	1,971,000	4,866,180	3,602,550	1,263,630	26%	2.47
Project #10	3,036,800	7,849,544	5,202,856	2,646,688	34%	2.58
Project #1	N/A	2,515,945	1,628,156	887,790	35%	N/A
Project #2	N/A	998,072	513,868	484,204	49%	N/A
Project #11	901,550	No Cold Water Data Available			N/A	N/A
Project #12	1,043,900	No Cold Water Data Available			N/A	N/A
Project #13	620,500	No Water Data Available			N/A	N/A
Project #14	3,896,375	No Water Data Available			N/A	N/A
Project #15	1,551,250	No Water Data Available			N/A	N/A
				Mean:	30%	2.10

In electric territory, energy trust claims savings for embedded energy in the water treatment system.

$$Embedded\ electric\ savings\ =\ Embedded\ energy\ rate\ (kWh/1000\ gal)\ x\ Total\ water\ savings\ (gal)$$

Summary of Energy Savings, NEBs, and Installed System Costs

The resulting annual savings per lb washer capacity are:

Table 7 Saving per Installed Laundry Capacity lbs.

Water Heating Fuel	Total Annual Gas Savings (therms)	Annual Site Electric Savings (kwh)	Annual Embedded Electric Savings (kwh)	Total Annual Electric Savings (kwh)	Water Savings (gallons)
Gas	44.65	0	10.26	10.26	2789
Electric	0	1025.81	10.26	1036.08	2789

Table 8 provides a summary of energy and water savings by water heating fuel, utility territory, and installed washer capacity range.

Table 8 Summary of Energy Savings, NEBs and Installed System Costs

Laundry System Water Heating Fuel, Utility Territory, and Total Installed Laundry Capacity Range	Total annual Therm savings	Total annual kWh savings	Annual Water savings (gallons)
Gas WH- Dual Fuel Territory - less than 75 lbs. laundry capacity	2,232.29	513.18	139,450
Gas WH- Dual Fuel Territory - 75 to 125 lbs. laundry capacity	4,464.57	1,026.35	278,900
Gas WH- Dual Fuel Territory - 126 to 400 lbs. laundry capacity	11,719.50	2,694.18	732,114
Gas WH- Dual Fuel Territory - 401 to 600 lbs. laundry capacity	22,322.85	5,131.77	1,394,502
Gas WH- Dual Fuel Territory - more than 600 lbs. laundry capacity	31,251.99	7,184.48	1,952,303
Gas WH- Gas Only Territory - less than 75 lbs. laundry capacity	2,232.29	0.00	139,450
Gas WH- Gas Only Territory - 75 to 125 lbs. laundry capacity	4,464.57	0.00	278,900
Gas WH- Gas Only Territory - 126 to 400 lbs. laundry capacity	11,719.50	0.00	732,114
Gas WH- Gas Only Territory - 401 to 600 lbs. laundry capacity	22,322.85	0.00	1,394,502
Gas WH- Gas Only Territory - more than 600 lbs. laundry capacity	31,251.99	0.00	1,952,303
Gas WH- Non-qualifying rate - less than 75 lbs. laundry capacity	0.00	513.18	139,450
Gas WH- Non-qualifying rate - 75 to 125 lbs. laundry capacity	0.00	1,026.35	278,900
Gas WH- Non-qualifying rate - 126 to 400 lbs. laundry capacity	0.00	2,694.18	732,114
Gas WH- Non-qualifying rate - 401 to 600 lbs. laundry capacity	0.00	5,131.77	1,394,502
Gas WH- Non-qualifying rate - more than 600 lbs. laundry capacity	0.00	7,184.48	1,952,303
Elec. WH- Dual Fuel and Elec.-only - less than 75 lbs. laundry capacity	0.00	51,803.91	139,450
Elec. WH- Dual Fuel and Elec.-only - 75 to 125 lbs. laundry capacity	0.00	103,607.82	278,900
Elec. WH- Dual Fuel and Elec.-only - 126 to 400 lbs. laundry capacity	0.00	271,970.52	732,114
Elec. WH- Dual Fuel and Elec.-only - 401 to 600 lbs. laundry capacity	0.00	518,039.09	1,394,502
Elec. WH- Dual Fuel and Elec.-only - more than 600 lbs. laundry capacity	0.00	725,254.73	1,952,303

Energy use of the ozone generation system itself are neglected due to uncertainty.

Measure Life

Useful life of an ozone generator system is assumed to be 10 years. This is sourced from the 2023 Illinois TRM v11.0[4] for the same measure and is based on typical lifetime of an ozone generator's corona discharge unit.

Load Profile

- Electric Load Profile- Lodging Hot Water
- Gas Load Profile- Clotheswasher

Cost

Installed costs were sourced from vendors and other efficiency programs.

[4] 2023 Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 11.0, IL-TRM-Version-11.0-Volumes-1-4-Compiled-Final.pdf (ilsag.info)

Total cost estimates for installed ozone generator system of different capacities were collected from Nutek International Inc., who is one of the major vendors serving hospitality, healthcare, assisted living, and prisons. The cost estimates vary by capacity of laundry the ozone generator system can serve at a time..**A** A single quote for a 70lb/50lb capacity system was obtained from Omni Solutions.

Installed cost data from Southern California Gas Company's customized energy efficiency program[5] in 2016.

- 10 projects installed in hotel rooms with <250 guest rooms
- 5 projects installed in hotel rooms with >250 guest rooms and
- 7 projects installed in nursing facilities

Table 9 shows the average cost per size bin.

Table 9 Summary of Estimated Total Installed Costs

Laundry Capacity Served	System Installed Cost	Avg. laundry capacity	Cost/lb. average laundry capacity
Ozone Laundry System - less than 75 lbs. laundry capacity	$10,093	50	$201.85
Ozone Laundry System - 75 to 125 lbs. laundry capacity	$13,479	100	$134.79
Ozone Laundry System - 126 to 400 lbs. laundry capacity	$25,434	263	$96.89
Ozone Laundry System - 401 to 600 lbs. laundry capacity	$39,816	500	$79.63
Ozone Laundry System - more than 600 lbs. laundry capacity	$47,958	700	$68.51

Non Energy Benefits

Laundry machines equipped with Ozone laundry systems require less water and thus produce water savings and associated embedded electric savings (from reduced electricity required for water treatment). As noted in the savings methodology section above, water savings are estimated to be 2,789 gallons/lb. laundry capacity. Water bill savings are estimated at $19.71/1000 gallons in most of Oregon. In gas-only territory the embedded energy savings are included, increasing the NEB to $20.16/1000 gallons. In Washington the rate is $12.04/1000 gallons.

For measure applications with gas water heat on non-qualifying gas rates, the natural gas savings is counted as a NEB in addition to the above noted water savings as a NEB.

Additional NEBs from reduced detergent and fabric softener use are expected, but not quantifiable at this time.

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 project, according to the total installed capacity size bin.

Follow-Up

It is recommended that project data on actual laundry capacity connected to installed ozone generator systems(s) is collected and used to validate/update installed cost of the measure.

This analysis ignores the electricity use by the ozone generating system. This should be researched and corrected.

Supporting Documents

The cost effectiveness screening for these measures is number 80.2.1. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Commercial and Industrial\Process Equipment\Laundry\ozone laundry

80.2.1 OR-WA CEC
2024 v1.2 Ozone Lau

Version History and Related Measures

Energy Trust has offered Ozone Laundry measures for many years. These measures predate our measure approval documentation process and exceed our record retention timeframe. Table 10 may be incomplete, especially for measures approve prior to 2013.

Table 10 Version History

Date	Version	Reason for revision
5/20/2010	x	Ozone laundry introduction.
01/05/15	80.1	Discontinue ozone laundry measures in Oregon. Washington measures remained. (This was allowed to expire 12/31/2017)
TBD	80.2	Reintroduce ozone laundry in both Oregon and Washington with all new analysis.

Table 11 Related Measures

Measures	MAD ID
Commercial Clothes Washers	89

Approved & Reviewed by

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[5] Southern California Gas Company (SCG). 2016. "SCG Ozone Project Data.xlsx" https://www.caetrm.com/media/reference-documents/SCG_Ozone_Project_Data.xlsx

Disclaimer

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Measure Approval Document for Commercial and Multifamily Condensing Boilers

Valid Dates
1/1/2023 through 12/31/2025

End Use or Description
Gas-fired commercial and multifamily condensing hot water boilers used in hydronic (HVAC) 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 Buildings
- New Buildings
- Production Efficiency

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

- Multifamily
- Healthcare (outpatient and hospitals)
- Office
- Restaurant
- Retails
- School
- Hotel
- Warehouse

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

- New
- Replacement

Purpose of Re-Evaluating Measure
The boiler baseline efficiencies were updated from code to Full Market, reflecting Energy Trust influence, reducing claimed savings substantially.

Savings were disaggregated by building type.

The per 100 SF measure applications were removed.

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 2023-v1.0. In Oregon the electric avoided cost year is 2023 and the gas avoided cost year is 2023. In Washington the gas avoided cost year is 2023. The values in these tables are per kBtu/h of boiler input capacity.

Table 1 Cost Effectiveness Calculator Oregon, per kBtu/h of Boiler Input Capacity

#	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	Condensing Boiler - Multifamily	25	0.00	1.16	6.64	$0.00	$6.64	4.1	4.1	0%	100%
2	Condensing Boiler - Healthcare	25	0.00	2.67	6.64	$0.00	$6.64	9.4	9.4	0%	100%
3	Condensing Boiler - Office	25	0.00	0.80	6.64	$0.00	$6.64	2.8	2.8	0%	100%
4	Condensing Boiler - Restaurant	25	0.00	1.33	6.64	$0.00	$6.64	4.7	4.7	0%	100%
5	Condensing Boiler - Retail	25	0.00	1.19	6.64	$0.00	$6.64	4.2	4.2	0%	100%
6	Condensing Boiler - School	25	0.00	0.93	6.64	$0.00	$6.64	3.3	3.3	0%	100%
7	Condensing Boiler - Hotel	25	0.00	1.78	6.64	$0.00	$6.64	6.3	6.3	0%	100%
8	Condensing Boiler - Warehouse	25	0.00	1.44	6.64	$0.00	$6.64	5.0	5.0	0%	100%

Table 2 Cost Effectiveness Calculator Washington, per kBtu/h of Boiler Input Capacity

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Condensing Boiler - Multifamily	25	1.16	6.64	$0.00	$6.64	5.6	5.6	0%	100%
2	Condensing Boiler - Healthcare	25	2.67	6.64	$0.00	$6.64	13.8	13.8	0%	100%
3	Condensing Boiler - Office	25	0.80	6.64	$0.00	$6.64	4.1	4.1	0%	100%
4	Condensing Boiler - Restaurant	25	1.33	6.64	$0.00	$6.64	6.9	6.9	0%	100%
5	Condensing Boiler - Retail	25	1.19	6.64	$0.00	$6.64	6.2	6.2	0%	100%
6	Condensing Boiler - School	25	0.93	6.64	$0.00	$6.64	4.8	4.8	0%	100%
7	Condensing Boiler - Hotel	25	1.78	6.64	$0.00	$6.64	9.2	9.2	0%	100%
8	Condensing Boiler - Warehouse	25	1.44	6.64	$0.00	$6.64	7.4	7.4	0%	100%

Requirements

- New/Replacement boiler efficiency shall be 94% or greater (either AFUE or Thermal Efficiency depending on boiler rating)
- New/Replacement boiler shall have a turndown ratio of 5:1 or greater.
- Only boilers for hydronic (HVAC) heating qualify for this measure.
  - Boilers used for domestic hot water (DHW), or pool heating do not qualify for this measure.
  - Boilers (heat adders) serving the water loops in water-source heat pump (WSHP) systems do not qualify for this measure.
- Back-up or redundant boilers do not qualify for this measure.
  - Redundant boilers and back-up boilers are assumed to not operate regularly and therefore do not qualify for this measure.

- For new construction projects, hydronic heating systems must be designed for return water temperatures that allow boilers to operate in condensing mode.
- This measure may not be used in conjunction with the measures approved in MAD 142 – Modulating Boiler Burners.

Mixed use buildings shall be classified by the space type with the greatest square footage covered by the heating water system. The classification shall be used to determine the applicable measure application. For example, for a mixed used building with offices and retails space, if most of the conditioned space is office, the project shall use measure application number 3: Condensing Boiler – Office.

Baseline

This measure uses a Full Market Baseline.

Findings from ETO's Commercial and Industrial Boiler Market Characterization Memo[1] show a high prevalence of above-code (typically condensing) efficient boilers. Therefore, the assumed baseline is a mix of non-condensing (minimally code complaint) and above-code (condensing) efficient boilers. The efficiencies and market shares are based on the RTF's current practice assumptions listed in their Commercial Gas Boiler Standard Protocol (Standard Protocol),[2] which are summarized in Table 3.

Table 3: RTF Current Practice Assumptions

Boiler Capacity	Scenario	Scenario Weight	Rated Efficiency	Burner Type	Control Type
< 300 kBtu/h	Scenario 1: Non-condensing boiler	47%	83 AFUE	Single stage	Balanced, non-condensing
	Scenario 2: Condensing boiler	53%	92 AFUE	Modulating, 5:1 turndown	Balanced, condensing
300 to 2,500 kBtu/h	Scenario 1: Non-condensing boiler	60%	83% thermal efficiency	Single stage	Balanced, non-condensing
	Scenario 2: Condensing boiler	40%	94% thermal efficiency	Modulating, 5:1 turndown	Balanced, condensing

The efficiencies of condensing and non-condensing boilers can't be combined to calculate a baseline energy consumption because each boiler type requires a different calculation methodology. Therefore, the baseline energy consumption is the weighted average of condensing and non-condensing boilers using the scenario weights listed in Table 3 above.

Measure Analysis

The analysis used the RTF's Commercial Gas Boiler Calculator[3] to determine annual energy use for each building subsector. The energy savings are the difference between the baseline and measure case annual energy gas consumptions. The baseline energy use is the weighted average of condensing and non-condensing energy consumption. The following equation is adopted from the RTF's Commercial Gas Boiler Standard Protocol.

$$\text{Savings}_{\text{NewBoiler}} = \text{CPShare}_{\text{NonCondensing}} * \text{Gas}_{\text{NonCondensingCP}} + \text{CPShare}_{\text{Condensing}} * \text{Gas}_{\text{CondensingCP}} - \text{Gas}_{\text{new}}$$

Where:

$\text{Savings}_{\text{NewBoiler}}$	=	annual energy savings, therms
$\text{CPShare}_{\text{NonCondensing}}$	=	current practice share of non-condensing boilers
$\text{Gas}_{\text{NonCondensingCP}}$	=	baseline annual gas consumption non-condensing boilers, therms
$\text{CPShare}_{\text{Condensing}}$	=	current practice share of condensing boilers
$\text{Gas}_{\text{CondensingCP}}$	=	baseline annual gas consumption condensing boilers, therms
Gas_{New}	=	measure annual gas consumption condensing boilers, therms

The calculator uses CBECs average EUIs multiplied by factors that adjust the annual heating load by heating zone, building type, building size category, and vintage. The adjusted EUI is multiplied by a user defined square footage and an RTF assumed annual seasonal efficiency to determine the annual thermal load.

DOE prototype building hourly heating loads are used to determine equivalent full load hours (EFLH) of operation. The EFLHs are used with the annual thermal load discussed above to estimate the peak hourly heating load, which is used to size the boiler for a given building subsector. The calculator's DOE prototype hourly heating loads were updated with model outputs using TMY3 weather files for Corvallis and Redmond for HZ1 and HZ2 respectively.

The calculator uses the hourly heating loads and boiler capacity to determine boiler loading, which is correlated to default efficiency curves used to calculate part-load gas usage. The efficiency curves are dependent on part load ratio, boiler type (condensing vs non-condensing), outside air temperature, return water temperature, and burner type (single stage, modulating, etc.)

Savings

The savings were calculated for all building subsectors for Heating Zones 1 and 2. The subsector savings were averaged, weighted by their sample weights reported in CBSA 4-2019.[4] Table 4 summarizes the measure application building types, building subsectors, and subsector weights.

[1] EnergyTrust_CIGasBoilerMarketResearch-Memo_FINAL.pdf
[2] https://nwcouncil.box.com/v/ComGasBoilersSPv1-2
[3] https://nwcouncil.box.com/v/ComGasBoilersCalcv1-2
[4] https://neea.org/data/commercial-building-stock-assessments

Table 4: Building Types and Subsector Weights

Building Type	Building Sub-Sectors	Weight
Multifamily	Apartment - Mid Rise	1.00
Healthcare	Hospital	0.15
	Outpatient Healthcare	0.85
Office	Office - Large	0.33
	Office - Medium	0.33
	Office - Small	0.33
Restaurant	Restaurant - full service	0.31
	Restaurant - quick service	0.69
Retail	Retail - stand alone	0.61
	Retail - strip mall	0.39
School	School - Primary	0.96
	School - Secondary	0.04
Lodging	Hotel - large	0.50
	Hotel - small	0.50
Warehouse	Warehouse	1.00

The subsector weights were applied to the subsector savings which are summarized in Table 5 and Table 6 for Heating Zone 1 and Heating Zone 2 respectively. The tables also summarize the DOE prototype building square footage, boiler output capacity, baseline energy use, and measure case energy use. Energy savings were normalized by boiler output capacity.

Table 5: Heating Zone 1 Energy Use and Savings by Building Subsector

Building sub-sectors	Building Area [SF]	Total Boiler Capacity [kBtu/h]	Baseline Energy Use [therm]	Measure Energy Use [therm]	Energy Savings [therm]	Energy Savings [therm/kBtuh]
Apartment - Mid Rise	33,744	400	4,497	4,012	484	1.14
Hospital	241,525	3,120	152,457	141,083	11,375	3.43
Outpatient Healthcare	40,950	270	13,031	12,343	688	2.39
Office - Large	498,637	22,950	133,223	113,722	19,501	0.80
Office - Medium	53,600	6,930	13,613	12,071	1,542	0.21
Office - Small	5,503	180	1,859	1,601	258	1.35
Restaurant - full service	5,503	80	1,605	1,480	126	1.48
Restaurant - quick service	2,501	50	740	675	65	1.23
Retail - stand alone	24,695	370	4,587	4,133	454	1.15
Retail - strip mall	22,502	340	4,454	4,021	433	1.20
School - Primary	73,699	1,620	17,564	15,989	1,575	0.91
School - Secondary	210,907	4,470	50,328	45,801	4,528	0.95
Hotel - large	122,132	890	16,438	14,654	1,784	1.88
Hotel - small	43,206	270	5,426	4,959	467	1.63
Warehouse	52,050	460	7,779	7,079	700	1.43

Table 6: Heating Zone 2 Energy Use and Savings by Building Subsector

Building sub-sectors	Building Area [SF]	Total Boiler Capacity [kBtu/h]	Baseline Energy Use [therm]	Measure Energy Use [therm]	Energy Savings [therm]	Energy Savings [therm/kBtuh]
Apartment - Mid Rise	33,744	490	5,493	4,743	750	1.44
Hospital	241,525	5,330	186,185	165,718	20,467	3.61
Outpatient Healthcare	40,950	360	16,329	14,751	1,577	4.12
Office - Large	498,637	25,020	157,814	132,965	24,848	0.93
Office - Medium	53,600	3,560	16,029	13,833	2,196	0.58
Office - Small	5,503	210	1,525	1,362	163	0.73
Restaurant - full service	5,503	100	1,912	1,727	185	1.73
Restaurant - quick service	2,501	60	887	792	95	1.48
Retail - stand alone	24,695	440	5,530	4,858	672	1.44
Retail - strip mall	22,502	410	5,419	4,770	649	1.49
School - Primary	73,699	2,100	21,473	18,982	2,492	1.12
School - Secondary	210,907	4,980	60,021	53,553	6,468	1.22
Hotel - large	122,132	1,120	19,373	16,898	2,475	2.08
Hotel - small	43,206	370	6,835	5,985	850	2.16
Warehouse	52,050	820	9,726	8,417	1,310	1.50

Final savings are based weighted by heating zone, assuming 92% of projects in HZ1 and 8% in HZ2 and HZ3.

Comparison to RTF or other programs

This analysis uses the RTF's Commercial Gas Boiler Protocol Calculator to determine savings for all building types. The embedded weather files are for Seattle, Elko, and Soda Springs for HZ1, HZ2, and HZ3. The measure analysis updated the TMY3 weather files to Station ID 726945 (Corvallis) for HZ1 and station ID 726835 (Redmond) for HZ2/3.

The RTF's calculator uses hourly heating loads based on the DOE's prototype models, which use Seattle WA, Boulder CO, and Helena MT weather files. The measure analysis updated the hourly heating loads using the above refenced Corvallis and Redmond weather files.

Measure Life

The measure life is assumed to be 25 years based on findings from the following sources:

ETO's Commercial and Industrial Boiler Market Characterization Memo

- The memo reports that 72% of the hot water boilers were manufactured in the last 20 years.

ASHRAE Owning and Operating Cost Data: average/median equipment age for hot water boilers[5]

- Filtering for Pacific Region data, the average age at replacement ranged between 18.0 to 25.0 years while the median age ranged between 18.5 to 25.0 years.

RTF Commercial Boiler UES

- The RTF developed a small (<300 kBtu/h) commercial boiler UES based on their boiler standard protocol. The Lifetime Analysis section of the Summary tab reports a 25-year life with a medium level of uncertainty.

Load Profile

The multifamily boiler's gas load profile is Res Heating. All other measures' gas profiles are Com Heating. The electric profile is None for all measures.

Cost

Equipment pricing for boilers <2,500 MBH was sourced from vendor/distributor online pricing, which typically did not report costs for boilers larger than 2,500 MBH. Pricing for this larger class of boilers was sourced from the DOE's Energy Conservation Standards for Commercial Packaged Boilers; Final Rule[6], however, the reported values were adjusted to 2023 dollars using the RTF's Standard Information Workbook's[7] inflation factors. The manufacturer suggested cost was also adjusted to account for contractor and other delivery channel markup using values listed in Table 6.8.4 of the DOE's Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Packaged Boilers.[8]

Incremental cost for each equipment category was weighted by its project uptake share, which is summarized in Table 7. The weighted average incremental cost across all equipment categories is $6.64.

Table 7: Baseline, Measure, and Incremental Costs by Boiler Size

Boiler Size [kBtu/h]	Baseline Cost Non-Condensing [$/MBH]	Baseline Cost Condensing [$/MBH]	Average Baseline Cost [$/MBH]	Measure cost [$/MBH]	Incremental cost [$/MBH]	Percent of Total Projects	Weighted Incremental Cost [$/MBH]
<300	25.02	35.01	30.31	37.22	6.91	13%	0.92
≥300 & ≤2,500	16.94	26.53	20.78	26.53	5.75	71%	4.11
>2,500 & ≤10,000	7.37	18.01	11.63	18.01	6.38	15%	1.61

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 of boiler output capacity.

Follow-Up

At the next update, the Program should consider the following:

- Validate/update full market baseline assumptions based on any newer market characterization memo or RTF current practice assumptions.
- Check the RTF for updates to its boiler standard protocol and calculator or for a Commercial Gas Boiler UES for boilers 300 kBtu/h and larger.
- Consider combining MAD 88 and MAD 142 – Modulating Boiler Burners using the RTF calculator to determine savings for all measure applications.
- Consider developing a new calculator or modifying the RTF's one to directly calculate the annual design peak heating loads using the DOE prototype building models with ETO recommended TMY3 weather files.

Supporting Documents

The cost effectiveness screening for these measures is number 88.3.2. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Commercial and Industrial\Commercial HVAC\boilers\Condensing hot water boiler\Bencost

88.3.2 OR-WA-CE Calculator_2023_v_1

CommercialGasBoilers_ProtocolCalculat

Version History and Related Measures

Energy Trust has been offering boiler measures for many years. These predate our measure approval documentation process and record retention requirements. Table 8 may be incomplete, particularly for measures approved prior to 2013.

[5] http://weblegacy.ashrae.org/publicdatabase/system_service_life.asp?c_region=13&state=NA&building_function=NA&c_size=0&c_age=0&c_height=0&c_class=0&c_location=0&selected_system_type=5&c_equipment_type=NA

[6] https://www.energy.gov/eere/buildings/downloads/issuance-2016-12-28-energy-conservation-program-energy-conservation-1

[7] https://nwcouncil.box.com/v/RTF-SIW-v4-6

[8] https://www.regulations.gov/document?D=EERE-2013-BT-STD-0030-0083

Table 8 Version History

Date	Version	Reason for revision
12/23/2003	88.x	Hot water boilers approved for commercial and multifamily applications.
10/30/2008	88.x	Multifamily boilers removed from MAD 88 due to differing loads.
6/23/2009	88.x	All new savings calculations. Base savings and incentive on boiler capacity. Recombine multifamily and commercial boilers into MAD 88.
6/9/2014	88.x	Add maximum incentives.
2/11/2015	88.x	Add Production Efficiency.
8/26/2015	88.1	Commercial Boilers separated from Multifamily. New commercial analysis based on building modeling and 94% efficiency requirement.
10/06/2015	147.1	Multifamily boilers separated from other commercial boilers. New analysis based on building modeling and 94% efficiency requirement. Measure life increased to 35 years.
4/01/2017	147.2	Add Washington to Multifamily. Clarifies requirements for larger sizes.
6/30/2019	88.2	Recombine multifamily and commercial boilers into a single MAD. MAD 147 will be retired. Separates new and existing buildings into separate measures. Updated baseline for 2019 code update, updated cost. Unitized to sqft.
8/22/2022	88.3	The boiler baseline efficiencies were updated to Full Market. Savings were disaggregated by building type. The per 100 SF measure applications were removed.

Table 9 Related Measures

Measures	MAD ID
Modulating boiler burners and controls	142
Process hot water boiler calculator tool	226
Commercial condensing tankless water heaters	72
Pool Heaters	238

Approved & Reviewed by

Jackie Goss, PE
Sr. Engineer – Planning & Evaluation

Disclaimer

EnergyTrust of Oregon

Measure Approval Document for Commercial Clothes Washers

Valid Dates
January 1, 2024 – December 31, 2026

End Use or Description
This measure applies to commercial clothes washers that serve high use facilities such as a laundromat or multifamily common washing areas. Commercial clothes washers are rated by their Modified Energy Factor (MEF-J_2) which is an efficiency metric with units of ft^3/kWh/cycle. An MEF-J_2 combines mechanical energy used by the washer, water heating, and energy required to remove moisture content after the spin cycle. This measure replaces or installs new clothes washers that have a MEF-J_2 of 2.0-2.19 (Tier 1) or meet the Energy Star rating requirements (Tier 2). These tier definitions are for ease of Energy Trust documentation, they are not descriptors that the market uses and should not be used in customer facing materials.

Another efficiency metric is the Water Factor (WF), which is the gallons of water per cycle per unit volume of laundry, however it has not been applied within the scope of this measure.

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
- New Buildings
- New Multifamily
- Existing Multifamily
- Residential (in Washington, where the residential program serves small multifamily customers)

Within these programs, applicability is primarily expected to the following building types:
- Commercial facilities with laundry loads such as lodging and hospitals
- Laundromats
- Multifamily with shared laundry rooms

Within these programs, the measure is expected in program tracks where customer's hot water and dryer fuel can be ascertained. This may prevent use in midstream offerings.

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

Purpose of Re-Evaluating Measure
Updated costs, baseline, savings, and NEBs.

Additionally, tier 1 products were determined to be incrementally cost-effective with tier 2 and are now included as an approved standard offering. Previously tier 1 products were approved for customer service use, but were not a standard offering. The programs may choose to continue to not offer tier 1 products.

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 2024-v1.2. In Oregon the electric avoided cost year is 2024 and the gas avoided cost year is 2024. In Washington the gas avoided cost year is 2024. The values in these tables are per unit.

Measure descriptions in cost effectiveness tables observe the following nomenclature: Sector, Dryer Fuel, Water Heater Fuel, Tier, Territory (if applicable).

Table 1 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	% Ele	% Gas
1	MF Commercial Washer Ele Dryer Ele WH Tier 1	11	621.35	0.00	$492.06	$149.78	$429.53	1.0	3.5	100%	0%
2	MF Commercial Washer Ele Dryer Ele WH Tier 2	11	854.23	0.00	$531.15	$228.00	$531.15	1.1	4.8	100%	0%
3	MF Commercial Washer Ele Dryer Gas WH Tier 1	11	433.97	8.53	$492.06	$149.78	$396.69	1.0	3.4	76%	24%
4	MF Commercial Washer Ele Dryer Gas WH Tier 2	11	588.37	12.10	$531.15	$228.00	$531.15	1.0	4.7	75%	25%
5	MF Commercial Washer Gas Dryer Ele WH Tier 1	11	219.45	15.37	$492.06	$149.78	$325.92	1.0	3.3	47%	53%
6	MF Commercial Washer Gas Dryer Ele WH Tier 2	11	312.74	20.71	$531.15	$228.00	$450.92	1.0	4.5	48%	52%
7	MF Commercial Washer Gas Dryer Gas WH Tier 1	11	32.07	23.90	$492.06	$149.78	$293.09	1.0	3.2	8%	92%
8	MF Commercial Washer Gas Dryer Gas WH Tier 2	11	46.88	32.81	$531.15	$228.00	$404.33	1.0	4.4	8%	92%
9	Commercial Washer Ele Dryer Ele WH Tier 1	7	849.47	0.00	$492.06	$200.95	$377.64	1.0	3.2	100%	0%
10	Commercial Washer Ele Dryer Ele WH Tier 2	7	1,167.84	0.00	$531.15	$307.05	$519.17	1.0	4.4	100%	0%
11	Commercial Washer Ele Dryer Gas WH Tier 1	7	593.29	11.66	$492.06	$200.95	$352.13	1.0	3.1	75%	25%
12	Commercial Washer Ele Dryer Gas WH Tier 2	7	804.37	16.55	$531.15	$307.05	$482.98	1.0	4.3	74%	26%
13	Commercial Washer Gas Dryer Ele WH Tier 1	7	300.02	21.01	$492.06	$200.95	$292.60	1.0	3.0	46%	54%
14	Commercial Washer Gas Dryer Ele WH Tier 2	7	427.56	28.31	$531.15	$307.05	$404.60	1.0	4.2	47%	53%
15	Commercial Washer Gas Dryer Gas WH Tier 1	7	43.84	32.67	$492.06	$200.95	$267.09	1.0	2.9	7%	93%
16	Commercial Washer Gas Dryer Gas WH Tier 2	7	64.09	44.86	$531.15	$307.05	$368.41	1.0	4.1	8%	92%
17	MF Commercial Washer Ele Dryer Gas WH Tier 1 GOT	11	0.00	8.53	$492.06	$185.76	$96.70	1.0	3.4	0%	100%
18	MF Commercial Washer Ele Dryer Gas WH Tier 2 GOT	11	0.00	12.10	$531.15	$276.91	$137.20	1.0	4.7	0%	100%
19	MF Commercial Washer Gas Dryer Ele WH Tier 1 GOT	11	0.00	15.37	$492.06	$168.66	$174.22	1.0	3.3	0%	100%
20	MF Commercial Washer Gas Dryer Ele WH Tier 2 GOT	11	0.00	20.71	$531.15	$254.94	$234.73	1.0	4.5	0%	100%
21	MF Commercial Washer Gas Dryer Gas WH Tier 1 GOT	11	0.00	23.90	$492.06	$153.72	$270.92	1.0	3.2	0%	100%
22	MF Commercial Washer Gas Dryer Gas WH Tier 2 GOT	11	0.00	32.81	$531.15	$233.75	$371.93	1.0	4.5	0%	100%
23	Commercial Washer Ele Dryer Gas WH Tier 1 GOT	7	0.00	11.66	$492.06	$250.12	$88.38	1.0	3.2	0%	100%
24	Commercial Washer Ele Dryer Gas WH Tier 2 GOT	7	0.00	16.55	$531.15	$373.92	$125.39	1.0	4.4	0%	100%
25	Commercial Washer Gas Dryer Ele WH Tier 1 GOT	7	0.00	21.01	$492.06	$226.75	$159.22	1.0	3.0	0%	100%
26	Commercial Washer Gas Dryer Ele WH Tier 2 GOT	7	0.00	28.31	$531.15	$343.88	$214.52	1.0	4.2	0%	100%
27	Commercial Washer Gas Dryer Gas WH Tier 1 GOT	7	0.00	32.67	$492.06	$206.33	$247.60	1.0	3.0	0%	100%
28	Commercial Washer Gas Dryer Gas WH Tier 2 GOT	7	0.00	44.86	$531.15	$314.91	$339.91	1.0	4.1	0%	100%
29	MF Commercial Washer Ele Dryer Gas WH Tier 1 EOT	11	433.97	0.00	$492.06	$159.85	$299.99	1.0	3.4	100%	0%
30	MF Commercial Washer Ele Dryer Gas WH Tier 2 EOT	11	588.37	0.00	$531.15	$242.27	$406.72	1.0	4.7	100%	0%
31	MF Commercial Washer Gas Dryer Ele WH Tier 1 EOT	11	219.45	0.00	$492.06	$167.91	$151.70	1.0	3.2	100%	0%
32	MF Commercial Washer Gas Dryer Ele WH Tier 2 EOT	11	312.74	0.00	$531.15	$252.42	$216.19	1.0	4.5	100%	0%
33	Commercial Washer Ele Dryer Gas WH Tier 1 EOT	7	593.29	0.00	$492.06	$214.70	$263.75	1.0	3.1	100%	0%
34	Commercial Washer Ele Dryer Gas WH Tier 2 EOT	7	804.37	0.00	$531.15	$326.56	$357.59	1.0	4.3	100%	0%
35	Commercial Washer Gas Dryer Ele WH Tier 1 EOT	7	300.02	0.00	$492.06	$225.73	$133.37	1.0	3.0	100%	0%
36	Commercial Washer Gas Dryer Ele WH Tier 2 EOT	7	427.56	0.00	$531.15	$340.44	$190.07	1.0	4.1	100%	0%

Table 2 Cost Effectiveness Calculator Washington, per Unit

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Other NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Ele	% Gas
1	MF Commercial Washer Ele Dryer Gas WH Tier 1	11	8.53	$492.06	$115.56	$98.09	1.0	2.3	0%	100%
2	MF Commercial Washer Ele Dryer Gas WH Tier 2	11	12.10	$531.15	$174.25	$139.18	1.0	3.2	0%	100%
3	MF Commercial Washer Gas Dryer Ele WH Tier 1	11	15.37	$492.06	$98.06	$176.73	1.0	2.2	0%	100%
4	MF Commercial Washer Gas Dryer Ele WH Tier 2	11	20.71	$531.15	$151.76	$238.11	1.0	3.0	0%	100%
5	MF Commercial Washer Gas Dryer Gas WH Tier 1	11	23.90	$492.06	$82.77	$274.82	1.0	2.1	0%	100%
6	MF Commercial Washer Gas Dryer Gas WH Tier 2	11	32.81	$531.15	$130.06	$377.29	1.0	2.9	0%	100%
7	Commercial Washer Ele Dryer Gas WH Tier 1	7	11.66	$492.06	$151.63	$89.24	1.0	2.1	0%	100%
8	Commercial Washer Ele Dryer Gas WH Tier 2	7	16.55	$531.15	$230.16	$126.62	1.0	2.9	0%	100%
9	Commercial Washer Gas Dryer Ele WH Tier 1	7	21.01	$492.06	$129.05	$160.79	1.0	1.9	0%	100%
10	Commercial Washer Gas Dryer Ele WH Tier 2	7	28.31	$531.15	$201.15	$216.63	1.0	2.7	0%	100%
11	Commercial Washer Gas Dryer Gas WH Tier 1	7	32.67	$492.06	$109.33	$250.03	1.0	1.9	0%	100%
12	Commercial Washer Gas Dryer Gas WH Tier 2	7	44.86	$531.15	$173.16	$343.25	1.0	2.6	0%	100%

Requirements

- Hot water or dryer fuel must be provided by a participating Energy Trust utility.
- Clothes washers must be front-loading machines.
- Tier 1 products must have a Minimum Modified Energy Factor (MEF-J2) of 2.0.
- Tier 2 products must be Energy Star rated.[1]
- Sites which use propane or other fuels for water heat or dryer fuel must use the Electric-only Territory (EOT) measures.
- Leased equipment is applicable for new equipment only.

Baseline

This measure uses a Full Market Baseline.

The baseline developed by the RTF is based on California Energy Commission (CEC) appliance database values coupled with DOE test procedures found in the technical support document (TSD) for the energy efficiency of commercial clothes washers published in 2010.[2] From the CEC database, the RTF distinguished commercial washers which had been added in 2018 or later and met federal efficiency standards. It then applied DOE test procedures to disaggregate the total energy reported in the CEC by its individual components (machine, dryer, hot water). The Unit Energy Consumption (UEC) is averaged per component, configuration (top-load, front-load), and efficiency level (federal standard, Energy Star).

The baseline component values are weighted sums of the configuration and efficiency categories. They are weighted based on the Association of Home Appliance Manufacturers (AHAM)[3] market share splits for top-loading (73%) and front-loading (27%) washers. This market share division is corroborated by the Residential Building Stock Assessment (RBSA II)[4] which saw a similar saturation (74%) of top-loading washers in multifamily buildings with common-space laundry facilities.

The RTF measure savings and data analysis supports front-loading washers with efficiencies between federal standards and Energy Star and those meeting Energy Star efficiencies. Front-load non-Energy Star units are categorized as Tier 1, while front-load Energy Star units are categorized as Tier 2.

Measure Analysis and Savings

Measure analysis is taken directly from RTF's latest workbook, ComClothesWasher v7.0, approved in 2021[5].

Savings are based on the following assumptions aligned with the DOE TSD and RTF assumptions:

- 1,095 cycles per year for multifamily and 1,497 cycles per year for the commercial sector.
- Electric water heating efficiency is 100% and gas water heating efficiency is 75%.
- Average washer load is 7.7 lbs of dry clothes per load.

Savings result from multiple sources. For each source, savings are the baseline use minus the efficient product use. Savings from each source are summarized in Table 4.

Washing Machine Energy

Machine energy is based on 2010 TSD and is a constant value regardless of top vs front. It was the value for the highest efficiency level washer at the time and current standards are assumed to be at or near these efficiency levels.

Tier 1 washers use the same amount of electricity as market baseline washers, but savings are gained through decreased dryer and hot water energy use.

Dryer Energy

Test procedure: ELECTRONIC CODE OF FEDERAL REGULATIONS Title 10, Chapter II, Subchapter D, Part 430, Subpart B, Appendix J, Section 4.3[6]

Dryer use is calculated as follows:

$$D_E = \left[(F_{max} \cdot Max\ load\ weight) + \left(F_{avg} \cdot Avg\ load\ weight\right) + (F_{min} \cdot Min\ load\ weight)\right] \times (RMC_{corr} - 4\%) \cdot DEF \cdot DUF$$

where:

F_{max} = 0.12
F_{avg} = 0.74
F_{min} = 0.14
RMC_{corr} = Remaining Moisture Content after final spin cycle, (expressed as a fraction)
4% = 4% residual moisture content per the DOE testing procedure (expressed as a fraction)
DEF = 0.5 kWh/lb of moisture
DUF = 0.91

Table 3 Dryer Energy Calcuation Assumptions and Variables

Variable	Title	Definition
F_{max}, F_{avg}, F_{min}	Load Usage Factors	factors per loading category
RMC	Remaining Moisture Content	moisture content after final spin cycle
4%	4% RMC	residual moisture content per the DOE testing procedure
DEF	Dryer Energy Factor	the nominal energy required for clothes dryer to remove moisture
DUF	Dryer Usage Factor	the ratio of dryer cycles to clothes washer cycles per year

The RTF also adjusts the dryer energy using NEEA lab test data of real-world RMC and real-world dryer energy factor based on the RTF residential dryer workbook v4.1. The intent of NEEA's testing was to estimate washer performance under a wider range of settings and loads than the DOE test procedure.

[1] https://www.energystar.gov/products/appliances/clothes_washers/key_product_criteria
[2] DOE TSD: https://downloads.regulations.gov/EERE-2012-BT-STD-0020-0017/content.pdf
[3] Based on 2013 market share data provided by AHAM to the DOE: U.S. DOE's 2014-12-15 Commercial Clothes Washers Final Rule Technical Support Document: Chapter 9. Shipments Analysis. Table 9.3.5
[4] RBSA II: https://neea.org/resources/rbsa-ii-combined-database
[5] RTF Commercial Clothes Washers https://rtf.nwcouncil.org/measure/clothes-washers
[6] D_E test procedure: https://www.ecfr.gov/cgi-bin/text-idx?SID=cc6bec3d86a4298f612fe525018b252f&mc=true&node=pt10.3.430&rgn=div5

Water Heating Energy

Hot water energy is determined by deducting the machine and dryer consumption from the total kWh consumption per cycle as shown below:

$$Water\ heating\ energy\ = (tub\ volume/MEF)\ -\ (Machine\ Energy)\ -\ (Dryer\ Energy)$$

where,

Tub volume (ft^3) is specific to each qualifying unit as determined in the CEC database
MEF (modified energy factor, (ft^3/kWh/cycle)) is specific to each qualifying unit as determined in the CEC database
Machine energy = 0.114 kWh/cycle for top or front loads with MEF-J2 ≥ 1.6

Embedded Energy in Water

Based on RTF judgement, 50% of fresh water and 50% of wastewater are aggregated to determine the embedded water savings. This is because some fresh water remains in clothing and is dried, rather than becoming wastewater and embedded energy of water value is based on both the freshwater and wastewater treatment and distribution systems. Water savings are converted to electric savings using 3.68 kWh/1000 gallons in alignment with the 7th power plan.

Total savings by savings source are shown in Table 4.

Table 4 Annual Washer Savings by savings source

Measures	Electricity (kWh)				Gas (therms)			Water (gallons)	
	Total	Dryer	Hot Water	Embedded Water	Total	Dryer	Hot Water	Fresh water	Wastewater
MF Commercial Washer Ele Dryer Ele WH Tier 1	589	402	187	32	0	0	0	8,747	8,666
MF Commercial Washer Ele Dryer Ele WH Tier 2	807	541	266	47	0	0	0	12,782	12,673
MF Commercial Washer Ele Dryer Gas WH Tier 1	402	402	0	32	9	0	9	8,747	8,666
MF Commercial Washer Ele Dryer Gas WH Tier 2	541	541	0	47	12	0	12	12,782	12,673
MF Commercial Washer Gas Dryer Ele WH Tier 1	187	0	187	32	15	15	0	8,747	8,666
MF Commercial Washer Gas Dryer Ele WH Tier 2	266	0	266	47	21	21	0	12,782	12,673
MF Commercial Washer Gas Dryer Gas WH Tier 1	0	0	0	32	24	15	9	8,747	8,666
MF Commercial Washer Gas Dryer Gas WH Tier 2	0	0	0	47	33	21	12	12,782	12,673
Commercial Washer Ele Dryer Ele WH Tier 1	406	242	165	32	7	6	1	8,747	8,666
Commercial Washer Ele Dryer Ele WH Tier 2	559	326	233	47	10	8	1	12,782	12,673
Commercial Washer Ele Dryer Gas WH Tier 1	806	549	256	44	0	0	0	11,958	11,848
Commercial Washer Ele Dryer Gas WH Tier 2	1,104	740	363	64	0	0	0	17,475	17,326
Commercial Washer Gas Dryer Ele WH Tier 1	549	549	0	44	12	0	12	11,958	11,848
Commercial Washer Gas Dryer Ele WH Tier 2	740	740	0	64	17	0	17	17,475	17,326
Commercial Washer Gas Dryer Gas WH Tier 1	256	0	256	44	21	21	0	11,958	11,848
Commercial Washer Gas Dryer Gas WH Tier 2	363	0	363	64	28	28	0	17,475	17,326

Comparison to RTF or other programs

Analysis is aligned with RTF Commercial Clothes Washer v7.0 measure.

This measure focuses on common area clothes washers and laundromats. In-unit clothes washers in multifamily are residential-class appliances and are described under MAD 152 for multifamily. Those products have different physical characteristics and usage patterns and purchasing methods, resulting in different savings and costs.

Measure Life

Measure life is unchanged from the previous iteration and is sourced from the RTF analysis which uses 7 years for commercial applications and 11 years for multifamily applications based on the DOE TSD.

Load Profile

Electric load profiles: The electric load profiles are updated to reflect the different market segments for this measure

- For multifamily applications, the Res Clotheswasher profile aligns with the expected usage pattern.
- For laundromats and other commercial laundries, the usage pattern is relatively flatter throughout the day, this measure uses the Commercial Other Process load profile.

Gas load profiles:

- The gas load profile is set to Clotheswasher and is unchanged from the previous analysis.

Cost

The costs are sourced from the 2014 US DOE TSD for commercial clothes washers. The DOE TSD utilizes cost data submitted by AHAM and bottom-up analysis to develop commercial clothes washer manufacturer cost, installation, material costs. These values are sourced by the RTF analysis. This analysis adjusts the incremental cost numbers from the RTF analysis to forecasted 2024 dollars. The incremental cost for Tier 1 washers is $492 and the incremental cost for Tier 2 washers is $531.

Non-Energy Benefits

There are several Non-Energy Benefit components.

Operations and Maintenance NEB

There is an increased cost associated with the annual operation and maintenance of efficient products, as shown in DOE TSD Chapter 8 Life-cycle cost and back period analysis. This is based on manufacturer feedback and analysis showing higher efficiency clothes washers see increased repair costs. This cost is annualized and treated as a negative non-energy benefit.

- Multifamily O&M NEB = -$24/year
- Laundromat O&M NEB = -$37/year

Water Savings NEB

Water savings are valued based on blended commercial water/sewer rates based on freshwater savings. Embedded energy savings not included in out of territory measure applications.

- Oregon

    - Dual and Electric Only Territories: $19.71/1,000 gallons
    - Gas Only Territories: $20.16/1,000 gallons
- Washington $12.04/1,000 gallons.

Table 5 Non-Energy Benefits from avoiding water use

Measure	Fresh Water Savings (Annual Gallons)	Oregon Water NEB (Annual $)	Washington Water NEB (Annual $)
MF Commercial Washer Tier 1	8,747	$150	$83
MF Commercial Washer Tier 2	12,782	$228	$130
Commercial Washer Tier 1	11,958	$201	$109
Commercial Washer Tier 2	17,475	$307	$173

Out of Territory Bill Savings

In areas where Energy Trust does not partner with the relevant utilities, and cannot claim gas or electric savings, customer bill savings are considered as NEBs.

- Oregon Commercial Electric rate $0.080/kwh
- Oregon Commercial Gas rate $1.179/therm
- In Oregon, other fuels, such as propane, are assumed to have the same value as gas

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. The highest Tier 1 incentive that would be applicable to all combinations is $88. The highest Tier 2 incentive that would be applicable to all combinations is $125*.* If both Tier 1 and Tier 2 measures are offered, Tier 2 incentives should be no more than $39 more than Tier 1, which is the expected average cost difference.

Follow-Up

This measure should be updated following any changes to federal standards or ENERGY STAR specifications. Maintaining alignment with the RTF is preferred. Costs should be updated in the next revision. If propane is a common fuel, measure applications using propane NEBs should be created.

Supporting Documents

The cost-effective screening for these measures is number 89.5.3. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Commercial and Industrial\Commercial Appliances\clothes washer

89_5_3_OR-WA-CEC
_2024-v1.2_Com_Clo

Version History and Related Measures

Energy Trust has been offering Commercial Clothes Washers for many years. These predate our measure approval documentation process and record retention requirements. Table 6 may be incomplete, particularly for measures approved prior to 2013.

Table 6 Version History

Date	Version	Reason for revision
6/27/2005	x	Approve commercial clothes washers for multifamily and laundromats. MEF>1.8
12/08/2006	x	Change incentives
3/09/2007	x	Update measure to MEF>2.0
3/06/2009	x	Update measure to align with CEE tier II specifications. MEF ≥ 2.0 WF ≤ 6.0. Blend Multifamily and laundromat savings
3/10/2009	x	Add partial territory clarifications and correct errors
11/06/2015	89.x	Update for ENERGY STAR 7.1. Split analysis for multifamily and commercial settings, add additional commercial building types. Weights water and dryer fuels. MEF >2.2.
1/22/2016	89.1	Adds residential new homes small multifamily as applicable program
9/19/2017	89.2	Update water NEBs and embedded energy, maximum incentives.
10/22/2020	89.3	Extend expiration date to allow for PMC transition in Q1 2021
11/16/2020	89.4	Add measure identifiers for water heater/dryer fuel combinations, additional tier at MEF 2.0-2.19.
10/6/2023	89.5	Update energy values and costs in alignment with RTF v7.0 and inflation.

Table 7 Related Measures

Measures	MAD ID
Residential Clothes Washers	4
Residential Clothes Dryers	231
Shift Model Top-Loading Residential Clothes Washers	218
Multifamily in-unit clothes washers	152
Two Stage Gas Valve on Clothes Dryers	291
Ozone Laundry	80

Approved & Reviewed by

Kenji Spielman
Planning Engineer

Disclaimer

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Measure Approval Document for Commercial & Industrial Pipe Insulation

Valid Dates
1/1/2023 to 12/31/2025

End Use or Description
Pipe insulation on previously uninsulated hot water or steam piping. This measure is available for Domestic Hot Water (DHW), heating hot water (HHW) (hydronic heating), low pressure and medium pressure steam (LPS, MPS) distribution systems in existing commercial buildings and LPS, MPS, and process hot water (PHW) applications in industrial facilities.

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
- Production Efficiency

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

- Retrofit

Purpose of Re-Evaluating Measure
Measure costs were updated.
Process Hot Water (PHW) measures introduced.
Savings for industrial measure applications were differentiated by narrow pipe diameter ranges.
Installed insulation requirements for MPS pipes increased

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 2023-v1.0. In Oregon the electric avoided cost year is 2023 and the gas avoided cost year is 2023. In Washington the gas avoided cost year is 2023. The values in these tables are per linear foot.

Table 1 Cost Effectiveness Calculator Oregon, per linear 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	Commercial DHW 1" pipe insulated to 1.5"	15	0.00	2.11	$18.41	$0.00	$18.41	1.3	1.3	0%	100%
2	Commercial DHW 2" pipe insulated to 2.0"	15	0.00	3.68	$25.49	$0.00	$25.49	1.7	1.7	0%	100%
3	Commercial DHW 3" pipe insulated to 2.0"	15	0.00	5.22	$31.47	$0.00	$31.47	1.9	1.9	0%	100%
4	Commercial DHW 4" pipe insulated to 2.0"	15	0.00	6.53	$37.46	$0.00	$37.46	2.0	2.0	0%	100%
5	Commercial HHW 1" pipe insulated to 1.5"	15	0.00	2.68	$33.48	$0.00	$33.48	1.3	1.3	0%	100%
6	Commercial HHW 2" pipe insulated to 2.0"	15	0.00	4.65	$40.56	$0.00	$40.56	1.9	1.9	0%	100%
7	Commercial HHW 3" pipe insulated to 2.0"	15	0.00	6.57	$46.54	$0.00	$46.54	2.3	2.3	0%	100%
8	Commercial HHW 4" pipe insulated to 2.0"	15	0.00	8.22	$52.53	$0.00	$52.53	2.5	2.5	0%	100%
9	Commercial LPS 1" pipe insulated to 1.5"	15	0.00	4.49	$33.48	$0.00	$33.48	2.2	2.2	0%	100%
10	Commercial LPS 2" pipe insulated to 2.0"	15	0.00	7.81	$40.56	$0.00	$40.56	3.1	3.1	0%	100%
11	Commercial LPS 3" pipe insulated to 2.0"	15	0.00	11.01	$46.54	$0.00	$46.54	3.8	3.8	0%	100%
12	Commercial LPS 4" pipe insulated to 2.0"	15	0.00	13.78	$52.53	$0.00	$52.53	4.2	4.2	0%	100%
13	Commercial MPS 1" pipe insulated to 2.0"	15	0.00	4.63	$33.48	$0.00	$33.48	2.2	2.2	0%	100%
14	Commercial MPS 2" pipe insulated to 2.5"	15	0.00	8.01	$40.56	$0.00	$40.56	3.2	3.2	0%	100%
15	Commercial MPS 3" pipe insulated to 2.5"	15	0.00	11.29	$46.54	$0.00	$46.54	3.9	3.9	0%	100%
16	Commercial MPS 4" pipe insulated to 2.5"	15	0.00	14.13	$52.53	$0.00	$52.53	4.3	4.3	0%	100%
17	Industrial LPS 0.5-1" pipe insulated to 1.5"	10	0.00	12.51	$33.03	$0.00	$33.03	2.9	2.9	0%	100%
18	Industrial LPS 1.25-1.5" pipe insulated to 1.5"	10	0.00	17.47	$35.72	$0.00	$35.72	3.7	3.7	0%	100%
19	Industrial LPS 2.0-2.5" pipe insulated to 2.0"	10	0.00	25.26	$42.05	$0.00	$42.05	4.5	4.5	0%	100%
20	Industrial LPS 3.0-3.5" pipe Insulated to 2.0"	10	0.00	34.68	$48.04	$0.00	$48.04	5.4	5.4	0%	100%
21	Industrial LPS 4-6" pipe Insulated to 2.0"	10	0.00	49.21	$58.51	$0.00	$58.51	6.3	6.3	0%	100%
22	Industrial LPS 8-10" pipe Insulated to 2.0"	10	0.00	80.56	$82.46	$0.00	$82.46	7.4	7.4	0%	100%
23	Industrial MPS 0.5-1" pipe insulated to 2.0"	10	0.00	21.14	$33.03	$0.00	$33.03	4.8	4.8	0%	100%
24	Industrial MPS 1.25-1.5" pipe insulated to 2.0"	10	0.00	29.54	$35.72	$0.00	$35.72	6.2	6.2	0%	100%
25	Industrial MPS 2.0-2.5" pipe insulated to 2.5"	10	0.00	42.34	$42.05	$0.00	$42.05	7.6	7.6	0%	100%
26	Industrial MPS 3.0-3.5" pipe insulated to 2.5"	10	0.00	58.14	$48.04	$0.00	$48.04	9.1	9.1	0%	100%
27	Industrial MPS 4-6" pipe insulated to 2.5"	10	0.00	82.56	$58.51	$0.00	$58.51	10.6	10.6	0%	100%
28	Industrial MPS 8-10" pipe insulated to 2.5"	10	0.00	135.22	$82.46	$0.00	$82.46	12.4	12.4	0%	100%
29	Industrial PHW 0.5-1" pipe insulated to 1.5"	10	0.00	7.36	$33.03	$0.00	$33.03	1.7	1.7	0%	100%
30	Industrial PHW 1.25-1.5" pipe insulated to 1.5"	10	0.00	10.20	$35.72	$0.00	$35.72	2.2	2.2	0%	100%
31	Industrial PHW 2.0-2.5" pipe insulated to 2.0"	10	0.00	14.72	$42.05	$0.00	$42.05	2.6	2.6	0%	100%
32	Industrial PHW 3.0-3.5" pipe insulated to 2.0"	10	0.00	20.24	$48.04	$0.00	$48.04	3.2	3.2	0%	100%
33	Industrial PHW 4-6" pipe insulated to 2.0"	10	0.00	28.76	$58.51	$0.00	$58.51	3.7	3.7	0%	100%
34	Industrial PHW 8-10" pipe insulated to 2.0"	10	0.00	47.40	$82.46	$0.00	$82.46	4.3	4.3	0%	100%

Table 2 Cost Effectiveness Calculator Washington, per foot

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Commercial DHW 1" pipe insulated to 1.5"	15	2.11	$18.41	$0.00	$18.41	1.7	1.7	0%	100%
2	Commercial DHW 2" pipe insulated to 2.0"	15	3.68	$25.49	$0.00	$25.49	2.1	2.1	0%	100%
3	Commercial DHW 3" pipe insulated to 2.0"	15	5.22	$31.47	$0.00	$31.47	2.4	2.4	0%	100%
4	Commercial DHW 4" pipe insulated to 2.0"	15	6.53	$37.46	$0.00	$37.46	2.5	2.5	0%	100%
5	Commercial HHW 1" pipe insulated to 1.5"	15	2.68	$33.48	$0.00	$33.48	1.9	1.9	0%	100%
6	Commercial HHW 2" pipe insulated to 2.0"	15	4.65	$40.56	$0.00	$40.56	2.7	2.7	0%	100%
7	Commercial HHW 3" pipe insulated to 2.0"	15	6.57	$46.54	$0.00	$46.54	3.3	3.3	0%	100%
8	Commercial HHW 4" pipe insulated to 2.0"	15	8.22	$52.53	$0.00	$52.53	3.7	3.7	0%	100%
9	Commercial LPS 1" pipe insulated to 1.5"	15	4.49	$33.48	$0.00	$33.48	3.2	3.2	0%	100%
10	Commercial LPS 2" pipe insulated to 2.0"	15	7.81	$40.56	$0.00	$40.56	4.5	4.5	0%	100%
11	Commercial LPS 3" pipe insulated to 2.0"	15	11.01	$46.54	$0.00	$46.54	5.6	5.6	0%	100%
12	Commercial LPS 4" pipe insulated to 2.0"	15	13.78	$52.53	$0.00	$52.53	6.2	6.2	0%	100%
13	Commercial MPS 1" pipe insulated to 2.0"	15	4.63	$33.48	$0.00	$33.48	3.3	3.3	0%	100%
14	Commercial MPS 2" pipe insulated to 2.5"	15	8.01	$40.56	$0.00	$40.56	4.7	4.7	0%	100%
15	Commercial MPS 3" pipe insulated to 2.5"	15	11.29	$46.54	$0.00	$46.54	5.7	5.7	0%	100%
16	Commercial MPS 4" pipe insulated to 2.5"	15	14.13	$52.53	$0.00	$52.53	6.3	6.3	0%	100%
17	Industrial LPS 0.5-1" pipe insulated to 1.5"	10	12.51	$33.03	$0.00	$33.03	3.6	3.6	0%	100%
18	Industrial LPS 1.25-1.5" pipe insulated to 1.5"	10	17.47	$35.72	$0.00	$35.72	4.6	4.6	0%	100%
19	Industrial LPS 2.0-2.5" pipe insulated to 2.0"	10	25.26	$42.05	$0.00	$42.05	5.7	5.7	0%	100%
20	Industrial LPS 2.5-3.5" pipe Insulated to 2.0"	10	34.68	$48.04	$0.00	$48.04	6.8	6.8	0%	100%
21	Industrial LPS 4-6" pipe Insulated to 2.0"	10	49.21	$58.51	$0.00	$58.51	7.9	7.9	0%	100%
22	Industrial LPS 8-10" pipe Insulated to 2.0"	10	80.56	$82.46	$0.00	$82.46	9.2	9.2	0%	100%
23	Industrial MPS 0.5-1" pipe insulated to 2.0"	10	21.14	$33.03	$0.00	$33.03	6.0	6.0	0%	100%
24	Industrial MPS 1.25-1.5" pipe insulated to 2.0"	10	29.54	$35.72	$0.00	$35.72	7.8	7.8	0%	100%
25	Industrial MPS 2.0-2.5" pipe insulated to 2.5"	10	42.34	$42.05	$0.00	$42.05	9.5	9.5	0%	100%
26	Industrial MPS 2.5-3.5" pipe insulated to 2.5"	10	58.14	$48.04	$0.00	$48.04	11.4	11.4	0%	100%
27	Industrial MPS 4-6" pipe insulated to 2.5"	10	82.56	$58.51	$0.00	$58.51	13.3	13.3	0%	100%
28	Industrial MPS 8-10" pipe insulated to 2.5"	10	135.22	$82.46	$0.00	$82.46	15.4	15.4	0%	100%
29	Industrial PHW 0.5-1" pipe insulated to 1.5"	10	7.36	$33.03	$0.00	$33.03	2.1	2.1	0%	100%
30	Industrial PHW 1.25-1.5" pipe insulated to 1.5"	10	10.20	$35.72	$0.00	$35.72	2.7	2.7	0%	100%
31	Industrial PHW 2.0-2.5" pipe insulated to 2.0"	10	14.72	$42.05	$0.00	$42.05	3.3	3.3	0%	100%
32	Industrial PHW 2.5-3.5" pipe insulated to 2.0"	10	20.24	$48.04	$0.00	$48.04	4.0	4.0	0%	100%
33	Industrial PHW 4-6" pipe insulated to 2.0"	10	28.76	$58.51	$0.00	$58.51	4.6	4.6	0%	100%
34	Industrial PHW 8-10" pipe insulated to 2.0"	10	47.40	$82.46	$0.00	$82.46	5.4	5.4	0%	100%

Requirements

- Must not have any existing pipe insulation.
- Incentives and savings are based on straight linear feet of pipe, not equivalent length. Therefore, fittings and pipe bends shall not be accounted for in savings and incentive calculation.
- Jacketing that provides an appropriate level of protection for the insulation under the given environmental conditions will be required for pipe insulation projects to maintain the life of the insulation. This will commonly be All Service Jacketing (ASJ) or PVC in indoor applications and aluminum or stainless-steel jacketing for outdoor projects.
- Water heaters/boilers providing hot water/steam to uninsulated pipes must be natural gas-fired.
- Pipe insulation for steam at pressures above 200 psig or process fluids above 388 °F are not approved and should be referred to the Custom Industrial program.
- Table 3 shows required insulation thickness based on nominal pipe diameter, and steam pressure classifications for commercial and industrial applications.

Table 3 Minimum Required Insulation Thickness for Commercial and Industrial Applications

	Pipe Diameter	
Fluid	**≤ 1.5"**	**> 1.5"**
Domestic Hot Water (DHW)	1.5”	2.0”
Heating Hot Water (HHW)		
Process Hot Water (PHW)		
Low Pressure Steam (LPS) (< 15 psig)		
Med Pressure Steam (MPS) (15-200 psig)	2.0”	2.5”

Baseline

This measure uses an existing condition baseline.

The baseline is assumed to be an uninsulated schedule 40 steel pipe.

Savings and Measure Analysis

Savings were based on a 2010 ICF study conducted on behalf of the Energy Trust of Oregon. The study analyzed the impact of pipe insulation in commercial and industrial applications. A bare pipe baseline was used to describe sites that had missing, severely deteriorated, or uninsulated piping. Modifications to the original analysis have since been made.

Several different applications and their associated operating hours and fluid temperatures were looked at, assumptions for the analysis are listed in Table 4.

Table 4 Input Parameter Summary

Input Parameter	Value	Units
DHW, LPS, MPS Heater/Boiler Efficiency	80%	N/A
HHW, PHW Boiler Efficiency	83%	N/A
Thermal conductivity, steel pipe (k)	314.4	Btu-in/hr-ft^2-F
Thermal conductivity, insulation (k)	0.29	Btu-in/hr-ft^2-F
Ambient Temperature	70	°F
DHW Supply/Return Temperature	130/124	°F
Medium-pressure Steam Supply/Return Temperature	338/212	°F
Heating Hot Water System Supply/Return Temperature	180/160	°F
Low-pressure Steam Supply/Return Temperature	250/212	°F
Process Hot Water Supply/Return Temperature	180/160	°F
Emissivity of steel and insulation	0.8	N/A

The assumed efficiency for HHW boilers was updated based on the findings in the ‘Oregon Commercial and Industrial Boilers Market Characterization’ report (Dec 2020)[1]. Based on the above points, an updated commercial hot water boiler efficiency was estimated using the following assumptions:

- Assumed condensing boiler efficiency when operating in condensing mode- 94%
- Assumed non-condensing boiler efficiency- 80%
- 63% of commercial condensing hot water boilers are condensing type (based on the report).
- 90% of condensing boilers are not operating in condensing mode (based on the report), therefore efficiency of a condensing boiler operating in non-condensing mode is lesser than 94% and is assumed to be approx. 84%[2].

The estimated commercial hot water boiler efficiency using the above facts and assumptions is 83.0% and is used for calculations for HHW and PHW measure applications. The report does not mention efficiency of steam boilers and therefore the assumed efficiency for steam boilers was unchanged and remains 80%.

The analysis assumes that 90% of pipes will be located indoors and 10% will be located outdoors. Savings were determined by using heat transfer engineering equations to model a horizontal pipe with internal fluid flow along with empirical relations for the necessary heat transfer coefficients. The following equation was used to determine heat loss from the pipe:

$$q = \frac{Q}{L} = \frac{\pi \Delta T}{R_1 + R_{pipe} + R_{ins} + R_2}$$

Where,

q = Energy loss per length of pipe (Btu/hr/ft)

Q = Energy loss (Btu/hr)

L = Pipe length (ft)

ΔT = Temperature difference between fluid and air ($T_{fluid} - T_{air}$,) (°F)

The R values in the denominator represent the thermal resistance factors that impede the flow of heat. R values vary and be solved for with physical properties and heat transfer coefficients.

R1 = Thermal resistance due to convection between fluid and inside pipe surface

Rpipe = Thermal resistance due to conduction through pip

Rins = Thermal resistance due to conduction through insulation

R2 = Thermal resistance due to convection and radiation at the exterior insulation surface.

The heat loss for bare and insulated pipes were calculated and used to find the incremental heat loss per hour. Using the heat loss rate, the savings were determined by multiplying the heat loss by the operating hours and dividing by the assumed boiler efficiency. Table 5 lists the assumed operating hours for the different applications.

[1] https://www.energytrust.org/wp-content/uploads/2021/05/EnergyTrust_CIGasBoilerMarketResearch-Memo_FINAL.pdf
[2] https://kw-engineering.com/how-to-optimize-condensing-boiler-system-maximum-energy-savings/

Table 5 Assumed Operating Hours

Application	Operating Hours
Small Commercial DHW	2,500 hours
Small Commercial Medium Pressure Steam	2,200 hours
Large Commercial DHW	6,500 hours
Large Commercial Heating	2,900 hours
Large Commercial Low-Pressure Steam	2,900 hours
Industrial Low-Pressure Steam	8,400 hours
Industrial Medium Pressure Steam	8,400 hours
Industrial Process Hot Water	8,400 hours

2021 Oregon Energy Efficiency Specialty Code, which is based on the ASHRAE 90.1 Standard was used to develop target insulation levels for each case based on the expected fluid type and pipe size.

For commercial measures, savings were calculated for pipe diameters of 1”, 2”, 3”, and 4” for each application. The calculated savings estimates for supply and return piping were averaged so that contractors will not have to distinguish the direction of flow during installation and we have a single savings estimate for each measure application. For DHW applications in small and large commercial buildings, the savings were averaged for each pipe diameter so that the program will not have to discern what constitutes a small versus a large commercial building. The operating hours, were the only variance between the two applications, mitigating the impact of combining these applications.

For industrial measures, savings were calculated for supply and return piping with nominal pipe diameters of 0.5”, 0.75”, 1”, 1.25”, 1.5”, 2”, 2.5”, 3”, 3.5”, 4”, 5”, 6”, 8”, and 10” and then savings for each pipe size were grouped in six bins (0.5-1”, 1.25-1.5”, 2.0-2.5”, 3.0-3.5”, 4-6”, and 8-10”) and savings from supply and return piping were averaged. The 0.5-1" pipe size bins have been weighted to account for more frequent installations of 1" pipe insulation. 75% of these projects are expected to be 1" pipe, 20% to be 0.75" and 5% to be 0.5". These percentages were used to generate a weighted average. These percentages were estimated based on experience delivering the measure over the past year of the program, where many 1" pipe installations were seen, only a small amount of 0.75" (which was then ineligible), and zero 0.5" pipes. Any 0.5" or 0.75" pipes are expected to be very short runs near the point-of-use, so this weighted average should still be a conservative estimate of savings.

Comparison to RTF or other programs

This MAD exists alongside MAD 111 – Multifamily Pipe Insulation and MAD 249 – Direct Install Industrial Pipe Insulation. All three draw from the same analysis and methodology, although savings differ primarily due to differences in hours of operation and insulation thickness requirements. MAD 111 does not offer MPS pipe insulation measures.

Pipe insulation for commercial and industrial applications is not offered by the RTF.

Measure Life

The 2007 ASHRAE Handbook assigns a 20-year measure life to modeled insulation, and a 2005 DEER Database report referencing CALMAC data lists 15 years for pipe wrap. Although pipe insulation in high traffic areas would likely deteriorate faster than these estimates, the program assumes that OSHA requirements would already require pipe insulation (especially on steam systems) to be installed in these high exposure areas. Therefore, most of the insulation installed through the existing buildings program is expected to be done on piping found in low traffic areas, above ceiling spaces, or in wall cavities. A measure life of 15 years for commercial pipe insulation was used as a conservative estimate.

For industrial measure applications, a measure life of 10 years was used to screen for cost-effectiveness to account for the more frequent change out of process piping and expected re-insulation.

In both sectors, because insulation is rarely maintained and could potentially become damaged earlier than the equipment it is connected to would need replacement, (particularly in the case of boilers) the program will require installing ASJ on indoor piping and aluminum jacketing on outdoor piping to ensure savings realization for the life of the measure.

Load Profile

Measures serving DHW will use a DHW gas load profile. Measures serving HVAC loads use commercial heating gas load profile. Industrial measures use a flat gas load profile.

Cost

The installed cost of pipe insulation was determined from Program Tracker (PT) data from commercial and industrial projects and then scaled to vary with pipe diameter and insulation thickness.

The past project data from PT for commercial, industrial and multifamily pipe insulation projects was combined. Project data from 2020 to 2022 was used for HHW/LPS/MPS pipe insulation installed cost and it is $40.56 per LF from 16 projects. For DHW pipes, project data was available only from 2016 and 2018 and therefore it was used with cost inflation factors derived from the RTF’s Standard Information Workbook v4.7[3] and is estimated at $25.49 per LF from 11 projects. The data revealed that the average cost of installed insulation per linear feet for DHW pipes is notably less than and the weighted average cost for LPS and HHW pipes, so they were not combined. Pipe diameter was not consistently tracked in PT.

Review of pipe insulation costs from RS Means and online vendors Grainger & McMaster Carr showed that pipe insulation costs increase with increased insulation thickness and increased pipe diameter. The cost data gathered from RSMeans reflected the assumed measure materials: fiberglass insulation with kraft paper ASJ (indoors) and aluminum jacketing (outdoors). A two-variable regression analysis established a relationship of cost dependence on two primary parameters: pipe diameter and insulation thickness. Table 6 shows the regression analysis coefficients in which pipe diameter and insulation thickness are the independent variables and resultant costs vary by insulation thickness and pipe diameter.

[3] https://nwcouncil.box.com/v/RTF-SIW-v4-7

Table 6 RSMeans and online vendor cost regression to pipe diameter and insulation thickness

	Pipe Diameter (in)	Insulation Thickness (in)	Intercept
Slope	5.99	2.18	3.805307
Standard error	0.30	0.18	0.67292
R2	0.91	1.90	
F	312.39	59.00	

Finally, the regression dependence on these two factors was applied to PT data by assuming the average per linear foot cost from past projects represented the average condition of 2-inch pipe with 2-inch-thick insulation. The slopes of the regression were used to increase or decrease cost as dimensions increased or decreased from that average condition. This results in a cost distribution across pipe and insulation dimensions based on PT data as the primary source, scaled to different dimensions based on the observed cost dependence in RSMeans and online vendor (Grainger & McMaster Carr) data. The cost for each measure application assumed 90% interior piping (ASJ) and 10% exterior piping (average of aluminum and PVC jacketing) and excludes any incidental costs such as painting, pipe identification or consulting, overtime, and shift work.

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 linear foot.

Follow-Up

Any additional studies or evaluation results on commercial or industrial pipe insulation should be evaluated for inclusion in the analysis. Costs should be reviewed during the next measure update. Also, any feedback from the Program Operations or Energy Advisor team should be included.

Supporting Documents

The cost effectiveness screening for these measures is number 91.4.3. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Commercial and Industrial\Process Equipment\pipe insulation\Commercial Industrial pipe insulation

91.4.3 OR-WA CEC 2023 v1.0 C&I Pipe I

Version History and Related Measures

Energy Trust has been offering pipe measure for many years. These predate our measure approval documentation process and record retention requirements. Table 7 may be incomplete, particularly for measures approved prior to 2013.

Table 7 Version History

Date	Version	Reason for revision
2010	91.x	Introduce pipe insulation measures
11/17/2010	91.1	Change insulation thickness requirements
5/30/2019	91.2	Separate measures for insulation on domestic hot water and heating hot water pipes. Re-weight DHW and commercial steam savings.
11/8/2019	91.3	Update requirements
9/21/2022	91.4	Savings for industrial measure applications differentiated by pipe diameter, insulation req. for MPS pipes increased, process hot water application introduced, assumed efficiency for hot water boilers updated

Table 8 Related Measures

Measures	MAD ID
Multifamily Pipe Insulation	111
Industrial DI Pipe Insulation	249

Approved & Reviewed by

Jackie Goss, PE
Sr. Engineer – Planning & Evaluation

Disclaimer

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Measure Approval Document for Commercial Foodservice Cooking Measures

Valid Dates
July 1, 2023 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
- New Buildings
- 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 classes:
- New
- Replacement

Purpose of Re-Evaluating Measure
This mid-cycle update reintroduces the Rack Oven – Gas – Double measure application for Oregon. Costs were updated for this measure. In addition, all the commercial oven ES v2.2 measure applications have been removed, and only the v3.0 measure applications remain due to an ENERGY STAR requirement update that took effect January 12, 2023[1].

There are no other changes to previously approved measure applications' savings or costs. Max incentives, allocations, and NEBs have been updated based on the updated cost effectiveness tool.

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 2024-v1.2. In Oregon, the electric avoided cost year is 2024, and the gas avoided cost year is 2024. In Washington, the gas avoided cost year is 2024. The values in these tables are per cooking appliance.

Table 1 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	1.2	1.2	100%	0%
8	Rack Oven - Gas - Double	12	0.00	218.44	$2,079.78	$0.00	$2,079.78	1.2	1.2	0%	100%
11	Convection Oven - Electric - Half-size	12	912.22	0.00	$359.75	$0.00	$359.75	2.0	2.0	100%	0%
12	Convection Oven - Electric - Full-size	12	989.16	0.00	$703.11	$0.00	$703.11	1.1	1.1	100%	0%
15	Combination Oven - Electric 3-4 pan Capacity	12	973.78	0.00	$1.00	$0.00	$735.00	1.0	769.4	100%	0%
16	Combination Oven - Electric 5-40 pan Capacity	12	3,303.27	0.00	$1.00	$0.00	$2,000.00	1.3	2610.0	100%	0%
22	Steam Cookers - Electric	12	13,612.88	0.00	$1.00	$82.75	$3,400.00	3.2	11510.5	100%	0%
23	Steam Cookers - Gas	12	0.00	555.32	$1.00	$263.46	$3,400.00	1.9	8971.4	0%	100%
25	Conveyor Broilers with belt width < 20”	12	7,143.84	1,145.29	$2,523.03	$0	$2,523.03	7.6	7.6	29%	71%
26	Conveyor Broilers with belt width 20” - 26”	12	6,403.32	1,932.84	$3,145.87	$0	$3,145.87	8.9	8.9	18%	82%
27	Conveyor Broilers with belt width > 26”	12	23,849.10	3,161.26	$3,658.65	$0	$3,658.65	15.4	15.4	34%	66%
28	Conveyor Broilers with belt width < 20” - Electric Only Territory	12	7,143.84	0.00	$2,523.03	$1,351	$2,523.03	2.2	7.1	100%	0%
29	Conveyor Broilers with belt width 20” - 26” - Electric Only Territory	12	6,403.32	0.00	$3,145.87	$2,280	$3,145.87	1.6	8.2	100%	0%
30	Conveyor Broilers with belt width > 26” - Electric Only Territory	12	23,849.10	0.00	$3,658.65	$3,728	$3,658.65	5.2	14.4	100%	0%
31	Conveyor Broilers with belt width < 20” - Gas Only Territory	12	0.00	1,145.29	$2,523.03	$569	$2,523.03	5.4	7.4	0%	100%
32	Conveyor Broilers with belt width 20” - 26” - Gas Only Territory	12	0.00	1,932.84	$3,145.87	$510	$3,145.87	7.3	8.7	0%	100%
33	Conveyor Broilers with belt width > 26” - Gas Only Territory	12	0.00	3,161.26	$3,658.65	$1,901	$3,658.65	10.2	15.0	0%	100%

[1] https://www.energystar.gov/products/spec/commercial_ovens_specification_version_3_0_pd

Table 2 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	$2,273.15	1.0	0.8	0%	100%
2	Rack Oven – Gas - Double	12	218.44	$2,079.78	$0.00	$2,079.78	1.8	1.8	0%	100%
5	Convection Oven - Gas - Full-size	12	62.15	$798.04	$0.00	$798.04	1.4	1.4	0%	100%
8	Combination Oven – Gas	12	207.91	$3,425.02	$0.00	$3,425.02	1.1	1.1	0%	100%
13	Steam Cookers - Gas	12	555.32	$1.00	$263.46	$3,400.00	2.9	12273.5	0%	100%
15	Conveyor Broilers with belt width < 20”	12	1,145.29	$2,523.03	$550.09	$2,523.03	7.9	10.1	0%	100%
16	Conveyor Broilers with belt width 20” - 26”	12	1,932.84	$3,145.87	$493.03	$3,145.87	10.7	12.3	0%	100%
17	Conveyor Broilers with belt width > 26”	12	3,161.26	$3,658.65	$1,836	$3,658.65	15.1	20.0	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.

Equipment-specific requirements

- All products must meet the criteria shown in Table 3.
- 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 3 Required Efficiency Levels

Equipment	Required Efficiency levels
Hot Food Holding Cabinets	ENERGY STAR version 2.0[2]
Convection, Combination, Rack Ovens	ENERGY STAR version 3.0[3]
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 a 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’[4] 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 4 summarizes the ENERGY STAR market penetration rates used for each equipment.

Table 4 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%

The market penetration rates are assumed to not have changed substantively when ENERGY STAR versions for commercial ovens were updated in January 2023.

Steam Cookers Baseline

Per House Bill 2062[5] 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 makes 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).[6] 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:

[2] https://www.energystar.gov/ia/partners/product_specs/program_reqs/Commercial_HFHC_Program_Requirements_2.0.pdf
[3] https://www.energystar.gov/products/spec/commercial_ovens_specification_version_3_0_pd
[4] https://www.energystar.gov/sites/default/files/asset/document/2019%20Unit%20Shipment%20Data%20Summary%20Report.pdf
[5] https://olis.oregonlegislature.gov/liz/2021R1/Downloads/MeasureDocument/HB2062/Introduced
[6] “Automatic Conveyor Broiler, Commercial.” https://www.caetrm.com/measure/SWFS017/02/

- 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[7] 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 5. 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 5 Cooking equipment usage assumptions.

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 6 through Table 10. 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 4.

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 6.

Table 6 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. The double size is cost effective in Oregon, but the single size is not cost effective and, thus, not approved. In Washington, single and double sized rack ovens are approved. Rack oven efficiency metrics are shown in Table 7.

Table 7 Rack Ovens ENERGY STAR v3.0 – Gas –Efficiency Values

Rack Ovens ENERGY STAR v3.0 - 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 changed from v2.2 to v3.0 in January 2023.

Electric convection ovens are rated in half and full sizes and shown in Table 8.

[7] Fisher-Nickel, Inc. 2017. "Energy Efficient Underfired Broilers, ET ProjectNumber: ET16PGE1941." Prepared on behalf of Pacific Gas & Electric. March 24, 2017.

Table 8 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 and shown in Table 9. Gas convection ovens are not approved or cost effective in Oregon. They are approved in Washington.

Table 9 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 changed from v2.2 to v3.0 in January 2023.

Error! Reference source not found. and **Error! Reference source not found.**1 show efficiency metrics for ENERGY STAR version 3.0 electric and gas combination ovens, respectively. ENERGY STAR v3.0 requirements for electric combination ovens includes a sizing parameter based on pan capacity, which 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 80 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 91 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 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 102 shows efficiency metrics for both gas and electric steam cookers, including water use.

Table 102 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 113. 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

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

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 113 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. Most measure applications use RTF’s 2021 cost, while the newly approved measure application (Double Rack Ovens – Gas) includes additional inflation factors to 2023 dollars using RTF’s SIW v4.8[8]. 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.

[8] RTFStandardInformationWorkbook_v4_8: https://rtf.nwcouncil.org/standard-information-workbook/

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 12 includes a summary of inefficient, efficient, market baseline based on the weighting shown in Table 4, and incremental costs for all approved equipment. For measure applications where the incremental cost indicates a negative cost, $1 is used in cost effectiveness testing.

Table 12 - 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	$21,066.78	$23,231.46	$25,311.24	$2,079.78
Convection Oven - Electric - Half-size	$4,452.50	$4,826.93	$5,186.68	$359.75
Convection Oven - Electric - Full-size	$5,367.22	$6,099.03	$6,802.14	$703.11
Convection Oven - Gas - Full-size	$6,297.25	$7,127.86	$7,925.90	$798.04
Combination Oven - Electric 3-4 pan Capacity	$8,038.43	$6,727.68	$5,468.33	-$1,259.35
Combination Oven - Electric 5-40 pan Capacity	$21,742.58	$20,206.78	$18,731.20	-$1,475.58
Combination Oven - Gas	$26,192.40	$29,757.22	$33,182.24	$3,425.02
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. 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

- Any future code and standards 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 effectiveness screening for these measures is number 10.5.3 It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Commercial and Industrial\Food Service\Cooking Equipment

2021_MAD 101_All Equipment Savings .   101.5.3 OR-WA CEC_2024_v_1_2_Foo

Version History and Related Measures

Energy Trust has been offering the food service measure suite 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 135 Version History

Date	Version	Reason for revision
4/7/2005	x.x	Revise gas fryer measures
4/8/2005	x.x	Approve gas griddles
12/12/2005	x.x	Approve electric hot food holding cabinets and steam cookers
3/22/2007	x.x	Revise gas fryer savings, add gas convection oven
10/14/2009	101.x	Merge several cooking approvals into single document, revise all savings and costs, remove electric griddles and electric fryers.
7/16/2013	101.x	Update fryer costs
9/23/2013	101.x	Change format to include maximum incentives
8/7/2014	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
7/25/2018	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.
4/16/2019	233.3	Correct requirements regarding venthood types
10/12/2021	101.4	Removing several equipment types. Update costs and savings. Merged with MAD 233 which will be retired. Fryers moved to MAD 272
6/20/2023	101.5	Reintroduction of Rack Oven - Gas – Double for Oregon

Table 16 Related Measures

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

Approved & Reviewed by

Jackie Goss, PE
Sr. Engineer – Planning & Evaluation

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Measure Approval Document for Greenhouse Measures

Valid Dates
1/1/2023-12/31/2025

End Use or Description
Greenhouse weatherization and heating measures
- IR Film Polyethylene Greenhouse Covers on inner walls reduces heating loads in greenhouses by reducing heat loss through the walls and ceiling.
- Greenhouse thermal curtains are typically designed to be deployed horizontally above the growing zone within a greenhouse.
- Under-Bench heating systems are an alternative to unit heaters for keeping plant root zones warm. Typically, these are hydronic systems.

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 WA

Within these programs, applicability to the following building types are expected:
- Greenhouses

Within these programs, the measure is applicable to the following cases:
- Retrofit
- New, IR film and thermal curtain only

Purpose of Re-Evaluating Measure
There are no changes to the savings in this update. Costs 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 2023-v1.0. In Oregon the electric avoided cost year is 2023 and the gas avoided cost year is 2023. In Washington the gas avoided cost year is 2023. The values in these tables are per sqft of film or floor space.

Table 1 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	IR Poly Film (per SF of film)	4	0.00	0.23	$0.08	$0.00	$0.08	13.2	13.2	0%	100%
2	Thermal Curtain (per SF floor space)	10	0.00	0.41	$1.15	$0.00	$1.15	4.1	4.1	0%	100%
3	Under Bench Heating (per SF floor space)	12	0.00	1.25	$2.19	$0.00	$2.19	7.7	7.7	0%	100%

Table 2 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	IR Poly Film (per SF of film)	4	0.23	$0.08	$0.00	$0.08	19.5	19.5	0%	100%
2	Thermal Curtain (per SF floor space)	10	0.41	$1.15	$0.00	$1.15	6.0	6.0	0%	100%
3	Under Bench Heating (per SF floor space)	12	1.25	$2.19	$0.00	$2.19	11.3	11.3	0%	100%

Requirements
IR Film Polyethylene Greenhouse Cover
- Must be infrared polyethylene plastic with an anti-condensate coating.
- Must be upgrading from a non-IR cover.
- Must have a minimum life expectancy of 4 years.
- Minimum thinness of 6 mil.

Thermal Curtain
- Must be installed above heated space and drawn closed automatically at night
- Must be designed primarily to be a heat curtain
- Must have a rated energy savings rate of 40% or higher
- Must have a minimum life expectancy of 5 years.

Under-Bench Heating
- Heating system must use hydronic heat distribution located directly on or under plant bench, on the floor or in the floor.
- Must replace unit heaters as the primary heat source
- Remaining unit heaters must be controlled to turn on only as an emergency backup

Existing Condition Requirements
- These measures require natural gas as the heating fuel source.

Baseline
This measure uses a:
- Full Market Baseline for IR film and thermal curtains
- Existing Condition Baseline for under-bench heating

The baseline equipment consists of a representative single bay, 8,192 square foot greenhouse with an 80% efficient unit heater, no thermal curtain, and no IR film as outlined in ICF's greenhouse research piece[1]. There are no codes that apply to the equipment considered in these measures.

We assume IR film retrofits in the baseline of 16.8% of heated greenhouses based on experience of Cascade Energy. In the case of new construction thermal curtains, we assume the efficient equipment has minimal market share and new greenhouses are generally built without thermal curtains in the absence of incentives[2].

Measure Analysis

All savings are based on research conducted by ICF for Energy Trust completed in 2007. The eQUEST hourly simulation tool was used to model energy consumption for a baseline greenhouse. An additional 13 scenarios were modeled representing various combinations of the energy efficiency measures. Key modeling parameters included:

- Baseline Greenhouse – Single bay, 8,192 sf, 80% efficient unit heater, no thermal curtain, no IR film
- Heating System Options – 80% efficient unit heater (baseline), 86% efficient unit heater, under-bench heating system with 80% efficient hot water boiler
- Climate Zones – Willamette Valley and Bend/Redmond were modeled, but just one combination of measures was done at the Bend/Redmond climate zone. All savings are based on Willamette Valley climate zone, where the majority of projects are expected. This results in conservative savings. Projects in the Bend/Redmond climate zone.

Combining these measures in the same greenhouse will yield lower savings than the sum of the individual savings, particularly the combination of IR Film and Thermal Curtain. The interactive effects were modeled and used in the measure analysis, but deemed savings assume each measure is installed independently. Energy Trust revised these savings in 2015 to align with the latest knowledge, best practices and technology in the greenhouse sector.

IR Film

IR film on inner walls reduces heating loads in greenhouses by reducing heat loss through the walls and ceiling. The greenhouse modeled had a double layer inflated polyethylene roof and walls. Both the inner and outer layers were assumed be 6 mill clear polyethylene for the baseline case. For modeling scenarios with IR film, the inner film was assumed to be IR enhanced (outer layer remained clear polyethylene). A floor area to film area ratio of 60% was applied to correlate the savings to the film surface area. That rate of efficient base case has is assumed to be to 16.8% based on analysis completed by Cascade Energy in 2009.

Thermal Curtain

Greenhouse thermal curtains are typically designed to be deployed horizontally above the growing zone within a greenhouse. Side wall curtains, although less common, are also used. For horizontal curtains, energy is saved in three ways. First, horizontal curtains trap air above the curtain and below the roof line. This trapped air forms an insulating barrier that reduces heat losses due to conduction through the roof. Second, curtains reduce the volume of air inside the greenhouse that needs to be heated, and effectively contain the conditioned air within the desired heated space. Third, curtain fabrics are often constructed with aluminum strips or other reflective materials. These reflective curtains help reflect heat back into the greenhouse, thereby reducing the amount of radiation that escapes through the roof or side walls.

Modeling showed the impact of adding thermal curtains and IR film as separate measures to the baseline greenhouse, as well as adding both measures. Alone, the addition of a thermal curtain reduced energy consumption in the models approximately 24%, 0.41 therms/sf.

Under-Bench Heating

Bench heating systems are an alternative to unit heaters for keeping plant root zones warm. With under-bench heating systems, pipe or tubing is located below the bench, and hot water is circulated through the system to keep the plant beds warm. Depending on the water temperature, either plastic or metal materials can be used for the water circulation loop. Bench heating systems are known to reduce energy use compared to unit heaters because these systems offer a more efficient means of keeping plant root zones at the desired temperature. With bench systems, the volume of greenhouse air that is heated to achieve a desired root zone temperature is reduced compared to unit heaters, thereby reducing natural gas consumption. One contributing factor to the reduced natural gas consumption for under-bench heating systems is that the greenhouse setpoint temperature can typically be reduced for an under bench system compared to a unit heater.

For the eQUEST modeling it was assumed that the setpoint temperature can be reduced 7° F for an under-bench system, while still maintaining the same root zone temperature. This setpoint reduction contributes to 74% gas use reduction, 1.25 therms/sf. Gas savings were calculated from ICF data. The percent energy savings was calculated from the incremental energy intensity between the baseline standard (80%) efficiency unit heater (0.92 therms/sqft) and the upgrade standard (80%) efficiency underbench heater (0.24 therms/sqft). This represents a reduction of 0.68 therms/sqft or 74%. This savings ratio was then applied to the baseline greenhouse energy intensity of 1.69 therms/sqft to arrive at 1.25 therms/sqft of savings.

Measure Life

IR Film

IR film is generally sold with a 1-year or 4-year lifetime expectation, the program requires products to have a 4-year expected life.

Thermal Curtains

Thermal curtain systems have can be considered in two parts, the mechanical support and control system and the curtain itself. Curtains are typically rated at 5 years, which is the typical manufacturer claim and the measure life in use in other areas. Distributers in our area indicate that 5-8 years is normal. However, the costs and baseline assumptions used in this analysis assume a new curtain system not a replacement and include the costs of the mechanicals. Mechanical portions of the system are expected to have a life exceeding 10 years. A measure life of 10 years is used, with the assumption that an additional curtain will be purchased within that time.

Under-Bench Heating

Under-bench heating systems are expected to have a measure life of 12 years, although some components, such as the boilers are expected to persist much longer.

Load Profile

Com Heating

[1] ICF International, (August 2007). *Natural Gas Energy Efficiency Measures for Greenhouses*
[2] Southern California Edison. (2009). *Greenhouse Thermal Curtains* (Work Paper PGECOAGR101 Ver00)

Cost
Costs are averages of projects that participated in Energy Trust programs between 2010 and 2015. There was not sufficient evidence that costs have changed significantly from more recent project data.

IR Film
IR film costs ranged from $0.06 to $0.22 with an average cost of $0.10 per sf. Only 2 projects were over $0.20. Even the most expensive installation is cost effective. The costs for IR Poly were adjusted to account for the 16.8% full market penetration.

Thermal Curtains
Thermal curtains ranged from $0.26 to $2.63 per sf with an average cost of $0.90. Two projects over this period have been more expensive than the limits of the cost effectiveness test. These appear to be anomalous cases of particularly small greenhouses, which did not achieve an economy of scale for labor or shipping costs. On the low end of the cost range is a project whose invoice only includes the cost of the curtain and does not include the mechanical portion of the project cost. Conversation with the suppliers indicated that curtains account for approximately 40% of project cost. The cost of a replacement curtain was assumed for year six, and the present value of that cost ($0.25) added to the initial cost of the curtain and mechanicals, for a total of $1.15.

Under-bench Heating
Under-bench heating systems ranged from $0.89 to $5.00 per sf with the average cost of $2.19. All projects are within the cost effective range. This is a particularly large range because while savings are best measured on a per SF basis, the cost of the heating system is also defendant other variables such as spacing of growing benches and existing equipment on site.

Non Energy Benefits
IR film and thermal curtains save electricity in addition to gas. The amount of electricity is too small per square foot to be processed or quantified reliably, about 0.1 kWh/sf. Customers in large sites may benefit from reduced electricity bills.

Incentive Structure
The maximum incentives listed in Table 1 and Table 2 are for reference only and are not suggested incentives. IR film incentives are based on square footage of film, while thermal curtains and under-bench heating are based on conditioned floor area. Incentives are not to exceed project costs.

While this measure is primarily used by the Production Efficiency program in Oregon, it may also be implemented by the Existing Buildings program in Washington, where EB has responsibility for industrial and agricultural gas projects including greenhouses. Alignment of incentives between the programs is recommended.

Follow-Up
New materials may become available that could extend the service life of the IR Poly measure. If these materials become common, the measure life for this measure should be reevaluated.

The prevalence of under-bench heating in the market baseline should be considered in the next update which could make that measure available to new construction.

The EUL for each measure application should be reevaluated.

Assumptions and methodology used in the eQUEST models may be revisited.

Supporting Documents
The cost effectiveness screening for these measures is number 104.3.2. It is attached and can be found along with supporting documentation at: \\Etoo.org\home\Groups\Planning\Measure Development\Commercial and Industrial\Agriculture\greenhouse\Greenhouse film curtains under bench

104.3.2 CE Calculator_2023_v_1

Version History and Related Measures
Energy Trust has been offering Greenhouse Measures for many years. These predate our measure approval documentation process and record retention requirements. Table 3 may be incomplete, particularly for measures approved prior to 2013.

Table 3 Version History

Date	Version	Reason for revision
11/2/2007	104.x	Introduce Greenhouse Measures
9/18/2014	104.x	Updated all measures, add existing buildings in Washington, removed unit heater
6/15/2015	104.1	Incremental cost update, update measure life
6/04/2019	104.2	Extend expiration date, update max incentives
9/29/2022	104.3	Updated costs and avoided costs

Table 4 Related Measures

Measures	MAD ID
Greenhouse Controller	103
Condensing Unit Heaters in Greenhouses	134

Approved & Reviewed by

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Jackie Goss, PE
Sr. Engineer – Planning & Evaluation

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Measure Approval Document for Greenhouse Measures

Valid Dates
1/1/2023-12/31/2025

End Use or Description
Greenhouse weatherization and heating measures
- IR Film Polyethylene Greenhouse Covers on inner walls reduces heating loads in greenhouses by reducing heat loss through the walls and ceiling.
- Greenhouse thermal curtains are typically designed to be deployed horizontally above the growing zone within a greenhouse.
- Under-Bench heating systems are an alternative to unit heaters for keeping plant root zones warm. Typically, these are hydronic systems.

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 WA

Within these programs, applicability to the following building types are expected:
- Greenhouses

Within these programs, the measure is applicable to the following cases:
- Retrofit
- New, IR film and thermal curtain only

Purpose of Re-Evaluating Measure
There are no changes to the savings in this update. Costs 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 2023-v1.0. In Oregon the electric avoided cost year is 2023 and the gas avoided cost year is 2023. In Washington the gas avoided cost year is 2023. The values in these tables are per sqft of film or floor space.

Table 1 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	IR Poly Film (per SF of film)	4	0.00	0.23	$0.08	$0.00	$0.08	13.2	13.2	0%	100%
2	Thermal Curtain (per SF floor space)	10	0.00	0.41	$1.15	$0.00	$1.15	4.1	4.1	0%	100%
3	Under Bench Heating (per SF floor space)	12	0.00	1.25	$2.19	$0.00	$2.19	7.7	7.7	0%	100%

Table 2 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	IR Poly Film (per SF of film)	4	0.23	$0.08	$0.00	$0.08	19.5	19.5	0%	100%
2	Thermal Curtain (per SF floor space)	10	0.41	$1.15	$0.00	$1.15	6.0	6.0	0%	100%
3	Under Bench Heating (per SF floor space)	12	1.25	$2.19	$0.00	$2.19	11.3	11.3	0%	100%

Requirements
IR Film Polyethylene Greenhouse Cover
- Must be infrared polyethylene plastic with an anti-condensate coating.
- Must be upgrading from a non-IR cover.
- Must have a minimum life expectancy of 4 years.
- Minimum thinness of 6 mil.

Thermal Curtain
- Must be installed above heated space and drawn closed automatically at night
- Must be designed primarily to be a heat curtain
- Must have a rated energy savings rate of 40% or higher
- Must have a minimum life expectancy of 5 years.

Under-Bench Heating
- Heating system must use hydronic heat distribution located directly on or under plant bench, on the floor or in the floor.
- Must replace unit heaters as the primary heat source
- Remaining unit heaters must be controlled to turn on only as an emergency backup

Existing Condition Requirements
- These measures require natural gas as the heating fuel source.

Baseline
This measure uses a:
- Full Market Baseline for IR film and thermal curtains
- Existing Condition Baseline for under-bench heating

The baseline equipment consists of a representative single bay, 8,192 square foot greenhouse with an 80% efficient unit heater, no thermal curtain, and no IR film as outlined in ICF's greenhouse research piece[1]. There are no codes that apply to the equipment considered in these measures.

We assume IR film retrofits in the baseline of 16.8% of heated greenhouses based on experience of Cascade Energy. In the case of new construction thermal curtains, we assume the efficient equipment has minimal market share and new greenhouses are generally built without thermal curtains in the absence of incentives[2].

Measure Analysis

All savings are based on research conducted by ICF for Energy Trust completed in 2007. The eQUEST hourly simulation tool was used to model energy consumption for a baseline greenhouse. An additional 13 scenarios were modeled representing various combinations of the energy efficiency measures. Key modeling parameters included:

- Baseline Greenhouse – Single bay, 8,192 sf, 80% efficient unit heater, no thermal curtain, no IR film
- Heating System Options – 80% efficient unit heater (baseline), 86% efficient unit heater, under-bench heating system with 80% efficient hot water boiler
- Climate Zones – Willamette Valley and Bend/Redmond were modeled, but just one combination of measures was done at the Bend/Redmond climate zone. All savings are based on Willamette Valley climate zone, where the majority of projects are expected. This results in conservative savings. Projects in the Bend/Redmond climate zone.

Combining these measures in the same greenhouse will yield lower savings than the sum of the individual savings, particularly the combination of IR Film and Thermal Curtain. The interactive effects were modeled and used in the measure analysis, but deemed savings assume each measure is installed independently. Energy Trust revised these savings in 2015 to align with the latest knowledge, best practices and technology in the greenhouse sector.

IR Film

IR film on inner walls reduces heating loads in greenhouses by reducing heat loss through the walls and ceiling. The greenhouse modeled had a double layer inflated polyethylene roof and walls. Both the inner and outer layers were assumed be 6 mill clear polyethylene for the baseline case. For modeling scenarios with IR film, the inner film was assumed to be IR enhanced (outer layer remained clear polyethylene). A floor area to film area ratio of 60% was applied to correlate the savings to the film surface area. That rate of efficient base case has is assumed to be to 16.8% based on analysis completed by Cascade Energy in 2009.

Thermal Curtain

Greenhouse thermal curtains are typically designed to be deployed horizontally above the growing zone within a greenhouse. Side wall curtains, although less common, are also used. For horizontal curtains, energy is saved in three ways. First, horizontal curtains trap air above the curtain and below the roof line. This trapped air forms an insulating barrier that reduces heat losses due to conduction through the roof. Second, curtains reduce the volume of air inside the greenhouse that needs to be heated, and effectively contain the conditioned air within the desired heated space. Third, curtain fabrics are often constructed with aluminum strips or other reflective materials. These reflective curtains help reflect heat back into the greenhouse, thereby reducing the amount of radiation that escapes through the roof or side walls.

Modeling showed the impact of adding thermal curtains and IR film as separate measures to the baseline greenhouse, as well as adding both measures. Alone, the addition of a thermal curtain reduced energy consumption in the models approximately 24%, 0.41 therms/sf.

Under-Bench Heating

Bench heating systems are an alternative to unit heaters for keeping plant root zones warm. With under-bench heating systems, pipe or tubing is located below the bench, and hot water is circulated through the system to keep the plant beds warm. Depending on the water temperature, either plastic or metal materials can be used for the water circulation loop. Bench heating systems are known to reduce energy use compared to unit heaters because these systems offer a more efficient means of keeping plant root zones at the desired temperature. With bench systems, the volume of greenhouse air that is heated to achieve a desired root zone temperature is reduced compared to unit heaters, thereby reducing natural gas consumption. One contributing factor to the reduced natural gas consumption for under-bench heating systems is that the greenhouse setpoint temperature can typically be reduced for an under bench system compared to a unit heater.

For the eQUEST modeling it was assumed that the setpoint temperature can be reduced 7° F for an under-bench system, while still maintaining the same root zone temperature. This setpoint reduction contributes to 74% gas use reduction, 1.25 therms/sf. Gas savings were calculated from ICF data. The percent energy savings was calculated from the incremental energy intensity between the baseline standard (80%) efficiency unit heater (0.92 therms/sqft) and the upgrade standard (80%) efficiency underbench heater (0.24 therms/sqft). This represents a reduction of 0.68 therms/sqft or 74%. This savings ratio was then applied to the baseline greenhouse energy intensity of 1.69 therms/sqft to arrive at 1.25 therms/sqft of savings.

Measure Life

IR Film

IR film is generally sold with a 1-year or 4-year lifetime expectation, the program requires products to have a 4-year expected life.

Thermal Curtains

Thermal curtain systems have can be considered in two parts, the mechanical support and control system and the curtain itself. Curtains are typically rated at 5 years, which is the typical manufacturer claim and the measure life in use in other areas. Distributers in our area indicate that 5-8 years is normal. However, the costs and baseline assumptions used in this analysis assume a new curtain system not a replacement and include the costs of the mechanicals. Mechanical portions of the system are expected to have a life exceeding 10 years. A measure life of 10 years is used, with the assumption that an additional curtain will be purchased within that time.

Under-Bench Heating

Under-bench heating systems are expected to have a measure life of 12 years, although some components, such as the boilers are expected to persist much longer.

Load Profile

Com Heating

[1] ICF International, (August 2007). *Natural Gas Energy Efficiency Measures for Greenhouses*
[2] Southern California Edison. (2009). *Greenhouse Thermal Curtains* (Work Paper PGECOAGR101 Ver00)

Cost

Costs are averages of projects that participated in Energy Trust programs between 2010 and 2015. There was not sufficient evidence that costs have changed significantly from more recent project data.

IR Film

IR film costs ranged from $0.06 to $0.22 with an average cost of $0.10 per sf. Only 2 projects were over $0.20. Even the most expensive installation is cost effective. The costs for IR Poly were adjusted to account for the 16.8% full market penetration.

Thermal Curtains

Thermal curtains ranged from $0.26 to $2.63 per sf with an average cost of $0.90. Two projects over this period have been more expensive than the limits of the cost effectiveness test. These appear to be anomalous cases of particularly small greenhouses, which did not achieve an economy of scale for labor or shipping costs. On the low end of the cost range is a project whose invoice only includes the cost of the curtain and does not include the mechanical portion of the project cost. Conversation with the suppliers indicated that curtains account for approximately 40% of project cost. The cost of a replacement curtain was assumed for year six, and the present value of that cost ($0.25) added to the initial cost of the curtain and mechanicals, for a total of $1.15.

Under-bench Heating

Under-bench heating systems ranged from $0.89 to $5.00 per sf with the average cost of $2.19. All projects are within the cost effective range. This is a particularly large range because while savings are best measured on a per SF basis, the cost of the heating system is also defendant other variables such as spacing of growing benches and existing equipment on site.

Non Energy Benefits

IR film and thermal curtains save electricity in addition to gas. The amount of electricity is too small per square foot to be processed or quantified reliably, about 0.1 kWh/sf. Customers in large sites may benefit from reduced electricity bills.

Incentive Structure

The maximum incentives listed in Table 1 and Table 2 are for reference only and are not suggested incentives. IR film incentives are based on square footage of film, while thermal curtains and under-bench heating are based on conditioned floor area. Incentives are not to exceed project costs.

While this measure is primarily used by the Production Efficiency program in Oregon, it may also be implemented by the Existing Buildings program in Washington, where EB has responsibility for industrial and agricultural gas projects including greenhouses. Alignment of incentives between the programs is recommended.

Follow-Up

New materials may become available that could extend the service life of the IR Poly measure. If these materials become common, the measure life for this measure should be reevaluated.

The prevalence of under-bench heating in the market baseline should be considered in the next update which could make that measure available to new construction.

The EUL for each measure application should be reevaluated.

Assumptions and methodology used in the eQUEST models may be revisited.

Supporting Documents

The cost effectiveness screening for these measures is number 104.3.2. It is attached and can be found along with supporting documentation at: \\Etoo.org\home\Groups\Planning\Measure Development\Commercial and Industrial\Agriculture\greenhouse\Greenhouse film curtains under bench

104.3.2 CE Calculator_2023_v_1

Version History and Related Measures

Energy Trust has been offering Greenhouse Measures for many years. These predate our measure approval documentation process and record retention requirements. Table 3 may be incomplete, particularly for measures approved prior to 2013.

Table 3 Version History

Date	Version	Reason for revision
11/2/2007	104.x	Introduce Greenhouse Measures
9/18/2014	104.x	Updated all measures, add existing buildings in Washington, removed unit heater
6/15/2015	104.1	Incremental cost update, update measure life
6/04/2019	104.2	Extend expiration date, update max incentives
9/29/2022	104.3	Updated costs and avoided costs

Table 4 Related Measures

Measures	MAD ID
Greenhouse Controller	103
Condensing Unit Heaters in Greenhouses	134

Approved & Reviewed by

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Jackie Goss, PE
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Measure Approval Document for Multifamily Insulation

Valid Dates
1/1/2023 – 12/31/2025

End Use or Description
Insulation for attics, ceiling, and floors of stacked multifamily (MF) buildings. Improved insulation reduces heat losses and gains from the building envelope, and this reduces heating and cooling loads on the HVAC system and produces energy 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

Within these programs, applicability to the following building types is required:

- Existing Multifamily buildings with 5 or more units

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

- Retrofit

Purpose of Re-Evaluating Measure
110.4:

- Clarify measure names to describe required minimum existing condition instead of nominal existing condition.

100.3:

- The savings calculation methodology was updated, wall insulation measures were introduced, and measure costs were updated.
- This update removed the flat-roof measure because they were not expected to be cost effective. The program received very low participation for it, and this did not support justifying an OPUC exception.

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 2023-v1.0. In Oregon the electric avoided cost year is 2023 and the gas avoided cost year is 2023. In Washington the gas avoided cost year is 2023. The values in these tables are per square feet (sf).

Table 1 Cost Effectiveness Calculator Oregon, per SF

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
2	MF Attic Insulation R11 or less - R49 HZ1 Zonal Elec. Res. Heat	45	0.97	0.00	1.41	$0.00	$1.41	1.2	1.2	100%	0%
3	MF Floor Insulation R11 or less - R30 HZ1 Zonal Elec. Res. Heat	45	1.38	0.00	1.90	$0.00	$1.90	1.3	1.3	100%	0%
4	MF Wall Insulation R6 or less - R11 HZ1 Zonal Elec. Res. Heat	45	2.09	0.00	2.24	$0.00	$2.24	1.6	1.6	100%	0%
5	MF Attic Insulation R11 or less - R49 HZ2 Zonal Elec. Res. Heat	45	1.07	0.00	1.41	$0.00	$1.41	1.3	1.3	100%	0%
6	MF Floor Insulation R11 or less - R30 HZ2 Zonal Elec. Res. Heat	45	1.76	0.00	1.90	$0.00	$1.90	1.6	1.6	100%	0%
7	MF Wall Insulation R6 or less - R11 HZ2 Zonal Elec. Res. Heat	45	2.76	0.00	2.24	$0.00	$2.24	2.2	2.2	100%	0%
8	MF Attic Insulation R11 or less - R49 HZ1 Gas Heat	45	0.02	0.05	1.41	$0.00	$1.41	1.1	1.1	8%	92%
9	MF Floor Insulation R11 or less - R30 HZ1 Gas Heat	45	0.03	0.06	1.90	$0.00	$1.90	1.1	1.1	8%	92%
10	MF Wall Insulation R6 or less - R11 HZ1 Gas Heat	45	0.05	0.10	2.24	$0.00	$2.24	1.5	1.5	8%	92%
11	MF Attic Insulation R11 or less - R49 HZ2 Gas Heat	45	0.02	0.05	1.41	$0.00	$1.41	1.2	1.2	6%	94%
12	MF Floor Insulation R11 or less - R30 HZ2 Gas Heat	45	0.02	0.08	1.90	$0.00	$1.90	1.4	1.4	6%	94%
13	MF Wall Insulation R6 or less - R11 HZ2 Gas Heat	45	0.04	0.13	2.24	$0.00	$2.24	2.0	2.0	6%	94%
15	MF Attic Insulation R11 or less - R49 HZ1 Gas Heat G.o.T	45	0.00	0.05	1.41	$0.00	$1.41	1.0	1.1	0%	100%
16	MF Floor Insulation R11 or less - R30 HZ1 Gas Heat G.o.T	45	0.00	0.06	1.90	$0.00	$1.90	1.0	1.0	0%	100%
17	MF Wall Insulation_R6 or less - R11_HZ1_Gas Heat_G.o.T	45	0.00	0.10	2.24	$0.01	$2.24	1.4	1.4	0%	100%
18	MF Attic Insulation R11 or less - R49 HZ2 Gas Heat G.o.T	45	0.00	0.05	1.41	$0.00	$1.41	1.1	1.2	0%	100%
19	MF Floor Insulation R11 or less - R30 HZ2 Gas Heat G.o.T	45	0.00	0.08	1.90	$0.00	$1.90	1.3	1.3	0%	100%
20	MF Wall Insulation R6 or less - R11 HZ2 Gas Heat G.o.T	45	0.00	0.13	2.24	$0.00	$2.24	1.9	1.9	0%	100%

Table 2 Cost Effectiveness Calculator Washington, per SF

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	MF Attic Insulation R11 or less - R49 HZ1 Gas Heat	45	0.05	1.41	$0.00	$1.41	1.4	1.5	0%	100%
2	MF Floor Insulation R11 or less - R30 HZ1 Gas Heat	45	0.06	1.90	$0.00	$1.90	1.4	1.4	0%	100%
3	MF Wall Insulation R6 or less - R11 HZ1 Gas Heat	45	0.10	2.24	$0.00	$2.24	1.9	2.0	0%	100%
4	MF Attic Insulation R11 or less - R49 HZ2 Gas Heat	45	0.05	1.41	$0.00	$1.41	1.6	1.6	0%	100%
5	MF Floor Insulation R11 or less - R30 HZ2 Gas Heat	45	0.08	1.90	$0.00	$1.90	1.8	1.8	0%	100%
6	MF Wall Insulation R6 or less - R11 HZ2 Gas Heat	45	0.13	2.24	$0.00	$2.24	2.6	2.6	0%	100%

Requirements

- All insulation must be installed in areas of the building envelope that separate conditioned space and unconditioned space. Insulation installed between conditioned spaces does not qualify.
- Attic insulation requirements:
  - For unconditioned attics, the attic floor must be retrofitted to R49 or highest R-value insulation approaching R49 that can be practically installed. Existing insulation installed on the attic floor must be R11 or less.
  - For conditioned attics, the attic ceiling or underside of roof deck must be retrofitted to R49 or highest R-value insulation approaching R49 that can be practically installed. Existing insulation installed on the attic ceiling or underside of roof deck must be R11 or less.
- Floor insulation requirements:
  - Existing insulation must be R11 or less.
  - Must retrofit to R30 or highest R-value insulation approaching R30 that can be practically installed.
- Wall insulation requirements:
  - Existing insulation must be R6 or less.
  - Must retrofit to R11 or highest R-value insulation approaching R11 that can be practically installed.

Baseline

This measure uses an Existing Condition Baseline.

The baseline is a multifamily building with little or no existing insulation in attics, floors, or building walls.

Measure Analysis and Savings Methodology

The analysis is based on the RTF's Res MF Weatherization Workbook v5.0[1] (April 18, 2022). The sub-sections below describe the methodology used to estimate heating and cooling savings.

Heating Energy Savings

Heating savings estimates are based on RTF's Res MF Weatherization Workbook v5.0 without any modifications to the assumptions or results. The RTF workbook results are based on multiple runs of the calibrated SEEM simulation engine, which are documented in the MFWeatherizationSEEMWorkbookV2 6[2] (Jan 18, 2019). This SEEM model has been calibrated using the MF RBSA data for buildings with electric heating.

SEEM simulations were run to generate heating energy use for baseline and measure cases for different heating system types and heating zones. Energy savings results for only zonal electric resistance and natural gas-fired forced air furnace heating system types and heating zones HZ1 & HZ2 were used in this analysis. The savings are calculated as the difference of heating energy use in baseline and measure cases. Internal gains, thermostat set point (68F) and parameters such as ceiling assembly effective R-value, wall assembly effective R-value, floor assembly effective R-value, window U-value and solar heat gain coefficient, are the key SEEM inputs for this measure. Assumed values for none of the above parameters were modified. The detailed assumptions for these parameters are described thoroughly in the 'Summary' sheet of the Res MF Weatherization Workbook v4.3[3].

For gas heating systems, the electric heating energy output from the SEEM runs for electric forced air furnace are divided by the gas heating system efficiency (assumed to be 80%) and then converted from kWh to therms to estimate the annual heating energy use in therms. Fan savings are neglected.

Cooling Energy Savings

The RTF's analysis does not estimate cooling savings. The cooling savings were estimated using the following assumptions and steps:

- For homes with cooling, heating savings are assumed to be proportional to HDD and cooling savings proportional to CDD in each climate zone. Put another way, the ratio of CDD to HDD is assumed to be equal to the ratio of cooling savings to heating savings. Using the above assumption, the cooling savings are calculated as the product of heating savings and ratio of CDD to HDD as shown in the equation below:

$$Cooling\ Savings = \frac{CDD}{HDD} \times Heating\ Savings$$

- Cooling savings were weighted per the prevalence of existing cooling installed in Multifamily buildings in the region. The RBSA II (2016-17) for Multifamily Buildings[4] estimates that 28% of the MF units have cooling installed.

The 2022 Measure Development Technical Guidelines was used for CDD and HDD estimates. Cooling zones CZ1 and CZ2 were blended using the population weightings shown in Table 3. CZ3 was not included in the weighting as it represents a very small population.

[1] Res MF Weatherization Workbook v5.0, Regional Technical Forum
[2] MFWeatherizationSEEMWorkbook v2.6, Regional Technical Forum
[3] Res MF Weatherization Workbook v4.3, Regional Technical Forum
[4] Residential Buildings Stock Assessment (RBSA) – II for Multifamily Buildings (2016-17), Northwest Energy Efficiency Alliance (NEEA)

Table 3 Energy Trust Cooling Zones and Population Weightings

Cooling Zone	Territory Average CDD	Energy Trust Population Weighting	Weighted CDD from CZ1 and CZ2
1	214	40%	320
2	405	50%	
3	759	10%	

Table 4 Energy Trust Heating Zones and Calculated weighted CDD/HDD ratio

Heating Zone	Territory Average HDD	CZ1/CZ2	Weighted cooling savings as a percent of heating savings
1	4590	7%	2.0%
2	6530	5%	1.4%

For MF buildings with electric heating and cooling, the units for the above equation are consistent in kWh. Whereas for MF buildings with natural gas heating, cooling savings were calculated as a percentage of heating savings (in Therms) and then were multiplied by an assumed boiler efficiency of 80% and converted to kWh using the relation 1 Therm = 29.31 kWh.

Total Savings

Table 5 summarizes total savings as a sum of heating and cooling savings for a sample of measures with different type of heating systems and heating zones. Note that total kWh savings for all rows are rounded up to two decimal places.

Table 5 Total Savings for Select Measures

CEC row	Measure Application	Heating Savings		Cooling Savings (kWh/sf)	Total kWh Savings (kWh/sf)	Total Therm Savings (Therm/sf)	Cooling Savings/Total Savings
		kWh/sf	Therms/sf				
2	Attic Insulation_R11 - R49_HZ1_Zonal Elec. Res. Heat	0.95	0.00	0.02	0.97	0.00	2.0%
5	Attic Insulation_R11 - R49_HZ2_Zonal Elec. Res. Heat	1.05	0.00	0.01	1.07	0.00	1.3%
8	Attic Insulation_R11 - R49_HZ1_Gas Heat	0.00	0.05	0.02	0.02	0.05	2.0%

Comparison to RTF or other programs

The heating energy estimates used for this measure are based on the RTF's Multifamily Weatherization UES. Cooling savings were not estimated in the RTF's analysis and were estimated using the methodology described above.

MAD 58 approves single family and small multifamily insulation retrofits, which is applicable to single-family homes, existing manufactured homes, and small multifamily buildings with up to 4 units. Savings a different than these measures due to differences in building construction and design.

Measure Life

The measure life for residential-style insulation is 45 years, and this is consistent with the RTF's assumption and other Energy Trust insulation measures.

Load Profile

Table 6 Electric and Gas Load Profiles

	Electric Load Profile	Gas Load Profile
Measures with electric heat	Res Zonal Ele Heat	None- gas
Measures with gas heat	Res Window AC	Res Heating

Cost

Project Tracker data was used to estimate the full installed cost of insulation. Data single family and small multifamily insulation retrofits (Jan 2020 to May 2022) was used to estimate costs because data for very few projects was available for the MF insulation measure (less than 10 projects for each type of insulation). A median of the cost data (in $/sq. ft.) was calculated and is shown in Table 7 for attic, floor, and wall insulation projects.

Table 7 Incremental Costs by Measure

Measure Type	Incremental cost ($ per sf)
Attic insulation	$1.41
Floor insulation	$1.90
Wall insulation	$2.24

Non Energy Benefits

Electric savings in gas-only territory are calculated and valued as a non-energy benefits. The kWh savings estimate is multiplied with the blended residential electricity rate of $0.116/kWh in Oregon and $0.082/kWh in Washington.

There are significant, non-quantifiable non-energy benefits from improved insulation including thermal comfort, noise reduction, and reduction of heat/cold-related illnesses[5].

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 feet of installed insulation.

Follow-Up

If RTF's methodology and savings results are used in the next MAD update, the Program should review the latest RTF workbook for MF Weatherization UES.

The RTF's Research Strategy for Weatherization in Multifamily Homes with Electric-Resistance Heat approved in July, 2020[6] states the partially calibrated SEEM modeling results (which are used in this analysis) provide some basis for estimating the correlation

[5] Health and Household-related Benefits Attributable to the Weatherization Assistance Program, Oak Ridge National Laboratory, 2014
[6] Research Strategy for Weatherization in Multifamily Homes with Electric Resistance Heat, July 2020, Regional Technical Forum

between energy consumption and building shell efficiency, but they are of limited precision. The research strategy proposes collecting pre/post billing and audit data of weatherized MF buildings. The next update should review the status of this approved research strategy. If its results were used to update RTF's Multifamily Weatherization energy savings results, then it is recommended to update the savings results for this MAD using the latest RTF Multifamily Weatherization workbook.

Supporting Documents

The cost effectiveness screening for these measures is number 110.4.3. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Residential\Multifamily\Weatherization\Multifamily insulation\insulation

110.4.3 OR WA CE Calculator 2023 v1.0

Version History and Related Measures

Energy Trust has been offering multifamily insulation measures for many years. These predate our measure approval documentation process and record retention requirements. Table 8may be incomplete, particularly for measures approved prior to 2013.

Table 8 Version History

Date	Version	Reason for revision
6/10/2005	x	Introduce large multifamily insulation measures
3/1/2007	x	Ceiling, Floor and Wall insulation for single family
9/10/2007	106	Knee Wall insulation for single family and small multifamily
2010	x	Update large multifamily insulation savings based on Robison Analysis
5/9/2011	x	Includes small multifamily on all existing single family insulation measures
2/27/2013	110.x	Combine all multifamily insulation measures into one document. Supersedes the use of single family MADs for multifamily insulation measures. Update heating load assumptions for smaller multifamily properties. Update costs and tax credits for both buildings types.
4/5/2013	110.x	Corrected error affecting gas savings for larger properties.
10/14/2016	110.1	Add flat roof insulation
9/30/2019	110.2	Side by side measures moved to Res MAD 58. Cooling savings added. Costs updated. Tax credit removed. Add Washington and gas-only measures
8/22/2022	110.3	Methodology aligned with RTF, wall insulation measure introduced, flat-roof insulation measure removed, costs updated.
10/6/2022	110.4	Clarified measures names.

Table 9 Related Measures

Measures	MAD ID
Single Family and small multifamily Insulation	58
Commercial Insulation	68

Approved & Reviewed by

Jackie Goss, PE
Sr. Engineer – Planning & Evaluation

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Measure Approval Document for Multifamily Pipe Insulation

Valid Dates
1/1/2023 – 12/31/2025

End Use or Description
Pipe insulation reduces heat loss from uninsulated low-pressure steam (LPS) pipes, domestic hot water (DHW) pipes, or heating hot water (HHW) pipes for space heating. This reduced heat loss from piping reduces natural gas consumption in a boiler/water heater and produces energy 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

Within these programs, applicability to the following building types is required:

- Existing Multifamily buildings with 5 or more units

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

- Retrofit

Purpose of Re-Evaluating Measure
Savings calculations and measure costs were updated, resulting in changes to approved pip size ranges.
Heating hot water measure applications were added.
PVC was added as an allowable jacketing, in addition to aluminum, for exterior piping.

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 2023-v1.0. In Oregon the electric avoided cost year is 2023 and the gas avoided cost year is 2023. In Washington the gas avoided cost year is 2023. The values in these tables are per linear foot (LF).

Table 1 Cost Effectiveness Calculator Oregon, per LF

#	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	3/4" DHW MF pipe insulated to 1.5"	15	0.00	2.27	$16.91	$0.00	$16.91	1.5	1.5	0%	100%
2	1" DHW MF pipe insulated to 1.5"	15	0.00	2.79	$18.41	$0.00	$18.41	1.7	1.7	0%	100%
3	2" DHW MF pipe insulated to 2"	15	0.00	4.87	$25.49	$0.00	$25.49	2.2	2.2	0%	100%
4	3" DHW MF pipe insulated to 2"	15	0.00	6.88	$31.47	$0.00	$31.47	2.5	2.5	0%	100%
5	4" DHW MF pipe insulated to 2"	15	0.00	8.61	$37.46	$0.00	$37.46	2.6	2.6	0%	100%
7	1" LPS (<15 psig) MF pipe insulated to 1.5"	15	0.00	2.12	$33.48	$0.00	$33.48	1.0	1.0	0%	100%
8	2" LPS (<15 psig) MF pipe insulated to 2"	15	0.00	3.69	$40.56	$0.00	$40.56	1.5	1.5	0%	100%
9	3" LPS (<15 psig) MF pipe insulated to 2"	15	0.00	5.19	$46.54	$0.00	$46.54	1.8	1.8	0%	100%
10	4" LPS (<15 psig) MF pipe insulated to 2"	15	0.00	6.49	$52.53	$0.00	$52.53	2.0	2.0	0%	100%
14	3" HHW MF pipe insulated to 2"	15	0.00	3.13	$46.54	$0.00	$46.54	1.1	1.1	0%	100%
15	4" HHW MF pipe insulated to 2"	15	0.00	3.91	$52.53	$0.00	$52.53	1.2	1.2	0%	100%

Table 2 Cost Effectiveness Calculator Washington, per LF

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	3/4" DHW MF pipe insulated to 1.5"	15	2.27	$16.91	$0.00	$16.91	2.0	2.0	0%	100%
2	1" DHW MF pipe insulated to 1.5"	15	2.79	$18.41	$0.00	$18.41	2.2	2.2	0%	100%
3	2" DHW MF pipe insulated to 2"	15	4.87	$25.49	$0.00	$25.49	2.8	2.8	0%	100%
4	3" DHW MF pipe insulated to 2"	15	6.88	$31.47	$0.00	$31.47	3.2	3.2	0%	100%
5	4" DHW MF pipe insulated to 2"	15	8.61	$37.46	$0.00	$37.46	3.4	3.4	0%	100%
6	3/4" LPS (<15 psig) MF pipe insulated to 1.5"	15	1.73	$31.98	$0.00	$31.98	1.2	1.2	0%	100%
7	1" LPS (<15 psig) MF pipe insulated to 1.5"	15	2.12	$33.48	$0.00	$33.48	1.4	1.4	0%	100%
8	2" LPS (<15 psig) MF pipe insulated to 2"	15	3.69	$40.56	$0.00	$40.56	2.0	2.0	0%	100%
9	3" LPS (<15 psig) MF pipe insulated to 2"	15	5.19	$46.54	$0.00	$46.54	2.4	2.4	0%	100%
10	4" LPS (<15 psig) MF pipe insulated to 2"	15	6.49	$52.53	$0.00	$52.53	2.7	2.7	0%	100%
11	3/4" HHW MF pipe insulated to 1.5"	15	1.05	$31.98	0.00	22.84	1.0	0.7	0%	100%
12	1" HHW MF pipe insulated to 1.5"	15	1.28	$33.48	0.00	27.98	1.0	0.8	0%	100%
13	2" HHW MF pipe insulated to 2"	15	2.22	$40.56	$0.00	$40.56	1.2	1.2	0%	100%
14	3" HHW MF pipe insulated to 2"	15	3.13	$46.54	$0.00	$46.54	1.5	1.5	0%	100%
15	4" HHW MF pipe insulated to 2"	15	3.91	$52.53	$0.00	$52.53	1.6	1.6	0%	100%

Additional Oregon measure applications were developed but ultimately not approved due to failing TRCs, details can be found in the cost effectiveness calculator. There is no measure-level cost effectiveness requirement in Washington.

Requirements

- Incentives and savings are based on straight linear feet of pipe, not equivalent length. Therefore, fittings and pipe bends shall not be accounted for in savings and incentive calculation.
- All Service Jacketing (ASJ) shall be required for indoor pipe insulation and aluminum or PVC jacketing for outdoor piping insulation to maintain the life of the measure.
- Steam systems must be low pressure (≤15 psig).
- Domestic Hot water, heating hot water, and low-pressure steam heating must be provided by a central gas-fired systems.
- The following minimum insulation thicknesses are required based on pipe size:
  - 1.5” pipe diameter or smaller – 1.5” insulation or greater.
  - Greater than 1.5” pipe diameter – 2” insulation or greater.

Program Requirements

- Installed insulation thickness must be tracked as it will support more accurate cost estimates.
- Project invoices must be checked for ineligible or unassociated costs (such as for fittings or non-installation labor).

Details

The 2021 Oregon Energy Efficiency Specialty Code was referenced to determine insulation levels required for participation. The minimum insulation thickness for DHW pipes was set incrementally above code. The minimum HHW insulation thickness was set to code. The LPS insulation minimum thickness is below code due to feedback from the field indicating that code level insulation thicknesses were physically difficult to apply to existing pipe configurations in many cases. Since existing properties are not subject to code level requirements for insulation, this is not expected to be a barrier to installation and will ideally result in more applications becoming eligible for insulation measures.

Baseline

This measure uses an Existing Condition Baseline.

The baseline is assumed to be existing, uninsulated schedule 40 steel pipe.

Measure Analysis

Heat Transfer

Savings were based on a 2010 ICF study[1] performed on behalf of Energy Trust of Oregon that analyzed the impact of pipe insulation in commercial and industrial applications. The analysis looked at several different applications and their associated operating hours and fluid temperatures that would commonly be found at each facility. Table 3 is a summary of some of the analysis assumptions.

Table 3 Input Parameter Summary

Input Parameter	Value	Units
DHW and LPS Boiler Efficiency	78%	N/A
HHW Boiler Efficiency	80%	N/A
Thermal conductivity, steel pipe (k)	314.4	Btu-in/hr-ft^2-°F
Thermal conductivity, insulation (k)	0.29	Btu-in/hr-ft^2-°F
Ambient Temperature	70	°F
DHW Fluid Temperature Supply/Return	130/124	°F
Steam Fluid Temperature Supply/Return	250/212	°F
HHW Fluid Temperature Supply/Return	180/160	°F
Steam pressure	15	psig
Surface emittance, pipe (ε)	0.8	N/A
Surface emittance, insulation (ε)	0.8	N/A

The analysis assumes that 90% of pipes will be located indoors and 10% will be located outdoors. All indoor pipes were modeled with ASJ while all outdoor piping insulation was modeled with aluminum/PVC jacketing.

The study determined savings by using heat transfer engineering equations to model a horizontal pipe with internal fluid flow along with empirical relations for the necessary heat transfer coefficients. The following equation was used to determine heat loss from the pipe:

$$q = \frac{Q}{L} = \frac{\pi \Delta T}{R_1 + R_{pipe} + R_{ins} + R_2}$$

Where R_1 is the thermal resistance due to convection between the fluid and inside pipe surface:

$$R_1 = \frac{1}{h_1 D_1}$$

R_2 is the thermal resistance due to convection and radiation at the exterior insulation surface:

$$R_2 = \frac{1}{h_{3,c} D_3} + \frac{1}{h_{3,r} D_3}$$

Where $h_{3,c}$ and $h_{3,r}$ are the convection and radiation heat transfer coefficients respectively.

R_{pipe} and R_{ins} are represented by:

$$R_{pipe} = \frac{\ln\left(\frac{D_2}{D_1}\right)}{2k_{pipe}}$$

[1] Impact of Pipe Insulation on Natural Gas Consumption Commercial and Industrial Applications. April 2010. Prepared for Energy Trust of Oregon. ICF International Company. ICF Report No. 20902D.

$$R_{ins} = \frac{\ln\left(\frac{D_3}{D_2}\right)}{2k_{ins}}$$

Where applicable, the following subscripts refer to:

1 – fluid to pipe inner diameter surface
2 – pipe outer diameter to insulation inner diameter surface
3 - insulation outer diameter to air surface

The equations above are solved using the following empirical relations:

$$h_1 = \left(\frac{k_{fluid}}{D_1}\right) Nu = \left(\frac{k_{fluid}}{D_1}\right) 23Re^{0.8}Pr^{\frac{1}{3}}$$

$$h_{3,c} = 0.503\left(\frac{\Delta T}{D}\right)^{\frac{1}{4}}$$

$$h_{3,r} = \frac{\varepsilon\sigma\left(T_{3,R}^4 - T_{air,R}^4\right)}{\Delta T}$$

Hours of Operation

The hours of use were estimated as follows:

- DHW – 5,840 hours/year - The hours of use for domestic hot water systems were calculated based on assumed usage hours from 6 AM to 10 PM (16 hours/day).
- LPS and HHW: 1,344 hours/year - The hours of use for low pressure steam systems and heating hot water systems were estimated as the average of the following three values:
  - Case Study – Apartments A – estimated 2,014 effective full load hours (EFLH) based on billing data and estimated existing boiler efficiency for LPS
  - Case Study – Apartments B – estimated 1,064 EFLH based on billing data and estimated existing boiler efficiency for LPS
  - Contractor feedback and TMY3 data – estimated 954 EFLH based on contractor estimate of 5,000 hours of operation per year for LPS

Savings

Savings by piping type are shown in Table 4, Table 5, and Table 6.

Table 4 DHW Savings (5,840 Operating Hours per Year)

	3/4" SCH 40 Pipe	1" SCH 40 Pipe	2" SCH 40 Pipe	3" SCH 40 Pipe	4" SCH 40 Pipe	Average
Thickness, insulation (in.)	1.5	1.5	2	2	2	-
Heat savings (Btu/hr/LF)	177.2	217.6	379.5	536.7	671.6	396.5
Annual Energy Savings (therms/year/LF)	2.3	2.8	4.9	6.9	8.6	5.1

Table 5 LPS Savings (2,079 Operating Hours per Year)

	3/4" SCH 40 Pipe	1" SCH 40 Pipe	2" SCH 40 Pipe	3" SCH 40 Pipe	4" SCH 40 Pipe	Average
Thickness, insulation (in.)	1.5	1.5	2	2	2	-
Heat savings (Btu/hr/LF)	208.8	255.9	445.0	626.7	783.5	464.0
Annual Energy Savings (therms/year/LF)	2.7	3.3	5.7	8.0	10.0	5.9

Table 6 HHW Savings (2,079 Operating Hours per Year)

	3/4" SCH 40 Pipe	1" SCH 40 Pipe	2" SCH 40 Pipe	3" SCH 40 Pipe	4" SCH 40 Pipe	Average
Thickness, insulation (in.)	1.5	1.5	2	2	2	-
Heat savings (Btu/hr/LF)	129.4	158.5	274.5	387.4	484.3	286.8
Annual Energy Savings (therms/year/LF)	1.6	2.0	3.4	4.8	6.1	3.6

Comparison to RTF or other programs

Pipe insulation for Multifamily buildings is not offered by the RTF.

Other pipe insulation measures offered by the Energy Trust of Oregon are:

- MAD 91- Commercial and Industrial Pipe Insulation: This measure offers piping insulation for commercial DHW, commercial HHW, commercial low-pressure steam (LPS) & medium-pressure steam pipes (MPS). It also includes piping insulation for industrial LPS and MPS pipes. Savings for industrial measures are higher due to higher fluid temperatures and higher hours of operation. All existing commercial and industrial facilities are eligible.
- MAD 249- DI Pipe Insulation: This direct install-only measure includes pipe insulation for industrial LPS, MPS and process heating water (PHW) applications up to 200 psi(g) and 388ºF. Each application (LPS, MPS, or PHW) has measure applications in different pipe diameters (0.5-1”, 1.25-2”, etc.).

Measure Life

A measure life of 15 years for multifamily pipe insulation.

The 2007 ASHRAE Handbook assigns a 20 year measure life to molded insulation and a 2005 DEER Database report referencing CALMAC data lists 15 years for pipe wrap. Although pipe insulation in high traffic areas would likely deteriorate faster than these estimates, the program assumes that OSHA requirements would already require pipe insulation (especially on steam systems) to be installed in these high exposure areas. Because insulation is rarely maintained and could potentially become damaged, the Program requires installing ASJ on indoor piping and aluminum or PVC jacketing on outdoor piping to ensure savings realization for the full measure life.

Load Profile

The gas load profiles for the measures are DHW for the DHW application and Residential Heating for the LPS and HHW applications. There is no electric load profile.

Cost

The installed cost of pipe insulation was determined from Program Tracker (PT) data from commercial and multifamily projects and then scaled to vary with pipe diameter and insulation thickness.

The past project data from PT for commercial, industrial and multifamily pipe insulation was combined. Project data from 2020 to 2022 was used for HHW/LPS pipe insulation installed cost and it is $40.56 per LF from 16 projects. For DHW pipes, project data was available only from 2016 and 2018 and therefore it was used with cost inflation factors derived from the RTF's Standard Information Workbook v4.7[2] and is estimated at $25.49 per LF from 11 projects. The data revealed that the average cost of installed insulation per linear feet for DHW pipes is notably less than and the weighted average cost for LPS and HHW pipes, so they were not combined. Pipe diameter was not consistently tracked in PT.

Review of pipe insulation costs from RS Means and online vendors Grainger & McMaster Carr showed that pipe insulation costs increase with increased insulation thickness and increased pipe diameter. The cost data gathered from RSMeans reflected the assumed measure materials: fiberglass insulation with kraft paper ASJ (indoors) and aluminum jacketing (outdoors). A two-variable regression analysis established a relationship of cost dependence on two primary parameters: pipe diameter and insulation thickness. **Error! Reference source not found.** shows the regression analysis coefficients in which pipe diameter and insulation thickness are the independent variables and resultant costs vary by insulation thickness and pipe diameter.

Table 7 RSMeans and online vendor cost regression to pipe diameter and insulation thickness

	Pipe Diameter (in)	Insulation Thickness (in)	Intercept
Slope	5.99	2.18	3.805307
Standard error	0.30	0.18	0.67292
R2	0.91	1.90	
F	312.39	59.00	

Finally, the regression dependence on these two factors was applied to PT data by assuming the average per linear foot cost from past projects represented the average condition of 2-inch pipe with 2-inch thick insulation. The slopes of the regression were used to increase or decrease cost as dimensions increased or decreased from that average condition. This results in a cost distribution across pipe and insulation dimensions based on PT data as the primary source, scaled to different dimensions based on the observed cost dependence in RSMeans and online vendor (Grainger & McMaster Carr) data. The cost for each measure application assumed 90% interior piping (ASJ) and 10% exterior piping (average of aluminum and PVC jacketing) and excludes any incidental costs such as painting, pipe identification or consulting, overtime, and shift work.

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 linear feet (LF) of insulation, not including any fittings.

Follow-Up

- Any additional studies or evaluation results on multifamily pipe insulation should be evaluated for inclusion in the analysis.
- Costs should be reviewed during the next measure update.
- The operating hours for both the DHW and space heating applications may be low and should be reviewed during the next MAD update.
- For DHW pipes, the Program should consider developing separate measure applications for MF buildings with existing recirculation systems. If separate measure applications are not preferred, sources used in MAD 66 can provide data on prevalence of existing MF buildings with/without recirculation and that data can be used to create measure applications with savings weighted by share of buildings with recirculation and without recirculation.
- For LPS and HHW measure applications, Program should investigate using total heating hours rather than EFLH and evaluate if using total heating hours would yield more accurate savings estimates. Fluids in LPS or HHW systems will most likely be always circulating whenever there is heating load and not only for a reduced time equivalent to a fully loaded situation.
- Pipe fittings were not included in the savings and cost calculations. However, these comprise a significant portion of the costs and a minor portion of energy savings. Future MAD update could include costs for the fittings and introduce savings from insulation fittings.

Supporting Documents

The cost effectiveness screening for these measures is number 111.3.2. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Commercial and Industrial\Process Equipment\pipe insulation\multifamily pipe insulation

111.3.2 CE calcuator
2023 v1.0_MF Pipe Ir

Version History and Related Measures

Energy Trust has been offering the multifamily pipe insulation measure for many years. These predate our measure approval documentation process and record retention requirements. Table 8 may be incomplete, particularly for measures approved prior to 2013.

[2] https://nwcouncil.box.com/v/RTF-SIW-v4-7

Table 8 Version History

Date	Version	Reason for revision
02/08/2012	111.x	Introduce pipe insulation on LPS pipes in multifamily
11/28/2012	111.1	Add pipe insulation to DHW distribution systems. Updated hours of operation. Changed average measure to only include pipes less than 2"
04/25/2019	111.2	Updated hours of operation, corrected error in analysis. Removed average measure, now use distinct savings for each size
9/16/2022	111.3	Updated measure costs, removed fitting savings, expanded exterior jacketing options, added HHW application.

Table 9 Related Measures

Measures	MAD ID
Commercial and Industrial Pipe Insulation	91
Multifamily DHW re-circulation controls	66
Commercial and Multifamily Steam Traps	42
Condensing tank water heaters (central DHW)	21
Multifamily condensing tankless <199 kBtu (central DHW)	196
Commercial condensing tankless >199 kBtu (central DHW)_	72

Approved & Reviewed by

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Sr. Engineer – Planning & Evaluation

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Measure Approval Document for Prescriptive Demand Controlled Kitchen Ventilation

Valid Dates
1/1/2023 – 12/31/2025

End Use or Description
This measure describes demand-controlled kitchen ventilation in commercial kitchens. Energy savings are produced when speed-controlled motors in both the vent hood and make-up air units which automatically vary the fan speed based on cooling load and/or time of day.

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
- Production Efficiency

Within these programs, applicability to the following buildings/facilities with onsite commercial kitchens is expected:

- Restaurant
- Cafeteria
- Grocery

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

- Retrofit

Purpose of Re-Evaluating Measure
Average savings and Size requirements for dual fuel measures were updated because smaller horsepower systems became cost effective and were included in the dual fuel average savings calculations.

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 2023-v1.0. In Oregon the electric avoided cost year is 2023 and the gas avoided cost year is 2023. In Washington the gas avoided cost year is 2023. The values in these tables are per horsepower (HP).

Table 1 Cost Effectiveness Calculator Oregon, per HP

#	Measure	Measure Life (years)	Savings (kWh)	Savings (Therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
37	DCKV - gas heat – dual fuel	15	1,068.28	142.00	$2,187.50	0.00	$2,187.50	1.5	1.5	29%	71%
38	DCKV - electric heat	15	4,397.01	0.00	$2,187.50	0.00	$2,187.50	1.8	1.8	100%	0%
39	DCKV – gas heat -gas only	15	0.00	142.00	$2,187.50	$83.22	$2,187.50	1.0	1.5	0%	100%
40	DCKV - gas or other heat in electric only	15	1,068.28	0.00	$2,187.50	$418.90	$931.56	1.0	2.5	100%	0%

Table 2 Cost Effectiveness Calculator Washington, per HP

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
8	DCKV – gas heat -gas only	15	142.00	$2,187.50	$82.26	$2,187.50	1.5	2.0	0%	100%

Requirements

- Motor speeds must be controlled by a programmable controller, with scheduling, occupancy sensing, and heat sensing capabilities.
- Variable speed control must be installed on both the make-up air unit fan motor and the hood exhaust fan motor.
- Make-up air must be conditioned.
- Retrofit motor horsepower must not exceed total existing horsepower of make-up air unit and exhaust fan motor.
- Sites that use propane or other heating fuels may use measure 40.
- Minimum size requirements for different permutations of state, heating fuel, electric and gas utility are summarized in Table 3Table 3 *Utility Participation mapping and size requirements*. Projects with smaller total horsepower may use the vent hood calculator (MAD 184) and test for cost effectiveness on a project-by-project basis.

Table 3 Utility Participation mapping and size requirements

State	Heating Fuel	Electric Utility	Gas Utility	Minimum Total Controlled Motor HP	CEC Row Number
Oregon	Electric	Yes	Yes or No	1.0 HP	38
	Gas	Yes	Yes	1.0 HP	37
	Gas	No	Yes	1.0 HP	39
	Gas	Yes	No	1.0 HP	40
	Other	Yes	Yes or No	1.0 HP	40
Washington	Gas	No	Yes	1.0 HP	8

Baseline
This measure uses an existing condition baseline.

The baseline for this measure is an existing vent hood without demand control ventilation.

Measure Analysis
The measure analysis relied on the Kitchen Vent Hood Calculator (MAD 184) designed by Energy Trust's New Buildings Program. This prescriptive measure uses the analysis method from the Kitchen Vent Hood Calculator tool (MAD 184), which is used to provide custom incentives for projects going beyond code requirements in New Buildings and the assumptions for annual operating hours,

percent fan turndown, and site location are based on typical commercial applications, operating conditions, and total project costs as described in the subsections 'Heating Savings' and 'Fan Savings' below.

For each configuration, the savings at approved sizes are included in per horsepower average.

Heating and Cooling Savings

Electric and gas energy savings are projected using an hourly bin analysis with TMY3 data from Portland Intl Airport. Key assumptions are based on typical restaurant applications. While this measure is approved for other commercial kitchen spaces and regions, these assumptions are expected to be typical for most projects.

- Annual operating hours assumed to be 14 hours per day, 6 days per week
- Fan system and VFD performance assumptions (See Fan Savings below)
- VFD turndown ratio during off-peak operating hours (See Fan Savings below)
- A dedicated make-up air unit supplies the exhaust hood required air volume

A range of motor sizes were input into the Kitchen Hood Calculator to determine savings for typical system sizes.

Building heating and fan motor loads are impacted by exhaust system characteristics, since makeup air must be conditioned before entering the kitchen space. When make-up air and exhaust fan motors operate at full speed, full flow is produced, and maximum energy is consumed by the system.

The baseline assumption is that both the make-up air unit and the vent hood are running at 100% flow during both peak and off-peak periods. The heating and cooling loads for the baseline case and measure case are calculated as follows:

$$Q=CFM \times (t_{outside}-t_{inside})\times 1.08 Btuh$$

Where:

Q *is the change in heat (heat rate) of the air stream (Btu/hr).*
CFM *is the volume flow rate of air entering the kitchen (cubic feet per minute).*
$T_{outside}$ *is the outside air temperature (°F).*
T_{inside} *is the air temperature supplied to the kitchen (°F).*
1.08 *is a constant to approximate the sensible heat required to change the temperature of air*

The model then calculates the proposed energy needed based on peak and off-peak heat loss and heat gain. The proposed energy and baseline energy are both calculated as follows:

$$Proposed\ (Baseline)\ Energy=\sum(Number\ of\ Hours \times Q)_{Off\ Peak}+\sum(Number\ of\ Hours \times Q)_{Peak}$$

Where:

Proposed (Baseline) Energy *is the heating/cooling energy output of the HVAC system over the course of a year.*
$\sum$***(Number of Hours ×Q)***$_{Off\ Peak}$ *sums up all the hourly heat rates during non-peak kitchen operation (Btu).*
$\sum$***(Number of Hours ×Q)***$_{Peak}$ *sums up all the hourly heat rates during peak kitchen operation (Btu).*

Where the annual operating hours are assumed to match the NEEA 2019 Commercial Building Stock Assessment weekly hours of operation for restaurants.

The baseline and proposed energy are then divided by system efficiencies, which default to code minimum values and are converted to therms and kWh as appropriate for heating and cooling. The differences between these final values provides the heating and cooling savings for the measure.

Fan Savings

Additional savings result from reduced fan motor energy which is calculated using fan affinity laws. The analysis assumed the following:

- Static pressure: 2 in. w.c. assumed, which is the low end of vent hood normal operating pressures with grease extraction
- Fan motor and VFD efficiency: Based on nominal motor size as established in the MAD 184 calculator tool.
- VFD turndown ratio: With the typical range being 50% - 75%, the assumption used is 70% to be conservative
- Fan motor load factor: A load factor of 75% is used. Industry practice over-sizes motors, on average, by 25%.

Off-peak flow periods use VFD and motor efficiency reduction factors which account for reduced efficiency under the part load conditions.

Fan energy savings due to speed reduction are the sum of make-up air fan motor and exhaust hood fan motor savings.

The heating energy savings are then added to the fan motor energy savings to provide the total measure savings.

Comparison to RTF or other programs

The RTF does not have an active prescriptive measure, but does have a calculated measure.[1]

Energy Trust's New Buildings program uses a calculator tool rather than a prescriptive measure for kitchen demand control ventilation. That tool is approved in MAD 184 and shares a calculation method with this measure.

Measure Life

The measure life of 15 years aligns with DEER exhaust demand-controlled ventilation systems.

Load Profile

All the measures with electric savings have a Restaurant Ventilation load profile for electricity use.

All measures with gas savings use Commercial Heating gas load profile.

Cost

Costs estimates were obtained from review of past project data. Costs ranged from $1,750 to $3,100 per horsepower, with smaller systems costing more per horsepower.

[1] https://rtf.nwcouncil.org/measure/advanced-kitchen-ventilation-controls/

For cost effectiveness calculations, costs of the approved size range for each configuration were used. For example, gas heated buildings in electric-only territory are limited to 1 HP (total) and above, so costs of systems ranging from 1-10 HP were averaged resulting in a cost of $2,187.50/HP.

Non-Energy Benefits

Gas/other fuel or electricity cost savings is included as a non-energy benefit where there are unclaimed electricity/gas/other fuel savings. In gas only territory, unclaimed electric energy cost savings, is $83.22 per HP. For other heat or gas heat in electric only territory, unclaimed fuel cost savings is $418.90 per HP based on propane costs.

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 HP. Due to the complexity of configuration requirements; Planning suggests that the same incentive be used for all configurations, which indicates a maximum incentive of $931.56/HP.

Follow-Up

Future OEESC updates may change requirements for kitchen ventilation systems and should be reviewed at the next update.

Supporting Documents

The cost effectiveness screening for these measures is number 122.3.2 It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Commercial and Industrial\Food Service\venthoods\venthood calculator

122.3.2 OR-WA-CEC 2023 v1.0 DC Kitcher

184.3 Kitchen Hood Calculator_unlockec

Version History and Related Measures

Energy Trust has been offering MAD 122 measure for many years. These predate our measure approval documentation process and record retention requirements. Table 4 may be incomplete, particularly for measures approved prior to 2013.

Table 4 Version History

Date	Version	Reason for revision
12/12/2005	122.x	Approval to use a PG&E kitchen ventilation calculator tool
3/06/2009	122.x	Change to prescriptive measure, update costs, calculation methods, measure life and tempered air requirements.
10/17/2014	122.1	Change size requirements, change maximum incentives
7/05/2019	122.2	Update savings calculation methods, costs, maximum incentives, change size requirements, clarify partial territory configuration
8/29/22	122.3	Requirements and cost effectiveness updated.

Table 5 Related Measures

Measures	MAD ID
Demand Controlled Kitchen Ventilation Calculator tool	184

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Measure Approval Document for Condensing Unit Heaters in Greenhouses

Valid Dates
1/1/2023-12/31/2025

End Use or Description
Unit heaters are used to heat greenhouses, typically to maintain overnight or winter temperatures. Typical applications include one or more unit heaters per greenhouse in the range of 180-310 kBtu/h input capacity. Projects are likely to replace more than one heater at a time.

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 WA

Within these programs, applicability to the following building types are expected:
- Greenhouses

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

Purpose of Re-Evaluating Measure
Costs are updated. No other changes.

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 2023-v1.0. In Oregon the gas avoided cost year is 2023. In Washington the gas avoided cost year is 2023. The values in these tables are per kBtu/h.

Table 1 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	Condensing Unit Heaters in Greenhouses	12	0.00	6.29	13.90	$0.00	$13.90	6.1	6.1	0%	100%

Table 2 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	Condensing Unit Heater in Greenhouses	12	6.29	13.90	$0.00	$13.90	8.9	8.9	0%	100%

Requirements
- Heater must be installed in a greenhouse with transparent or translucent sides and roof – this measure is not appropriate for warehouses heating or indoor grow applications.
- Must heat to 55 degrees or greater for a least two months per year
- Minimum greenhouse size 1,000 sq. ft

Baseline
This measure uses a Full Market Baseline.

Federal guidelines for unit heaters do not have a specific efficiency requirement, requiring only that the design uses a power vent or automatic flue damper[1]. The baseline for this measure is a standard 80% efficient power vent or gravity fed unit heater. We assume the efficient equipment has little to no market share.

Measure Analysis
Savings for greenhouse heating depend on crop type, which influences set points, and climate so deemed savings from other regions are not suitable comparisons. Additionally, greenhouse construction also has a large impact on savings. Savings were calculated based on 32 completed greenhouse projects that went through the PE program between 2011 and 2015. Using actual participant project information allows for a project mix representative of growers in Energy Trust territory. Savings for each of these projects was calculated using the Department of Agriculture's Virtual Grower Tool, a greenhouse energy modeling application which uses a variety of inputs including greenhouse materials, heating set points and local weather data.

While savings from these projects have not fallen perfectly along a linear path, the results do indicate a clear trend as seen in Figure 1. A best-fit line was used to generate an average savings of 6.29 therms per kBtu/h. Installations in new greenhouses and greenhouses with other efficiency measures in place will achieve fewer savings from condensing heaters as less heat is wasted and operating hours are less. Installations at high elevations will have higher savings.

[1] Federal Register Vol. 70 No. 200, 10/18/2005 (https://www.govinfo.gov/content/pkg/FR-2005-10-18/pdf/FR-2005-10-18.pdf)

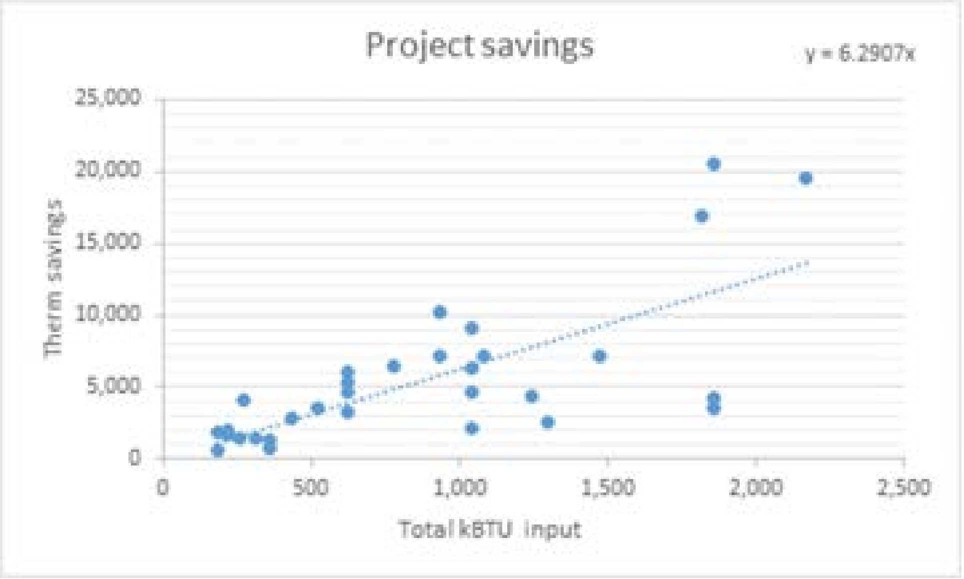

Figure 1: Savings versus kBtu Input

Measure Life
A measure life of 12 years is assumed for unit heaters, in line with unit heater measures in other applications.

Load Profile
Com Heating and none-ele

Cost
Costs for both condensing and non-condensing unit heaters were collected from primary manufacturers of unit heaters in 2022. Incremental prices range from $5 to $18 per kBtu/h. An average incremental cost of $13.90 was used in the cost effectives testing, representing the average incremental cost/kBtu/h for all sizes of the more expensive manufacturer.

Incentive Structure
Since this is most often a replacement measure, the maximum incentive listed in Table 1 and Table 2 is the incremental cost. This is listed for reference only and is not a suggested incentive. Incentives will be structured per kBtu/h input capacity.

While this measure is primarily used by the Production Efficiency program in Oregon, it may also be implemented by the Existing Buildings program in Washington, where EB has responsibility for industrial and agricultural gas projects including greenhouses. Alignment of incentives between the programs is recommended.

Follow-Up
If there is a dramatic increase in greenhouse new construction using this measure, this measure should be re-examined to account for a different mix of typical installations. Costs and EUL should also be revisited in the next update.

Supporting Documents
The cost effectiveness screening for these measures is number 134.3.2. It is attached and can be found along with supporting documentation at: \\Etoo.org\home\Groups\Planning\Measure Development\Commercial and Industrial\Agriculture\greenhouse\Greenhouse unit heaters

134.3.2 OR WA CE Calculator_2023_v_1

Version History and Related Measures
Energy Trust has been offering Condensing Unit Heaters for many years. These predate our measure approval documentation process and record retention requirements. Table 3 may be incomplete, particularly for measures approved prior to 2013.

Table 3 Version History

Date	Version	Reason for revision
6/18/2015	134.1	Introduce Condensing Unit Heaters in Greenhouses measure
6/3/2019	134.2	Update avoided costs
9/27/2022	134.3	Update costs

Table 4 Related Measures

Measures	MAD ID
Greenhouse Controller	103
Greenhouse Measures	104

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EnergyTrust of Oregon

Measure Approval Document for Building Operator Certificate

Valid Dates
1/1/2023 – 12/31/2025

End Use or Description
Class training for building operators in commercial and multifamily buildings through the Building Operator Certificate (BOC) 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 is expected:
- Existing Multifamily
- Commercial Buildings

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

Purpose of Re-Evaluating Measure
Savings have been updated using BOC-influenced savings listed in Table 16 of NEEA's Building Operator Certificate Expansion Initiative Market Progress Evaluation Report (MPER) #3.

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 2023-v1.0. In Oregon the electric avoided cost year is 2023 and the gas avoided cost year is 2023. In Washington the gas avoided cost year is 2023. The values in these tables are per certification.

Table 1 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	BOC - Existing Buildings	3	34,998.26	1,592.80	$1,895.00	$0.00	$1,895.00	6.6	6.6	52%	48%
2	BOC - Multifamily	3	9,186.50	626.04	$1,895.00	$0.00	$1,895.00	2.1	2.1	40%	60%
3	BOC - Existing Buildings - Electric Heat	3	34,610.84	0.00	$1,895.00	$0.00	$1,895.00	3.4	3.4	100%	0%
4	BOC - Existing Buildings - Gas Only Territory	3	0.00	1,592.80	$1,895.00	$2,726.34	$1,895.00	3.2	7.1	0%	100%
6	BOC - Multifamily - Gas Only Territory	3	0.00	626.04	$1,895.00	$1,065.45	$1,895.00	1.2	2.8	0%	100%

Table 2 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	BOC in Existing Buildings	3	1,592.80	$1,895.00	$2,694.87	$1,895.00	4.7	8.6	0%	100%
2	BOC in Multifamily	3	626.04	$1,895.00	$707.36	$1,895.00	1.8	2.9	0%	100%

Requirements
Participation Requirements
- Participant must operate a building where primary space heating fuel is provided by an eligible utility
- Participants may not receive incentives – and Energy Trust will not claim savings – for both level 1 and level 2 certification within three years
- Heating must be served by a central system
- Multifamily buildings must be gas heated
- Total square footage of building must be greater than 70,000 sq. ft.

Program Tracking Requirement
- Building square footage will be tracked
- Building primary heating system type will be tracked

Details
Savings are claimed per participant. Savings may be captured for additional building operators in the same building. For the purpose of savings calculations, where areas of responsibilities in buildings overlap between multiple operators, the average area per operator shall be the quotient of the overall building area by the total number of operators.

Baseline
This measure uses an Existing Condition Baseline.

The existing condition is a building operator that has not received BOC as defined in the Participation Requirements above.

Measure Analysis
Total gas and electric savings per operator are the product of savings percentage estimates, commercial gas and electric energy intensities, and average number of square feet served per operator. Commercial electric and gas savings percentages due to BOC-influenced improvements to building O&M are detailed in Table 16 of the Northwest Energy Efficiency Alliance's (NEAA) latest *Market*

Progress Evaluation Report (MPER) #3.[1] The table also lists estimates of electric and gas energy intensities based on the 2014 Commercial Building Stock Assessment[2] (CBSA).

The total annual savings for each fuel type is the product of building square footage per operator, EUI and percent electric or gas savings:

$$\Delta E = A_{buildings} * EUI_{elec} * Savings_{elec}$$

$$\Delta G = A_{buildings} * EUI_{gas} * Savings_{gas}$$

Where:

ΔE	=	Annual Electric Savings, kWh
ΔG	=	Annual Gas Savings, therm
$A_{building}$	=	Building Area, ft^2
EUI_{elec}	=	Energy Use Intensity, kWh/ft^2
EUI_{gas}	=	Energy Use Intensity, $therm/ft^2$
$Savings_{elec}$	=	Electric Savings, %
$Savings_{gas}$	=	Gas Savings, %

The multifamily energy intensities were sourced from the *Residential Building Stock Assessment* II (RBSA II) - *Multifamily Homes Report 2016-2017.*[3] The multifamily BOC-influenced percent savings are assumed to scale to the ratio of the multifamily to commercial EUIs from the RBSA II and MPER sources respectively.

$$Savings_{elecMF} = \frac{EUI_{elecMF}}{EUI_{elecComm}} * Savings_{elecComm}$$

$$Savings_{gasMF} = \frac{EUI_{gasMF}}{EUI_{gasComm}} * Savings_{gasComm}$$

Where:

$Savings_{elecMF}$	=	*Multifamily Electric Savings, %*
$Savings_{gasMF}$	=	*Multifamily Gas Savings, %*
$Savings_{elecComm}$	=	*Commercial Electric Savings, %*
$Savings_{gasComm}$	=	*Commercial Gas Savings, %*
EUI_{elecMF}	=	*Multifamily Energy Use Intensity,* kWh/ft^2
EUI_{gasMF}	=	*Multifamily Energy Use Intensity,* $therm/ft^2$
$EUI_{elecComm}$	=	*Commercial Energy Use Intensity,* kWh/ft^2
$EUI_{gasComm}$	=	*Commercial Energy Use Intensity,* $therm/ft^2$

Project Tracker (PT) data of past projects were used to calculate typical commercial project square footage for the Existing Buildings measure applications. To avoid overestimating square footage per operator, a projects site's square footage was divided by the number of projects IDs (number of certifications) for that site.

Given the low number of PT data for multifamily projects, the MPER's 77,721 average square footage per operator was used as a proxy for the typical multifamily building area in the savings calculations.

Savings

Savings per fuel and building type are summarized in Table 3 below. The electric savings are added as NEBs for gas-only territory measure applications.

Table 3: Savings by Fuel and Building Type

Case	Annual Electric Savings [kWh]	Annual Gas Savings [therm]
BOC in Existing Buildings	34,998	1,593
BOC in Multifamily	9,186	626

The reported electric EUI in the CBSA includes both electric and gas heated buildings. Therefore, the dual-fuel measure applications overestimate savings. However, given the prevalence of gas heating, the overestimate is likely not significant. The electrically heated measure applications only report the electric savings (matching those of their dual fuel application counterpart), which is likely a savings underestimate. Adding the gas savings to electric heated buildings significantly overestimates savings given the CBSA electric EUI reporting method and low prevalence of electric heating in commercial buildings.

The multifamily electric heated measure application was found to not be cost effective and is therefore not included in Table 1.

Comparison to RTF or other programs

This measure is not offered by the RTF.

Measure Life

Measure life is three years, consistent with other operations and maintenance measures and participation requirements.

[1] BOC-Expansion Initiative Market Progress Evaluation Report #3
[2] https://neea.org/data/commercial-building-stock-assessments
[3] https://neea.org/img/documents/Residential-Building-Stock-Assessment-II-Multifamily-Homes-Report-2016-2017.pdf

Load Profile

Dual Fuel Measure Applications:

- Electric: Other Ventilation or Lodging Ventilation
- Gas: Com-Heating

Electric Heat Measure Applications:

- Electric: Other Ventilation
- Gas: Non - gas

Gas-only territory

- Electric: None – ele
- Gas: Com-Heating

Cost

The full BOC training cost is currently $1,895 per level – sourced from the Northwest Water and Energy Education Institute at Lane Community College.[4]

Non Energy Benefits

None other than electric savings in gas only territories, which are reported as NEBs in for the purposed of testing cost effectiveness.

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 BOC certification.

Follow-Up

Measure should be updated to include the most recent NEEA BOC-E MPER results and CBSA/RBSA data. Updated program data should be included to update typical project square footage and primary heating type.

Supporting Documents

The cost-effective screening for these measures is number 2023-v1.0. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Commercial and Industrial\Whole Building and Controls\Builder Operator Certificate

137_5_3_OR_WA_CE
C_2023_v_1_0_BOC.x

Version History and Related Measures

Energy Trust has been offering the building operator certificate since measure for many years. This predates our measure approval documentation process and record retention requirements. Table 4 may be incomplete, particularly for measures approved prior to 2013.

Table 4 Version History

Date	Version	Reason for revision
8/12/15	137.X	First release
9/17/15	137.1	Corrected CEC error
6/19/18	137.2	Added Multifamily
10/22/18	137.3	Added level 2 and clarified Washington
8/1/2019	137.4	Updated savings based on MPER #3 and 2016-2018 program data, updated incremental costs
8/2/2022	137.5	Updated savings based on BOC-influenced savings (MPER #3 – Table 16)

Approved & Reviewed by

Kenji Spielman
Planning Engineer

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[4] https://www.nweei.org/professional-development/building-operators-certification-boc.html

Measure Approval Document for Modulating Boiler Burners

Valid Dates
From 1/1/2023 to 12/31//2025

End Use or Description
Modulating burners on hydronic heating boilers. Modulating burners increase boiler turndown, which increases dynamic efficiency by reducing cycling and associated off-cycle energy losses.

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

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

- Office
- Lodging
- Public Assembly
- Healthcare
- Education

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

- Retrofit

Purpose of Re-Evaluating Measure
Savings and costs were 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 2023-v1.0. In Oregon the electric avoided cost year is 2023 and the gas avoided cost year is 2023. In Washington the gas avoided cost year is 2023. The values in these tables are per burner input capacity in kBtu/h.

Table 1 Cost Effectiveness Calculator Oregon, per input 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	Modulating Boiler Burner - 5:1 turndown or higher	20	0.87	13.03	$0.00	$13.03	1.3	1.3	0%	100%

Table 2 Cost Effectiveness Calculator Washington, per input 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	Modulating Boiler Burner - 5:1 turndown or higher	20	0.87	13.03	$0.00	$13.03	2.0	2.0	0%	100%

Requirements
- Burner must be installed on a natural gas-fired boiler
- Burner installation must be for hydronic heating (HVAC) boilers
  - Boilers used for process heating, domestic hot water, or pool heating are not eligible.
- Modulating burner must have 5-to-1 turndown ratio or higher
- Modulating burner installation must replace either:
  - A single state burner
  - A dual stage burner
- This measure may not be combined with MAD 88 - Commercial and Multifamily Condensing Boilers.

Details
Modulating burners improve boiler efficiency by reducing cycling losses. Cycling occurs in boilers operating at part loads below their minimum turndown ratio. Single stage burners can only operate at 100% capacity, or a 1:1 minimum turndown. Dual stage burners can operate at either 100% or 50% capacity, i.e., 2:1 turndown. Loads below the minimum turndown require the boiler to cycle on and off to meet the load.

Boiler cycling requires a pre-purge, a standby period, and a post purge. Pre- and post-purges operate the combustion fan to evacuate flammable gas mixtures that may accumulate in the boiler. The purge air removes heat from the boiler, which is lost from the stack. The cycling operation affects the boiler's overall efficiency for a given load level. The dynamic efficiency accounts for effect of load, return water temperature (RWT) and cycling losses. The dynamic efficiency differences are greater at boiler part-load, i.e., lower firing rates, with modulating boilers generally having greater dynamic efficiency at the same load level as single or dual stage burners.

Baseline
This measure uses an Existing Condition Baseline.

The existing condition baseline is assumed to be a mix of single and dual stage burners. CBSA 4-2019[1] was used to determine the weighted average efficiency and share of single and dual stage burners for non-condensing, condensing, and steam boilers. Boiler type weightage was also determined using the CBSA data. Table 3 summarizes the market share of burners by number of stages and boiler type.

Table 3: Efficiencies and Burner Stage by Boiler Type

Boiler Type	Weighted Efficiency [%]	Weight - Single Stage	Weight - Dual Stage	Weight - Boiler Type
non-condensing	80.3	0.78	0.22	0.834
condensing	89.8	0.28	0.72	0.066
steam	80.0	1.00	0.00	0.100

[1] https://neea.org/data/commercial-building-stock-assessments

Measure Analysis

Savings were calculated using methodologies based on the RTF's Commercial Boiler Standard Protocol[2]. TMY3 weather data was used to determine hourly boiler part load ratio as a function of outside dry bulb temperature. The analysis used Station ID 726945 (Corvallis) and station ID 726835 (Redmond) to calculate savings for HZ1 and HZ2 respectively. The savings were averaged, weighted by heating zone population of 92% for HZ1 and 8% for HZ2 as recommended by the Energy Trust's Measure Development Technical Guidelines 2022.

The boiler firing rate is assumed to be linear with outside temperature and sized using the 99.6% annual heating dry bulb temperatures listed in the 2021 ASHRAE Handbook – Fundamentals: Chapter 14, Climatic Design Information. Station ID 726945 (Corvallis) was used for HZ1 and station ID 726920 (Redmond) for HZ2. Boiler sizing included a 15% safety factor and assumed balance point temperatures of 55°F and 60°F for occupied and unoccupied schedules respectively. The safety factor and balance point temperatures shift the boiler's design operating point towards colder outside air, i.e., the boiler will operate a lower part load ratios for more hours during the heating season as anticipated in actual practice.

For example: the 99.6% ASHRAE winter design temperature for Corvallis is 24.8°F. Given a room set point of 70°F and an occupied balance point temperature of 55°F assumes that solar and internal heat gains contribute on average 15°F of "free heat." Thus, the boiler will fire at ~87% (accounting for the 15% safety factor) when the outside air temperature is 24.8°F – 15°F = 9.8°F. For the unoccupied case, the room setpoint and balance point temperatures are assumed to be 60°F and 50°F respectively. During unoccupied hours, the boiler will fire at ~87% when the outside air temperature is 24.8°F – 10°F = 14.8°F.

The boiler part load ratios were correlated to dynamic efficiency, which accounts for cycling losses, load level, and return water temperatures. The dynamic efficiency for on/off, 2-stage, and 5:1 turndown boilers was calculated using the methodology from the RTF's commercial gas boiler protocol, which is outlined below.

$$\mathrm{Eff_{dynamic}} = \frac{\mathrm{LoadLevel} * \mathrm{RatedOutputCapacity}}{\mathrm{OnCycle\%} * \mathrm{OnCycleFuelRate} + \mathrm{OffCycle\%} * \mathrm{OffCycleLossRate}}$$

Where:

Load Level	=	boiler part load ratio at given outside air temperature
Rated Output Capacity	=	boiler rated capacity at 100% firing rate and RWT
On Cycle %	=	percent time the boiler is operating
On Cycle Fuel Rate	=	fuel rate at the maximum turndown (100% for on/off boilers, 50% for dual stage, and 20% for 5:1)
Off Cyle %	=	percent time the boiler is not operating
Off Cycle Loss Rate	=	rate of energy loss from the boiler during the off cycle

For non-condensing and condensing boilers, the rated efficiency is adjusted based on the actual load level and assumed RWT schedule, which is dependent of outside air temperature. For non-condensing boilers, the off-cycle loss rate is assumed to be constant at 3.4% of input fuel rate (at rated conditions). For non-condensing boilers, the protocol's model for the off-cycle loss rate is dependent on RWT.

The steam boiler's dynamic efficiency model does not adjust the rated efficiency for either load level or return water temperature as the protocol's assumptions are based on hot water boilers. The off-cycle loss rate is assumed to be the same as that of the non-condensing boiler, which is 3.4% of input fuel rate.

The dynamic efficiency was used to calculate the annual fuel use for each boiler type (non-condensing, condensing, and steam) and each burner control (single stage, dual stage and 5:1 modulating) and was normalized by burner input capacity in kBtu/h. The baseline fuel use was weighted by share of single vs dual stage burners for each boiler type. Savings are the difference between the baseline and 5:1 modulating fuel use. The savings across the boiler types were averaged, weighted by their share as reported in the CBSA 4-2019: *hydronic_systems-boilers.csv* file.

Savings were calculated for five building types: Office, Lodging, Public Assembly, Healthcare, and Education. The occupancy schedules for each building type determined the occupied vs unoccupied hours, and thus the room and balance point temperatures used in the boiler's part load ratio calculation at a given outside air dry bulb. The savings for each building type were averaged, weighted by their share reported in the CBSA 4-2019: *CBSA Public Summary Tables 6102020.xlsx* file

Savings

For a given boiler type (non-condensing, condensing, and steam), the energy use for single and dual stage burners were averaged, weighted by the shares summarized in Table 3 to determine the baseline energy use. The measure case (5:1 modulating burner) energy uses in subtracted from the baseline to determine the savings by boiler type and heating zone. Saving across all boiler types are averaged, weighted by the boiler type share reported in Table 3. The savings for each HZ1 and HZ2 are averaged, weighted at 92% and 8% respectively. The heating zone averaged savings by building type are summarized in the Table 4 below along with the final weighted average across all building types.

Table 4: Savings Summary by Building Type

Building Type	Savings [therm/MBH]	Building Weights	Weighted Savings [therm/MBH]
Office	0.91	18%	0.17
Lodging	0.77	38%	0.29
Public Assembly	0.89	13%	0.12
Healthcare	0.93	2%	0.02
Education	0.95	29%	0.28
All Buildings	**NA**	**100%**	**0.87**

Comparison to RTF or other programs

The analysis leveraged the methodology and assumptions listed in the RTF's Commercial Gas Boiler Standard Protocol and Commercial Gas Boiler Calculator. However, the protocol and calculator rely on hourly heating loads from DOE's Commercial Reference Model simulations, while the methods used in this analysis used outside air dry-bulb temperature as a proxy for heating loads to determine boiler part load ratios. The protocol and calculator group heating loads and hours of operation into a smaller set of loading conditions, while this analysis calculated boiler part load for each of the 8,760 hours reported in the TMY3 weather files.

[2] https://nwcouncil.box.com/v/ComGasBoilersSPv1-2

Measure Life
The measure life is assumed to be 20 years based on SEED program guidelines.[3]

Load Profile
Electric Load Profile: None – ele
Gas Load Profile: Com Heating

Cost
Project Tracker data was used to determine the cost per kBtu/h of input capacity. There were only nine projects between 2016 and 2021, therefore the 3rd quartile was chosen as a conservative estimate. Project cost statistics are summarized in Table 5.

Table 5: Project Cost Summary Statistics

Statistic	Value [$/kBtuh]
min	2.85
max	20.45
average	9.83
median	8.66
Quartile - 3rd	13.03
IQR	6.45

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 of burner input capacity.

Follow-Up
The analysis used an hourly spreadsheet analysis leveraging inputs, assumptions, and methodologies from the RTF's Commercial Gas Boiler Standard Protocol. At the next update, the Program should consider using the RTF's calculator directly to estimate savings by building type.

Savings are wide ranging across building types. At the next update, the Program should consider offering building-specific measure applications and/or a semi-prescriptive calculator for use in custom project to potentially realize greater savings.

The measure's expiration date coincides with that of MAD 88 – Commercial and Multifamily Condensing Boilers, whose savings are based on the RTF's calculators. At the next update cycle, the Program should consider combining this MAD and MAD 88 with savings for all measure applications based on the RTF's calculator.

At the next update, the Program should review the RTF's standard protocol and calculator for any updates to inputs, assumptions, and methodologies.

Currently, steam boilers are not addressed in the RTF's standard protocol or calculator. At the next update, the Program should review assumptions and methodologies for adjusting rated efficiency of steam boilers operating at non-rated conditions or part load.

Supporting Documents
The cost effectiveness screening for these measures is number 142.3.2. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Commercial and Industrial\Commercial HVAC\boilers\Modulating boiler burners

142.3.2 OR-WA-CE Calculator_2023_v_1

Version History

Table 6 Version History

Date	Version	Reason for revision
9/8/2015	142.1	Introduce Modulating Boiler Burners as a field test
9/3/2019	142.2	Update savings and cost, transition to regular measure
8/16/2022	142.3	Updated savings leveraging the RTF's Commercial Gas Boiler Standard Protocol and cost using the latest PT data.

Table 7 Related Measures

Measures	MAD ID
Commercial and Multifamily Boilers	88
Commercial Steam Traps	42

Approved & Reviewed by

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[3] http://www.oregon.gov/energy/CONS/SEED/docs/AppendixJ.pdf

Energy Trust of Oregon

Measure Approval Document for Multifamily Windows

Valid Dates
1/1/2023 – 12/31/2025

End Use or Description
Low U-value windows reduce heat loss and gains from the building envelope. This reduces the heating and cooling loads on the HVAC system in multifamily (MF) buildings which results in energy 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

Within these programs, applicability to the following building types is required:
- Existing Multifamily buildings with 5 or more units

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

Purpose of Re-Evaluating Measure
- The savings calculation methodology and costs are updated.
- Measures for MF buildings heated with natural gas and double pane windows are reintroduced
- Measures now approved for Washington
- Storm windows added
- Efficiency tiers modified

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 2023-v1.0. In Oregon the electric avoided cost year is 2023 and the gas avoided cost year is 2023. In Washington the gas avoided cost year is 2023. The values in these tables are per square feet (sf).

Table 1 Cost Effectiveness Calculator Oregon, per SF

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Inc Costs ($)	Total NEB (Annual $)	Max Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
	Single Pane Measure Applications										
2	Single Pane Window to 0.22 < U value ≤ 0.30 Window HZ1 Zonal Elec Res.	45	24.34	0.00	24.70	$0.00	$24.70	2.2	2.2	100%	0%
3	Single Pane Window to 0.22 < U value ≤ 0.30 Window HZ2 Zonal Elec Res.	45	32.00	0.00	24.70	$0.00	$24.70	3.0	3.0	100%	0%
4	Single Pane Window to U value ≤ 0.22 Window HZ1 Zonal Elec Res.	45	27.01	0.00	28.60	$0.00	$28.60	2.2	2.2	100%	0%
5	Single Pane Window to U value ≤ 0.22 Window HZ2 Zonal Elec Res.	45	35.55	0.00	28.60	$0.00	$28.60	2.8	2.8	100%	0%
6	Storm Window for Single Pane Window (Non-metal Frame) HZ1 Zonal Elec Res.	20	19.26	0.00	10.46	$0.00	$10.46	2.8	2.8	100%	0%
7	Storm Window for Single Pane Window (Non-metal Frame) HZ2 Zonal Elec Res.	20	25.40	0.00	10.46	$0.00	$10.46	3.6	3.6	100%	0%
8	Storm Window for Single Pane Window (Metal Frame) HZ1 Zonal Elec Res.	20	24.72	0.00	10.46	$0.00	$10.46	3.5	3.5	100%	0%
9	Storm Window for Single Pane Window (Metal Frame) HZ2 Zonal Elec Res.	20	32.34	0.00	10.46	$0.00	$10.46	4.6	4.6	100%	0%
10	Single Pane Window to 0.22 < U value ≤ 0.30 Window HZ1 Gas heating	45	0.53	1.15	24.70	$0.00	$24.70	1.6	1.6	8%	92%
11	Single Pane Window to 0.22 < U value ≤ 0.30 Window HZ2 Gas heating	45	0.49	1.51	24.70	$0.00	$24.70	2.1	2.1	6%	94%
12	Single Pane Window to U value ≤ 0.22 Window HZ1 Gas heating	45	0.58	1.27	28.60	$0.00	$28.60	1.5	1.5	8%	92%
13	Single Pane Window to U value ≤ 0.22 Window HZ2 Gas heating	45	0.54	1.68	28.60	$0.00	$28.60	2.0	2.0	6%	94%
14	Storm Window for Single Pane Window (Non-metal Frame) HZ1 Gas heating	20	0.42	0.92	10.46	$0.00	$10.46	2.0	2.0	8%	92%
15	Storm Window for Single Pane Window (Non-metal Frame) HZ2 Gas heating	20	0.39	1.22	10.46	$0.00	$10.46	2.5	2.5	6%	94%
16	Storm Window for Single Pane Window (Metal Frame) HZ1 Gas heating	20	0.54	1.18	10.46	$0.00	$10.46	2.5	2.5	8%	92%
17	Storm Window for Single Pane Window (Metal Frame) HZ2 Gas heating	20	0.50	1.55	10.46	$0.00	$10.46	3.2	3.2	6%	94%
	Double Pane Measure Applications										
20	Double Pane Window to 0.22 < U value ≤ 0.30 Window HZ1 Zonal Elec Res.	45	13.11	0.00	24.70	$0.00	$24.70	1.2	1.2	100%	0%
21	Double Pane Window to 0.22 < U value ≤ 0.30 Window HZ2 Zonal Elec Res.	45	17.55	0.00	24.70	$0.00	$24.70	1.6	1.6	100%	0%
22	Double Pane Window to U value ≤ 0.22 Window HZ1 Zonal Elec Res.	45	15.78	0.00	28.60	$0.00	$28.60	1.3	1.3	100%	0%
23	Double Pane Window to U value ≤ 0.22 Window HZ2 Zonal Elec Res.	45	21.10	0.00	28.60	$0.00	$28.60	1.7	1.7	100%	0%
24	Storm Window for Double Pane Window (Metal Frame) HZ1 Zonal Elec Res.	20	12.50	0.00	10.46	$0.00	$10.46	1.8	1.8	100%	0%
25	Storm Window for Double Pane Window (Metal Frame) HZ2 Zonal Elec Res.	20	16.70	0.00	10.46	$0.00	$10.46	2.4	2.4	100%	0%
26	Double Pane Window to 0.22 < U value ≤ 0.30 Window HZ1 Gas	45	0.28	0.62	24.70	$0.00	$19.33	1.1	0.9	8%	92%
27	Double Pane Window to 0.22 < U value ≤ 0.30 Window HZ2 Gas	45	0.27	0.83	24.70	$0.00	$24.70	1.1	1.1	6%	94%
28	Double Pane Window to U value ≤ 0.22 Window HZ1 Gas	45	0.34	0.75	28.60	$0.00	$23.33	1.1	0.9	8%	92%
29	Double Pane Window to U value ≤ 0.22 Window HZ2 Gas	45	0.32	1.00	28.60	$0.00	$28.60	1.2	1.2	6%	94%

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Inc Costs ($)	Total NEB (Annual $)	Max Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
30	Storm Window for Double Pane Window (Metal Frame) HZ1 Gas	20	0.27	0.60	10.46	$0.00	$10.46	1.3	1.3	8%	92%
31	Storm Window for Double Pane Window (Metal Frame) HZ2 Gas	20	0.26	0.80	10.46	$0.00	$10.46	1.7	1.7	6%	94%
	Gas-only Territory (G.O.T) Measures										
34	Single Pane Window to 0.22 < U value ≤ 0.30 Window HZ1 Gas heating G.O.T	45	0.00	1.15	24.70	$0.06	$24.70	1.5	1.5	0%	100%
35	Single Pane Window to 0.22 < U value ≤ 0.30 Window HZ2 Gas heating G.O.T	45	0.00	1.51	24.70	$0.06	$24.70	1.9	2.0	0%	100%
36	Single Pane Window to U value ≤ 0.22 Window HZ1 Gas heating G.O.T	45	0.00	1.27	28.60	$0.07	$28.60	1.4	1.5	0%	100%
37	Single Pane Window to U value ≤ 0.22 Window HZ2 Gas heating G.O.T	45	0.00	1.68	28.60	$0.06	$28.60	1.9	1.9	0%	100%
38	Storm Window for Single Pane Window (Non-metal Frame) HZ1 Gas heating G.O.T	20	0.00	0.92	10.46	$0.05	$10.46	1.8	1.9	0%	100%
39	Storm Window for Single Pane Window (Non-metal Frame) HZ2 Gas heating G.O.T	20	0.00	1.22	10.46	$0.05	$10.46	2.4	2.4	0%	100%
40	Storm Window for Single Pane Window (Metal Frame) HZ1 Gas heating G.O.T	20	0.00	1.18	10.46	$0.06	$10.46	2.3	2.4	0%	100%
41	Storm Window for Single Pane Window (Metal Frame) HZ2 Gas heating G.O.T	20	0.00	1.55	10.46	$0.06	$10.46	3.0	3.1	0%	100%
42	Double Pane Window to 0.22 < U value ≤ 0.30 Window HZ1 Gas heating G.O.T	45	0.00	0.62	24.70	$0.03	$18.40	1.1	0.8	0%	100%
43	Double Pane Window to 0.22 < U value ≤ 0.30 Window HZ2 Gas heating G.O.T	45	0.00	0.83	24.70	$0.03	$24.70	1.1	1.1	0%	100%
44	Double Pane Window to U value ≤ 0.22 Window HZ1 Gas heating G.O.T	45	0.00	0.75	28.60	$0.04	$22.15	1.1	0.9	0%	100%
45	Double Pane Window to U value ≤ 0.22 Window HZ2 Gas heating G.O.T	45	0.00	1.00	28.60	$0.04	$28.60	1.1	1.1	0%	100%
46	Storm Window for Double Pane Window (Metal Frame) HZ1 Gas heating G.O.T	20	0.00	0.60	10.46	$0.03	$10.46	1.2	1.2	0%	100%
47	Storm Window for Double Pane Window (Metal Frame) HZ2 Gas heating G.O.T	20	0.00	0.80	10.46	$0.03	$10.46	1.6	1.6	0%	100%

Table 2 Cost Effectiveness Calculator Washington, per SF

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
	Single Pane Measure Applications									
2	Single Pane Window to 0.22 < U value ≤ 0.30 Window HZ1 Gas heating	45	1.15	24.70	$0.04	$24.70	2.1	2.1	0%	100%
3	Single Pane Window to 0.22 < U value ≤ 0.30 Window HZ2 Gas heating	45	1.51	24.70	$0.04	$24.70	2.7	2.7	0%	100%
4	Single Pane Window to U value ≤ 0.22 Window HZ1 Gas heating	45	1.27	28.60	$0.05	$28.60	2.0	2.0	0%	100%
5	Single Pane Window to U value ≤ 0.22 Window HZ2 Gas heating	45	1.68	28.60	$0.04	$28.60	2.6	2.6	0%	100%
6	Storm Window for Single Pane Window (Non-metal Frame) HZ1 Gas heating	20	0.92	10.46	$0.03	$10.46	2.4	2.4	0%	100%
7	Storm Window for Single Pane Window (Non-metal Frame) HZ2 Gas heating	20	1.22	10.46	$0.03	$10.46	3.2	3.2	0%	100%
8	Storm Window for Single Pane Window (Metal Frame) HZ1 Gas heating	20	1.18	10.46	$0.04	$10.46	3.1	3.1	0%	100%
9	Storm Window for Single Pane Window (Metal Frame) HZ2 Gas heating	20	1.55	10.46	$0.04	$10.46	4.0	4.1	0%	100%
	Double Pane Measure Applications									
12	Double Pane Window to 0.22 < U value ≤ 0.30 Window HZ1 Gas	45	0.62	24.70	$0.02	$24.70	1.1	1.1	0%	100%
13	Double Pane Window to 0.22 < U value ≤ 0.30 Window HZ2 Gas	45	0.83	24.70	$0.02	$24.70	1.5	1.5	0%	100%
14	Double Pane Window to U value ≤ 0.22 Window HZ1 Gas	45	0.75	28.60	$0.03	$28.60	1.2	1.2	0%	100%
15	Double Pane Window to U value ≤ 0.22 Window HZ2 Gas	45	1.00	28.60	$0.03	$28.60	1.5	1.6	0%	100%
16	Storm Window for Double Pane Window (Metal Frame) HZ1 Gas	20	0.60	10.46	$0.02	$10.46	1.6	1.6	0%	100%
17	Storm Window for Double Pane Window (Metal Frame) HZ2 Gas	20	0.80	10.46	$0.02	$10.46	2.1	2.1	0%	100%

Exceptions

On October 7, 2022, OPUC staff granted Energy Trust a minor exception to offer the non-cost effective large multifamily window measures shown in Table 1. These exceptions are based on exception criteria A, C and d. In particular "there are significant non-quantifiable non-energy benefits for multifamily residents from increased comfort from drafts and sound; the measure is consistent with other offerings in the region; and inclusion of the measure helps increase participation by increasing participation in the multifamily program." or until the measure become > 5% of the Program's savings or a new MAD is produced and the TRC drops. The OPUC defined an incentive cap of the avoided costs plus 10% less the value of bill savings for two years.

Requirements

- U-value of retrofitted window must be either:
  - 0.22 < U-value ≤ 0.30 or
  - U-value ≤ 0.22
- Window frame material can be either metal or non-metal (including but not limited to wood, vinyl, or fiberglass).
- Retrofitted windows must be certified and labeled for U-factor by the National Fenestration Rating Council Incorporated (NFRC).
- For storm window retrofits:
  - Storm windows must use glazing materials with an emissivity less than or equal to 0.22 and a solar transmittance greater than 0.55.
  - Storm windows must be of the same opening type as the existing prime window and should be permanently installed.
  - Exterior storm windows shall be oriented with the low-e coating facing toward the interior of the house.
  - For installations with metal framed prime windows, the storm window's frame shall not be in direct contact with the prime window frame.

- Sites in heating zone 3 (HZ3) may use measures designed for heating zone 2 (HZ2).

Details

The proposed specification for efficient windows in the recently released ENERGY STAR draft v7.0[1] for residential windows requires U-value ≤ 0.22 in the Northern region, which includes Oregon. The proposed specification's tentative effective date is January 1, 2023. The Residential Buildings Program plans to move Energy Trust's most efficient window tier to U-value ≤ 0.22, which would align with the ENERGY STAR's proposed specification. In addition, the RTF's highest efficiency window tier in its Multifamily Weatherization UES is also with a U-value ≤ 0.22.

Baseline

This measure uses an Existing Condition Baseline.

Existing Multifamily buildings are assumed to either have existing single pane windows or double pane windows with window frame material as either metal or non-metal (including but not limited to wood, vinyl, fiberglass). Buildings are assumed to be heated with gas or electric resistance. 28% of MF units are assumed to have some form of cooling.

Measure Analysis and Savings Methodology

The analysis is based on the RTF's Res MF Weatherization Workbook v5.0[2] (April 18, 2022). Table 3 shows the baseline and measure case U-values used in the analysis and their details are available in the 'Multifamily Measures' sheet of the SEEM Workbook.

Table 3 Baseline and Measure case U-values

RTF MF Weatherization Workbook v5.0 Measure Applications	Baseline U-value	Measure U-value
Single Pane window to window with U value 0.22 or less	1.09	0.22
Double Pane window to window with U value 0.22 or less	0.80	0.22
Single Pane window to window with U value 0.30 or less	1.09	0.30
Double Pane window to window with U value 0.30 or less	0.80	0.30
Storm window installed on Single Pane Window (Non-metal Frame)	0.88	0.35
Storm window installed on Single Pane Window (Metal Frame)	1.09	0.41
Storm window installed on Double Pane Window (Metal Frame)	0.69	0.33

Heating Energy Savings

Heating savings estimates are based on RTF's Res MF Weatherization Workbook v5.0 without any modifications to the assumptions or results. The RTF workbook results are based on multiple runs of the calibrated SEEM simulation engine, which are documented in the MFWeatherizationSEEMWorkbookV2.6[3] (Jan 18, 2019). This SEEM model has been calibrated using the MF RBSA data for buildings with electric heating.

SEEM simulations were run to generate heating energy use for baseline and measure cases for each heating system type (zonal electric resistance or natural gas were used in this analysis) and heating zone in the analysis (HZ1 and HZ2 were used in this analysis). The savings are calculated as the difference of heating energy use in baseline and measure cases. Internal gains, thermostat set point (68F) and parameters such as ceiling assembly effective R-value, wall assembly effective R-value, floor assembly effective R-value, window U-value and solar heat gain coefficient, are the key SEEM inputs for this measure. The detailed assumptions for these parameters are described thoroughly in the 'Summary' sheet of the Res MF Weatherization Workbook v4.3[4].

For gas heating systems, the electric heating energy output from the SEEM runs for electric forced air furnace are divided by the gas heating system efficiency (assumed to be 80%) and then converted from kWh to therms to estimate the annual heating energy use in therms. Fan savings are neglected.

Cooling Energy Savings

The RTF's analysis does not estimate cooling savings. The cooling savings were estimated using the following assumptions and steps:

- For homes with cooling, heating savings are assumed to be proportional to HDD and cooling savings proportional to CDD in each climate zone. Put another way, the ratio of CDD to HDD is assumed to be equal to the ratio of cooling savings to heating savings.

$$Cooling\ Savings = \frac{CDD}{HDD} \times Heating\ Savings$$

- Cooling savings were weighted per the prevalence of existing cooling installed in Multifamily buildings in the region. The RBSA II (2016-17) for Multifamily Buildings[5] estimates that 28% of the MF units have cooling installed.

The 2022 Measure Development Technical Guidelines was used for CDD and HDD estimates. Cooling zones CZ1 and CZ2 were blended using the population weightings shown in Table 4. CZ3 was not included in the weighting as it represents a very small population. Heating Zone average HDD and the ratios are shown in Table 5.

Table 4 Energy Trust Cooling Zones and Population Weightings

Cooling Zone	Territory Average CDD	Energy Trust Population Weighting	Blended CDD from CZ1 and CZ2
1	214	40%	320
2	405	50%	
3	759	10%	

Table 5 Energy Trust Heating Zones and Population Weightings

Heating Zone	Territory Average HDD	Ratio CEE/HDD
1	4590	7%
2	6530	5%

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[1] ENERGY STAR Product Specification for Residential Windows, Doors, and Skylights draft v7.0
[2] Res MF Weatherization Workbook v5.0, Regional Technical Forum
[3] MFWeatherizationSEEMWorkbook v2.6, Regional Technical Forum
[4] Res MF Weatherization Workbook v4.3, Regional Technical Forum
[5] Residential Buildings Stock Assessment (RBSA) – II for Multifamily Buildings (2016-17), Northwest Energy Efficiency Alliance (NEEA)

Prevalence of existing cooling installed (any type) in multifamily units is 28%. Applying this weighting to the cooling savings estimated above, the estimated weighted cooling savings in multifamily buildings by heating zone is shown in Table 6:

Table 6 Cooling Savings as a Percent of Heating Savings

Heating Zone	Cooling savings as a percent of heating savings	Prevalence of existing cooling in MF units	Weighted cooling savings as a percent of heating savings
HZ1	7.0%	28.0%	1.93%
HZ2	5.0%		1.36%

For MF buildings with electric heating and cooling, the units for the above equation are consistent in kWh. Whereas for MF bldgs. with natural gas heating, heating savings are in therms and cooling savings are in kWh. In such cases, cooling savings were first calculated as a percentage of heating savings (using Table 6 estimates) and expressed in therms. Then the cooling savings expressed in therms were multiplied by assumed boiler efficiency of 80% and converted to kWh using the relation 1 Therm = 29.31 kWh.

For example, estimation of total savings as a sum of heating and cooling savings for the single pane measure in CEC row 2 and the double pane measure in CEC row 21 for Oregon is shown in Table 7.

Table 7 Total Savings for Select Measures

CEC row	Measure Application	Heating Savings (kWh/sq ft)	Cooling Savings (kWh/sq ft)	Total Savings (kWh/sq ft)	Cooling Savings / Total Savings
2	Single Pane Window to 0.22 < U value ≤ 0.30 Window HZ1 Zonal Elec Res.	23.87	0.47	24.34	1.93%
21	Double Pane Window to 0.22 < U value ≤ 0.30 Window HZ2 Zonal Elec Res.	17.31	0.24	17.55	1.36%

Comparison to RTF or other programs

The heating energy estimates used for this measure are based on the RTF's Multifamily Weatherization UES.

The Residential Program has MAD 28 – Residential High-Performance Windows, which is applicable to single-family homes, existing manufactured homes, and small multifamily buildings with up to 4 units. These measures assume replacement installations and use a market baseline.

Measure Life

Measure life for framed windows is 45 years and for storm windows is 20 years, this is consistent with other Energy Trust windows measures and the RTF.

Load Profile

Table 8 Electric and Gas Load Profiles

	Electric Load Profile	Gas Load Profile
Measures with electric heat	Res Zonal Ele Heat	None- gas
Measures with gas heat	Res Window AC	Res Heating

Cost

Costs are based on RTF's Multifamily Weatherization UES and are described in the Res MF Weatherization Workbook v5.0. The incremental costs by measure type are shown in Table 9.

Table 9 Incremental Costs by Measure

Measure Type	Incremental cost ($ per sq. ft.)
Single/Double Pane Window to window with 0.22 < U value ≤ 0.30	$24.70
Single/Double Pane Window to window with Window with U-value ≤ 0.22	$28.60
Storm window retrofit	$10.46

As of this writing, we expect the 2022 federal Inflation Reduction Act to include incentives or tax credits for Energy Star Windows. The details of such incentives are not yet settled. If they can be applied to large multifamily properties, these are expected to reduce the cost of the higher tier widows. Federal funds are not expected to be high enough to make the non-cost effective measures pass the TRC.

Non Energy Benefits

Electric savings in gas-only territory are calculated and valued as a non-energy benefit. The kWh savings estimate is multiplied with the blended residential electricity rate of $0.116/kWh in Oregon and $0.082/kWh in Washington.

Improved windows can reduce noise and improve thermal comfort by reducing both drafts and heat loss. These benefits are not quantifiable but are expected to improve occupant comfort.

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 feet.

The OPUC defined an incentive cap of the avoided costs plus 10% less the value of bill savings for two years. This is included in the maximum incentives .

Follow-Up

If RTF's methodology and savings results are used in the next MAD update, the Program should review the latest RTF workbook for MF Weatherization UES.

The RTF's Research Strategy for Weatherization in Multifamily Homes with Electric-Resistance Heat approved in July 2020[6] states that the partially calibrated SEEM modeling results (which are used in this analysis) provide some basis for estimating the correlation between energy consumption and building shell efficiency, but they are of limited precision. The research strategy proposes collecting

[6] Research Strategy for Weatherization in Multifamily Homes with Electric Resistance Heat, July 2020, Regional Technical Forum

pre/post billing and audit data of weatherized MF buildings. The next update should review the status of this approved research strategy and update the savings results based on the outcome of RTF's research, if it is conducted.

Supporting Documents

The cost effectiveness screening for these measures is number 171.4.2. It is attached and can be found along with supporting documentation at: \\Etoo.org\home\Groups\Planning\Measure Development\Residential\Multifamily\Weatherization\Multifamily windows

171.4.2 OR_WA CE Calculator_2023 v1.(

Version History and Related Measures

Energy Trust has been offering the multifamily windows measures for many years. These predate our measure approval documentation process and record retention requirements. Table 10 may be incomplete, particularly for measures approved prior to 2013.

Table 10 Version History

Date	Version	Reason for revision
2004	X	Approve windows in multifamily buildings with aluminum window frames in existing condition.
7/11/2008	X	Add replacement of vinyl windows in poor condition
Unknown	171.x	Measure redesign based on Stellar Processes report and tools. Aluminum frame single and double pane, and wood frame single pane existing conditions. Large multifamily, gas or electric heat. Retrofit U ≤ 0.30
2012	171.x	Adds storm windows in existing condition
3/20/2012	171.x	Clarifications for storm windows in existing condition
5/08/2013	171.x	Merged small and large multifamily
5/09/2016	171.1	Updated savings based on RTF calibrated models. Removed gas heated buildings. Separated stacked structures from 2-4 units and side by side units, 2-4 and side by side now included in MAD 28. Requirements based on exception details
11/8/2017	171.2	Remove double pane. Updated for 2018 avoided costs and requirements based on exception details.
5/13/2019	171.3	Measure analysis is updated to include cooling savings.
10/11/2022	171.4	Methodology aligned with RTF. Reintroduced measures for buildings heated with natural gas, and double pane. Add storm windows. Update tiers, cost updates.

Table 11 Related Measures

Measures	MAD ID
Residential and small multifamily windows	28

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

Measure Approval Document for Kitchen Vent Hood Calculator

Valid Dates
1/1/2023 through 12/31/2025

End Use or Description
The kitchen hood calculator tool (version date 6/28/19) determines eligibility under OEESC 2014, ASHRAE 90.1 2016 and ASHRAE 90.1-2019. The tool calculates electricity and natural gas savings for variable-speed controls on commercial kitchen vent hood systems. Controls modulate airflows based on sensed cooking activity.

Outputs from the tool may be used through custom or semi-custom program tracks, when cost effective.

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 are expected:

- Commercial Kitchens

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

- New (systems <5,000 cfm total exhaust)
- Retrofit (systems ≤5,000 cfm total exhaust; systems >5,000 cfm total exhaust may also be eligible contingent on program evaluation of code applicability.)

Purpose of Re-Evaluating Measure
The measure has been reviewed to ensure alignment with requirements of ASHRAE 90.1-2019, which has been adopted as the current Oregon code (2021 Oregon Energy Efficiency Specialty Code). This tool can now be used for projects using either OEESC 2014, 2019, or 2021.

Cost Effectiveness
Cost effectiveness must be determined individually for each project and is not evaluated in this MAD. Incremental cost for this measure is customarily equivalent to the labor and material costs of installing VFDs and necessary controls on exhaust and makeup air fan motors. Incremental cost for this measure does not generally scale linearly with motor size (i.e., a smaller, single motor may have identical incremental cost as a single larger motor), so it is expected that larger systems will generally have improved chances at passing cost effectiveness testing. This is especially important in consideration of new construction projects where systems >5,000 cfm are not eligible.

Requirements
- Incremental costs and cost effectiveness must be determined for each project. Only cost effective projects will qualify.
- Kitchen exhaust systems in new construction must be ≤ 5,000 cfm total exhaust airflow
- Existing building projects >5,000 cfm total exhaust must be evaluated to determine if they are subject to code required controls
- Controls must modulate airflows based on sensed cooking activity (i.e., infrared, optical, and/or temperature sensors)
- All other code requirements must be met for projects determined to be subject to code (i.e., requirements listed in section 6.5.7.2 Kitchen Exhaust Systems, ASHRAE Standard 90.1-2019)
- Tool is to be used only for OEESC 2014, OEESC 2019, or OEESC 2021
- While this tool is designed for Oregon's codes, it may be used in Washington as well

Baseline
This measure uses an:

- Existing Condition Baseline
- Full Market Baseline

Existing Condition Baseline is appropriate for retrofit projects with >5,000 cfm total kitchen hood exhaust airflow when they are determined not to be subject to code required controls. Baseline conditions will be entered by the user.

Full Market Baseline is assumed to be code baseline for all new construction projects and all replacement projects determined to be subject to code required controls.

Measure Analysis
Savings in this measure may be generated by any or all of three different methods:

1. reduction in the amount of fan energy due to reduced airflow during times when the fan speed is reduced (off-peak hours)
2. cooling and/or heating savings from reducing the annual amount of outside air brought in
3. electricity savings from higher efficiency fan motors than baseline

Fan energy savings
The "Motor Savings" tab calculates the motor energy saved due to reduced flow during off-peak periods. The schedule entered by the user will create the temperature bins for the fans' operational hours. Those are further broken down to peak and off-peak periods of operation. The user must enter the off-peak airflow as a percent of full airflow (between 50% and 75%).

Savings for reduced fan motor energy are primarily based on the Affinity Laws for fans:

$$Bhp_2 \;/\; Bhp_1 \;=\; CFM_2{}^3 \;/\; (CFM_1)^3$$

Which results in:

$$Bhp_{off-peak} \;=\; Bhp_{peak}\; x\; Flow\; x\; (CFM_{off-peak}\%)^3$$

Where:

- Bhp is brake horsepower.

Conversions from nameplate HP to Bhp are performed using motor and VFD efficiency values, but the nameplate HP is first de-rated by 25% to account for typical oversizing observed in industry practice. Instead of using $(CFM_{off\text{-}peak\ \%})^3$, the calculator uses $(CFM_{off\text{-}peak\ \%})^{2.5}$ to produce a more conservative estimate of off-peak Bhp.

Heating and cooling savings
Savings come from the reduction of heating and cooling energy when the equipment is running at reduced capacity during off-peak periods.

Unless "no heating" or "no cooling" is selected, the make-up for the kitchen hood exhaust is conditioned. The heating and cooling loads are generally calculated as follows:

$$Q = CFM\ x\ (t_{outside} - t_{inside})\ x\ 1.08\ Btu/h$$

Where:

- Q is the heat content or load over an hour. Only sensible heat load is calculated. Latent is relatively minor and is therefore not calculated.
- $t_{outside}$ is the outside air DB temperature
- t_{inside} is the indoor temperature setpoint

For this calculation, the heating setpoint of 65 deg. and cooling setpoint of 75 deg can both be overridden by the user. It is assumed that the heating for the make-up air (MUA) unit is disabled when the outside air (OSA) is above the heating setpoint, and AC cooling is disabled when the OSA is below the cooling setpoint.

Using the BinMaker software, dry bulb temperature bins have been created for 6 representative climatic zones in Oregon. The schedule entered by the user will create the temperature bins for the fans' operational hours. Those are further broken down to peak and off-peak periods of operation. The user must enter the off-peak airflow as a percent of full airflow (between 50% and 75%). The model calculates the peak and off-peak heat loss and heat gain.

Baseline heating and cooling energy output calculations are based on the MUA unit and exhaust hood both running at 100% flow during hood operational hours (peak plus off-peak hours). Total heating and cooling energy is calculated based on the modeled peak and off-peak operations:

$$Total\ Energy = Energy_{\ off-peak} + Energy_{\ peak}$$

Where:

$$Energy_{\ off-peak} = \sum (Number\ of\ Hours\ \ x\ Q\ )_{off-peak}$$
$$Energy_{\ peak} = \sum (Number\ of\ Hours\ x\ Q)_{peak}$$

The Kitchen Hood Calculator tab has a pull-down menu to select the kitchen heating system (gas, electric, heat pump, and no heat) and Cooling/No Cooling. Heating and cooling systems use default efficiency values of 0.8 for gas, COP of 1 for electric, and HSPF of 8 for HP. A SEER of 14 is used for AC. These default efficiencies are equivalent to code minimum values and can be overridden by the user. Efficiencies are always assumed to be the same for the base case and proposed case.

Motor efficiency savings
Motor efficiencies for proposed motors may be adjusted to account for installation of premium motors which may exceed minimum code efficiencies. Baseline motor efficiencies may not be adjusted from default code values for new construction projects. However, motor efficiencies may be adjusted to reflect lower than code minimum existing motors in existing building applications. Because motors and VFDs exhibit reduced efficiency under the part load condition, appropriate part load motor and VFD efficiency reduction factors have been identified and are used in the calculations for peak and off-peak flow periods.

Comparison to RTF or other programs
RTF approved a new standard protocol for estimating savings of demand controlled kitchen ventilation systems at the July 2022 meeting with an associated calculator. Similar to the Kitchen Vent Hood Calculator associated with this MAD, the RTF calculator estimates savings for three components of demand-controlled kitchen ventilation systems in commercial kitchens: 1. Fan energy savings, 2. Makeup air heating savings, and 3. Makeup air cooling savings. The RTF calculator and standard protocol will be available from the RTF Standard Protocols webpage at: https://rtf.nwcouncil.org/standard-protocols/.

Existing Buildings has a standard measure for retrofit application, MAD 122 for a limited range of fan motor sizes.

Measure Life
The measure life of 15 years aligns with DEER exhaust demand control ventilation.

Load Profile
The appropriate load profile will be determined per project but for electricity this is expected to be restaurant cooking, and if there are heating savings from a gas heating system due to reducing the annual amount of outside air brought in the appropriate load profile for gas would be heating.

Cost
Incremental costs will be provided to the program on a case by case basis for cost effectiveness testing. Incremental cost for this measure is customarily equivalent to the labor and material costs of installing VFDs and necessary controls on exhaust and makeup air fan motors.

The calculator will allow below-code efficiency baseline motors for replacement projects only. Incremental cost in these cases should represent not only controls equipment and labor, but also an appropriate cost for incremental improvement in motor efficiency.

Incentive Structure
Appropriate custom (Existing Buildings) or special measure (New Buildings) incentive rates should be used for all therm and electric savings generated by the kitchen hood calculator.

Follow-Up

Current indications are that Oregon will be adopting ASHRAE 90.1-2022 at some point in 2023. When available for review, the new code requirements should be reviewed and any necessary measure adjustments be made at that time. The tool must be approved at the next major update. Minor updates that do not change calculation methods do not require re-approval.

Supporting Documents

The placeholder cost effectiveness calculator is number 184.3.2. It is attached as is a copy of the tool. Further supporting documents can be found at: I:\Groups\Planning\Measure Development\Commercial and Industrial\Food Service\venthoods\venthood calculator

184.3.2 OR-WA-CE Calculator_2023_v_1

184.3 Kitchen Hood Calculator_unlockec

Version History and Related Measures

Table 1 Version History

Date	Version	Reason for revision
5/13/2016	184.1	Introduce kitchen hood calculator for New Buildings
6/28/2019	184.2	Calculation methodology was reviewed and refined. Alignment with 2020 code changes. Retrofit options added, now approved for Existing Buildings.
8/19/2022	184.3	Alignment with 2021 code

Table 2 Related Measures

Measures	MAD ID
Prescriptive Vent Hoods	122

Approved & Reviewed by

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Measure Approval Document for Manufacturer-Installed Rooftop Unit Controls

Valid Dates
1/1/2024 – 12/31/2024 or mandatory date of 2024 Oregon energy code, whichever is sooner

Description
This measure is applicable to economizers, demand controlled ventilation (DCV), and variable speed supply fans on new rooftop units (RTUs) which are not required by code to include these features. These controls must be included as factory options in new units, not as third-party add-ons. Only the DCV measure is applicable to projects in Washington or in Oregon gas-only territory, as this is the only measure that results in gas savings.

Variable speed fans are often controlled by variable frequency drives (VFD), though other speed control devices are also applicable.

At the time of authorship of this MAD, next code mandatory date is unknown and based on best available information from Oregon Building Codes Division could be as soon as April 2024 or as late as October 2024. At that time programs should refrain from promoting these measures.

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, the measure is applicable to the following classes:
- New
- Replacement

Purpose of Re-Evaluating Measure
This update allows for the measure to be offered until the next energy code becomes mandatory. The next Oregon energy code to be effective in 2024 is expected to reduce opportunity for this measure, due to the limited duration of this offer. There are no updates to savings or costs.

Variable Supply fans in gas units are no longer approved due to reduced cost effectiveness.

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 2024-v1.2. The Oregon electric avoided cost year is 2024 and the Oregon gas avoided cost year is 2024. The Washington gas avoided cost year is 2024. The values in these tables are per ton.

Table 1 Cost Effectiveness Calculator Oregon, per ton

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
19	Economizer, New gas heat RTU	15	174.31	(0.03)	$45.22	$0.00	$45.22	4.0	4.0	100%	0%
25	DCV, New gas heat RTU	15	16.00	21.46	$38.28	$0.00	$38.28	11.6	11.6	4%	96%
29	DCV, New gas heat RTU, gas only territory	15	0.00	21.46	$38.28	$1.28	$38.28	11.2	11.5	0%	100%
22	Economizer, New heat pump RTU	15	174.15	0.00	$45.22	$0.00	$45.22	4.0	4.0	100%	0%
27	DCV, New heat pump RTU	15	196.48	0.00	$38.28	$0.00	$38.28	6.5	6.5	100%	0%
28	Variable Supply fan, New heat pump RTU	15	489.26	0.00	$418.99	$0.00	$418.99	1.1	1.1	100%	0%

Table 2 Cost Effectiveness Calculator Washington, per ton

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
25	DCV, New gas heat RTU	15	21.46	$38.28	$1.23	$38.28	16.0	16.3	0%	100%

Requirements
- These measures are only applicable to installations of new rooftop units with DX cooling and either gas furnace or heat pump heating. Retrofits or add-on equipment to existing rooftop units are approved in MAD 256.

Economizers:
- Economizer savings may only be claimed when installed on rooftop units with cooling capacities less than 54,000 Btu/h.
- This measure is not applicable to projects in Washington or Oregon's gas-only territory.

DCV:
- DCV savings may only be claimed when installed in units which also have economizers.
- DCV savings may only be claimed for units which serve spaces that are not required by code to have DCV.
- A list of spaces by building type which are not required to have DCV accompanies this document – all spaces not listed are required by code to have DCV, or are expected to have negligible DCV savings and so are excluded from this measure. The most common expected spaces in which DCV is not code-required are office spaces (excluding conference rooms and reception areas) and retail sales floors (excluding mall common areas).
- Due to COVID-19 and the latest building ventilation guidelines, many buildings are disabling DCV. Sites that install but do not fully commission DCV may participate. It is assumed DCV will eventually be enabled within the measure life.

Variable Speed Supply Fan:
- May be controlled by VFD, EC motor or other speed control mechanism.
- Supply fan savings may only be claimed when installed in units which also have both DCV and economizers.

- Supply fan savings may only be claimed when installed in units with cooling capacity less than 65,000 Btu/h.
- This measure is not applicable to projects with gas heat

Existing fuel requirements

- These new and replacement measures may be used to replace systems of any fuel. There are no requirements related to existing fuels.

Baseline

This measure uses a Market Baseline. The Market Baseline is assumed to be code.

Each of these measures may be code required in particular locations and sizes of equipment and is considered baseline in those situations. These measures were designed using a rolling baseline approach. Using this approach allows savings to be calculated for controls which are not required by code, even if they are combined with other controls that are required by code.

The baseline equipment for the economizer measure is an RTU with no economizer, of a size where an economizer is not required.

- 2021 Oregon Energy Efficiency Specialty Code (OEESC) adopts ASHRAE Standard 90.1-2019, which requires economizers on units greater than 54,000 Btu/h per Section 6.5.1.

The baseline equipment for the DCV measure is an RTU with an economizer, in a location where DCV is not required.

- In Oregon, code requirements for DCV are set forth in ASHRAE Standard 90.1-2019 Section 6.4.3.8, with ventilation requirements outlined in 2022 Oregon Mechanical Specialty Code Section 403.3.
- In Washington, code requirements for DCV are set forth in 2021 Washington State Energy Code (WSEC) Section C403.7.1.1 which references Table 403.3.1.1 of the International Mechanical Code (IMC).

The baseline equipment for the variable speed supply fan measure is an RTU with an economizer and DCV of a size where a VFD or similar is not required.

- 2021 OEESC requires VFDs on supply fans for units with cooling capacities 65,000 Btu/h or greater per ASHRAE Standard 90.1-2019 Section 6.5.3.2.1.

Measure Analysis

Savings for the advanced rooftop unit controls measure were modeled by CLEAResult's new construction engineering team in 2017 using the New Buildings program's prototype models for the Small Office, Strip Mall Retail, and Primary School building types in eQuest 3.65. These models are meant to represent typical code-minimum new construction. Controls are likely to be installed in one of three potential combinations and were modeled accordingly. These combinations are:

- Economizer
- Economizer + DCV
- Economizer + DCV + Variable Speed Supply Fan

Economizers were modeled by allowing HVAC units to vary the amount of outside air in response to outside air temperature. Economizers were modeled with integrated operation (compressors are not locked out and economization is used in conjunction with mechanical cooling when needed) and with a high-limit cutoff of 70 degrees F.

DCV was modeled by changing the minimum air flow in spaces in which DCV is not code required to the code-prescribed per-square-foot value. Outside air flow in these spaces is then allowed to modulate in response to hourly occupancy, increasing the outside air flow based on the code-prescribed per-person value.

Variable speed supply fans were modeled by assigning variable speed performance curves to HVAC supply fans, and allowing supply fans to ramp down to a minimum of 30% of design speed (in line with typical recommended VFD minimums).

The measures were modeled for three Oregon climates (Coast/Astoria HZ1CZ1, Valley/Portland HZ1CZ2, Central/Redmond HZ2CZ1). The savings for each climate were combined into a weighted average using the following program-assumed weightings:

- Coast: 3%
- Valley: 87%
- Central: 10%

The weighted average savings for each building type were combined into a weighted average using the following weightings, based on New Buildings Program enrollments from 2015 and 2016:

- Office: 44%
- Retail: 25%
- School: 30%

Savings

Savings for these measures were determined using a rolling baseline approach, allowing a discrete savings value to be assigned to each control addition.

$$Savings_{DCV} = Savings_{Economizer} \quad - Savings_{Economizer}$$

$$Savings_{VFD} = Savings_{Economizer+D} \quad - Savings_{Economizer+DCV}$$

Comparison to RTF or other programs

The Regional Technical Forum (RTF) does not have a standard measure equivalent to these measures. They do have a standard protocol for supply fan VFD, which is study method and does not indicated a deemed savings. Bonneville Power Administration (BPA) has preliminary deemed savings for advanced rooftop controllers (ARCs) which include many of the features of these measures, though it's assumed that most ARC savings are from the VFDs. BPA's savings are in the same range as the total savings for all the measures included in this analysis.

The RTF also has a UES measure for Advance Rooftop Controls (ARC) that is related but differs in that it applies to retrofits of existing packaged units and it has different measure options, which Energy Trusts ARC retrofit measure (MAD 256) is based on. Savings for the retrofit ARC measures are categorized in bins of RTU operating hours and products are designated as Full ARC and ARC-lite. The modeled savings values for new RTU controls are comparable to that RTF measure for the appropriate operating hours ranges and measure categories. The Variable Supply Fan savings are comparable to the ARC-light savings, and the combined Economizer + DCV + Variable Supply Fan savings are comparable to the Full ARC savings.

The modeled savings are compared to available estimates from PNNL's ARC retrofit field-test results[1], PNNL's Rooftop Unit Comparison Calculator[2], and PG&E's work papers for retrofit add-on of economizers, DCV, and supply fan VFDs. The comparison showed that the modeled savings were reasonably in the same range as these other sources, with expected differences arising from different assumptions regarding baselines, climates, applications, etc.

Measure Life

The measure life is assumed to be 15 years, consistent with standard program assumptions regarding HVAC controls measures on new equipment.

Load Profile

The assigned load profiles are shown in Table 3.

Table 3 Load Profiles

Measure	Electric Load Profile	Gas Load Profile
Economizer, New gas heat RTU	Small Office Cooling	Com Heating
DCV, New gas heat RTU	Small Office Cooling	Com Heating
DCV, New gas heat RTU, gas only territory	None - ele	Com Heating
Economizer, New heat pump RTU	Small Office Cooling	None – gas
DCV, New heat pump RTU	Small Office Heating	None – gas
Variable Supply fan, New heat pump RTU	Small Office Ventilation	None – gas

Cost

Two leading HVAC manufacturers active in Oregon were surveyed to determine the estimated cost of adding these control features to a 3 ton, 4-5 ton, and 7.5 ton rooftop unit. The manufacturers gave similar costs for the combination of all three measures, however the breakdown of the cost among the individual control features differed. Based on program staff experience, the breakdown from one of the respondents was deemed more representative of typical pricing, where the primary cost driver is VFD and associate sensors. The total per unit cost provided by the second respondent was re-distributed based on the allocations from the other. The manufacturer costs were averaged, then normalized by cooling capacity to determine a $/ton value for each measure. The cost information is summarized in Table 4 and Table 5.

Table 4 Manufacturer-Provided Cost Estimates

	Feature	Factory Installed Price			
		MFGR1	MFGR2	MFGR2 - Adjusted per MFGR 1 breakdown	Average
3 Ton	Advanced Digital Economizer	$200.00	$1,080.00	$129.58	$164.79
	CO2 sensor	$200.00	$475.00	$129.58	$164.79
	Variable speed supply fan motor (and additional sensors for variable flow)	$2,000.00	$0.00	$1,295.83	$1,647.92
	Digital Economizer, CO2, and SF VFD	$2,400.00	$1,555.00	$1,555.00	$1,977.50
4-5 Ton	Advanced Digital Economizer	$200.00	$1,080.00	$119.62	$159.81
	CO2 sensor	$200.00	$475.00	$119.62	$159.81
	Variable speed supply fan motor (and additional sensors for variable flow)	$2,200.00	$0.00	$1,315.77	$1,757.88
	Digital Economizer, CO2, and SF VFD	$2,600.00	$1,555.00	$1,555.00	$2,077.50
7.5 Ton	Advanced Digital Economizer	$200.00	$1,477.00	$165.80	$182.90
	CO2 sensor	$200.00	$1,010.00	$165.80	$182.90
	Variable speed supply fan motor (and additional sensors for variable flow)	$2,600.00	$0.00	$2,155.40	$2,377.70
	Digital Economizer, CO2, and SF VFD	$3,000.00	$2,487.00	$2,487.00	$2,743.50

Table 5 Average Costs Normalized by Cooling Capacity

Measure	Tons	Average Price	$/ton	Avg $/ton
Economizer	3	$164.79	$54.93	$45.22
	4.5	$159.81	$35.51	
DCV	3	$164.79	$54.93	$38.28
	4.5	$159.81	$35.51	
	7.5	$182.90	$24.39	
VFD	3	$1,647.92	$549.31	$418.99
	4.5	$1,757.88	$390.64	
	7.5	$2,377.70	$317.03	

Incentive Structure

Incentives will be structured per ton of cooling capacity. Like the savings values, incentive values will be calculated using an additive approach in which incentives are only added for the installed features which are not code-required.

The maximum incentives listed in Table 1 and Table 2 are for reference only and are not suggested incentives. Bonuses or promotions must not raise incentives above those in Table 1 and Table 2.

[1] PNNL Advanced Rooftop Control (ARC) Retrofit: Field-Test Results http://www.pnl.gov/main/publications/external/technical_reports/PNNL-22656.pdf
[2] PNNL Rooftop Unit Comparison Calculator http://www.pnnl.gov/uac/costestimator/main.stm

Follow-Up

This measure has multiple applicability requirements based on sections of the OEESC and the OMSC. The next Oregon energy code, based on ASHRAE 90.1-2022, to be effective in 2024, is expected to reduce opportunity for this measure. In particular:

- 90.1-2022 has stricter requirements for economizers (required on units >33,000 Btu/h (2.75 tons), compared to >54,000 Btu/h (4.5 tons)
- Demand control ventilation (DCV) requirements are also changing, which introduces an area-based component that could make implementing this measure in the program more burdensome (under the current measure, only space type needs to be verified; under the new requirements, space type and space area would need to be verified).

Any future revision much consider the latest code as well as any federal RTU or commercial heat pump standards.

Climate zone weightings, representative cities, and building type weighting should be updated at any future revision.

Supporting Documents

The cost effectiveness screening for these measures is number 195.3.2. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Commercial and Industrial\Commercial HVAC\Economizers and controls\new RTU with controls

195.3.2 OR-WA-CE Calculator_2024_v_1 | RTU Controls_Batch Results_10132016.xl: | DCV - Eligible Space Types.docx

Version History and Related Measures

Energy Trust has been offering economizers and DCV measures for many years and the offerings have evolved over time and have often been bundled with other measures. The approval of these measures predates our current measure approval documentation process and record retention requirements. Table 6 may be incomplete, particularly for measures approved prior to 2013.

Table 6 Version History

Date	Version	Reason for revision
12/22/05	185.x	Approves air, water and ground source heat pumps, chillers, heat exchangers and DCV for use in New Buildings
6/05/08	185.x	Add Existing buildings to above.
6/19/08	185.x	Add PE to above.
7/24/09	194.x	Rooftop tune-up pilot approval. Rooftop tune-up included contractor-installed economizers and DCV on existing RTUs.
4/05/10	194.x	Transition rooftop tune-up from pilot to standard offer. Updates to savings and structure based on pilot evaluation.
8/11/10	194.x	Add split-systems and other updates to tune-up offer.
10/6/10	96.x	New Buildings DCV prescriptive measure, aligned with 194.x. Superseded DCV in 185.x above.
2/11/11	185.x	Approval for New Buildings HVAC calculator for unitary equipment including air, ground and water-source heat pumps and air conditioners.
2/14/11	185.x	Adds Existing Buildings and PE as applicable programs to 185.
2/14/11	96.x	Approval for DCV calculator module of New Buildings HVAC calculator, replaces prescriptive DCV for New Buildings.
5/25/11	194.x	Add Production Efficiency as applicable program to tune-up offer.
7/14/11	x	Approval of Economizer module of New Buildings HVAC Calculator.
12/21/11	185.x	Replaces New Buildings HVAC calculator with prescriptive measures for unitary HVAC and economizers for use in New and Existing Buildings.
3/14/12	185.x	Add PE to above.
12/31/13	194.x	Tune up offering canceled, economizers and DCV no longer approved for Existing Buildings. MAD 194 moved to inactive.
3/1/17	195.1	New approval for Economizers, DCV and VFD on supply fans for New and Existing Buildings and PE. With this update, the New Buildings HVAC calculator is no longer in use for any measure. This economizer measure here supersedes the economizers in 185.x This DCV measure supersedes 96.x, which will be moved to inactive.
9/16/20	195.2	Updated requirements based on updated code
7/25/23	195.3	Extend Expiration, drop non CE measures

Table 7 Related Measures

Measures	MAD ID
Advanced Rooftop controls retrofit	256
Ground and water-source heat pumps (Inactive)	185
Duplicate of 185, (inactive)	121

Approved & Reviewed by

Jackie Goss, PE
Sr. Engineer – Planning & Evaluation

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

Valid Dates
January 1, 2023 – December 31, 2025

End Use or Description
Single or multiple condensing tankless water heaters (CTWH) sized <200 kBtu/h, serving as a central domestic hot water (DHW) system in multifamily 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, Multifamily
- New Buildings, Multifamily

Within these programs, applicability to the following building types are expected:
- Stacked multifamily structures 4 stories or greater

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

Purpose of Re-Evaluating Measure
The baseline was updated from code to full market. Savings and requirements were updated to align with methodologies and inputs used in other condensing tankless water heater measures offered by Energy Trust. Costs were updated using current online pricing.

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 2023-v1.0. In Oregon the electric avoided cost year is 2023 and the gas avoided cost year is 2023. In Washington the gas avoided cost year is 2023. The values in these tables are per CTWH unit.

Table 1 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	Multifamily - Condensing Tankless Water Heater <200 kBtu/h	20	0.00	25.67	$140.21	$0.00	$140.21	2.6	2.6	0%	100%

Table 2 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	Multifamily - Condensing Tankless Water Heater <200 kBtu/h	20	25.67	$140.21	$0.00	$140.21	3.4	3.4	0%	100%

Requirements
- Must be installed in stacked multifamily structures with central water heating.
- Installed equipment shall be a condensing tankless water heater with input capacity less than 200kBtu/h.
    - Commercially sized equipment ≥200kBtu/h is approved through MAD ID 72 with different savings and requirements.
- Installed equipment Uniform Energy Factor (UEF) shall be to 0.94 or greater.
- Installed equipment must be on the AHRI certified product list.
- Additional storage tanks are not allowed.

Existing Condition Requirements
These measures are intended as replacement at/near burn out or new. There are no existing fuel requirements.

Details
Central domestic water heating system are being increasingly served by multiple residential-sized tankless water heaters (typically 199 kBtu/h and under) installed in parallel. Within the tankless water heater (THW) market, users are purchasing both condensing and non-condensing tankless water heaters. Regional sales data indicate that the market share of condensing is significantly larger than 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 lower efficiency condensing tankless water heaters and discourage the addition of storage tanks, which may cause standby 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 storge tank water heaters. The full market baseline was based on an analysis of tankless water heater distributor sales data and product efficiencies listed in the AHRI database.

Distributor Sales Data and AHRI Database Findings
Distributor sales data between 2018 and 2020 for Oregon was used to determine the market share of condensing versus non-condensing THWs. Condensing tankless water heaters represented 86% of sales while the remaining 14% were non-condensing tankless water heaters. The AHRI database was used to establish condensing and non-condensing tankless water heaters average thermal efficiencies, which were used to determine the baseline thermal efficiency used in the savings calculations. Table 3 summarizes the sales data, AHRI average efficiency, and the weighted average baseline thermal efficiency.

Table 3: Sales Data, AHRI Average Efficiencies, and Full Market Baseline Efficiency

Type	Count	Share	Average Recovery Efficiency	Baseline Thermal Efficiency
Condensing	3,476	86%	96%	**94.4%**
Non-Condensing	563	14%	84%	

Measure Analysis

Savings are based on spreadsheet calculations, whose primary inputs are annual hot water demand, peak hot water demand (total TWH capacity), and water temperature rise. The main input sources are from the Department of Energy's (DOE) Technical Support Document (TSD): Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment[1] and related sources. The site-level assumptions for calculating annual hot water and CTWH capacity requirements are based on the DOE's High-rise apartment building characterization.

Hot Water Demand – WHAM Energy Consumption Equation

The DOE's Water Heater Analysis Model (WHAM)[2] for tankless water heaters is used to calculate the total water heater input energy. The equation uses the estimated total annual hot water demand in gallons, estimated temperature rise, the specific heat capacity of water, the average density of water, the thermal efficiency, and an adjustment factor to account for actual observed performance.

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

Where:

- Q_{in} = total water heater energy consumption, Btu
- vol = annual water use, gal
- 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, %
- PAi_{wh} = performance adjustment factor

The total heat input required by the water heaters is converted to therms. The total savings are the difference between the baseline and proposed measure case total input therms.

$$\text{Annual Savings}_{therms} = Q_{in\ Baseline} - Q_{in\ Measure}$$

Annual Hot Water Demand

The annual hot water demand was determined using the daily hot water load schedules and normalized peak demand listed in Appendix 7B of the US DOE's TSD for the high-rise apartment building type. The DOE used the LBNL hot water model[3], but to prevent outlier occupancies from charactering the entire building, the model was normalized to the number of housing unit occupants in each age group using RECS 2009 data on household members. The product of the normalized peak and hourly ratios yield the hourly demand in a 24-hour period, which is assumed constant throughout the year. Table 4 below summarizes the daily and annual hot water demands.

Table 4: Daily and Annual Hot Water Demand

Prototype Buildings	Daily DHW [gal]	Annual DHW [gal]
High-Rise Apartment	3,458	1,263,215

Peak Hot Water Demand – Total Tankless Water Heater Capacity Requirements

The annual savings were normalized per water heater, which required determining the number of tankless water heater units to meet the peak hot water demand. Rather than estimating the peak flow demand, the high-rise apartment tank-type hot water heater storage and heating capacities listed in the Table 2.2 of the DOE's Enhancements to ASHRAE Standard 90.1 Prototype Building Models[4] were converted to tankless capacity using the methodology in section 7.7 of the DOE's TSD. This effectively establishes the equivalent total tankless water heater capacity required to meet the peak hot water demand.

$$Q_{tankless} = \left(Q_{tank} + dT * C_p * y * Vol * Tank_u / t_{load}\right) * Adj_{tankelss}$$

Where:

- $Q_{tankless}$ = adjusted tankless capacity, Btu/h
- Q_{tank} = tank water heater capacity, Btu/h
- dT = temperature rise, °F
- C_p = specific heat of water, 1.000743 Btu/lb·°F
- y = specific weight of water, 8.29 lb/gal
- Vol = tank volume, gallons
- $Tank_u$ = fraction of hot water in the tank that is usable
- $Adj_{tankless}$ = tankless adjustment factor
- t_{load} = maximum load duration, hr

The total required tankless water heater capacity is divided by unit size, which is assumed to be 199 kBtu/h.

Temperature Rise Input Assumptions

The inlet water temperature is determined by using the Regional Technical Forum's (RTF) Standard Information Workbook's (SIW)[5] ground water temperatures by heating zone. The temperatures were averaged, weighted by their share of project uptake using Project Tracker (PT) data. The water heater outlet temperature is assumed to be 128°F, which is adopted from the RTF's residential gas water heater measure.[6]

The average inlet temperature and zone weightings by project uptake between 2017 and 2021 are listed in Table 5.

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1 https://downloads.regulations.gov/EERE-2014-BT-STD-0042-0016/attachment_1.pdf
2 https://downloads.regulations.gov/EERE-2006-STD-0129-0149/attachment_1.pdf
3 https://www.govinfo.gov/content/pkg/FR-2010-04-16/pdf/2010-7611.pdf
4 https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-23269.pdf
5 https://nwcouncil.box.com/v/RTFSIW--v4-5
6 https://nwcouncil.box.com/v/ResGasWH-v2-0

Table 5: Heating Zone Weighted Average Inlet Temperature

Heating Zone	Temperature by Zone [°F]	Projects by Zone	Average Inlet Temperature [°F]
1	55.3	97%	**55.2**
2	51.7	3%	
3	49.1	0%	

Thermal Efficiency to Uniform Energy Factor Correlation

The WHAM equation requires the thermal efficiency (TE) to calculate the TWH energy consumption. However, tankless water heaters in this size category are rated by Uniform Energy Factor (UEF), which is used by federal regulations covering minimum efficiency requirements for tankless water heaters.[7]

A target thermal efficiency of 97% was established based on the AHRI product availability. The target thermal efficiency was correlated to UEF though three different methods:

1. Average UEF for all equipment with a TE of 97% and greater
2. Average of UEF to TE ratio for all condensing TWHs times 97% TE
3. Linear regression of UEF vs TE

Table 6 summarizes the results of the three methods described above and their average, which establishes the UEF for measure eligibility.

Table 6: Measure Case UEF

Method	Assumed TE	UEF	Measure UEF
Average UEF of all units with 97% TE	97%	0.937	**0.94**
Average UEF/TE * 97% TE		0.941	
Linear Regression - UEF @ 97% TE		0.941	

Savings

Table 7 summarizes savings per CTWH along with total required input capacity, CTWH quantity, annual hot water demand, baseline and measure energy uses, and total annual savings. The annual savings are based on the DOE's prototypical high-rise apartment building characterized in the TSD, which assumes is 84,360 square feet and with a normalized peak hot water demand of 274.92 GPH. The annual savings were divided by the quantity of water heaters in the prototypical model to determine the savings per CTWH.

Table 7: Summary of Energy Use and Savings

CTHW input Capacity [kBtu/h]	Quantity of CTHW [#]	Hot Water Demand [gal/yr]	Baseline Energy Use [kBtu/yr]	Measure Energy Use [kBtu/yr]	Annual Savings [kBtu]	Total Annual Savings [therm]	Savings per CTWH [therm]
1,540	7.74	1,263,215	886,345	866,481	19,865	199	25.67

Comparison to RTF or other programs

The RTF does have a residential gas water heater workbook[8], which includes storage tank and tankless water heater savings. The workbook uses the WHAM methodology to calculate tankless water heater energy consumption as done by this measure's analysis. Annual hot water demand is determined using SEEM, which differs from this analysis' use of the DOE's TSD water use schedules and normalized peak hot water demand.

Energy Trust offers Commercial Condensing Tankless Water Heaters <200 kBtu/h, via MAD 212 which also assumes the typical CTWH size is 199 kBtu/h, but targets commercial market segments such as gyms, coin-op laundries, motels, and schools. Energy Trust also offers Commercial Condensing Tankless Water Heaters ≥200 kBtu/h, via MAD 72 which targets the commercial market segments but is better suited for projects requiring larger capacity CTWHs or where space constraints limit the number of smaller CTWHs that can be installed.

Measure Life

The measure life is assumed to be 20 years, which matches other tankless water heater measures offered by Energy Trust.

Load Profile

Electric: None – ele
Gas: DHW

Cost

Equipment costs

A dataset of tankless water heaters from various online retailers collected in November of 2020 was updated with current pricing and used to determine the equipment costs at various efficiencies. The dataset consists of 106 models and was updated using currently online published costs. Overall, the average cost increase from November 2020 to May 2022 was 17%. This data will also be used in MAD 212 (Commercial Tankless Water Heaters <200 kBtu/h).

The water heaters were categorized into different efficiency categories as follows:

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

Each tankless water heater was categorized under one of the efficiency levels defined above and its costs was normalized per kBtu/h. The costs for the non-condensing units and the average of all condensing units were used to establish the full market baseline costs. The costs for high efficiency condensing units were used for the proposed measure case costs.

[7] https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32
[8] https://rtf.nwcouncil.org/measure/residential-gas-water-heaters-0/

Labor and Ancillary Costs
Labor and ancillary material costs were adopted from the California Codes and Standards Enhancement (CASE) report for high efficiency water heaters[9]. Because the report is dated from 2013, the costs were inflated to 2023 dollars using the RTF's Standard Information Workbook inflation factors.[10]

The labor and ancillary estimates used in this analysis only include incremental cost between the non-condensing and condensing water heaters. For non-condensing water heaters this includes costs of steel venting materials for the hotter exhaust gases. For condensing water heaters this includes costs of PVC venting materials, condensate drain connection, condensate neutralizer, and condensate pump.

Table 8 summarizes the total baseline, measure, and incremental costs. Baseline costs were weighted by share of condensing and non-condensing TWH sales summarized in Table 5.

Table 8: Baseline, Measure, and Incremental Costs per CTWH

Case	Cost/unit
Baseline	$2,194.59
Measure	$2,334.80
Incremental	$140.21

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.

Follow-Up
- The market baseline should be reevaluated at the next update to comprehend the share of condensing vs non-condensing THW sales.
- Annual hot water demand should be reevaluated using the latest DOE's prototype building model hot water load schedule or other consistent sources.
- Costs should be updated or compared to actual project costs. The 2013 CASE source in particular is getting dated.

Supporting Documents
The cost-effective screening for these measures is number 196.5.2. 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\Multifamily Tankless less than 199

196.5.2_OR-WA-CE Calculator_2023_v_1

Version History and Related Measures
Energy Trust has been offering tankless water heaters measure for many years. These predate our measure approval documentation process and record retention requirements. Table 9 may be incomplete, particularly for measures approved prior to 2013.

Table 9 Version History

Date	Version	Reason for revision
3/30/2017	196.1	New measure
4/10/2017	196.2	Include New Multifamily
1/25/2018	196.3	Correct requirement to < 200 kBtu, to allow for 199.999 kBtu units
7/26/2019	196.4	Adjusted assumed units per building and updated with RBSA II.
9/19/2022	196.5	Savings updated. Requirement change to 0.94 UEF.

Table 10 Related Measures

Measures	MAD ID
Commercial and Multifamily Condensing Tankless ≥200 kBtu/h	72
Commercial and Multifamily Condensing Tankless <200 kBtu/h	212
Commercial and Multifamily Condensing Tank Water Heaters	21
Multifamily DHW Recirculation Demand Control	66
New Homes Tankless	178

Approved & Reviewed by

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[9] 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
[10] https://nwcouncil.box.com/v/RTF-SIW-v4-6

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 1 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 2 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:

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

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 3

Table 3 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 4 Related Measures

Measures	MAD ID
Commercial Steam Traps	42
Multifamily Steam Traps	40

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Measure Approval Document for New Refrigerated Cases with Doors

Valid Dates
1/1/2024 – 12/31/2026

End Use or Description
Installation of new refrigerated cases with doors instead of open cases. Doors reduce the ambient air infiltration to the case, which lowers the refrigeration load. The addition of doors also lowers the HVAC heating load.

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:

- Convenience stores
- Grocery stores
- Big box retail stores with grocery sections

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

- New
- Replacement

Purpose of Re-Evaluating Measure
Cost and savings were updated. The analysis methodology was updated using a spreadsheet analysis instead of building energy modeling.

The measure life was updated to 10 years to align with MAD 186 and the RTF's Commercial Refrigerators/Freezers UES measure.

Measures are no longer differentiated by building type.

Horizontal Low temperature case measure applications were added. Horizontal Low temperature cases with self-contained condensing units were added, in limited circumstances only.

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 2024-v1.2. The Oregon electric avoided cost year is 2024 and the Oregon gas avoided cost year is 2024. The Washington gas avoided cost year is 2023. The values in these tables are per linear foot of case.

Table 1 Cost Effectiveness Calculator Oregon, per Linear 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	Refrigeration Case w/ Door - remote condensing, vertical med temp - Electric Heat	10	2,198.07	0.00	293.82	$0.00	$293.82	4.5	4.5	100%	0%
2	Refrigeration Case w/ Door - remote condensing, horizontal med temp - Electric Heat	10	850.19	0.00	293.82	$0.00	$293.82	1.8	1.8	100%	0%
3	Refrigeration Case w/ Door - remote condensing, vertical med temp - Gas Heat	10	729.34	66.40	293.82	$0.00	$293.82	4.7	4.7	32%	68%
4	Refrigeration Case w/ Door - remote condensing, horizontal med temp - Gas Heat	10	282.10	25.68	293.82	$0.00	$293.82	1.8	1.8	32%	68%
5	Refrigeration Case w/ Door - remote condensing, vertical med temp - Gas Heat, GOT	10	0.00	66.40	293.82	$58.13	$293.82	3.2	4.8	0%	100%
6	Refrigeration Case w/ Door - remote condensing, horizontal med temp - Gas Heat, GOT	10	0.00	25.68	293.82	$22.49	$293.82	1.3	1.9	0%	100%
7	Refrigeration Case w/ Door - remote condensing, horizontal low temp - Electric Heat	10	852.29	0.00	293.82	$0.00	$293.82	1.8	1.8	100%	0%
8	Refrigeration Case w/ Door - remote condensing, horizontal low temp - Gas Heat	10	500.36	15.91	293.82	$0.00	$293.82	1.8	1.8	57%	43%
9	Refrigeration Case w/ Door - remote condensing, horizontal low temp - Gas Heat, GOT	10	0.00	15.91	293.82	$39.88	$227.92	1.0	1.8	0%	100%
19	Refrigeration Case w/ Door - remote condensing, vertical med temp - Gas Heat, EOT	10	729.34	0.00	293.82	$78.31	$293.82	1.5	3.6	100%	0%
20	Refrigeration Case w/ Door - remote condensing, horizontal med temp - Gas Heat, EOT	10	282.10	0.00	293.82	$30.29	$170.83	1.0	1.4	100%	0%
21	Refrigeration Case w/ Door - remote condensing, horizontal low temp - Gas Heat, EOT	10	500.36	0.00	293.82	$18.77	$293.82	1.0	1.5	100%	0%
24	Refrigeration Case w/ Door - self-contained, horizontal low temp - Gas Heat, EOT	10	643.59	0.00	293.82	-$9.91	$293.82	1.3	1.1	100%	0%

Table 2 Cost Effectiveness Calculator Washington, per Linear Foot

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Refrigeration Case w/ Door - remote condensing, vertical med temp - Gas Heat	10	66.40	293.82	$56.16	$293.82	4.6	6.2	0%	100%
2	Refrigeration Case w/ Door - remote condensing, horizontal med temp - Gas Heat	10	25.68	293.82	$21.72	$293.82	1.8	2.4	0%	100%
3	Refrigeration Case w/ Door - remote condensing, horizontal low temp - Gas Heat	10	15.91	293.82	$38.53	$293.82	1.1	2.2	0%	100%

Requirements

- Must be a new refrigerated display case with doors in new construction or existing buildings where cases are being added or replaced.
- Doors must be transparent. Cases with solid doors don't qualify for this measure.
- Refurbished cases are not eligible for this measure.
- May not combine this measure with MAD 186.

Implementation Details

- Incentives are based on the total linear footage of refrigeration case.
- Measures are separated between low and medium temperature applications:
  - Low temperature includes freezers with operating temperatures <32°F.
  - Medium temperature includes coolers with operating temperature ≥32°F.
- Measures are separated between gas heated and electric heated buildings.
- For gas only territories, electric savings are accounted for as non-energy benefits.
- Measure applications ending in "EOT" are to be used by gas customers on a non-qualifying rate, or buildings heated with bulk fuels such as propane or fuel oil.

Baseline

This measure uses a Full Market Baseline.

The baseline is assumed to be a mix of refrigerated cases with and without doors that meet code maximum daily energy consumption as specified under 10 CFR 431.66(e)(1).[1] Unit shipment data from the DoE's Technical Support Document (TSD) was used to estimate the share of open cases as a proxy for local market practice. Table 3 below summarizes the percent open cases for each equipment class. Where no shipment data existed for an open refrigerated case, the percent market share was assumed to be 0%. Where no shipment data existed for a closed refrigerated case, the percent share for open cases was assumed to be 100%.

Table 3: Percent Market Share of Open Cases

Equipment Description	Equipment Class - open	Count - open	Equipment Class - closed	Count - closed	Percent Open Cases
Vertical Closed Remote Condensing - med temp	VOP.RC.M	127	VCT.RC.M	16	89%
Horizontal Closed Remote Condensing - med temp	HZO.RC.M	16	HCT.RC.M	0	100%
Vertical Closed Self-Contained - med temp	VOP.SC.M	16	VCT.SC.M	89	15%
Horizontal Closed Self-Contained - med temp	HZO.SC.M	1	HCT.SC.M	2	43%
Vertical Closed Remote Condensing - low temp	VOP.RC.L	4	VCT.RC.L	122	3%
Horizontal Closed Remote Condensing - low temp	HZO.RC.L	32	HCT.RC.L	0	100%
Vertical Closed Self-Contained - low temp	VOP.SC.L	0	VCT.SC.L	3	0%
Horizontal Closed Self-Contained - low temp	HZO.SC.L	2	HCT.SC.L	4	28%

Measure Analysis

Savings were based on the methodology of the RTF's Retrofit Doors on Grocery Displays.[2] Although intended for door retrofits to existing equipment, the savings are based on the difference in the code maximum daily energy consumption for open versus closed display cases meeting federal standards. The refrigeration energy consumptions for the open and closed cases assume a typical case height and width (or depth for horizontal configurations), which is defined in the RTF workbook.

The total savings also include indirect savings due to HVAC interactions, which are positive from the reduced HVAC heating load and negative from the increased cooling loads. HVAC savings were calculated using interaction values from the RTF's Standard Information Workbook, v4.8.[3] The equations below define the individual savings components and the overall savings for each measure application.

Direct Refrigeration Savings – store ambient air infiltration reduction due to door:

$$\frac{kWh_{ref}}{ft \cdot yr} = \frac{kW_{open} - kW_{closed}}{ft \cdot day} * \frac{days}{yr}$$

Indirect HVAC savings/penalties – reduction/increase in heating load to conditioned space:

$$\frac{kWh_{HVAC}}{ft \cdot yr} = \frac{kWh_{ref}}{ft \cdot yr} * \frac{EER_{ref}}{3.412} * HeatInteraction^{4}$$

Indirect HVAC savings/penalties – reduction/increase in cooling load to conditioned space:

$$\frac{kWh_{HVAC}}{ft \cdot yr} = \frac{kWh_{ref}}{ft \cdot yr} * \frac{EER_{ref}}{3.412} * CoolingInteraction$$

Total Savings – sum of the refrigeration and HVAC savings/penalties:

$$\frac{kWh_{Total}}{ft} = \frac{kWh_{ref} - kWh_{HVAC}}{ft \cdot yr}$$

[1] https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-431/subpart-C#p-431.66(e)(1)
[2] https://nwcouncil.box.com/v/retrofitdoorworkbook2-1
[3] https://nwcouncil.box.com/v/RTF-SIW-v4-8
[4] Equation is for electric fuel heat. Heat interaction units are heating fuel dependent.

The savings were calculated using interaction factors specific to gas versus electric heating fuel. The case type (remote condensing vs. self-contained) determines whether the HVAC interactions yield energy savings or penalties. Energy savings for gas heated stores were calculated in therms and reported separately in the Cost Effectiveness Calculator.

Savings

The measure applications were built-up by combining savings for the various components in Table 4, which summarizes the direct and indirect savings by equipment class, temperature, orientation, and condensing design. The yellow highlighted cases are presented here for reference only – new sales of vertical, low-temperature cases without doors are not expected to be a typical market practice.

Table 4: Savings by Component by Equipment Class, Temperature, Orientation, and Condensing Design

Case	Equipment Class - open	Equipment Class - closed	Refrigeration Savings [kWh/ft]	Cooling Savings [kWh/ft]	Heating Savings [kWh/ft]	Heating Savings [therm/ft]
Refrigeration Case w/ Door - remote condensing vertical med temp	VOP.RC.M	VCT.RC.M	863	-134	1469	66
Refrigeration Case w/ Door - remote condensing horizontal med temp	HZO.RC.M	HCT.RC.M	334	-52	568	26
Refrigeration Case w/ Door - self-contained vertical med temp	VOP.SC.M	VCT.SC.M	425	79	-342	-15
Refrigeration Case w/ Door - self-contained horizontal med temp	HZO.SC.M	HCT.SC.M	387	72	-311	-14
Refrigeration Case w/ Door - remote condensing vertical low temp	VOP.RC.L	VCT.RC.L	107	-6	71	3
Refrigeration Case w/ Door - remote condensing horizontal low temp	HZO.RC.L	HCT.RC.L	532	-32	352	16
Refrigeration Case w/ Door - self-contained vertical low temp	VOP.SC.L	VCT.SC.L	0	0	0	0
Refrigeration Case w/ Door - self-contained horizontal low temp	HZO.SC.L	HCT.SC.L	600	43	-188	-8

Comparison to RTF or other programs

This measure leverages the methodology of the RTF's Retrofit Doors on Grocery Displays workbook to determine the refrigeration and HVAC heating savings. However, this analysis includes cooling savings using interaction factors from the RTF's SIW. The interaction factors for this analysis were selected for each heating fuel type, while the RTF's analysis used factors assuming sector average fuel splits.

The Existing Buildings Program offers MAD 47 – Refrigerated Case Door Retrofit, which is based on the RTF's earlier version of their Retrofit Doors on Grocery Displays. However, MAD 47 does not offer measure applications for self-contained refrigeration cases.

Measure Life

The measure life is 10 years, consistent with other standard grocery refrigeration measures in Energy Trust and RTF programs.

Load Profile

Remote Condensing
- Electric Load Profile: Grocery Refrigeration
- Gas Load Profile
- Electric Heat: None – gas
- Gas Heat: Com Heating

Self-Contained
- Electric Load Profile: Restaurant Refrigeration
- Gas Load Profile
- Electric Heat: None – gas
- Gas Heat: Com Heating

Cost

Costs were determined from a mix of a custom project, contractor input, and the previous MAD version estimate. Table 5 below summarizes the values from each source. The third quartile of the data is $293.82 and was used as the cost basis for each equipment class using weights based on the DoE shipment data. Table 6 below summarized the weighted incremental costs by equipment class used in cost effectiveness testing for each measure application.

Table 5: Cost Data and Sources.

Source	Cost
MAD 201.2 Version Estimate	275.29
Custom Project CU_101772	200.00
Refrigeration Contractors, Inc. - low	275.00
Refrigeration Contractors, Inc. - high	300.00

Table 6: Weighted Incremental Costs by Equipment Class.

Equipment Description	Equipment Class - closed	Market Share	Weighted Incremental Cost [$]
Vertical Closed Remote Condensing - med temp	VCT.RC.M	89%	260.75
Horizontal Closed Remote Condensing - med temp	HCT.RC.M	100%	293.82
Vertical Closed Self-Contained - med temp	VCT.SC.M	15%	45.06
Horizontal Closed Self-Contained - med temp	HCT.SC.M	43%	127.17
Vertical Closed Remote Condensing - low temp	VCT.RC.L	3%	9.57
Horizontal Closed Remote Condensing - low temp	HCT.RC.L	100%	293.82
Vertical Closed Self-Contained - low temp	VCT.SC.L	0%	0.00
Horizontal Closed Self-Contained - low temp	HCT.SC.L	28%	81.14

Non Energy Benefits

In Energy Trust's single fuel territory, other fuel savings are calculated as non-energy benefits.

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 linear foot.

Follow-Up

At the next update the Program should check for any updates to the RTF's Retrofit Doors on Grocery Displays workbook and if a separate workbook has been developed to specifically address new case sales.

The federal standards should be reviewed for any updates to the energy efficiency requirements of whether doors become mandatory.

The market practice should be checked for updates.

Supporting Documents

The cost effectiveness screening for these measures is number 201.3.2. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Commercial and Industrial\Grocery\cooler doors\New coolers\bencost

10 CFR Part 431 Subpart C (up to date

201.3.2_OR-WA-CE Calculator_2024_v_1

Version History and Related Measures

Energy Trust has been offering refrigeration measures for many years. These predate our measure approval documentation process and record retention requirements. Table 7 may be incomplete, particularly for measures approved prior to 2013.

Table 7 Version History

Date	Version	Reason for revision
8/11/2017	201.1	Introduce case door measure for new cases.
9/9/2020	201.2	Update costs
10/9/2023	201.3	Updated savings, costs, and analysis methodology. Added low temperature cases, horizontal cases, and cases with self-contained condensing units.

Table 8 Related Measures

Measures	MAD ID
Cooler Door Retrofits	47
Commercial Reach-In Refrigerators and Freezers	186

Approved & Reviewed by

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Measure Approval Document for Condensing Furnaces in Multifamily

Valid Dates
1/1/2023 - 12/31/2025

End Use or Description
Condensing natural gas furnaces of less than 225,000 Btu/h input capacity installed in existing multifamily, serving more than one residence.

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

Within these programs, applicability to the following building types is expected:
- Existing Multifamily – stacked structures greater than four units
- Assisted living or retirement communities
- Dormitories
- Affordable or market rate apartments

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

Purpose of Re-Evaluating Measure
Costs have been updated.

New Buildings has been removed as code updates related to heat recovery in new multifamily buildings reduce furnace savings in new multifamily applications.

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 2023-v1.0. In Oregon the electric avoided cost year is 2023 and the gas avoided cost year is 2023. In Washington the gas avoided cost year is 2023. The values in these tables are per kBtu/h furnace input capacity.

Table 1 Cost Effectiveness Calculator Oregon, per kBtu/h furnace input capacity

#	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, 91%, Multifamily	18	0.00	1.41	8.43	0.00	8.43	3.2	3.2	0%	100%
2	Furnace, 95%, Multifamily	18	0.00	1.92	11.35	0.00	11.35	3.2	3.2	0%	100%
3	Furnace, 98%, Multifamily	18	0.00	2.31	14.90	0.00	14.90	2.9	2.9	0%	100%
4	Incremental, 91% to 95%	18	0.00	0.51	2.92	0.00	2.92	3.3	3.3	0%	100%
5	Incremental, 91% to 98%	18	0.00	0.90	6.47	0.00	6.47	2.6	2.6	0%	100%
6	Incremental, 95% to 98%	18	0.00	0.39	3.55	0.00	3.55	2.1	2.1	0%	100%

Table 2 Cost Effectiveness Calculator Washington, per kBtu/h furnace input capacity

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Furnace, 91%, Multifamily	18	1.34	8.43	0.00	8.43	4.0	4.0	0%	100%
2	Furnace, 95%, Multifamily	18	1.83	11.35	0.00	11.35	4.1	4.1	0%	100%
3	Furnace, 98%, Multifamily	18	2.20	14.90	0.00	14.90	3.7	3.7	0%	100%
4	Incremental, 91% to 95%	18	0.49	2.92	0.00	2.92	4.2	4.2	0%	100%
5	Incremental, 91% to 98%	18	0.86	6.47	0.00	6.47	3.3	3.3	0%	100%
6	Incremental, 95% to 98%	18	0.37	3.55	0.00	3.55	2.6	2.6	0%	100%

Rows 4-6 in Table 1 and Table 2 demonstrate the increments between the tiers is cost effective. This indicates that higher incentives for higher tiers of equipment may be appropriate, with maximum increments between tier incentives listed in the tables.

Requirements
- Furnace must be part of a centralized heating system serving at least two dwelling units or regularly occupied multifamily common space.
- Furnace must serve multifamily space with continuous occupancy (e.g. living units, common spaces). Furnaces in multifamily projects serving spaces without continuous occupancy (e.g. office spaces) do not qualify for this measure.
- Natural gas condensing furnace with input capacity less than 225,000 Btu/h
- For furnaces rated in both Et (thermal efficiency) and AFUE (annual fuel utilization efficiency), Et shall be used to determine qualification

Details
Condensing gas furnaces recover heat from the combustion exhaust air stream to preheat incoming water, increasing overall operating efficiency. This measure applies to furnaces with input capacities less than 225,000 Btu/h. Units larger than this size are better classified as condensing RTUs, which differ in a number of significant ways (e.g. costs, availability, efficiency standards) from furnaces included in this measure. Units may be rated as commercial or residential equipment. Furnaces are not a particularly common heating method in stacked multifamily buildings, but they are used occasionally. Participation is expected to be highest in assisted living and similar situations.

Baseline
This measure uses a Code Baseline.

The baseline equipment for this measure is a gas furnace with a thermal efficiency of 80%. This is the minimum required efficiency for gas fired warm air furnaces with input capacity less than 225,000 Btu/h, in the 2021 Oregon Energy Efficiency Specialty Code (OEESC)[1]. Multifamily property owners and managers are assumed to put in code minimum equipment typically.

Measure Analysis

Baseline and high efficiency condensing gas furnaces were modeled by CLEAResult's new construction engineering team using the New Buildings program's prototype models for the Small Office, Strip Mall Retail, Primary School, and Low-Rise Multifamily (40 units) building types in eQuest 3.65. These models are meant to represent typical code-minimum new construction. The measure was modeled by modifying the gas furnace heat input ratio (HIR) value in the models, calculating the HIR as the inverse of thermal efficiency (Et). HIRs were modeled representing thermal efficiencies of 80% (code minimum baseline), 91%, 92%, 93%, 94%, 95%, 96%, 97%, and 98%.

The modeling methodology varies the furnace thermal efficiency, the standard for the modeling software. However, furnaces of this size are often rated in AFUE instead of thermal efficiency. A furnace's AFUE is expected to be lower than its thermal efficiency, as the AFUE value takes seasonal performance and standby losses into account. Therefore, a condensing furnace with an AFUE of 91%, for example, would have higher performance than a condensing furnace with a thermal efficiency of 91%. As such, furnaces may qualify for this measure based on either AFUE or thermal efficiency. If a furnace is rated in both AFUE and thermal efficiency, the thermal efficiency rating shall be used to determine qualification.

The model assumes furnaces are perfectly sized to meet the heating loads, and are smaller than typical residential furnaces when serving a single dwelling unit or are shared between dwelling units, particularly in assisted living or similar situations. Expected sizes are 50-80 kBtu/h. In 2018 and 2019 participating projects included furnaces serving multiple dwelling units. These furnaces ranged from 60 to 120 kBtu/h on average and served both dwelling units and common areas and do not appear to be oversized.

The measures were modeled for the three Oregon regions (Coast/Astoria, Valley/Portland, Central/Redmond). The savings for each climate zone were combined into a weighted average using the following program-assumed weightings:

- Coast: 3%
- Valley: 87%
- Central: 10%

For Washington, the savings were weighted 100% for the Valley region, resulting in lower savings for Washington than Oregon.

Savings

Savings are normalized on a per-kBtu/h input basis, based on the furnace capacities calculated by the models. Since the model assumed a newly constructed building meeting code minimums, the savings are conservative for existing buildings, which often have aged shell conditions and may have been built to less stringent codes.

Savings for three specific efficiency tiers – 91%-94%, 95%-97%, and 98% – were selected for consideration, based on the distribution of efficiencies for units available in the market.

Results of modeling and other analysis demonstrated that savings from condensing furnaces in multifamily situations were higher than in other building types. Commercial furnace measures were not cost effective in offices, schools or retail. Savings for condensing furnaces in multifamily in the various tiers can be found in Table 1 and **Error! Reference source not found.**. Savings and other information regarding the performance of furnaces in these building types can be found in supporting documents.

Comparison to RTF or other programs

MADs 22 and 23 – Residential Gas Furnaces in Niche Markets in Oregon and SW Washington respectively – approve condensing furnaces in residential applications. These furnaces are assumed to be generally smaller than those for large multifamily, meeting loads of detached or partially detached homes. The offerings are unitized per furnace rather than per capacity.
MAD 270 – Commercial Condensing Furnace: is for use in non-multifamily commercial buildings, existing or new construction. The heating loads and hours are assumed to be different than in multifamily.

Measure Life

The measure life is 18 years. The California DEER[2] lists an effective useful life of 20 years for high efficiency furnace measures and the Illinois Statewide Technical Reference Manual[3] lists an expected measure life of 16.5 years for high efficiency furnace measures; this averages to 18 years.

Load Profile

The gas load profile is "Res Heating"; the electric load profile is "None – ele" as there are no electric savings associated with this measure.

Cost

Cost estimates were gathered from various sources, and incomplete information and outliers were excluded. The final cost estimate sources used are the US EIA (2018)[4], FurnacePriceGuides.com[5], and GasFurnaceGuide.com[6]. These sources were used to determine estimates of the incremental cost of a condensing furnace compared to a code baseline furnace. The cost estimate for the 91% efficiency level was determined by averaging the cost estimates for 90% and 92% efficient furnaces, as none of the sources include costs specifically for 91% efficient furnaces. The sources include costs specifically for 95% and 98% efficient furnaces, which were used in the cost effectiveness analysis. Costs are based on 80 kBtu/h input models, which are the most common size with the most readily available cost information. This size range does not exactly correspond to the modeled sizes.

Costs for different efficiency levels were normalized on a per-kBtu/h input capacity basis. There have not been enough projects in 2021 and 2022 to verify cost assumptions.

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[1] 2021 OEESC (available at https://www.oregon.gov/bcd/codes-stand/Documents/2021oeesc.pdf) is based on ASHRAE 90.1-2019, and minimum efficiency requirements for furnaces are listed in Table 6.8.1-5.
[2] California Public Utilities Commission (CPUC), Effective Useful Life and Remaining Useful Life table, EUL ID HV-EffFurn, available at https://www.caetrm.com/measure/SWHC031/02/value-table/224207/
[3] 2022 Illinois Statewide Technical Reference Manual for Energy Efficiency Version 10.0, September 24, 2021, p.266 of 814, available at https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010122_v10.0_Vol_2_C_and_I_09242021.pdf
[4] Updated Buildings Sector Appliance and Equipment Costs and Efficiencies, U.S. Energy Information Administration, June 2018, available at https://www.eia.gov/analysis/studies/buildings/equipcosts/pdf/full.pdf
[5] https://www.furnacepriceguides.com/gas-furnace/#afue
[6] https://www.gasfurnaceguide.com/compare/

Non Energy Benefits

There are no non-energy benefits identified 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 of furnace input capacity. If a tiered approach is taken, incentives must be selected such that incremental incentive between tiers does not exceed the maximums in rows 4-6.

Follow-Up

The next Oregon energy code is expected to adopt ASHRAE 90.1-2022, which should be published late in 2022 and should be reviewed for baseline implications.

Savings and costs should be reviewed at next update based on the actual sizes of furnaces installed.

Climate zones and weighting should be re-weighted based on Energy Trust technical guidelines.

Supporting Documents

The cost effectiveness screening for these measures is number 203.3.2. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Commercial and Industrial\Commercial HVAC\Furnaces\multifamily

203.3.2 OR-WA-CE Calculator_2023_v_1   Condensing Furnace Costs_2022   Condensing Furnace Savings Ana

Version History and Related Measures

Energy Trust has been offering the Condensing Furnaces in Multifamily measure for many years. These predate our measure approval documentation process and record retention requirements. Table 3 may be incomplete, particularly for measures approved prior to 2013.

Table 3 Version History

Date	Version	Reason for revision
2004	86.1	Approve various gas measures for commercial programs, including furnaces.
9/12/2017	203.1	New approval for commercial condensing furnaces multifamily buildings. MAD 86 retired.
6/21/2019	203.2	Update to screen at 2020 avoided costs
10/24/2022	203.3	Update to remove New Buildings, update incremental measure costs, and screen at 2023 avoided costs

Table 4 Related Measures

Measures	MAD ID
Residential Gas Furnace in small multifamily, single family rentals, manufactured home rentals, and Savings within Reach	22
Residential Gas Furnace in Washington	23
Commercial Condensing Furnace	270

Approved & Reviewed by

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

Valid Dates
July 1, 2023 – December 31, 2025

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 in 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, applicability to the following building types or market segments are expected:

- Gyms (including those within other building types such as hotels)
- Coin-op laundries
- Motels
- Schools
- Restaurants

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

- New
- Replacement

Purpose of Re-Evaluating Measure
Savings and costs have been updated and an "All Commercial" measure application was added. Savings were updated to align with methodologies and inputs used in other condensing tankless water heater measures (MADs 196, 72) offered by Energy Trust.

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 2024-v1.1. In Oregon the electric avoided cost year is 2024 and the gas avoided cost year is 2024. In Washington the gas avoided cost year is 2024. The values in these tables are per CTWH unit, which is assumed to be 199 kBtu/h.

Table 1 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	CTWH - Restaurant <200 kBtu/h	20	0.00	8.18	$140.21	$0.00	$140.21	1.1	1.1	0%	100%
2	CTWH - Motel <200 kBtu/h	20	0.00	14.46	$140.21	$0.00	$140.21	1.9	1.9	0%	100%
3	CTWH - School <200 kBtu/h	20	0.00	19.33	$140.21	$0.00	$140.21	2.6	2.6	0%	100%
4	CTWH - Coin-op Laundry <200 kBtu/h	20	0.00	47.12	$140.21	$0.00	$140.21	6.2	6.2	0%	100%
5	CTWH - Gym <200 kBtu/h	20	0.00	21.90	$140.21	$0.00	$140.21	2.9	2.9	0%	100%
6	CTWH - All Commercial	20	0.00	15.51	$140.21	$0.00	$140.21	2.1	2.1	0%	100%

Table 2 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	CTWH - Restaurant <200 kBtu/h	20	8.18	$140.21	$0.00	$140.21	1.2	1.2	0%	100%
2	CTWH - Motel <200 kBtu/h	20	14.46	$140.21	$0.00	$140.21	2.2	2.2	0%	100%
3	CTWH - School <200 kBtu/h	20	19.33	$140.21	$0.00	$140.21	2.9	2.9	0%	100%
4	CTWH - Coin-op Laundry <200 kBtu/h	20	47.12	$140.21	$0.00	$140.21	7.1	7.1	0%	100%
5	CTWH - Gym <200 kBtu/h	20	21.90	$140.21	$0.00	$140.21	3.3	3.3	0%	100%
6	CTWH - All Commercial	20	15.51	$140.21	$0.00	$140.21	2.3	2.3	0%	100%

Requirements
- The water heater units must function as a central water heating system and serve the primary water heating loads of the portion of the building indicated (ie: shower rooms for gyms, kitchens for restaurants, multiple motel rooms for motels)
- Installed equipment shall be condensing tankless water heaters with individual input capacities less than 200 kBtu/h.
  - Commercially sized equipment ≥200 kBtu/h is approved through MAD ID 72 with different savings and requirements.
- Installed equipment Uniform Energy Factor (UEF) shall be 0.94 or greater.
- Installed equipment must be on the AHRI certified product list.
- Additional storage tanks are not allowed.

Existing Condition Requirements
These measures are intended as replacement at/near burn out, or new. There are no existing fuel requirements.

Measure Selection
- Programs may not use the All Commercial measure 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: Car Wash, Recreation (casino), and Jail/Reformatory/Penitentiary.
- If program choose to use the All Commercial savings option, building type and/or served hot water loads must be recorded.
- If programs choose to apply the measure by specific building type, measures may be applied to areas of multi-use sites where hot water systems provide dedicated service to that area. For example, a university building with a cafeteria that has a dedicated hot water system may use the Restaurant measure applications.

Details

Central domestic water heating systems are being increasingly served by multiple residential-sized tankless water heaters (typically 199 kBtu/h and under) installed in parallel. Within the tankless water heater (THW) market, users are purchasing both condensing and non-condensing tankless water heaters. Regional sales data indicate that the market share of condensing is significantly larger than non-condensing tankless water heaters – see Baseline section below for details.

This measure is designed to encourage the use of the high-efficiency condensing tankless water heaters rather than non-condensing tankless water heaters or lower efficiency condensing tankless water heaters and discourage the addition of storage tanks, which may cause standby 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 storage tank water heaters. The full market baseline was based on an analysis of tankless water heater distributor sales data and product efficiencies listed in the AHRI database.

Distributor Sales Data and AHRI Database Findings

Distributor sales data between 2018 and 2020 for Oregon was used to determine the market share of condensing versus non-condensing THWs. Condensing tankless water heaters represented 86% of sales while the remaining 14% were non-condensing tankless water heaters. The AHRI database was used to establish condensing and non-condensing tankless water heaters average thermal efficiencies, which were used to determine the baseline thermal efficiency used in the savings calculations. Table 3 summarizes the sales data, AHRI average efficiency, and the weighted average baseline thermal efficiency.

Table 3: Sales Data, AHRI Average Efficiencies, and Full Market Baseline Efficiency

Type	Count	Share	Average Recovery Efficiency	Baseline Thermal Efficiency
Condensing	3,476	86%	96%	**94.4%**
Non-Condensing	563	14%	84%	

Measure Analysis

Savings were based on spreadsheet calculations, whose primary inputs are annual hot water demand, peak hot water demand (total TWH capacity), and water temperature rise. The main input sources are from the Department of Energy's (DOE) Technical Support Document (TSD): Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment[1] and related sources.
The site-level assumptions for calculating annual hot water and CTWH capacity requirements are based on the DOE's prototype building characterizations.

Hot Water Demand – WHAM Energy Consumption Equation

The DOE's Water Heater Analysis Model[2] (WHAM) for tankless water heaters is used to calculate the total water heater input energy. The equation uses the estimated total annual hot water demand in gallons, estimated temperature rise, the specific heat capacity of water, the average density of water, the thermal efficiency, and an adjustment factor to account for actual observed performance.

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

Where:

- Q_{in} = total water heater energy consumption, Btu
- vol = annual water use, gal
- 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

The total heat input required by the water heaters is converted to therms. The total savings are the difference between the baseline and proposed measure case total input therms.

$$\text{Annual Savings}_{therms} = Q_{in\ Baseline} - Q_{in\ Measure}$$

Annual Hot Water Demand

The annual hot water demand for most building types was determined using the daily hot water load schedules and normalized peak demand listed in Appendix 7B of the US DOE's TSD prototype buildings. The product of the normalized peak and hourly ratios yield the hourly demand in a 24-hour period, which is assumed constant throughout the year.

The gym annual hot water demand was similarly determined using daily hot water schedules and normalized peak demands, but the information was sourced from Table 11 of the DOE's U.S. Commercial Reference Building Models of the National Building Stock[3] report.

Because the DOE's TSD does not cover coin-op laundries, annual hot water demand was estimated based on typical number of machines per laundromat, loads per day per machine, and gallons of hot water per load.[4,5,6,7] Table 4 summarizes the daily and annual hot water demands for all building sub-sectors.

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[1] https://downloads.regulations.gov/EERE-2014-BT-STD-0042-0016/attachment_1.pdf
[2] https://downloads.regulations.gov/EERE-2006-STD-0129-0149/attachment_1.pdf
[3] http://www.nrel.gov/docs/fy11osti/46861.pdf
[4] Washer capacity values: https://calwep.org/wp-content/uploads/2021/03/Coin_Operated-Clothes-Washers-PBMP-2012.pdf
[5] Water factors: https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-431
[6] Usage per washer: https://downloads.regulations.gov/EERE-2012-BT-STD-0020-0036/attachment_8.pdf
[7] Wash per cycle: https://www.allianceforwaterefficiency.org/sites/www.allianceforwaterefficiency.org/files/assets/ws-commercial-water-sense-at-work-ci.pdf

Table 4: Daily and Annual Hot Water Demand

Building sub-sector	Daily DHW [gal]	Annual DHW [gal]
Restaurant – quick service	564	206,179
Restaurant – full service	1,592	581,622
Motel - main DHW	1,358	496,106
Motel - laundry	984	359,406
School - primary	627	228,986
School - secondary	2,580	942,467
Coin-op Laundry	3,892	1,421,418
Gym	1,100	401,816

Peak Hot Water Demand – Total Tankless Water Heater Capacity Requirements

The annual savings were normalized per water heater, which required determining the number of tankless water heater units to meet the peak hot water demand. Rather than estimating the peak flow demand, the tank-type hot water heater storage and heating capacities listed in the Table 2.2 of the DOE's Enhancements to ASHRAE 90.1 Prototype Buildings Models[8] were converted to tankless capacity using the methodology in section 7.7 of the DOE's TSD. This effectively establishes the equivalent total tankless water heater capacity required to meet the peak hot water demand.

$$Q_{\text{tankless}} = \left(Q_{\text{tank}} + dT * C_p * y * \text{Vol} * \text{Tank}_u / t_{load}\right) * \text{Adj}_{\text{tankelss}}$$

Where:

- $Q_{tankless}$ = adjusted tankless capacity, Btu/h
- Q_{tank} = tank water heater capacity, Btu/h
- dT = temperature rise, °F
- C_p = specific heat of water, 1.000743 Btu/lb·°F
- y = specific weight of water, 8.29 lb/gal
- Vol = tank volume, gallons
- $Tank_u$ = fraction of hot water in the tank that is usable
- $Adj_{tankless}$ = tankless adjustment factor
- t_{load} = maximum load duration, hr

The DOE's sources do not cover water heater capacities for the coin-op and gym sub-sector. The total required tankless water heater capacities were determined using estimates of hot water fixtures and the equivalent fixture units, which were used with the modified Hunter curve to estimate peak hot water demand. The total required tankless water heater capacity is divided by unit size, which is assumed to be 199 kBtu/h.

Temperature Rise Input Assumptions

The inlet water temperature was determined by using the Regional Technical Forum's (RTF) Standard Information Workbook's (SIW)[9] ground water temperatures by heating zone. The temperatures were averaged, weighted by their share of project uptake using Project Tracker (PT) data. The water heater outlet temperature is assumed to be 140°F, which is adopted from the RTF's commercial heat-pump water heater measure.[10]

The average inlet temperature and zone weightings by project uptake between 2018 and 2021 are listed in Table 5.

Table 5: Heating Zone Weighted Average Inlet Temperature

Heating Zone	Projects by Zone	Temperature by Zone [°F]	Weighted Average Temperature [°F]
1	73%	55.3	**54.4**
2	27%	51.7	
3	0%	49.1	

Thermal Efficiency to Uniform Energy Factor Correlation

The WHAM equation requires thermal efficiency (TE) to calculate the TWH energy consumption. However, tankless water heaters in this size category are rated by Uniform Energy Factor (UEF), which is used by federal regulations covering minimum efficiency requirements for tankless water heaters.[11]

A target thermal efficiency of 97% was established based on the AHRI product availability. The target thermal efficiency was correlated to UEF though three different methods:

1. Average UEF for all equipment with a TE of 97% and greater
2. Average of UEF to TE ratio for all condensing TWHs multiplied by 97% TE
3. Linear regression of UEF vs TE evaluated at 97% TE

Table 6 summarizes the results of the three methods described above and their average, which establishes the UEF for measure eligibility.

Table 6: Measure Case UEF

Method	Assumed TE	UEF	Measure UEF
Average UEF of all units with 97% TE	97%	0.937	**0.94**
Average UEF/TE * 97% TE		0.941	
Linear Regression - UEF @ 97% TE		0.941	

[8] https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-23269.pdf
[9] https://nwcouncil.box.com/v/RTFSIW--v4-5
[10] https://nwcouncil.box.com/v/ComHPWH-v3-0
[11] https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32

Building Sub-Sector Weighting

Savings across the schools and restaurants market segments were determined by the weightage associated for each of their sub-sectors as shown in Table 7.

Oregon Department of Education data[12] was used to determine the share of primary versus secondary schools and estimate the weightage for the school market segment. Restaurant sub-sector weightage was found using CBSA-4 2019[13] data to determine counts of quick-service versus full-service restaurants.

Table 7: Sub-Sector Weight Per Market Segment

Sub-Sector	Sub-sector Weights [%]	Weighted Savings per CTWH [therm]	Market Segment
Restaurant - quick service	69%	6.99	Restaurant <200 kBtu/h
Restaurant - full service	31%		
School - primary	77%	12.58	School <200 kBtu/h
School - secondary	23%		

All Commercial Weighting

The all-commercial measure application is the average of all other market segments savings weighted by historical project uptake. PT data reported 31 commercial projects for a total of 73 CTWHs installed between 2018 and 2021. The count of CTWHs units for each Product Descriptions were allocated to the appropriate market segment and are summarized in Table 8.

Table 8: Market Segment Weights for All-Commercial Measure Applications Savings

Market Segment	Count	Weight %
Restaurant (Food Service, Grocery)	43	58.9%
Motel (Lodging/Hotel/Motel, Meeting/Convention Center/Hall or Community Center)	0	0.0%
School (K-12 School)	1	1.4%
Coin-op Laundry	5	6.8%
Gym (Gym/Athletic Club)	24	32.9%

Savings

Table 9 summarizes savings per CTWH along with total required input capacity, CTWH quantity, annual hot water demand, baseline and measure energy uses, and total annual savings. The annual savings are based on the DOE's prototypical buildings characterized in the TSD. The savings for the Motel measure application are based the sum of the main DHW and laundry annual hot water savings and combined CTWH capacities. The annual savings were divided by the number of water heaters to determine the savings per CTWH.

Table 9: Summary of Energy Use and Savings by Building Sub-Sector

Sub-Sector	CTHW input Capacity [kBtu/h]	Quantity of CTHW [#]	Hot Water Demand [gal/yr]	Baseline Energy Use [kBtu/yr]	Measure Energy Use [kBtu/yr]	Annual Savings [kBtu]	Total Annual Savings [therm]	Savings per CTWH [therm]	Sub-sector Weight [%]	Weighted Savings per CTWH [therm]
Restaurant - quick service	1,045	5.25	206,179	170,236	166,421	3,815	38	7.26	69%	6.99
Restaurant - full service	2,090	10.50	361,838	298,760	292,064	6,696	67	6.37	31%	
Motel - main DHW	1,307	10.95	496,106	409,621	400,441	9,180	158	14.46	100%	14.46
Motel - laundry	872		359,406	296,752	290,101	6,651				
School - primary	473	2.38	143,250	118,278	115,627	2,651	27	11.15	77%	12.55
School - secondary	1,420	7.13	665,925	549,836	537,513	12,323	123	17.28	23%	
Coin-op Laundry	694	3.49	1,604,178	1,324,526	1,294,841	29,685	297	85.18	100%	85.18
Gym	914	4.59	401,816	331,768	324,333	7,436	74	16.18	100%	16.18
All Commercial										15.51

Comparison to RTF or other programs

The RTF does have a residential gas water heater workbook[14], which includes storage tank and tankless water heater savings. The workbook uses the WHAM methodology to calculate tankless water heater energy consumption as done by this measure's analysis. Annual hot water demand is determined using SEEM, which differs from this analysis' use of the DOE's TSD water use schedules and normalized peak hot water demand.

Energy Trust offers Multifamily Condensing Tankless Water Heaters <200 kBtu/h, via MAD 196, which also assumes a typical CTWH size is 199 kBtu/h, but targets exiting and new multifamily buildings. Energy Trust also offers Commercial Condensing Tankless Water Heaters ≥200 kBtu/h, via MAD 72, which also targets the commercial market segments but is better suited for projects requiring larger capacity CTWHs or where space constraints limit the number of smaller CTWHs that can be installed.

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.[15]

Load Profile

Electric: None – ele
Gas: DHW

Cost

Equipment costs

A dataset of tankless water heaters from various online retailers collected in November of 2020 was updated with current pricing and used to determine the equipment costs at various efficiencies. The water heaters were categorized into different efficiency categories as follows:

- Non-condensing (≤86% TE)

[12] Oregon Department of Education (https://www.oregon.gov/ode/reports-and-data/students/Pages/Student-Enrollment-Reports.aspx)
[13] https://neea.org/resources/cbsa-4-data-files
[14] https://rtf.nwcouncil.org/measure/residential-gas-water-heaters-0/
[15] California Public Utility Commission. Access 2021.DEER Database file "SupportTable_EUL.CSV." Accessed via the READI v2.5.1 tool.

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

Each TWH in the online data set was allocated under one of the above categories and its costs was normalized per kBtu/h. The costs for the non-condensing units and the average of all condensing units were used to establish the full market baseline costs. The costs for high efficiency condensing units were used for the proposed measure case costs.

Labor and Ancillary Costs

Labor and ancillary material costs used estimates from the California Codes and Standards Enhancement (CASE) report for high efficiency water heaters[16]. Because the report is dated from 2013, the costs were adjusted to 2023 dollars using the RTF's Standard Information Workbook inflation factors.[17]

The labor and ancillary estimates used in this analysis only include incremental cost between the non-condensing and condensing water heaters. For non-condensing water heaters this includes the costs of steel venting materials for the hotter exhaust gases. For condensing water heaters this includes costs of PVC venting materials, condensate drain connection, condensate neutralizer, and condensate pump.

Table 10 summarizes the total baseline, measure, and incremental costs. Baseline costs were weighted by share of condensing and non-condensing TWH sales summarized in Table 3.

Table 10: Baseline, Measure, and Incremental Costs per CTWH

Case	Cost/unit
Baseline	$2,194.59
Measure	$2,334.80
Incremental	$140.21

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 CTWH unit.

Follow-Up

The market baseline should be reevaluated at the next update to comprehend the share of condensing vs non-condensing THW sales.

Annual hot water demand should be reevaluated using the latest DOE's prototype building model hot water load schedule.

Costs should be updated or compared to actual project costs. In particular, the 2013 CASE data source is becoming dated.

The minimum number of CTWHs required to cover the peak hot water demand is relatively high for the full-service restaurant and motel sub-sectors. This may indicate that the assumed CTWH input capacity size of 199 kBtu/h for these sub-sectors may be unrealistic or the sizing methodology is overly conservative or they are not great applications of this measure. At the next update, the Program should review the typical number of CTWHs installed per project and compare against the calculated quantity derived to determine if the technology is appropriate for these building sub-sectors or if the methodology should be modified.

Supporting Documents

The cost-effective screening for these measures is number 212.5.3. 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_5_3_OR_WA_CE
C_2024_v_1_1_Com_

Version History and Related Measures

Table 11 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.
6/23/2023	212.5	Savings updated using WHAM methodology. Annual water consumption updated using DOE prototype building model. Inlet water temperature updated using the RTF's SIW data.

Table 12 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

[16] 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
[17] https://nwcouncil.box.com/v/RTF-SIW-v4-6

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Energy Trust of Oregon

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.

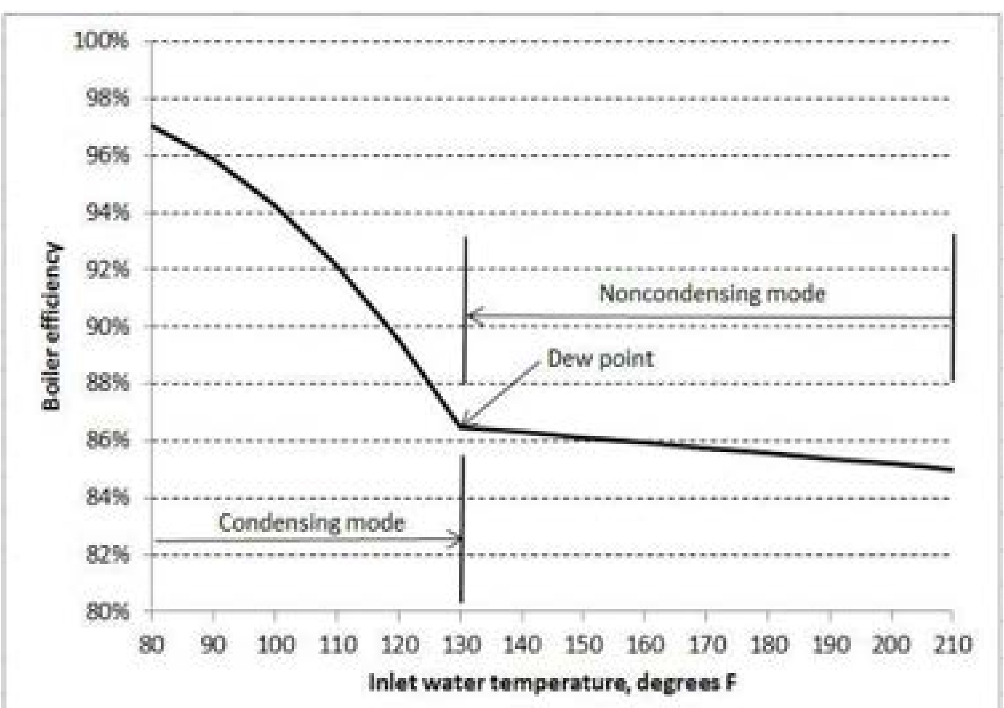


Figure 1 Effect of Inlet Water Temperature on Efficiency of Condensing Boilers (Figure 6, 2012 ASHRAE Handbook - HVAC Systems and Equipment)

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 1 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 2 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
Sr. Planning Engineer

Disclaimer

Measure Approval Document for Commercial Smart Thermostats

Valid Dates
May 25, 2023 – December 31, 2025

End Use or Description
Commercial smart thermostats serving single-zone HVAC systems. The thermostats save energy by optimizing fan mode scheduling and temperature set-back/set-ups during unoccupied hours. Primary savings are from heating load and fan energy reduction. Minor savings are expected from reduced cooling load.

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
- Production Efficiency

Within these programs, applicability to the following delivery channels, program tracks, and building types are expected, but not limited to:
- Delivery channels/tracks
  - Small Business Offering
  - Prescriptive
  - Utility Demand Response Programs, including their direct install efforts
- Buildings:
  - Office
  - Retail
  - Restaurants
  - Grocery Stores

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

Purpose of Re-Evaluating Measure
This is a standard offer similar the previous Commercial Smart Thermostat pilot, whose results were inconclusive and based on products that are not expected to have future market share. Because the pilot results could not be leveraged, the RTF's Commercial Connected Thermostats measure continues to be the basis for this offering.

Cost Effectiveness
Cost effectiveness is demonstrated for Oregon in Table 1**Error! Reference source not found.**, and Table 2. Cost effectiveness for Washington is demonstrated Table 3 in Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2024-v1.1. In Oregon the electric avoided cost year is 2024 and the gas avoided cost year is 2024. In Washington the gas avoided cost year is 2024. The values in these tables are per thermostat.

Table 1 Cost Effectiveness Calculator Oregon, per thermostat-

#	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	Smart Thermostat Grocery - Resistance Heat w/ Cooling (HZ1)	10	2,505.75	0.00	599.00	$0.00	$599.00	3.0	3.0	100%	0%
2	Smart Thermostat Grocery - Heat Pump w/ Cooling (HZ1)	10	1,475.50	0.00	599.00	$0.00	$599.00	1.8	1.8	100%	0%
3	Smart Thermostat Grocery - Gas Heat w/ Cooling (HZ1)	10	538.91	88.59	599.00	$0.00	$599.00	2.7	2.7	21%	79%
4	Smart Thermostat Grocery - Resistance Heat NO Cooling (HZ1)	10	2,496.30	0.00	599.00	$0.00	$599.00	3.0	3.0	100%	0%
5	Smart Thermostat Grocery - Gas Heat NO Cooling (HZ1)	10	529.47	88.59	599.00	$0.00	$599.00	2.7	2.7	21%	79%
6	Smart Thermostat Non-Grocery - Resistance Heat w/ Cooling (HZ1)	10	938.29	0.00	599.00	$0.00	$599.00	1.3	1.3	100%	0%
8	Smart Thermostat Non-Grocery - Gas Heat w/ Cooling (HZ1)	10	256.42	30.98	599.00	$0.00	$599.00	1.0	1.0	27%	73%
9	Smart Thermostat Non-Grocery - Resistance Heat NO Cooling (HZ1)	10	917.24	0.00	599.00	$0.00	$599.00	1.3	1.3	100%	0%
10	Smart Thermostat Non-Grocery - Gas Heat NO Cooling (HZ1)	10	235.38	30.98	599.00	$0.00	$597.31	1.0	1.0	26%	74%
11	Smart Thermostat Grocery - Gas Heat w/ Cooling (HZ1) - GOT	10	0.00	88.59	599.00	$42.96	$599.00	2.1	2.7	0%	100%
12	Smart Thermostat Grocery - Gas Heat NO Cooling (HZ1) - GOT	10	0.00	88.59	599.00	$42.20	$599.00	2.1	2.7	0%	100%
13	Smart Thermostat Non-Grocery - Gas Heat w/ Cooling (HZ1) - GOT	10	0.00	30.98	599.00	$20.44	$443.79	1.0	1.0	0%	100%
14	Smart Thermostat Non-Grocery - Gas Heat NO Cooling (HZ1) - GOT	10	0.00	30.98	599.00	$18.76	$443.79	1.0	1.0	0%	100%
15	Smart Thermostat Grocery - Resistance Heat w/ Cooling (HZ2)	10	2,877.71	0.00	599.00	$0.00	$599.00	3.4	3.4	100%	0%
16	Smart Thermostat Grocery - Heat Pump w/ Cooling (HZ2)	10	1,730.58	0.00	599.00	$0.00	$599.00	2.1	2.1	100%	0%
17	Smart Thermostat Grocery - Gas Heat w/ Cooling (HZ2)	10	687.72	98.58	599.00	$0.00	$599.00	3.1	3.1	23%	77%
18	Smart Thermostat Grocery - Resistance Heat NO Cooling (HZ2)	10	2,857.57	0.00	599.00	$0.00	$599.00	3.4	3.4	100%	0%
19	Smart Thermostat Grocery - Gas Heat NO Cooling (HZ2)	10	667.58	98.58	599.00	$0.00	$599.00	3.0	3.0	23%	77%
20	Smart Thermostat Non-Grocery - Resistance Heat w/ Cooling (HZ2)	10	1,324.64	0.00	599.00	$0.00	$599.00	1.9	1.9	100%	0%
21	Smart Thermostat Non-Grocery - Heat Pump w/ Cooling (HZ2)	10	811.22	0.00	599.00	$0.00	$599.00	1.1	1.1	100%	0%
22	Smart Thermostat Non-Grocery - Gas Heat w/ Cooling (HZ2)	10	344.47	44.52	599.00	$0.00	$599.00	1.4	1.4	26%	74%
23	Smart Thermostat Non-Grocery - Resistance Heat NO Cooling (HZ2)	10	1,284.88	0.00	599.00	$0.00	$599.00	1.8	1.8	100%	0%
24	Smart Thermostat Non-Grocery - Gas Heat NO Cooling (HZ2)	10	304.71	44.52	599.00	$0.00	$599.00	1.4	1.4	24%	76%
25	Smart Thermostat Grocery - Gas Heat w/ Cooling (HZ2) - GOT	10	0.00	98.58	599.00	$54.82	$599.00	2.4	3.1	0%	100%
26	Smart Thermostat Grocery - Gas Heat NO Cooling (HZ2) - GOT	10	0.00	98.58	599.00	$53.21	$599.00	2.4	3.1	0%	100%
27	Smart Thermostat Non-Grocery - Gas Heat w/ Cooling (HZ2) - GOT	10	0.00	44.52	599.00	$27.46	$599.00	1.1	1.4	0%	100%
28	Smart Thermostat Non-Grocery - Gas Heat NO Cooling (HZ2) - GOT	10	0.00	44.52	599.00	$24.29	$599.00	1.1	1.4	0%	100%

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.

$$Project\ Cost = Energy\ Trust\ Incentive\ +\ Customer\ Payment + Cofunding$$
$$Remaining\ Cost =\ Incremental\ Cost - Cofunding =\ Customer\ Payment + Energy\ Trust\ Incentive$$

Smart thermostats installed in non-grocery businesses with heat pumps are not cost effective without co-funding. This measure is approved in situation where the remaining cost is less than the maximum remaining cost shown in Table 4. For these applications, we anticipate remaining cost will be most often understood as the customer cost plus Energy Trust incentive.

Table 2 Cost Effectiveness Calculator for Oregon, per thermostat – With Required Co-funding

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Max Remaining Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
29	Smart Thermostat Non-Grocery - Heat Pump w/ Cooling (HZ1) - co-funding	10	581.12	0.00	486.50	$0.00	$486.50	1.0	1.0	100%	0%

Table 3 Cost Effectiveness Calculator Washington, per thermostat

#	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 Grocery - Gas Heat w/ Cooling (HZ1)	10	88.59	599.00	$41.50	$599.00	3.0	3.6	0%	100%
2	Smart Thermostat Grocery - Gas Heat NO Cooling (HZ1)	10	88.59	599.00	$40.77	$599.00	3.0	3.6	0%	100%
3	Smart Thermostat Non-Grocery - Gas Heat w/ Cooling (HZ1)	10	30.98	599.00	$19.74	$599.00	1.1	1.3	0%	100%
4	Smart Thermostat Non-Grocery - Gas Heat NO Cooling (HZ1)	10	30.98	599.00	$18.12	$599.00	1.1	1.3	0%	100%
5	Smart Thermostat Grocery - Gas Heat w/ Cooling (HZ2)	10	98.58	599.00	$52.95	$599.00	3.3	4.1	0%	100%
6	Smart Thermostat Grocery - Gas Heat NO Cooling (HZ2)	10	98.58	599.00	$51.40	$599.00	3.3	4.1	0%	100%
7	Smart Thermostat Non-Grocery - Gas Heat w/ Cooling (HZ2)	10	44.52	599.00	$26.52	$599.00	1.5	1.9	0%	100%
8	Smart Thermostat Non-Grocery - Gas Heat NO Cooling (HZ2)	10	44.52	599.00	$23.46	$599.00	1.5	1.8	0%	100%

Requirements and Implementation Details

- Measures are applicable to all commercial spaces
- Lodging, spaces with 24/7 operation, and semi-conditioned spaces are excluded from participation.
- Thermostats must control a single-zone HVAC system with its own supply fan.
- Multiple HVAC systems serving a large open space (retail, grocery, etc.) are allowed provided each system has its own controlling thermostat.
- Qualifying thermostats may be:
    - Pelican Wireless TS200 Commercial Grade Thermostat
    - Ecobee EMS Si Wi-Fi Commercial Programmable Thermostat
    - Pelican TC 1
    - Honeywell VisionPRO 8000
    - Thermostats listed in BPA's QPL[1]
- Thermostats meeting the following performance requirements:
    - Capable of start/stop schedules for seven different day-types per week
    - Capable of retaining programming and time setting during a loss of power for a period of at least 10 hours
    - Includes an accessible manual override that allows temporary operation of the system for up to 2 hours
    - Is capable of temperature setback down to 55°F during off hours
    - Is capable of temperature setup to 90°F during off hours
    - Web-connected (LAN or WAN) with remote programming capabilities
    - Capable of supporting multiple cooling stages
    - Is Demand Response capable
- These devices are not likely to be compatible with systems with demand-controlled ventilation or advanced rooftop controls. Installers must not disable such systems.
- Direct/Contractor Install incentives cannot exceed actual project costs.
- Direct/Contractor install cost cannot exceed the maximum remaining costs for the measure shown in Table 2

Installation and setpoint requirements:

- Where two or more HVAC systems serve "invisible zones" within a space, temperature setpoints, schedules, and dead-bands must match to avoid simultaneous heating and cooling.
- Temperature setback in heating mode shall be at least 10°F below the occupied heating setpoint.
- Temperature setup in cooling mode shall be at least 5°F above the occupied cooling setpoint.
- Fan schedule set to 'auto' mode during unoccupied hours (fan only runs when there's a call for heating or cooling)
- Manual setpoint override shall be limited to two hours or less
- Heat pump with auxiliary resistance heat shall enable lock-out with appropriate temperature set-points

Co-funding Requirements

- The measures in Table 1 and Table 3 may be used with or without co-funding. The measure in Table 2, thermostats in non-grocery businesses with heat pumps in heating zone 1, is approved only with enough co-funding to enable the measure to be cost effective.
- Internal Energy Trust Program staff must review each proposed application or funding agreement for these measures to ensure compliance with OPUC direction on measures utilizing other funding sources. These may be applied at the project or funding agreement level.

  The following equation describes the maximum remaining cost framework in the expected program design, utility led direct installs without site-specific costing. The costs passed on to the customer and to Energy Trust must be less than the Maximum Remaining Cost shown in Table 4. In the case of other program designs, where co-funders provide funds rather than direct services and equipment, the cofounding must meet or exceed the minimum shown in Table 4.

$$Customer\ Payment + Energy\ Trust\ Incentive\ \leq\ Max\ Remaining\ Cost$$

Table 4 Measures Requiring Co-funding

#	Measure	Max Remaining Costs ($)	Minimum Required Co-funding ($)
29	Smart Thermostat Non-Grocery - Heat Pump w/ Cooling (HZ1) - co-funding	486.50	$112.50

- Program must track co-funding, including
    - Co-funding entity
    - Per project co-funding and/or remaining cost of each project

Baseline

This measure uses an Existing Condition Baseline.

[1] https://www.bpa.gov/-/media/Aep/energy-efficiency/document-library/connected-thermostat-qualified-products-list.pdf

The baseline is assumed to be a mix of thermostats with and without scheduled temperature set-back/set-up or ability to place the fan in "auto" during unoccupied hours.

Measure Analysis

ETO conducted a commercial smart thermostat pilot, but the evaluation[2] results were inconsistent with the expected savings mechanisms and influences of Covid-19 on energy use could not be disaggregated reliably. Therefore, the savings are based on the RTF's Commercial Connected Thermostat v2.0 workbook[3], which summarizes savings by cooling, heating, and fan energy end-uses. This is the same sources as the pilot's initial assumptions.

The baseline energy consumption in kWh/ft^2 by end use (heating, cooling, fan) was determined through EnergyPlus models by building type, heating type, and climate. The models were calibrated to Commercial Building Stock Assessment (CBSA) billing data by adjusting model input parameters. Table 5 summarize the end-use EUIs for each of the following building models: Small Office, Retail Stand-alone, Retail Strip, and Grocery.

Table 5 EUI by End Use – By Building Type and Heating Zone

Building Type	NWPCC heating zone	Fans (kWh/sf)	Cooling (kWh/sf)	Electric Space Heat (kWh/sf)	Gas Space Heat (kBtu/sf)	Heat Pump Space Heat (kWh/sf)
Office, Small	1	1.18	0.23	2.40	11.11	1.15
	2	1.57	0.58	3.88	17.92	1.85
	3	1.63	0.33	5.26	24.32	2.51
Retail, Standalone	1	1.17	0.82	3.65	16.47	1.74
	2	1.40	1.28	5.10	23.01	2.43
	3	1.38	0.87	6.76	30.51	3.22
Retail, Strip	1	1.77	0.57	5.67	25.74	2.70
	2	2.25	1.26	7.27	33.01	3.46
	3	1.94	0.77	9.73	44.27	4.63
Supermarket	1	3.58	0.32	13.30	59.91	6.33
	2	4.52	0.68	14.81	66.68	7.05
	3	4.85	0.42	17.63	79.42	8.40

The CBSA data was also used to determine the typical HVAC system size in ft^2/ton rather than rely on the simulated capacity of the energy models. Table 6 summarizes the design load by building type.

Table 6 HVAC System Sizing Assumptions by Building Type

Building Type	Sizing Assumptions [ft2/ton]
Office, Small	443
Retail, Standalone	563
Retail, Strip	563
Supermarket	444

The product of the EUIs and typical system sizing yielded end use in kWh/ton and therm/ton, which is used to determine energy consumption of a typical single-zone HVAC system in commercial applications. The end use energy for office, retail standalone, and retail strip were average (weighted by NPCC 7th plan floor area) to create a "nongrocery" building type to represent commercial applications outside of supermarkets.

Savings

The savings estimates are the product of the energy consumption per ton and the percent savings rate listed in Table 7, which were determined by the RTF's form the following sources:

- Service vendor projects of performance-based contracts' pre/post data
- Preliminary results from Consumer Energy (Michigan) Pilot
- Preliminary results from Entergy (Arkansas) Pilot
- BPA RTU Servicing study

Table 7 Savings Rate by End Use

HVAC End Use	Savings Rate
Fan Energy	6.7%
Cooling Energy	1.3%
Heating Energy	6.7%

The inconclusive pilot notably seemed to indicate higher fan savings and lower heating and cooling savings than the RTF assumed.

Savings by end use are summarized in Table 8 by building type (grocery/nongrocery), heating type (electric resistance/heat pump/gas), presence of cooling (yes/no), and heating zone (HZ1/HZ2).

[2] Commercial Tstat Eval Report Final 111822 (energytrust.org)
[3] https://rtf.nwcouncil.org/measure/commercial-connected-thermostats/

Table 8 Savings by End Use

Measure (initial installation and programming)	Fan Savings [kWh/yr/ton]	Cooling Savings [kW/yr/ton]	Heating Savings [kWh/yr/ton]	Heating Savings [therm/yr/ton]
grocery_HZ1_resistanceheat_yescooling	106	2	393	0
grocery_HZ2_resistanceheat_yescooling	134	4	438	0
grocery_HZ1_heatpumpheat_yescooling	106	2	187	0
grocery_HZ2_heatpumpheat_yescooling	134	4	209	0
grocery_HZ1_gasheat_yescooling	106	2	0	18
grocery_HZ2_gasheat_yescooling	134	4	0	20
grocery_HZ1_resistanceheat_nocooling	106	0	393	0
grocery_HZ2_resistanceheat_nocooling	134	0	438	0
grocery_HZ1_heatpumpheat_nocooling	106	0	187	0
grocery_HZ2_heatpumpheat_nocooling	134	0	209	0
grocery_HZ1_gasheat_nocooling	106	0	0	18
grocery_HZ2_gasheat_nocooling	134	0	0	20
nongrocery_HZ1_resistanceheat_yescooling	47	4	136	0
nongrocery_HZ2_resistanceheat_yescooling	61	8	196	0
nongrocery_HZ1_heatpumpheat_yescooling	47	4	65	0
nongrocery_HZ2_heatpumpheat_yescooling	61	8	93	0
nongrocery_HZ1_gasheat_yescooling	47	4	0	6
nongrocery_HZ2_gasheat_yescooling	61	8	0	9
nongrocery_HZ1_resistanceheat_nocooling	47	0	136	0
nongrocery_HZ2_resistanceheat_nocooling	61	0	196	0
nongrocery_HZ1_heatpumpheat_nocooling	47	0	65	0
nongrocery_HZ2_heatpumpheat_nocooling	61	0	93	0
nongrocery_HZ1_gasheat_nocooling	47	0	0	6
nongrocery_HZ2_gasheat_nocooling	61	0	0	9

The end use energy savings were aggregated by fuel type and multiplied by the typical single-zone HVAC system capacity, assumed to be 5 tons aligning with the RTF's typical capacity assumptions used to determine the per-cooling-ton normalized costs. Table 9 summarizes savings for Heating Zone 1 and Heating Zone 2 for measure applications by building type, heating type, and cooling presence. HP measures with no cooling were not included as this combination is not expected in practice.

Table 9 Electric and Savings Summary by HZ, Building Type, Heating type, and Cooling Presence

Building Type	Heating Type	Cooling	Heating Zone 1		Heating Zone 2	
			Electric Savings [kWh/yr]	Gas Savings [therm/yr]	Electric Savings [kWh/yr]	Gas Savings [therm/yr]
Grocery	Resistance Heat	Yes	2506	0	1253	0
	Heat Pump	Yes	1476	0	738	0
	Gas	Yes	539	89	269	44
	Resistance Heat	No	2496	0	1248	0
	Gas	No	529	89	265	44
Not Grocery	Resistance Heat	Yes	938	0	469	0
	Heat Pump	Yes	581	0	291	0
	Gas	Yes	256	31	128	15
	Resistance Heat	No	917	0	459	0
	Gas	No	235	31	118	15

Comparison to RTF or other programs

Savings are directly leveraged from the RTF's Commercial Connected Thermostats v2.0 workbook.

The Residential program offers MAD 153 – Web Enabled Thermostats tailored to its own delivery channels and program tracks. These have different savings and costs as they are fundamentally different equipment controlling residential rather than commercial HVAC loads.

Measure Life

The measure life is 10 years based on findings from the following sources:

- California Database of Energy Efficiency Resources (DEER) estimate for programmable thermostats of 11 years.
- The RTF's workbook estimate of 5 years, which is low because it assumes a need for re-programming which they consider a unique measure.
- ASHRAE Owning and Operating Cost Data: Reports a mean and median of 22 years for electric thermostats, but there was only one sample.

While the straight average of the three values referenced above is 12.7 years, the Program will round down to 10 years given the small sample size from the ASHRAE source and to align more closely with residential thermostat measures (MAD 153.6).

Load Profile

Load profiles vary by measure application according to heating type and building type are shown in Table 10.

Table 10 Thermostat Load Profiles

Building Type	Heat Type	Electric Load Profile	Gas Load Profile
Grocery	Resistance Heat or Heat Pump	Grocery Heating	None
	Gas	Grocery Ventilation	Com Heating
Not Grocery	Resistance Heat or Heat Pump	Retail Heating	None
	Gas	Retail Ventilation	Com Heating

Cost
Equipment costs were sourced from an internet search of retail costs for qualified thermostats. The average cost was $266.45, and the median cost was $275.00, The median cost was selected.

Total equipment plus install labor costs were based on estimates from Resource Innovations (TRC Trade Ally), which ranged from $549.00 to $649.00. The average cost of $599.00 was used in cost effectiveness testing for all measure applications.

Incentive Structure
The maximum incentives listed in Table 1***Error! Reference source not found.*** *through* Table 3 *are for reference only and are not suggested incentives.* Incentives will be structured per thermostat.

Incentives may be paid directly to contractors or to customer in the form of incentives or equipment.

Follow-Up
At the next update, check of any updates to the RTF workbook and research strategy results, evaluations, or updates to the Smart Thermostat Pilot Evaluation report that may inform savings estimates. Energy Trust is considering further evaluation activities on this measure. If available, those results much be considered.

At the next update consider aligning assumptions with advanced rooftop controls measures where applicable.

Data collection suggestions, if not included as measure identifiers:
- HVAC system type and capacity
- Building type and square footage
- Presence of programmable thermostat in existing condition

Supporting Documents
The cost effectiveness screening for these measures is number 235.3.3. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Commercial and Industrial\Commercial HVAC\EMS and thermostats\connected SZ thermostats

235.3.3 OR-WA-CE Calculator_2024_v_1

Version History and Related Measures

Table 11 Version History

Date	Version	Reason for revision
5/10/2019	235.1	Approve commercial smart thermostat PGE pilot
9/8/2020	235.2	Continuation of PGE pilot (expired at pilot end in 2022)
5/24/2023	235.3	Transition to standard measures, applicable outside PGE efforts

Table 12 Related Measures

Measures	MAD ID
Commercial Advanced RTU controls retrofit	256
Commercial and Industrial RTU Controls on new RTUs	195
Residential Web Enabled Thermostats	153

Approved & Reviewed by

Jackie Goss, PE
Sr. Engineer – Planning & Evaluation

Disclaimer

Energy Trust of Oregon

Measure Approval Document for Efficient Commercial Pool Heaters

Valid Dates
January 1, 2023 to December 31, 2025

End Use or Description
Replacement of existing standard efficiency pool heaters with efficient non-condensing gas pool heaters between 84% and 87% efficiency or condensing gas pool heaters between 94% and 96% efficiency. Energy savings are achieved by reduced natural gas use from increased heater efficiency.

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/market segment is expected:
- Hospitality
- Fitness Centers & Spas
- Recreational Facilities
- Apartment buildings and complexes

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

Purpose of Re-Evaluating Measure
Savings, incremental costs, measure case pool heater efficiency requirements, and minimum required pool sizes have been updated. New measure applications for pools with existing covers have been 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 2023-v1.0. In Oregon the electric avoided cost year is 2023 and the gas avoided cost year is 2023. In Washington the gas avoided cost year is 2023. The values in these tables are per square foot (SF) of a pool.

Table 1 Cost Effectiveness Calculator Oregon, per SF

#	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	Non-condensing heater – uncovered, indoor pool	10	0.00	0.21	1.04	$0.00	$1.04	1.5	1.5	0%	100%
2	Non-condensing heater – uncovered, outdoor pool	10	0.00	0.38	1.04	$0.00	$1.04	2.8	2.8	0%	100%
3	Non-condensing heater – covered, indoor pool	10	0.00	0.12	0.98	$0.00	$0.94	1.0	1.0	0%	100%
4	Non-condensing heater - covered, outdoor pool	10	0.00	0.25	1.04	$0.00	$1.04	1.8	1.8	0%	100%
5	Condensing heater – uncovered, indoor pool	10	0.00	0.70	5.51	$0.00	$5.29	1.0	1.0	0%	100%
6	Condensing heater – uncovered, outdoor pool	10	0.00	1.29	8.78	$0.00	$8.78	1.1	1.1	0%	100%
7	Condensing heater – covered, indoor pool	10	0.00	0.42	3.27	$0.00	$3.14	1.0	1.0	0%	100%
8	Condensing heater – covered, outdoor pool	10	0.00	0.85	6.69	$0.00	$6.41	1.0	1.0	0%	100%

Table 2 Cost Effectiveness Calculator Washington, per SF

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Non-condensing heater – uncovered, indoor pool	10	0.21	1.04	$0.00	$1.04	1.9	1.9	0%	100%
2	Non-condensing heater – uncovered, outdoor pool	10	0.38	1.04	$0.00	$1.04	3.5	3.5	0%	100%
3	Non-condensing heater – covered, indoor pool	10	0.12	0.98	$0.00	$0.98	1.2	1.2	0%	100%
4	Non-condensing heater - covered, outdoor pool	10	0.25	1.04	$0.00	$1.04	2.3	2.3	0%	100%
5	Condensing heater – uncovered, indoor pool	10	0.70	5.51	$0.00	$5.51	1.2	1.2	0%	100%
6	Condensing heater – uncovered, outdoor pool	10	1.29	8.78	$0.00	$8.78	1.4	1.4	0%	100%
7	Condensing heater – covered, indoor pool	10	0.42	3.27	$0.00	$3.27	1.2	1.2	0%	100%
8	Condensing heater – covered, outdoor pool	10	0.85	6.69	$0.00	$6.69	1.2	1.2	0%	100%

Requirements
- Replacement gas-fired pool heater must have a maximum capacity of 400 kBtu/h. Total installed capacity from multiple replacement pool heaters (each up to 400 kBtu/h capacity) serving the same pool must not exceed 1,000 kBtu/h.
- Non-condensing replacement heater measures must have efficiency equal to or greater than 84%.
- Condensing replacement heater measures must have efficiency equal to or greater than 94%.
- Minimum required pool sizes are shown below:

Table 3 Minimum Pool Area Requirements

Measure	Minimum Required Pool Area (SF)
Non-condensing heaters, uncovered pools	
Indoor pool (CEC row 1) Outdoor pool (CEC row 2)	500
Non-condensing heaters, covered pools	
Indoor pool (CEC row 3)	850
Outdoor pool (CEC row 4)	500
Condensing heaters, uncovered pools	
Indoor pool (CEC row 5)	1,275
Outdoor pool (CEC row 6)	700
Condensing heaters, covered pools	
Indoor pool (CEC row 7)	2,150
Outdoor pool (CEC row 8)	1,050

- Site must be in eligible gas utility territory
- Pool heaters fired by natural gas shall not have continuously burning pilot lights.
- Eligible pool covers include solid track, bubble type, or foam type covers with storage reels specifically designed for swimming pools. Any other types of covers and pools without storage reels are not eligible for participation as a covered pool and may participate as an uncovered pool.
- Other pool covers such as liquid evaporation suppressants, solar disks, and mesh covers are not effective and pools with such covers shall use uncovered measure applications.

Existing Condition Requirements

There are no requirements regarding existing fuel type.

Details

All minimum allowable pool surface areas represent the minimum pool size required for the measure to be cost effective.

Below are short descriptions of accepted pool covers:

- 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.
- Bubble: A floating cover similar in form to bubble packaging material but constructed from a UV-inhibitor coated, thicker grade plastic.
- 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).

Baseline

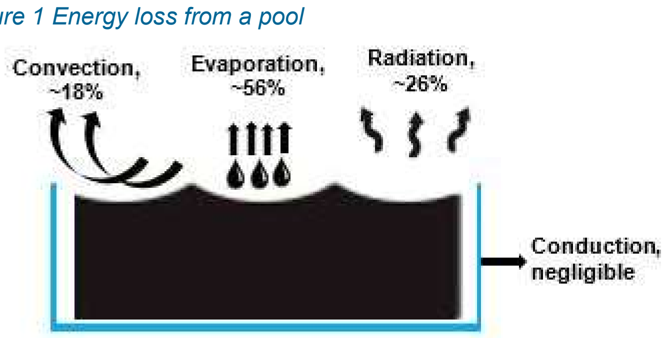
This measure uses a code baseline.

The baseline is assumed to be a minimally code-compliant 82% efficient natural-gas fired pool heater as specified by the Code of Federal Regulations 10 CFR Part 430.

Measure Analysis and Savings Methodology

There are four modes through which energy is lost from a pool. These include evaporation, radiation, convection, and conduction. All modes except conduction are significant and considered in determining the total energy that pool heaters must provide to maintain adequate water temperature. All modes of heat loss and their relative magnitude[1] are shown in Figure 1.

Figure 1 Energy loss from a pool



The following sub-sections describe methodology used to estimate energy losses from evaporation, and radiation and convection.

Estimation of energy losses by evaporation

Evaporation losses are estimated using the methodology in a 2014 published ASHRAE whitepaper titled "Methods for Calculation of Evaporation from Swimming Pools and Other Water Surfaces[2] . This method relies on empirical coefficients for swimming pools and spas for guidance in calculating evaporation rates in unoccupied and occupied swimming pools. The following numbered equations from the ASHRAE whitepaper are used to calculate evaporation rates in $lb/ft^2.hr$, and the key assumptions for the analysis are specified in Table 4.

Energy loss from outdoor pools via evaporation

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

[1] 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

[2] 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

$$E_0 = C r_w (r_r - r_w)^{\frac{1}{3}} (W_w - W_r) \tag{1}$$

Where:

E_0 = rate of evaporation from unoccupied pools (lb/ft^2.h)
C = 290 (constant derived from empirical data)
r_w = density of air at saturated water surface (lb/ft^3)
r_r = density of air at outdoor temperature and humidity (lb/ft^3)
W_w = specific humidity of air saturated at water surface temperature
W_r = specific humidity of air at outdoor temperature and humidity

$$E_0 = b(p_w - p_r) \tag{2}$$

Where:

b = 0.0346 (constant derived from empirical data)
p_w = partial pressure of water vapor in air at water surface (in.Hg)
p_r = partial pressure of water vapor in air at outdoor temperature and humidity (in.Hg)

$$E_0 = \mathrm{a}\left(\frac{u}{b}\right)^{0.7} \times (p_w - p_a) \tag{3}$$

Where:

a = 0.0346 (constant derived from empirical data)
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.

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

Where:

N = pool occupants per unit area

Energy loss from uncovered indoor pools via evaporation

Evaporation calculations for **indoor unoccupied** pools are based on assumptions described below from the ASHRAE whitepaper Table 5: 'Calculated Evaporation rate from Unoccupied Pools at Typical Design Conditions'.

Total energy loss from evaporation 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 Eq. 5.

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

Table 4 tabulates all assumptions used to calculate evaporative heat loss in pools and assumptions used for savings calculations from pool covers. Table 5 shows heat loss from all three modes in uncovered pools calculated using equations 1 through 5 for select measures (CEC rows 1, 2 & 4,and 8).

Table 4 Assumptions for Calculation of Evaporative Heat Loss from Uncovered Pools and from Installing Pool Covers

Parameter	Source	Application	Assumption/Value
Assumptions for Evaporative Heat Loos from Uncovered Pools			
Scheduling	Estimated from community pools in Portland	Outdoor Pool occupied hours	June-Sept, 10hrs/day
		Indoor Pool occupied hours	Year-round, 14 hrs/day
Pool Temperature	US Department of Energy[3]	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 ASHRAE Whitepaper paper provided density difference values for 50% and 60% relative humidity. For this analysis, 60% was assumed.	Outdoor Pools	Portland TMY3 weather data 60% RHT
Indoor Ambient Conditions	ASHRAE Journal Article[4]	Indoor Pools	82°F ambient air temperature 50% Relative Humidity
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
Assumptions for Estimating Savings from Installation of Pool Covers			
Total Reduction of Evaporation Losses	US Department of Energy[5]	Indoor & Outdoor Pools	Evaporation losses reduced by 40% due to a pool cover.
Reduction of Radiation and Convection Losses	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 total radiation and convection losses will be reduced by 42% due to a pool cover. Derived from operation hours

Convection and radiation losses in uncovered pools

For outdoor pools, convection and radiation losses were estimated as 44% of the calculated total energy loss per the magnitudes shown in Figure 1, which shows that convection makes up 18% of total energy loss and radiation makes up 26% of the total energy loss, thereby contributing to 44% of total energy losses (evaporation making up the remaining 56% of losses). Total energy loss was calculated using the known percent loss due to evaporation (56%) and calculated energy loss due to evaporation using the appropriate equations from 1 through 5.

For indoor pools, these losses were estimated as 30% of the calculated total energy loss per the methodology used for the Pool Covers measure (MAD 265) to ensure consistency between this and the Pool Covers MADs. Heat loss due to evaporation and radiation and convection in covered pools for select measures (CEC rows 16 and 20) are displayed in Table 5.

[3] US Department of Energy. "Managing Swimming Pool Temperature for Energy Efficiency". https://www.energy.gov/energysaver/managing-swimming-pool-temperature-energy-efficiency
[4] ASHRAE. "Natatoriums, The Inside Story". Volume 48. (April 2006) https://technologyportal.ashrae.org/journal/articledetail/55
[5] US Department of Energy. "Swimming Pool Covers" https://www.energy.gov/energysaver/swimming-pool-covers

Table 5 Energy Loss from Uncovered and Covered Pools for Select Measures

CEC Rows	Parameter	Application	Value
Calculated Annual Energy Loss from Uncovered Pools, per SF			
2	Total Loss Due to Evaporation	Non-cond., Uncovered Outdoor Pools	4.32 Therms per sf
	Total Loss Due to Radiation and Convection		3.39 Therms per sf (44% of Total Heat Loss)
5	Total Loss Due to Evaporation	Condensing heater, Uncovered Indoor Pools	2.93 Therms per sf
	Total Loss Due to Radiation and Convection		1.26 Therms per sf (30% of Total Heat Loss)
Calculated Annual Energy Loss from Covered Pools, per SF			
4	Total Loss Due to Evaporation	Non-cond., Covered Outdoor Pools	2.59 Therms per sf (60% of 4.32 Therms/SF from evaporation calculated for CEC rows 1, 2 & 4 shown above). 60% (1.0 - 0.4) comes from Table 4 assumptions for Pool Covers
	Total Loss Due to Radiation and Convection		2.51 Therms per sf (74% of 3.39 Therms/SF from rad. & conv. calculated for CEC rows 1, 2 & 4 shown above). 74% (1.0 – 0.26) comes from Table 4 assumptions for Pool Covers)
7	Total Loss Due to Evaporation	Cond. heater Covered Indoor Pools	1.76 Therms per sf (60% of 2.93 Therms/SF from evaporation calculated for CEC row 8 shown above)
	Total Loss Due to Radiation and Convection		0.73 Therms per sf (58% of 1.26 Therms/SF from rad. & conv. calculated for CEC row 8 shown above)

Covered Indoor and Outdoor Pools

Pool covers save energy by decreasing losses due to evaporation, radiation, and convection during unoccupied hours. The assumptions used for energy loss calculations with pool covers are shown in Table 4.

The percent savings assumptions from installing pool covers (shown in Table 4) are applied to appropriate energy loss values from uncovered pools (shown in Table 5) to determine the energy savings from installing pool covers. The energy loss for select measures due to evaporation and convection and radiation in a covered pool (calculated with a pool surface area of 800 square feet) are also shown in Table 5.

Calculation of Energy Savings

Energy savings are the result of the difference in efficiency between the baseline and proposed heaters applied to the appropriate measure case total heat loss value.

$$Savings\ (therms) = \frac{(Heat\ loss_{total}) \times (\%eff_{base} - \%eff_{measure})}{100000\ \frac{Btu}{therm}} \tag{6}$$

Where:

Heat loss$_{total}$ = total heat loss from evaporation, convection, and radiation in Btu's
%eff$_{base}$ = baseline efficiency
%eff$_{measure}$ = measure case heater efficiency

To capture savings across the range of proposed non-condensing and condensing heaters, final savings are the average savings of the lower and upper bounds of the measure case heater efficiencies (84% - 87% or 94% - 96% respectively).

Based on outreach team feedback, the typical pool size is 800 sq. ft., which was used as the area in the savings calculations. An area higher than 800 sq. ft. was used to achieve a TRC of 1.0 for those measures that were not cost effective at 800 sq. ft. Table 6 summarizes pool area at which measures are cost effective and pool area used to calculate energy savings and cost per SF.

Table 6 Pool areas used for non-condensing heater savings and cost calculations

CEC Row(s)	Heater/Pool combination	Minimum pool area at which measure is cost-effective	Pool area used to calculate energy savings and cost per SF
1, 2, 4	Non-condensing heaters for (i) indoor & outdoor uncovered pools and (ii) outdoor covered pools	500	800
3	Non-condensing heaters for indoor covered pools	850	850
5	Condensing heaters for indoor uncovered pools	1,275	1,275
6	Condensing heaters for outdoor uncovered pools	700	800
7	Condensing heaters for indoor covered pools	2,150	2,150
8	Condensing heaters for outdoor covered pools	1,050	1,050

Measure Life

The measure life is 10 years based on the average from the following sources:

- DOE[6] states a typical pool heater lasts 5 years or more
- Conversation with Anderson Poolworks (email included in CEC tab 'Measure Life') suggested an 11 year measure life.
- Manufacturers of heaters with stainless steel and titanium heat exchanges claim 15 year operation at listed efficiencies.

Load Profile

The load profile is flat-gas.

Cost

Incremental cost estimates for both types of heaters are based on cost estimates collected from contractors/vendors in Oregon in April 2022 (condensing heaters) and August 2022 (non-condensing heaters).

[6] US Department of Energy. "Gas Pool Heaters" https://www.energy.gov/energysaver/gas-pool-heaters#299555-tab-1

Baseline 82% efficient heater costs
Costs for 82% efficient pool heaters between 300-400 kBtu/h capacity for 6 models was collected from three different vendors. The average cost is $6,464 per heater.

Non-condensing heaters
Cost data for three non-condensing pool heater models with efficiency between 84%-87% was collected from vendors in Oregon. The average cost is estimated to be $7,298.

Incremental cost was calculated as the difference of average costs of baseline 82% efficient heaters and 84%-87% efficient heaters and is estimated to be $834.

Condensing heaters
Cost data for 5 condensing heater models (400 kBtu/h capacity) was collected from two vendors in Oregon and the average cost is $13,835.

Incremental cost for condensing heaters was calculated as the difference of average costs of baseline heaters and condensing heater costs, which is estimated to be $7,021.

Additional piping cost for non-condensing and condensing heaters
Flue gas temperature from exhaust piping of condensing pool heaters is lower than for non-condensing heaters, which allows the use of PVC as the material for exhaust piping. Non-condensing heaters require stainless steel exhaust piping due to higher exhaust temperatures. Per the information shared by contractors, PVC piping is cheaper ($5 per foot) than stainless steel ($40 per foot), and it is assumed that new piping is installed with replacement heaters. Per contractor estimates, average piping length of 10 ft. was assumed, which results in an additional cost of $400 ($40/ft. x 10 ft.) for stainless steel piping for non-condensing heaters and $50 ($5/ft. x 10ft.) for PVC piping for condensing heaters.

Table 7 summarizes the average and incremental pool heater costs.

Table 7 Pool heater average cost and incremental costs

Heater Efficiency	Average Cost ($)	Total Incremental Cost ($)
Baseline (82%)	**$6,864** ($6,464 (heater) + $400 (piping))	**NA**
Non-condensing (84% - 87%) replacement heater	**$7,698** ($7,298 (heater) + $400 (piping))	**$834** ($7,698 - $6,864)
Condensing (94% – 96%)	**$13,885** ($13,835 (heater) + $50 (piping))	**$7,021** ($13,885 - $6,864)

Costs per square foot, shown in Table 1 and Table 2, were calculated by dividing the incremental costs in Table 7 by pool areas in the of Table 6.

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 foot of pool area. Incentive should not exceed project cost.

Follow-Up
OEESC requirements and federal standards must be checked in the next update for pool heater efficiency.

Costs should also be evaluated to ensure they are up to date.

Supporting Documents
The cost effectiveness screening for these measures is number 238.2.2. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Commercial and Industrial\pools and spas\pool heaters

238.2.2 CEC_2023 v1.0 pool heaters.xls

Version History and Related Measures
Table 8 Version History

Date	Version	Reason for revision
8/1/2019	238.1	New Measure for commercial pool heaters with 96% efficiency.
9/19/2022	238.2	Added tiered incentives for high-efficiency non-condensing and condensing heaters, added measures with pool covers.

Table 9 Related Measures

Measures	MAD ID
Pool Covers	265
Commercial Pool Pumps	237
Spa Covers	99

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Measure Approval Document for Industrial Direct-Install Pipe Insulation

Valid Dates
January 1st, 2024 to December 31st, 2026

End Use or Description
This measure includes insulating hot water, steam, or process piping for industrial systems. This measure is available for low pressure and medium pressure steam (LPS, MPS) distribution systems, process heating water (PHW) applications, and other heated process fluids. These systems must operate year-round.

The delivery of this measure is direct install through approved Trade Ally insulation contractors.

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 – Standard Industrial Track

Within this program, applicability to the following delivery structure is expected:

- Direct Install

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

- Retrofit

Purpose of Re-Evaluating Measure
This measure is being updated for the following reasons:

- Adjust measure application to allow for 1" piping insulation on all pipe diameters to increase measure adoption.
- Removal of New Construction eligibility due to compliance with updates to Oregon code, now requiring insulation for steam and hot water piping for new construction projects.
- Updates to measure cost using existing program information and discussions with vendors.

Cost Effectiveness
Cost effectiveness is demonstrated for Oregon in Table 1. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2024-v1.2. The Oregon gas avoided cost year is 2024. The values in these tables are per lineal foot.

Table 1 Cost Effectiveness Calculator Oregon, per lineal foot

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	DI Industrial LPS 0.5-1" Pipe Insulation	10	0.00	12.03	$40.00	$40.00	3.0	3.0	0%	100%
2	DI Industrial LPS 1.25-2" Pipe Insulation	10	0.00	18.47	$45.00	$45.00	4.2	4.2	0%	100%
3	DI Industrial LPS 2.5-3.5" Pipe Insulation	10	0.00	30.31	$50.00	$50.00	6.1	6.1	0%	100%
4	DI Industrial LPS 4-6" Pipe Insulation	10	0.00	46.16	$55.00	$55.00	8.5	8.5	0%	100%
5	DI Industrial LPS 8-10" Pipe Insulation	10	0.00	75.31	$70.00	$70.00	10.9	10.9	0%	100%
6	DI Industrial MPS 0.5-1" Pipe Insulation	10	0.00	20.01	$40.00	$40.00	5.1	5.1	0%	100%
7	DI Industrial MPS 1.25-2" Pipe Insulation	10	0.00	30.76	$45.00	$45.00	6.9	6.9	0%	100%
8	DI Industrial MPS 2.5-3.5" Pipe Insulation	10	0.00	50.47	$50.00	$50.00	10.2	10.2	0%	100%
9	DI Industrial MPS 4-6" Pipe Insulation	10	0.00	76.94	$55.00	$55.00	14.2	14.2	0%	100%
10	DI Industrial MPS 8-10" Pipe Insulation	10	0.00	125.54	$70.00	$70.00	18.2	18.2	0%	100%
11	DI Industrial PHW 0.5-1" Pipe Insulation	10	0.00	7.35	$40.00	$40.00	1.9	1.9	0%	100%
12	DI Industrial PHW 1.25-2" Pipe Insulation	10	0.00	11.20	$45.00	$45.00	2.5	2.5	0%	100%
13	DI Industrial PHW 2.5-3.5" Pipe Insulation	10	0.00	18.42	$50.00	$50.00	3.7	3.7	0%	100%
14	DI Industrial PHW 4-6" Pipe Insulation	10	0.00	28.10	$55.00	$55.00	5.2	5.2	0%	100%
15	DI Industrial PHW 8-10" Pipe Insulation	10	0.00	46.19	$70.00	$70.00	6.7	6.7	0%	100%

Requirements
- Project site must be served by a participating natural gas utility in Oregon.
- Fluid within piping must be heated with a natural gas-fired steam or hot water boiler or water heater.
- The heating source must be operated year-round.
- Piping for dedicated HVAC systems is not eligible.
- Pipe insulation for steam at pressures in excess of 200 psig or process fluids in excess of 388 °F are not approved and should be referred to the custom industrial program.
- Insulation must be installed by an approved Energy Trust Direct Install Pipe Insulation Trade Ally.
- Pipe must not have any existing insulation (or existing insulation must be badly damaged/missing) to be eligible for incentive.
- The minimum required insulation thickness for all pipe diameters and steam pressure classifications is 1".
- At a minimum, All Service Jacketing (ASJ) or Polyvinyl Chloride (PVC) will be required for indoor pipe insulation projects, and aluminum jacketing for outdoor piping insulation projects to maintain the life of the insulation.
- Sections of piping and/or included components such as regulators and valves that require being exposed for maintenance may be insulated with serviceable blanket insulation. These sections are exempt from the minimum thickness requirements.

Baseline

This measure uses an Existing Condition Baseline.

The baseline for this measure is uninsulated, Schedule 40 steel pipe. For retrofit projects, severely damaged or missing insulation is assumed to have similar properties to an uninsulated pipe.

New construction projects are no longer eligible. The 2021 Oregon Energy Efficiency Specialty Code (OEESC)[1] relies on ASHRAE 90.1-2019 which requires industrial process hot water, steam, and other heated fluid process piping to be insulated as shown in Table 2.

Table 2 Pipe Insulation Tables from ASHRAE 90.1-2019

Table 6.8.3-1 Minimum *Piping* Insulation Thickness Heating and Hot Water Systems[a,b,c,d,e]
(Steam, Steam Condensate, Hot-Water Heating and Domestic Water *Systems*)

Fluid Operating Temperature Range (°F) and Usage	Insulation Conductivity		≥Nominal Pipe or Tube Size, in.				
	Conductivity, Btu-in/h-ft²-°F	Mean Rating Temperature, °F	<1	1 to <1-1/2	1-1/2 to <4	4 to <8	≥8
			Insulation Thickness, in.				
>350	0.32 to 0.34	250	4.5	5.0	5.0	5.0	5.0
251 to 350	0.29 to 0.32	200	3.0	4.0	4.5	4.5	4.5
201 to 250	0.27 to 0.30	150	2.5	2.5	2.5	3.0	3.0
141 to 200	0.25 to 0.29	125	1.5	1.5	2.0	2.0	2.0
105 to 140	0.22 to 0.28	100	1.0	1.0	1.5	1.5	1.5

Industry standard safety practices call for insulating hot piping at locations where people may come into contact with it and be injured.

Measure Analysis

Savings were based on a 2010 ICF study[2] conducted on behalf of the Energy Trust of Oregon. The study analyzed the impact of pipe insulation in commercial and industrial applications. A bare pipe baseline was used to describe sites that had missing, severely deteriorated, or uninsulated piping. Several different applications and their associated operating hours and fluid temperatures were looked at, assumptions for the analysis are listed in Table 3.

Table 3 Input Parameter Summary

Input Parameter	Value	Units
Boiler Efficiency	80%	N/A
Thermal conductivity, steel pipe (k)	314.4	Btu-in/hr-ft²-F
Thermal conductivity, insulation (k)	0.29	Btu-in/hr-ft²-F
Ambient Temperature	70	°F
Medium-pressure Steam Supply/Return Temperature	338/212	°F
Heating Water System Supply/Return Temperature	180/160	°F
Low-pressure Steam Supply/Return Temperature	250/212	°F
Emissivity of steel and insulation	0.8	N/A

The analysis assumes that 90% of pipes will be located indoors and 10% will be located outdoors. Savings were determined by using heat transfer engineering equations to model a horizontal pipe with internal fluid flow along with empirical relations for the necessary heat transfer coefficients. The following equation was used to determine heat loss from the pipe:

$$q = \frac{Q}{L} = \frac{\pi \Delta T}{R_1 + R_{pipe} + R_{ins} + R_2}$$

Where:

q = Energy loss per length of pipe (Btu/hr/ft)

Q = Energy loss (Btu/hr)

L = Pipe length (ft)

ΔT = Temperature difference between fluid and air ($T_{fluid} - T_{air}$,) (°F)

The R values in the denominator represent the thermal resistance factors that impede the flow of heat. R values vary and were solved for using physical properties and heat transfer coefficients.

R_1 = Thermal resistance due to convection between fluid and inside pipe surface

R_{pipe} = Thermal resistance due to conduction through pipe

R_{ins} = Thermal resistance due to conduction through insulation

R_2 = Thermal resistance due to convection and radiation at the exterior insulation surface.

The heat loss for bare and insulated pipes were calculated and used to find the incremental heat loss per hour. Using the heat loss rate, the savings were determined by multiplying the heat loss by the operating hours and dividing by the assumed boiler efficiency. The hours of operation are assumed to be 8,400 hours/year for industrial applications.

Savings

Savings were calculated for nominal pipe diameters of 0.5”, 0.75”, 1”, 1.25”, 1.5”, 2”, 2.5”, 3”, 3.5”, 4”, 5”, 6”, 8”, and 10”. The savings from each common pipe size are grouped in five bins (0.5-1”, 1.25-2”, 2.5-3.5”, 4-6”, and 8-10”) and supply/return piping were averaged and are displayed in Table 1. This was done so that contractors will not have to distinguish the direction of flow during installation, and projects with multiple pipe sizes are less likely to have differing incentive rates.

Experience with delivery of this measure has shown that some sections of pipe, valves, regulators, or other components require serviceable blanket insulation so that these areas can be accessed for maintenance without damaging the insulation. Typically, these

[1] 2021 Oregon Energy Efficiency Specialty Code (OEESC) https://www.oregon.gov/bcd/codes-stand/Documents/2021oeesc.pdf
[2] ICF (2010). Impact of Pipe Insulation on Natural Gas Consumption – Commercial and Industrial Applications. (ICF Report No. 201902D) Bellevue, WA

blankets are slightly thinner than the adjacent rigid insulation in order to allow forming the blanket to the component. It is assumed that the heat loss savings in these situations is at least as good as for an equal length section of pipe of the diameter of the connection to the component, since these components will be similar in external temperature to the pipe while at same time having a much larger surface area. For savings determination, the lower insulating value is assumed to made up for by the increased surface area. Therefore, these sections are conservatively assumed to have the same savings as an equal length section of pipe in the diameter of the connection to the component.

The 0.5-1" pipe size bins have been weighted to account for more frequent installations of 1" pipe insulation. 75% of these projects are expected to be 1" pipe, 20% to be 0.75" and 5% to be 0.5". These percentages were used to generate a weighted average. These percentages were estimated based on experience delivering the measure over the past year of the program, where many 1" pipe installations were seen, only a small amount of 0.75" (which was then ineligible), and zero 0.5" pipes. Any 0.5" or 0.75" pipes are expected to be very short runs near the point-of-use, so this weighted average should still be a conservative estimate of savings.

Savings for applications where the working fluid is not water or steam will be determined by matching the fluid supply temperature to the corresponding steam pressure through the use of commonly available steam tables. Fluids at temperatures lower than 212 °F will be treated as hot water for savings purposes.

Comparison to RTF or other programs

The industrial program also offers pipe insulation as a standard prescriptive measure. That offering, approved via MAD 91 uses more general assumptions and averages across pipe sizes, and different insulation thicknesses, resulting in different savings. That offer includes insulation of domestic hot water and HVAC heating hot water pipes with are not included in the direct install offering.

Energy Trust also offers pipe insulation in commercial buildings, approved in MAD 91 and in multifamily buildings approved in MAD 111. All the pipe insulation measures draw from the same analysis and methodology though savings differ primarily due to differences in hours of operation and piping sizes analyzed.

Measure Life

The 2007 ASHRAE Handbook assigns a 20-year measure life to modeled insulation, and a 2005 DEER Database report referencing CALMAC data lists 15 years for pipe wrap. Although pipe insulation in high traffic areas would likely deteriorate faster than these estimates, the program assumes that OSHA requirements would already require pipe insulation (especially on steam systems) to be installed in these high exposure areas. For industrial applications, a measure life of 10 years is used to account for the more frequent change out of process piping and expected re-insulation.

Load Profile

One of the requirements for this measure is that the process piping is in use year-round, and the hours of operation are assumed at 8,400 hours/year. This most closely matches the “FLAT” gas profile.

Cost

The direct install program design sets a maximum allowable incentive intended to cover the full cost of a project, therefore, the incentive is the cost. For this update, two vendors confirmed insulation pricing ranging from about $35 - $65 per lineal foot for straight piping in the range of expected sized, excluding bends and fittings. Their estimates assumed ASJ or PVC covering on indoor piping, and aluminum covering on exterior piping. An additional 10% was added to the total cost to account for bends and fittings and the resulting cost was rounded to the nearest $5 for ease of communication and marketing the offering.

Incentive Structure

The maximum incentives listed in ***Error! Reference source not found.*** are for reference only and are not suggested incentives. Incentives will be structured per lineal foot of insulation including insulated bends and fittings. Incentives will be paid directly to the insulation installation contractor and are intended to cover the full, installed cost of the insulation product.

Follow-Up

Incentives and costs should be re-examined at next update.

Supporting Documents

The cost effectiveness screening for these measures is number 249.3.3. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Commercial and Industrial\Process Equipment\pipe insulation\DI industrial pipe insulation

249.3.3_OR-WA-CE Calculator_2024_v_1

Version History and Related Measures

Energy Trust has been offering pipe insulation measure for many years. These predate our measure approval documentation process and record retention requirements. Table 4 may be incomplete, particularly for measures approved prior to 2013.

Table 4 Version History

Date	Version	Reason for revision
12/12/2019	249.1	Introduce direct-install pipe insulation offering
5/25/2021	249.2	Update measure to include additional pipe sizes, add applicability for other process fluids and new construction.
9/11/2023	249.3	Update measure to allow for 1” insulation across all pipe sizes.

Table 5 Related Measures

Measures	MAD ID
Commercial & Industrial Pipe Insulation	91
Multifamily Pipe Insulation	111
Process Boiler Calculator	226
Modulating Boiler Burners	142
Industrial Steam Traps	200

Approved & Reviewed by

Jackie Goss, PE
Sr. Engineer – Planning & Evaluation

Disclaimer

Measure Approval Document for Advanced Rooftop Controls Retrofit

Valid Dates
January 1, 2024 to December 31, 2026

End Use or Description
Installation of advanced rooftop-unit controls (ARC) on existing unitary systems with electric or gas heat, constant speed supply fan, modulating outdoor air damper, and cooling capacity equal to or greater than five tons. There are two types of qualifying retrofits, ARC-lite and ARC-full.

ARC-lite retrofit installs a supply fan VFD and controller, or a multispeed motor and controller on the existing RTU supply fan motor. Energy savings are achieved by reducing the fan speed during ventilation only operation.

ARC-full retrofit also installs a supply fan VFD but provides additional energy savings with the addition of a full range economizer control to increase free cooling hours and Demand Control Ventilation (DCV) to further reduce ventilation air during low occupancy.

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
- Production Efficiency

Within these programs, applicability to the following building types are expected (not limited to):

- Retail
- Office
- Restaurant
- Lodging

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

- Retrofit

Purpose of Re-Evaluating Measure
Costs were updated using recent project data. Savings remain the same. ARC-lite in gas heated buildings on alternative gas rates have been added.

Cost Effectiveness
Cost effectiveness for ARC-lite and ARC-full is demonstrated for Oregon in Table 1 and Table 2 respectively. Cost effectiveness for ARC-full in Washington is demonstrated in Table 3. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2024-v1.2. The Oregon electric avoided cost year is 2024 and the Oregon gas avoided cost year is 2024. The Washington gas avoided cost year is 2024. The values in these tables are per ton.

Table 1: Cost Effectiveness Calculator Oregon – ARC-lite, per ton

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
4	ARC-lite gas heat - Dual fuel eligible - 3500 to 4500 hrs	15	425.87	(6.72)	214.01	$0.00	$214.01	1.2	1.2	100%	0%
5	ARC-lite gas heat - Dual fuel eligible - 4500 to 5500 hrs	15	532.34	(8.40)	214.01	$0.00	$214.01	1.3	1.3	100%	0%
6	ARC-lite gas heat - Dual fuel eligible - 5500 to 6500 hrs	15	638.81	(10.09)	214.01	$0.00	$214.01	1.6	1.6	100%	0%
7	ARC-lite gas heat - Dual fuel eligible - 6500 to 7500 hrs	15	745.28	(11.77)	214.01	$0.00	$214.01	1.8	1.8	100%	0%
8	ARC-lite gas heat - Dual fuel eligible - 7500 to 8760 hrs	15	865.58	(13.67)	214.01	$0.00	$214.01	2.1	2.1	100%	0%
19	ARC-lite heat pump - 2500 to 3500 hrs	15	268.86	0	214.01	$0.00	$214.01	1.1	1.1	100%	0%
20	ARC-lite heat pump - 3500 to 4500 hrs	15	358.47	0	214.01	$0.00	$214.01	1.5	1.5	100%	0%
21	ARC-lite heat pump - 4500 to 5500 hrs	15	448.09	0	214.01	$0.00	$214.01	1.8	1.8	100%	0%
22	ARC-lite heat pump - 5500 to 6500 hrs	15	537.71	0	214.01	$0.00	$214.01	2.1	2.1	100%	0%
23	ARC-lite heat pump - 6500 to 7500 hrs	15	627.33	0	214.01	$0.00	$214.01	2.5	2.5	100%	0%
24	ARC-lite heat pump - 7500 to 8760 hrs	15	728.60	0	214.01	$0.00	$214.01	2.9	2.9	100%	0%
43	ARC-lite gas heat - Electric only eligible - 2500 to 3500 hrs	15	319.40	0	214.01	-$5.95	$214.01	1.3	1.0	100%	0%
44	ARC-lite gas heat - Electric only eligible - 3500 to 4500 hrs	15	425.87	0	214.01	-$7.93	$214.01	1.8	1.4	100%	0%
45	ARC-lite gas heat - Electric only eligible - 4500 to 5500 hrs	15	532.34	0	214.01	-$9.91	$214.01	2.1	1.6	100%	0%
46	ARC-lite gas heat - Electric only eligible - 5500 to 6500 hrs	15	638.81	0	214.01	-$11.90	$214.01	2.5	2.0	100%	0%
47	ARC-lite gas heat - Electric only eligible - 6500 to 7500 hrs	15	745.28	0	214.01	-$13.88	$214.01	2.9	2.2	100%	0%
48	ARC-lite gas heat - Electric only eligible - 7500 to 8760 hrs	15	865.58	0	214.01	-$16.12	$214.01	3.4	2.6	100%	0%

Table 2: Cost Effectiveness Calculator Oregon – ARC-full, per ton

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
9	ARC-full gas heat - Dual fuel eligible - 500 to 1500 hrs	15	417.88	15.20	425.70	$0.00	$425.70	1.6	1.6	56%	44%
10	ARC-full gas heat - Dual fuel eligible - 1500 to 2500 hrs	15	516.48	15.20	425.70	$0.00	$425.70	1.8	1.8	61%	39%
11	ARC-full gas heat - Dual fuel eligible - 2500 to 3500 hrs	15	615.09	15.20	425.70	$0.00	$425.70	2.0	2.0	65%	35%
12	ARC-full gas heat - Dual fuel eligible - 3500 to 4500 hrs	15	713.70	15.20	425.70	$0.00	$425.70	2.2	2.2	68%	32%
13	ARC-full gas heat - Dual fuel eligible - 4500 to 5500 hrs	15	812.31	15.20	425.70	$0.00	$425.70	2.3	2.3	70%	30%
14	ARC-full gas heat - Dual fuel eligible - 5500 to 6500 hrs	15	910.92	15.20	425.70	$0.00	$425.70	2.5	2.5	72%	28%
15	ARC-full gas heat - Dual fuel eligible - 6500 to 7500 hrs	15	1,009.52	15.20	425.70	$0.00	$425.70	2.7	2.7	74%	26%
16	ARC-full gas heat - Dual fuel eligible - 7500 to 8760 hrs	15	1,120.95	15.20	425.70	$0.00	$425.70	2.9	2.9	76%	24%
25	ARC-full heat pump - 500 to 1500 hrs	15	570.21	0	425.70	$0.00	$425.70	1.2	1.2	100%	0%
26	ARC-full heat pump - 1500 to 2500 hrs	15	668.81	0	425.70	$0.00	$425.70	1.4	1.4	100%	0%
27	ARC-full heat pump - 2500 to 3500 hrs	15	767.42	0	425.70	$0.00	$425.70	1.6	1.6	100%	0%
28	ARC-full heat pump - 3500 to 4500 hrs	15	866.03	0	425.70	$0.00	$425.70	1.8	1.8	100%	0%
29	ARC-full heat pump - 4500 to 5500 hrs	15	964.64	0	425.70	$0.00	$425.70	1.9	1.9	100%	0%
30	ARC-full heat pump - 5500 to 6500 hrs	15	1,063.24	0	425.70	$0.00	$425.70	2.1	2.1	100%	0%
31	ARC-full heat pump - 6500 to 7500 hrs	15	1,161.85	0	425.70	$0.00	$425.70	2.3	2.3	100%	0%
32	ARC-full heat pump - 7500 to 8760 hrs	15	1,273.28	0	425.70	$0.00	$425.70	2.5	2.5	100%	0%
33	ARC-full gas heat - Gas only eligible - 500 to 1500 hrs	15	0	15.20	425.70	$33.31	$302.69	1.0	1.6	0%	100%
34	ARC-full gas heat - Gas only eligible - 1500 to 2500 hrs	15	0	15.20	425.70	$41.17	$302.69	1.0	1.7	0%	100%
35	ARC-full gas heat - Gas only eligible - 2500 to 3500 hrs	15	0	15.20	425.70	$49.03	$302.69	1.0	1.9	0%	100%
36	ARC-full gas heat - Gas only eligible - 3500 to 4500 hrs	15	0	15.20	425.70	$56.89	$302.69	1.0	2.1	0%	100%
37	ARC-full gas heat - Gas only eligible - 4500 to 5500 hrs	15	0	15.20	425.70	$64.75	$302.69	1.0	2.3	0%	100%
38	ARC-full gas heat - Gas only eligible - 5500 to 6500 hrs	15	0	15.20	425.70	$72.61	$302.69	1.0	2.5	0%	100%
39	ARC-full gas heat - Gas only eligible - 6500 to 7500 hrs	15	0	15.20	425.70	$80.47	$302.69	1.0	2.7	0%	100%
40	ARC-full gas heat - Gas only eligible - 7500 to 8760 hrs	15	0	15.20	425.70	$89.35	$302.69	1.0	3.0	0%	100%
49	ARC-full gas heat - Electric only eligible - 500 to 1500 hrs	15	417.88	0	425.70	$17.92	$380.16	1.0	1.3	100%	0%
50	ARC-full gas heat - Electric only eligible - 1500 to 2500 hrs	15	516.48	0	425.70	$17.92	$425.70	1.1	1.6	100%	0%
51	ARC-full gas heat - Electric only eligible - 2500 to 3500 hrs	15	615.09	0	425.70	$17.92	$425.70	1.3	1.7	100%	0%
52	ARC-full gas heat - Electric only eligible - 3500 to 4500 hrs	15	713.70	0	425.70	$17.92	$425.70	1.5	2.0	100%	0%
53	ARC-full gas heat - Electric only eligible - 4500 to 5500 hrs	15	812.31	0	425.70	$17.92	$425.70	1.6	2.1	100%	0%
54	ARC-full gas heat - Electric only eligible - 5500 to 6500 hrs	15	910.92	0	425.70	$17.92	$425.70	1.8	2.3	100%	0%
55	ARC-full gas heat - Electric only eligible - 6500 to 7500 hrs	15	1,009.52	0	425.70	$17.92	$425.70	2.0	2.4	100%	0%
56	ARC-full gas heat - Electric only eligible - 7500 to 8760 hrs	15	1,120.95	0	425.70	$17.92	$425.70	2.2	2.7	100%	0%

Table 3: Cost Effectiveness Calculator Washington – ARC-full, per ton

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	ARC-full gas heat - 500 to 1500 hrs	15	15.20	425.70	$32.18	$425.70	1.0	1.9	0%	100%
2	ARC-full gas heat - 1500 to 2500 hrs	15	15.20	425.70	$39.77	$425.70	1.0	2.1	0%	100%
3	ARC-full gas heat - 2500 to 3500 hrs	15	15.20	425.70	$47.36	$425.70	1.0	2.3	0%	100%
4	ARC-full gas heat - 3500 to 4500 hrs	15	15.20	425.70	$54.95	$425.70	1.0	2.5	0%	100%
5	ARC-full gas heat - 4500 to 5500 hrs	15	15.20	425.70	$62.55	$425.70	1.0	2.7	0%	100%
6	ARC-full gas heat - 5500 to 6500 hrs	15	15.20	425.70	$70.14	$425.70	1.0	2.9	0%	100%
7	ARC-full gas heat - 6500 to 7500 hrs	15	15.20	425.70	$77.73	$425.70	1.0	3.1	0%	100%
8	ARC-full gas heat - 7500 to 8760 hrs	15	15.20	425.70	$86.31	$425.70	1.0	3.4	0%	100%

Requirements

- ARC-lite is offered to existing buildings commercial customers with greater than 3,500 annual operating hours only.
- ARC-full is available to all commercial customers with annual operating hours greater than 500.
- The installed equipment controls must be listed on BPA's qualifying product list for ARC-full and ARC-lite systems.
- For ARC-lite installations, the pre-existing unitary system must:
  - Have a nominal cooling capacity of 5 tons or greater.
  - Have a single speed supply fan or motor.
  - Not be equipped with a VSD.
- For ARC-full installations, the pre-existing unitary system must:
  - Have a nominal cooling capacity of 5 tons or greater.

- Have a single speed supply fan or motor.
- Not be previously equipped with a VSD or demand-controlled ventilation.

- ARC-lite is not approved in gas-only territory.
- Measures labeled as gas heat electric - only eligible are suitable for customers with gas heat but not on eligible gas rates, such as transport customers.

Implementation Details

ARC-lite

A variable speed drive shall be installed and controlled to reduce the supply fan motor to 40% of full speed during ventilation-only operation. The outdoor air damper shall be controlled to maintain proper ventilation rates according to ASHRAE Standard 62.2 under different fan speeds.

Exceptions to this are as follows:

- Where the volume of outdoor air required to comply with the ventilation requirements of the International Mechanical Code exceeds the volume of outdoor air that would be delivered with the supply fan motor at 40% of full speed and with the outdoor air damper in the maximum open position, the minimum speed shall be selected to provide the required ventilation air.
- Higher supply fan motor speeds are allowed during periods of cold outdoor air temperatures (e.g. below 30°F) in order to maintain comfortable supply air temperatures (e.g. above 60°F).

ARC-full

In addition to the ARC-lite equipment and operation noted above, economizer controls and a demand-controlled ventilation (DCV) system shall be installed.

Economizer controls

Controls must automatically allow the cooling system to supply outside air to reduce or eliminate the need for mechanical cooling during mild or cold weather. Controls with the following characteristics shall be installed:

- The economizer operation shall be integrated with the mechanical cooling system and be configured to provide partial cooling even when additional mechanical cooling is required to meet the remainder for the cooling load.
- The economizer controls and dampers shall be configured to sequence the dampers with mechanical cooling equipment and shall not be controlled by only mixed air temperature.
- The economizer controls shall have the mechanical cooling capacity control interlaced with the air economizer controls such that the outdoor air damper is at the 100% open position when mechanical cooling is on and the outdoor air damper does not begin to close to prevent coil freezing due to minimum compressor run time until the leaving air temperature is less than 45°F (7°C)
- Control shall not have fewer than two stages of cooling.
- The economizer shall be configured to automatically reduce outdoor air intake to the design minimum outdoor air quantity when outdoor air intake will no longer reduce cooling energy usage.
- High-limit shutoff can be accomplished using:
    - A differential dry-bulb setting, where the economizer shuts off when the outside air dry-bulb temperature is greater than return air dry-bulb temperature, or
    - A differential enthalpy with fixed dry-bulb temperature, where the economizer shuts off when the outside air enthalpy is greater than the return air enthalpy or when the outside air dry-bulb temperature is greater than 75°F.

DCV System

The ventilation control system shall be capable of providing automatic reduction of outdoor air intake below design rates when the actual occupancy of space served by the system is less than design occupancy.

- A DCV system using a CO2 sensor should be controlled based on the indoor space CO2 levels, as follows:
    - (a) When the CO2 level is 400ppm or less, the minimum ventilation rate for the space's floor area, calculated assuming zero occupants, is provided
    - (b) When the CO2 level is 1000 ppm or higher, ventilation is supplied at the design rate, calculated assuming full occupancy
    - (c) When the CO2 level is between 400 and 1000 ppm, ventilation is supplied at a rate equal to:

$$\left(CO2level_{ppm} - 400\right) \times \frac{(VentilationRate_b - VentilationRate_a)}{1000}$$

Baseline

This measure uses an existing condition baseline.

The baseline equipment is an existing RTU with a nominal cooling capacity of 5 tons or greater with a single speed supply fan motor and without a VFD, fully integrated economizer controls, or demand-controlled ventilation capability. This baseline was chosen to represent commercial systems which do not already have the upgrades which are part of this measure.

Savings and Measure Analysis

The savings are a summation of the fan energy savings, compressor energy savings, heating load, and cooling load savings. The full measure analysis was produced by the RTF[1] and was based on the PNNL field study "Advanced Rooftop Control (ARC) Retrofit: Field-Test Results" from July 2013.

Supply Fan Savings

Fan savings averages are estimated from the five sites included in the PNNL Advanced Rooftop Control (ARC) Retrofit: Field-Test Results. The RTF used savings determined for each of the five PNW sites and annualized and normalized to TMY3 weather data, per ton of nominal cooling capacity, and per hour of RTU-served space annual occupancy hours. Through their analysis, RTF determined that fan savings were an average of 99 kWh/ton/1000 hours of operation, which is shown in Table 4.

[1] https://rtf.nwcouncil.org/measure/advanced-rooftop-controls

Table 4 RTF's Average Fan Savings Per Ton Per 1000 Hours of Operation

kWh/ton/1000hrs basis		Fan Savings	Compressor Savings	Full ARC Savings
AC	Average	130 kWh	73 kWh	202 kWh
	SD	15 kWh	2 kWh	13 kWh
	CV	0.11	0.03	0.06
	Precision	13%	3%	7%
HP	Average	78 kWh	130 kWh	208 kWh
	SD	15 kWh	11 kWh	26 kWh
	CV	0.19	0.08	0.12
	Precision	18%	8%	12%
All	Average	99 kWh	107 kWh	206 kWh
	SD	31 kWh	33 kWh	20 kWh
	CV	0.32	0.30	0.10
	Precision	23%	22%	7%

Heating and Cooling Savings

In a gas RTU compressors are used for cooling and in a heat pump RTU they are used for both heating and cooling. The PNNL field study did not analyze gas usage so average compressor savings are estimated from the PNNL field study as the difference between the calculated RTU savings in the report and the supply fan savings. The average compressor savings for heat pump RTU and gas heated RTU with A/C is highlighted in Table 5 RTF's Average Compressor Savings Per Ton.

Table 5 RTF's Average Compressor Savings Per Ton

kWh/ton basis		Fan Savings	Compressor Savings	Full ARC Savings
AC	Average	554 kWh	319 kWh	873 kWh
	SD	43 kWh	7 kWh	36 kWh
	CV	0.08	0.02	0.04
	Precision	9%	3%	5%
HP	Average	278 kWh	472 kWh	750 kWh
	SD	68 kWh	123 kWh	187 kWh
	CV	0.24	0.26	0.25
	Precision	23%	25%	24%
All	Average	389 kWh	411 kWh	799 kWh
	SD	160 kWh	121 kWh	150 kWh
	CV	0.41	0.29	0.19
	Precision	30%	22%	14%

The total heating and cooling savings were then determined applying the fan HVAC interaction factors to fan energy reduction as indicated in Table 6.

Table 6 RTF's Standard Information Workbook Conversion Factors

RTU Type	HVAC Interaction Factor	
	Heating	Cooling
Heat Pump	-0.17 kWh/kWh	0.08 kWh/kWh
Gas/AC	-1.70 kWh/kWh	0.08 kWh/kWh

Operating hour bins were then used to scale the average PNNL savings to those offered in the measure. Table 7 summarizes the savings by end use for heat pump RTUs and Table 8 summarized savings for gas RTUs.

Table 7 Heat Pump RTU Savings by End Use and Occupied Hour Bin, kwh/ton

RTU Occupied Hours	ARC-lite			ARC-full		
	Fan Savings kWh/ton	Heating Savings kWh/ton	Cooling Savings kWh/ton	Fan Savings kWh/ton	Heating Savings kWh/ton	Cooling Savings kWh/ton
500 to 1500 hrs	99	-17	8	99	152	319
1500 to 2500 hrs	197	-34	16	197	152	319
2500 to 3500 hrs	296	-51	24	296	152	319
3500 to 4500 hrs	394	-67	31	394	152	319
4500 to 5500 hrs	493	-84	39	493	152	319
5500 to 6500 hrs	592	-101	47	592	152	319
6500 to 7500 hrs	690	-118	55	690	152	319
7500 to 8760 hrs	802	-137	64	802	152	319

Table 8 Gas RTU Savings by End Use and Occupied Hour Bin, kwh/ton

RTU Occupied Hours	ARC-lite			ARC-full		
	Fan Savings kWh/ton	Heating Savings therms/ton	Cooling Savings kWh/ton	Fan Savings kWh/ton	Heating Savings therms/ton	Cooling Savings kWh/ton
500 to 1500 hrs	99	-2	8	99	15.2	319
1500 to 2500 hrs	197	-3	16	197	15.2	319
2500 to 3500 hrs	296	-5	24	296	15.2	319
3500 to 4500 hrs	394	-7	31	394	15.2	319
4500 to 5500 hrs	493	-8	39	493	15.2	319
5500 to 6500 hrs	592	-10	47	592	15.2	319
6500 to 7500 hrs	690	-12	55	690	15.2	319
7500 to 8760 hrs	802	-14	64	802	15.2	319

Comparison to RTF or other programs

These measures use the RTF analysis to determine savings and cost. When screened for cost-effectiveness, ARC-lite systems measures are cost-effective only for heat pump and gas RTUs that operate for 3,500 hours or greater annually. When equipped with ARC-full systems, gas and heat pump RTUs are cost-effective for all annual operating hour bins. This is slightly different than BPA territory utilities such as EWEB and Clark PUD which both have incentives of $100/ton for ARC-lite retrofit and $200/ton for ARC-full retrofit with no limitations on operational hours.

Measure Life
The measure life is 15 years, which is consistent with assumed measure lifetimes for VFD and HVAC controls systems. This differs from the 20-year measure life used in MAD 195 for new RTUs with advanced controls. The shorter measure life accounts for the age of existing RTUs, which will likely have a shorter life expectancy than new RTUs.

Load Profile
Electric load profiles were determined based on the load profile of the most likely building in each operation bin set. The building types below are for example only – measure applications are to be applied by hours of use regardless of building type.

- Small office ventilation was used for below 2,500 hours/year
- Retail ventilation was used between 2,500 and 4,500 hours/year
- Grocery ventilation was used between 4,500 and 6,500 hours/year
- Lodging ventilation was used above 6,500 hours/year

The gas load profile "Com Heating" was used for all gas RTU measures.

Cost
Costs were sourced from Project Tracker (PT) data and compared against the RTF's estimates. The average ARC-lite cost in PT data was $214.01/ton for 44 projects. There was only one ARC-full project with a cost of $425.70/ton, which closely aligned with the RTF's ARC-full estimate of $418/ton.

Non Energy Benefits
Gas and electric savings for non-eligible utilities were included as NEBs.

Incentive Structure
The maximum incentives listed in Table 1, Table 2, and Table 3 are for reference only and are not suggested incentives. Incentives will be structured per ton.

Follow-Up
At the next update, the measure should be checked against the latest RTF's workbook and updated research. Although this is a retrofit measure, the Program should check the adopted version of the Oregon Energy Efficiency Specialty Code for any updates that may impact measure requirements.

At the next update program should consider aligning assumptions with smart thermostat measure where applicable.

Future updates may consider consolidating gas only measures into a single measure application.

Supporting Documents
The cost effectiveness screening for these measures is number 256.2.2. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Commercial and Industrial\Commercial HVAC\Economizers and controls\ARC retrofits

256.2.2 OR-WA-CE Calculator_2024_v_1

Version History and Related Measures
Energy Trust has been offering rooftop units and various control measures for many years. These predate our measure approval documentation process and record retention requirements. Table 9 may be incomplete, particularly for measures approved prior to 2013.

Table 9 Version History

Date	Version	Reason for revision
7/20/20	256.1	Introduce ARC-lite and ARC full measures as retrofits
7/24/23	256.2	Updated measure costs

Table 10 Related Measures

Measures	MAD ID
Unitary RTUs and economizers (inactive)	185
Commercial and Industrial RTU Controls on new equipment	195
Commercial Smart Thermostats	235

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Measure Approval Document for Pool Covers

Valid Dates
1/1/2024-12/31/2026

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

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:

- Fitness Centers
- Public Pools
- Hotels/Motels
- Multifamily Housing

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

- Retrofit

Purpose of Re-Evaluating Measure
Updates have been applied to the weather data, heating zone, costs, the analysis assumptions of pool size and occupancy, and the savings calculations.

Cost Effectiveness
Cost effectiveness is demonstrated for Oregon in Table 1Table 1 and Washington in Table 2. Cost effectiveness was calculated using the tool: OR-WA-CE Calculator 2024-v1.2. The Oregon electric avoided cost year is 2024 and the Oregon gas avoided cost year is 2024. The Washington gas avoided cost year is 2024. The values in these tables are per square foot of pool area.

Table 1 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	0.06	2.77	6.51	$0.34	$6.51	4.3	4.7	0%	100%
2	Outdoor Pool Cover - Condensing Gas Heater	10	0.06	2.37	6.51	$0.34	$6.51	3.7	4.1	0%	100%
3	Outdoor Pool Cover - Electric Resistance Heater	10	66.66	0.00	6.51	$0.34	$6.51	6.2	6.6	100%	0%
4	Outdoor Pool Cover - Electric Heat Pump Heater	10	13.38	0.00	6.51	$0.34	$6.51	1.2	1.7	100%	0%
5	Outdoor Pool Cover - Non-Condensing Gas Heater - Gas Only Territory	10	0.00	2.77	6.51	$0.35	$6.51	4.3	4.7	0%	100%
6	Outdoor Pool Cover - Condensing Gas Heater - Gas Only Territory	10	0.00	2.37	6.51	$0.35	$6.51	3.7	4.1	0%	100%
7	Indoor Pool Cover - Non-Condensing Gas Heater	10	0.04	2.09	6.51	$0.21	$6.51	3.3	3.5	0%	100%
8	Indoor Pool Cover - Condensing Gas Heater	10	0.04	1.78	6.51	$0.21	$6.51	2.8	3.0	0%	100%
9	Indoor Pool Cover - Electric Resistance Heater	10	50.22	0.00	6.51	$0.21	$6.51	4.7	4.9	100%	0%
10	Indoor Pool Cover - Electric Heat Pump Heater	10	10.07	0.00	6.51	$0.21	$6.12	1.0	1.2	100%	0%
11	Indoor Pool Cover - Non-Condensing Gas Heater - Gas Only Territory	10	0.00	2.09	6.51	$0.22	$6.51	3.2	3.5	0%	100%
12	Indoor Pool Cover - Condensing Gas Heater - Gas Only Territory	10	0.00	1.78	6.51	$0.22	$6.51	2.8	3.0	0%	100%

Table 2 Cost Effectiveness Calculator Washington, per square foot

#	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	2.77	6.51	$0.21	$6.51	4.6	4.9	0%	100%
2	Outdoor Pool Cover - Condensing Gas Heater	10	2.37	6.51	$0.21	$6.51	3.9	4.2	0%	100%
3	Indoor Pool Cover - Non-Condensing Gas Heater	10	2.09	6.51	$0.13	$6.51	3.5	3.6	0%	100%
4	Indoor Pool Cover - Condensing Gas Heater	10	1.78	6.51	$0.13	$6.51	3.0	3.1	0%	100%

Requirements

- Site cannot have had a pool cover within the 6 months prior to application.
- The cover must be specifically designed for swimming pools.
- The cover must fit the entire surface area of the pool.
- Liquid evaporation suppressants, solar disks, and mesh covers are ineligible.
- A storage reel is required.
- Pool heat fuel must be provided by a participating utility.
- Unheated pools do not qualify.
- Residential pools do not qualify.

Details

The following cover types have demonstrated the highest level of effectiveness[1] and are expected for participation:

1. **Solid Solar:** These covers are constructed from UV-stabilized polyethylene, polypropylene, or vinyl.
2. **Thermal (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 designed 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. Both solid solar and thermal covers may be paired with hand-crank reels, although automatic reels with tracks and paired with solid covers is currently the most common system, according to pool services in the Portland area.

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 through[2] and therefore would not be very effective for reducing evaporation losses and are considered ineligible.

Baseline

This measure uses an existing condition baseline.

The existing condition is a heated pool without a qualifying cover.

Measure Analysis

There are four avenues through which heat is lost from a pool. Heat loss methods include evaporation, radiation, convection, and conduction, although heat loss through conduction is considered negligible. Figure 1 shows the energy loss percentage for each transfer mode[3]. Indoor pools heat transfer modes are the same.

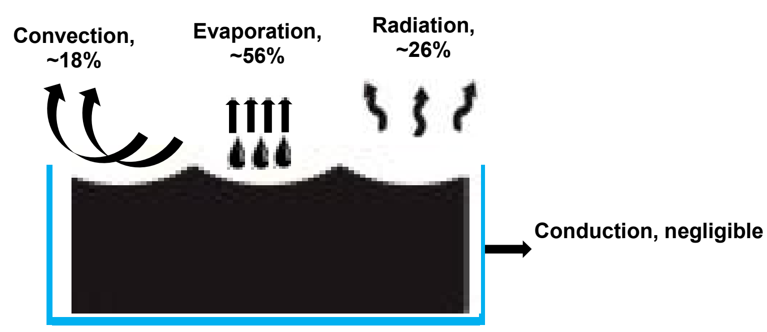

Figure 1: Heat loss ratios for outdoor swimming pools

The total heat loss was calculated from the evaporation losses where evaporation accounts for 56% of the total. Evaporation losses were estimated using the methodology outlined in “Methods for Calculation of Evaporation from Swimming Pools and Other Water Surfaces”.[4] The total evaporative loss for each pool category is the sum of the losses occurred during the occupied and unoccupied times, which are calculated using the different equations outlined in Table 3 and the following section.

Table 3: Conditions and equations used to determine evaporative losses.

Conditions	Outdoor	Indoor
Unoccupied	The greater of Equations 1, 2, or 3	The greater of Equations 1 or 2
Occupied	Equation 4	Equation 4

1. $E_0 = C\rho_w(\rho_r - \rho_w)^{\frac{1}{3}}(W_w - W_r)$

Where:

E_0 = rate of evaporation, unoccupied pools (lb/ft^2.h)
C = 290
ρ_w = density of air at water surface (lb/ft^3)
ρ_r = density of air at room temperature and humidity (lb/ft^3)
W_w = specific humidity ratio of air at water surface
W_r = specific humidity ratio of air at room temperature and humidity

4. 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)

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

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)

6. 4. $E_{occ} = (1.9 - 21(\rho_r - \rho_w) + 5.3N) * E_0$ [when N > 0.0046 people/sqft]

[1] 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
[2] 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.
[3] Smith, CC., Löf, G., Jones, R., “Measurement and analysis of evaporation from an inactive outdoor swimming pool”, Solar Energy, Volume 53, Issue 1, 1994, Pages 3-7: Measurement and analysis of evaporation from an inactive outdoor swimming pool - ScienceDirect
[4] 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

Where:
E_{occ} = rate of evaporation, occupied pools ($lb/ft^2.h$)
N = pool occupants per unit area

These equations provide evaporation rates with units of $lb/ft^2 \cdot hr$. To determine the total heat loss due to evaporation in BTU, the evaporation rates were multiplied by occupied and unoccupied hours during the months the pools would typically be operational, the area of a small-standard community pool, and the latent heat of evaporation at 80°F. This is expressed in the following formula:

7. $$Heat\ Loss_{evap.} = ((E_{unocc.} * \ hours_{unocc.}) + (E_{occ.} * \ hours_{occ.})) \cdot area \cdot 1048 \frac{btu}{lb}$$

Air densities, specific humidity ratios, and partial water pressures for outdoor pools were calculated based on the average relative humidity and dry-bulb temperatures from TMYx data[5] for station ID 726940 (Salem Municipal Airport – McNary Field) and station ID 726920 (Redmond Municipal Airport – Roberts Field). Heating zone weights were applied to these averages where Salem represented HZ1 and Redmond represented HZ2/3 at a 93% and 7% population respectively. The number of people used in the savings calculation is based on N>0.0046 for equation 4. When N>0.0046, pool occupancy becomes a negligible variable to the overall savings calculation which is then distilled to per square foot savings. For indoor pools, typical indoor pool characteristics were used. The details are summarized in Table 4.

Table 4: Parameters for Evaporation Calculations

Parameter	Value	Source
Occupancy Schedule	Outdoor: 10hrs/day, Jun-Sept	Estimated from community pools in Portland
	Indoor: 14hrs/day, All Year	
Avg Temp. (Jun-Sept)	67°F	TMYx data
Indoor Space Conditions	82°F	ASHRAE Journal Article[6]
Avg. Pool Temperature	80ºF	US Department of Energy[7]
Outdoor Relative Humidity	59% RH	TMYx data
Indoor Relative Humidity	50% RH	ASHRAE Journal Article (reference 4)
Pool Area	1834 ft^2	"Small" standard sized community pool[8]
Avg. # of People Pool	9	Turning point to steady-state evaporation rate

Savings

The total savings for outdoor pools were calculated by applying an evaporation abatement percentage estimated by the department of energy[9] and a radiation and convection abatement percentage calculated for a custom pool project by ETO to the appropriate losses categories. Indoor pools follow this same methodology with the adjustment that radiation and convection losses are assumed to be completely abated during hours the pool is unoccupied.

Water savings were calculated from the abated evaporation losses. Energy savings were calculated from total abated losses with respect to heater efficiencies (Table 5) and pool area. For customers in territories with electric savings, the embedded electricity in water is claimed. All savings were determined per ft^2 of pool area.

Table 5: Heater Efficiencies

Fuel Type	Heating Equipment	Efficiency	Source
Gas	Non-Condensing Heater	82%	ASHRAE 90.1 – 2019 and Federal Code[10]
	Condensing Heater	96%	Study of Swimming Pool Heater Performance[11]
Electric	Heat Pump	5.0 COP	US Department of Energy[12]
	Resistance	100% or 1.0 COP	US Department of Energy[13]

In addition to pool water heating savings, ventilation systems can often run less in indoor pool facilities due to pool cover deployment. These savings were not analyzed as they may require a control system upgrade. Also, the savings could vary greatly depending on the facility.

Measure Life

The measure life is 10 yrs. This is consistent with the measure life used for pool covers in Energy Trust custom studies.

Load Profile

The electric load profile is process heating. The gas load profile is either flat-gas or none for electric heaters.

Cost

Costs were sourced by surveying online cost from local pool servicing businesses. There is a significant difference in pricing between solid vinyl safety covers and their storage reels verse thermal covers and storage reels. A straight average was applied to the cost difference between the 2 cover types based on estimates from pool cover market analysis charts[14]. Given the cost data for covers and reels, the measure cost was determined to be $6.51/ft².

[5] https://climate.onebuilding.org/WMO_Region_4_North_and_Central_America/USA_United_States_of_America/index.html#IDOR_Oregon-
[6] ASHRAE. "Natatoriums, The Inside Story". Volume 48. (April 2006) https://technologyportal.ashrae.org/journal/articledetail/55
[7] US Department of Energy. "Managing Swimming Pool Temperature for Energy Efficiency". https://www.energy.gov/energysaver/managing-swimming-pool-temperature-energy-efficiency
[8] Community pool sizes: https://www.dimensions.com/element/community-swimming-pools
[9] US Department of Energy. "Swimming Pool Covers": https://www.energy.gov/energysaver/swimming-pool-covers
[10] 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
[11] 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
[12] US Department of Energy. "Heat Pump Swimming Pool Heaters" https://www.energy.gov/energysaver/heat-pump-swimming-pool-heaters
[13] 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 .
[14] Section - "What is the fastest-growing segment in the Swimming Pool Cover Market": https://www.technavio.com/report/swimming-pool-cover-market-analysis

Non Energy Benefits

Non-energy benefits are incurred due to the reduction in water loss from the pool cover. Non-energy benefits are based on regionally representative water and wastewater costs as outlined by Energy Trust. 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 electric or gas 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 square footage of the pool to be covered. Incentives should not exceed the project cost.

Follow-Up

If this measure is evaluated, more specific local data such as pool schedules, occupancy rates, and average pool sizes would be useful in the savings calculations. Additionally, methodology should be reviewed for the latest research on pool losses and dominant heat transfer mechanisms.

Costs should also be assessed for accuracy and possibly delineated by cover type for incentive offering.

Supporting Documents

The cost effectiveness screening for these measures is number 265.2.1. 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

265.2.2 OR WA-CE Calculator_2024_v_1

Version History and Related Measures

Table 6 Version History

Date	Version	Reason for revision
12/3/2020	265.1	First approval of pool covers
8/9/2023	265.2	Updated weather data, added heating zone weightings, updated costs, and updated savings calculation based on review of analysis assumptions.

Table 7 Related Measures

Measures	MAD ID
Commercial Pool Heater	238
Commercial Pool Pump	237
Residential Pool Pumps (inactive)	37
Spa Covers (inactive)	99

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Measure Approval Document for Energy Recovery Ventilation Calculator

Valid Dates
8/9/2023- 12/31/2025

End Use or Description
This measure is an internal-facing spreadsheet tool that calculates gas and electricity savings achieved by installing an air-air energy recovery device when not required by code. The calculator can also be used for situations where energy recovery is required, but the proposed device exceeds the effectiveness required by code.

This tool is used to calculate savings for custom projects or "special measures" that are tested individually for cost-effectiveness. Outputs from the tool may be used through custom or semi-custom program tracks, when cost effective. This approval is for version 2023 1.0.

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, the measure is applicable to the following classes:

- New
- Replacement

Purpose of Re-Evaluating Measure
This update includes more precise conversion between SEER2/EER2/HSPF2, SEER/EER/HSPF, and COP in savings calculations. Minor errors in the tool have been fixed.

Cost Effectiveness
Cost effectiveness must be determined individually for each project. Only projects that pass will be approved.

Requirements
- Incremental costs and cost-effectiveness must be determined for each project. Only cost-effective projects will qualify.
- The tool can account for any energy recovery device that has rated effectiveness values (with common device types being flat plate/membrane, rotary heat wheel, or run-around coils).
- Multifamily dwelling units should not be analyzed using this tool (the tool is not set up to accommodate code baseline effectiveness values for this space type).
- This tool should not be used for projects pursuing the VRF measure (MAD 216 – Air-Cooled VRF Multi-Split Heat Pump) to avoid double-counting savings, as that measure includes savings from heat recovery from an associated dedicated outside air system (DOAS)
- If energy recovery is required by code per ASHRAE 90.1-2022 section 6.5.6.1, installed energy recovery device must exceed code effectiveness values of 50% in cooling mode and heating mode.
- All other code requirements must be met for projects determined to be subject to code (i.e., requirements listed in section 6.5.6.1 Exhaust Air Energy Recovery, ASHRAE Standard 90.1-2022).
- Projects using a heat recovery device to satisfy the requirements of ASHRAE 90.1-2022 sections 6.5.7.3 (Laboratory Exhaust Systems) or 6.5.6.4 (Indoor Pool Dehumidifier Energy Recovery) are ineligible.
- Tool is intended for use in buildings permitted under the OZERCC 2019, OEESC 2021, and 2024 energy codes. Existing buildings projects and Washington projects must determine if proposed ERVs are required by applicable codes.
- While this tool is designed for Oregon codes, it may be used in Washington as well.

Baseline
This measure uses a Code Baseline.

ASHRAE 90.1-2022 section 6.5.6.1 determines where energy recovery is required, and in these cases the code minimum effectiveness is 50% in cooling and heating mode. The baseline for all other spaces is ventilation equipment without heat recovery.

Measure Analysis
User inputs
The tool collects the following inputs from the user that are relevant to the savings calculations:

Table 1 Calculator Inputs

Input	Description	Notes on how Program might obtain
Heat Recovery Method	Currently the only option is "Sensible Only", as the above calculations only calculate sensible heating and cooling savings; a future revision of the calculator could include latent heating and cooling savings	n/a
HVAC System Type	Dropdown with the following selections: • Heating only • Heating and Cooling • Cooling only	Mechanical plans
Heat Exchanger Type	Dropdown with the following selections: • Rotary • Flat Plate/Membrane	Mechanical plans or manufacturer documentation
Sensible Heating Effectiveness	Sensible heating effectiveness of the heat exchanger (in %)	AHRI certificate, manufacturer documentation, or calculated from temperatures listed in the mechanical plans (per "Additional Calcs" tab of the tool, Manual Effectiveness Calculation section)

Input	Description	Notes on how Program might obtain
Sensible Cooling Effectiveness	Sensible cooling effectiveness of the heat exchanger (in %)	AHRI certificate, project-specific submittal, manufacturer documentation, or calculated from temperatures listed in the mechanical plans (per "Additional Calcs" tab of the tool, Manual Effectiveness Calculation section)
Heating Setpoint (°F)	Heating temperature setpoint of the space to which the ventilation air is being provided – the tool assumes this to be equal to the return air temperature (RAT) passing through the heat exchanger when the space conditioning system is in heating mode	Mechanical plans, project-specific submittal, building staff, or on-site observation at thermostat(s)
Heating Fuel	Dropdown with the following selections: • Gas • Electric • Gas and Electric	Mechanical plans
Heating Efficiency Rating	Dropdown with the following selections for electric heat systems: • Heating COP @ 47°F • HSPF • HSPF2 And the following default for gas heat systems: • Thermal Efficiency, %	Mechanical plans
Heating Efficiency Value	User-input efficiency value	Mechanical plans
Portion of Heat Load Met by Each Fuel, %	For dual-fuel heating system types, the user enters the percentage of the heat load met by the electric fuel system and the calculator automatically attributes the remainder to the gas fuel system. This split can be calculated as the ratio of system heating capacities of each fuel type to the total heating capacity.	Mechanical plans, project-specific submittal, building staff, or on-site observation at thermostat(s)
Cooling Setpoint (°F)	Cooling temperature setpoint of the space to which ventilation air is being provided – the tool assumes this to be equal to the return air temperature (RAT) passing through the heat exchanger when the space conditioning system is in cooling mode	Mechanical plans or project-specific submittal
Cooling Efficiency Rating	Dropdown with the following selections for cooling efficiency rating: • SEER • EER • Cooling COP • SEER2 • EER2	Mechanical plans
Cooling Efficiency Value	User-input efficiency value	Mechanical plans
Enter SEER2/EER2/HSPF2 Equipment Type	Dropdown with the following selections for space conditioning equipment type for converting between SEER2/EER2/HSPF2 and SEER/EER/HSPF ratings: • Split-System Ducted • Split-System Ductless • Packaged	Mechanical plans
Supply Fan Design CFM	The supply airflow (passing through the heat exchanger) in cubic feet per minute	Mechanical plans or project-specific submittal
Supply Fan Nameplate Power	The supply fan nameplate power in horsepower	Mechanical plans or project-specific submittal
Fan Eff. Excluding Motor Eff. (%, if known)	The efficiency of the supply fan excluding motor efficiency (if unknown, a default of 81% is used)	Mechanical plans or project-specific submittal
HX Static Pressure Drop (in. WG, if known)	The pressure drop from the heat exchanger across the supply fan in inches of water gauge (if unknown, a default of 0.65 is used for plate exchanger or 1.0 for wheel exchanger)	Mechanical plans, project-specific submittal, or manufacturer documentation
Exhaust Fan Design CFM	The exhaust airflow (passing through the heat exchanger) in cubic feet per minute	Mechanical plans or project-specific submittal
Exhaust Fan Nameplate Power (HP)	The exhaust fan nameplate power in horsepower	Mechanical plans or project-specific submittal
Fan Eff. Excluding Motor Eff. (%, if known)	The efficiency of the exhaust fan excluding motor efficiency (if unknown, a default of 81% is used)	Mechanical plans or project-specific submittal
HX Static Pressure Drop (in. WG, if known)	The pressure drop from the heat exchanger across the exhaust fan in inches of water gauge (if unknown, a default of 0.65 is used for plate exchanger or 1.0 for wheel exchanger)	Mechanical plans, project-specific submittal, or manufacturer documentation
Location	Dropdown for the user to select the closest TMY3 location for the project (a hyperlink to an interactive map of Oregon is provided to aid in determination of the closest TMY3 location)	Project location
Operating Schedule(s)	The operating schedule(s) of the ERV and associated HVAC system; up to four schedules may be defined, though the user must take care to avoid overlap	Building staff

While code-minimum energy recovery performance (where required) is stated in terms of Enthalpy Recovery Ratio, the calculator takes Effectiveness inputs, which are more readily available from manufacturers. These metrics are equivalent in cases of balanced flow. When flow is unbalanced, the calculator adjusts effectiveness values accordingly.

Savings Calculations

Savings in this measure are realized by transferring energy between exhaust air and incoming ventilation air – this transfer essentially preconditions the incoming air and lessens the amount of energy required by the space conditioning equipment.

The tool uses a weather bin calculation approach to determine energy recovery savings. For each 5-degree F outside air (OSA) temperature bin, the sensible heat transfer between the supply and exhaust air is determined by the supply airflow rate (CFM) and temperature difference between the exhaust air (room setpoint) and OSA bin midpoint temperature. Total annual load transferred for each bin is determined by the number of annual hours in that bin during scheduled operation:

$$\mathrm{BTU_{bin}} = 1.08 \times \mathrm{CFM} \times \Delta\mathrm{T} \times \mathrm{hours_{bin}}$$

1.08 is a unit conversion constant that assumes standard density air (70°F, sea level (14.5psi)), which yields a density of 0.074887 lb/ft^3 specific heat of 0.24 Btu/lb·°F:

$$1.08 = 60\ min/hr \times 0.074887\ lb/ft^3 \times 0.24\ Btu/lb \cdot {}^\circ F$$

For both heating and cooling modes, the annual loads are summed and converted to energy savings using the efficiency (COP) of the heating and cooling systems and the effectiveness of the energy recovery system:

$$\mathrm{Savings_{heating}} = \sum \frac{\mathrm{BTU_{bin<heatin\ \ setpoint}}}{\mathrm{COP_{heating}}} \times \mathrm{eff_{ERV\ heating}}$$

$$\mathrm{Savings_{cooling}} = \sum \frac{\mathrm{BTU_{bin>cooling\ setpoint}}}{\mathrm{COP_{cooling}}} \times \mathrm{eff_{ERV\ cooling}}$$

For cases of unbalanced flow (i.e., where the supply and exhaust airflow rates are unequal), the effectiveness of the energy recovery system is multiplied by an adjustment factor per Figure 2 of the York Application Guide: AIR SYSTEMS – ENERGY SERIES Energy Recovery Wheels Form 102.20-AG6 (305)[1].

When COP is not the user input efficiency metric, it is calculated with one or more of the following equations[2], depending on the user input:

$$\mathrm{EER} = -0.0228 \times \mathrm{SEER}^2 + 1.1522 \times \mathrm{SEER}$$

$$\mathrm{COP_{cooling}} = \frac{\mathrm{EER}}{3.412}$$

$$\mathrm{COP_{heating}} = -0.0235 \times \mathrm{HSPF}^{\,2} + 0.6293 \times \mathrm{HSPF}$$

SEER2/EER2/HSPF2 inputs are converted to SEER/EER/HSPF for calculations using the Energy Trust crosswalk table.

Additional fan energy used by the system due to added static pressure drop (SP) across the heat exchanger is calculated for the supply and exhaust fans. Heat recovery wheel power is accounted for as well when applicable. In cases where no energy recovery is required by code, these additional fan and heat wheel energy uses are subtracted from electric savings (i.e., a baseline energy recovery device is assumed to have the same fan and/or wheel energy use as the proposed device and this energy use is not treated as a penalty):

$$\mathrm{BHP_{fan}} = \frac{\mathrm{CFM} \times \mathrm{SP}}{\mathrm{eff_{fan}} \times 6356}$$

$$\mathrm{kW_{fan}} = \frac{\mathrm{BHP_{fan}} \times 746}{1000}$$

$$\text{Electric Penalty} = \left(\mathrm{kW_{supply\ fan}} + \mathrm{kW_{exhaust\ fan}} + \mathrm{kW_{recovery\ wheel}}\right) \times \mathrm{hours_{total\ operation}}$$

Comparison to RTF or other programs

RTF does not have an air-to-air heat recovery measure.

Energy Trust's VRF measure (MAD 216 – Air-Cooled VRF Multi-Split Heat Pump) includes savings from heat recovery from the associated dedicated outside air system (DOAS). This calculator should not be used for projects pursuing the VRF measure to avoid double-counting savings. This calculator may be used for VRF systems that do not meet the requirements of the VRF measure but meet the requirements of this measure.

Measure Life

The measure life of 15 years aligns with the other HVAC measures and with the California Public Utilities Commission (CPUC) Database of Energy Efficiency Resources (DEER) effective useful life (EUL) for HVAC fan motors[3].

Load Profile

The appropriate load profile will be determined per project based on the building type and predominant end-use savings (heating, ventilation or cooling), though for Oregon the expected load profile is Heating (likely Building type Heating for electric heated buildings or Com Heating for gas heating buildings); energy recovery ventilation reduces conditioning of outside air. The user is expected to make the appropriate Sector and Sub-Sector selections relevant to the project.

Cost

Incremental costs compared to code baseline will be provided to the program on a case by case basis for use in cost effectiveness testing. Incremental costs are generally associated with material and labor costs of installing an energy recovery device in a ventilation unit. Costs are expected to be provided by project teams but in cases where unavailable may be estimated internally using (in order of priority) RSMeans, internet pricing, or comparable past projects. In cases where code requires energy recovery and the installed

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[1] https://www.johnsoncontrols.com/-/media/jci/be/united-states/airside-systems/air-handling-units/files/be_appguide_energyrecoverywheel_ahu.pdf - effectiveness values for unbalanced flows are adjusted per Figure 2 on p.2

[2] Hyojin Kim, Juan-Carlos Baltazar, and Jeff S. Haberl; April 2013, "Methodology for Calculating Cooling and Heating Energy-Input-Ratio (EIR) from the Rated Seasonal Performance Efficiency (SEER or HSPF)", ESL-TR-13-04-01, Texas A&M University, https://oaktrust.library.tamu.edu/bitstream/handle/1969.1/152118/ESL-TR-13-04-01.pdf (see equations (8) and (9))

[3] https://www.caetrm.com/cpuc/table/effusefullife/

recovery unit exceeds code effectiveness requirements, incremental cost would likely be the cost of the more effective energy recovery device minus the cost of a unit that just meets code effectiveness.

Incentive Structure

Approved custom (Existing Buildings) or special measure (New Buildings) incentive rates should be used for all therm and electric savings generated by the calculator.

Follow-Up

Current indications are that Oregon will be adopting ASHRAE 90.1-2022 at some point in 2024. When available for review, Oregon amendments to 90.1-2022 should be reviewed and any necessary measure adjustments be made at that time.

The tool must be approved at the next major update. Minor updates that do not change calculation methods do not require re-approval. At the next major update, tool should change to using TYMx rather than TYM3 weather data in line with Energy Trust's Technical Guidelines for efficiency measures.

Supporting Documents

The cost effectiveness screening for these measures is number 280.2.2. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Commercial and Industrial\Commercial HVAC\Energy Recovery

ERV_Calculator_2023.xlsm

280.2.2 OR-WA-CE Calculator_2024_v_1

Version History and Related Measures

Table 2 Version History

Date	Version	Reason for revision
9/16/2022	280.1	Introduce ERV calculator
8/9/2023	280.2	Updates conversion between SEER2/EER2/HSPF2, SEER/EER/HSPF, and COP

Table 3 Related Measures

Measures	MAD ID
Air Cooled VRF with DOAS	216

Approved & Reviewed by

Jackie Goss, PE
Sr. Engineer – Planning & Evaluation

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Energy Trust of Oregon

Measure Approval Document for Two-stage Valves for Commercial Gas Clothes Dryers

Valid Dates
1/1/2024 – 12/31/2026

End Use or Description
A two-stage gas valve, replacing the existing single-stage gas valve on an existing or new gas-fired clothes dryer. The two-stage valve (along with its electronic controller) lowers the gas firing rate in the burner towards the end of a drying cycle when moisture content in clothes has been reduced and there isn't a need for high heat in the dryer. This lowered firing rate reduces the natural gas consumption towards the end of a drying cycle when compared to a single-stage burner.

A single two-stage valve is installed per gas-fired commercial clothes dryer.

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, participation from (but not limited to) the following building types or market segments is expected:

- Lodging including hotels, motels
- Healthcare including hospitals, clinics
- Nursing homes, and assisted living centers
- Health/Fitness clubs, spas, and resorts
- Universities/colleges
- Fire stations, law enforcement
- Coin-operated laundromats (Washington only)
- Shared/common area laundry in stacked multifamily buildings with 5 or more units. (Washington only)

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

- Retrofit
- New

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 2024-v1.2. In Oregon the electric avoided cost year is 2024 and the gas avoided cost year is 2024. In Washington the gas avoided cost year is 2024. The values in these tables are per valve.

Table 1 Cost Effectiveness Calculator Oregon, per valve

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Total NEB (Annual $)	Maximum Incentive ($)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
3	Two-stage Gas Valve on Clothes Dryers in On-Premises Laundries	10	351.82	875.00	$0.00	$875.00	4.2	4.2	0%	100%

Table 2 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	Two-stage Gas Valve on Clothes Dryers in Multifamily Buildings	10	24.67	875.00	$0.00	$260.80	1.0	0.3	0%	100%
2	Two-stage Gas Valve on Clothes Dryers in Coin-Operated Laundromats	10	52.61	875.00	$0.00	$556.11	1.0	0.6	0%	100%
3	Two-stage Gas Valve on Clothes Dryers in On-Premises Laundries	10	351.82	875.00	$0.00	$875.00	4.3	4.3	0%	100%

Requirements
- Valves on commercial gas-fired dryers up to 200 lbs. of dry clothes capacity or up to 65 cubic feet dryer drum volume are eligible.
- Measure is applicable to existing and new gas-fired dryers in eligible commercial and multifamily buildings.

Baseline
This measure uses an existing condition baseline for retrofit measures and market baseline for new/replacement measures.

For retrofit measures, baseline equipment is assumed to be a conventional gas-fired clothes dryer used in commercial or multifamily buildings without the capability to modulate gas firing rate.

Due to lack of data on share of single-stage valve gas-fired fryers and two-stage valve gas-fired dryers, it is assumed that new dryers sold are conventional gas-fired dryers with single-stage valves. A review of commercial gas-fired clothes dryers available from brands including Speed Queen and Maytag did not reveal any models which offer modulating gas usage rate. Therefore, baseline equipment for new/replacement measures is also assumed to be a conventional gas-fired clothes dryer used in commercial or multifamily buildings without the capability to modulate gas firing rate.

Estimation of average dryer capacity (lbs. dry clothes) by facility
Average dryer capacities were estimated for common area/shared laundry rooms in multifamily buildings, coin-operated commercial laundromats, and on-premises laundries in facilities such as hotels, motels, nursing homes etc. The analysis leverages methodology used in the California eTRM measure for Gas Dryer Modulating Valve, Commercial and Multifamily in the California eTRM[1].

The methodology used for estimating average dryer capacity uses the 2015 California on-premises Laundromat Dryers Market Study[2]. The study included the following facilities: hotels & motels, nursing homes, health clubs, dry cleaners, universities & colleges, fire stations, law enforcement. The study also included state prisons & county jails, laundry services companies, and hospitals but these

[1] Gas Dryer Modulating Valve, Commercial and Multifamily, California eTRM, https://www.caetrm.com/measure/SWAP012/01/
[2] https://www.caetrm.com/media/reference-documents/NREL_On-Premise_Laundromat_Dryers_Market_Survey_2015.docx

facilities were not included in this analysis as the data showed that they use industrial-sized (> 200 lbs. of dry clothes capacity) dryers. Since the savings methodology used in this analysis is based on results of a pilot using commercial-sized dryers (< 200 lbs. of dry clothes), facilities using industrial-sized dryers were not included in this analysis.

The study includes estimates of actual total dryer capacities installed by facility type and installed dryer capacity ranges in lbs. as shown in **Error! Reference source not found.**. Although there is a large difference between Oregon and California's populations (which can have an influence on actual installed dryer capacity in respective states), the percent distribution of installed dryer capacity in California is assumed to be similar in Oregon. Thus, dryer capacity ranges and percent distribution of dryer capacity by facility type as shown in **Error! Reference source not found.** were used for estimating weighted average dryer capacity across all above noted facility types.

Table 3 On-Premises Laundry Market Survey Data from California

Facility Type	Installed Capacity in lbs. in CA	% Dist. of Installed Capacity in CA	Dryer Capacity Range (lbs. dry clothes) and Representative Avg. Capacity for Each Range					Weighted Avg. Capacity by Market Sector	Weighted Avg. Capacity All Sectors (lb.)
			<30	≥30 to <50	≥50 to <70	≥70 to <120	≥120 to <220		
			15	40	60	95	170		
Hotels & Motels	524,845	44%	0%	0%	42%	44%	14%	91	83.2
Nursing Homes	274,467	23%	0%	3%	17%	59%	21%	103	
Health Clubs	160,150	13%	0%	0%	100%	0%	0%	60	
Dry cleaners	111,938	9%	40%	17%	0%	43%	0%	54	
Universities & Colleges	85,767	7%	0%	52%	0%	48%	0%	66	
Fire Stations	25,050	2%	0%	100%	0%	0%	0%	40	
Law Enforcement	7,650	1%	0%	0%	0%	100%	0%	95	

As calculated from the data in **Error! Reference source not found.**, the average dryer capacity across all commercial sectors with on premises laundry is 83.2 lbs. of dry clothes.

To estimate the average dryer capacity for shared laundry in multifamily and coin-operated laundromats, data collected by Southern California Gas (SCG) and Pacific Gas & Electric (PG&E) in California[3] was used. The dataset includes 85 commercial gas-fired dryers and 27 dryers for multifamily application used to establish average dryer capacity. A linear regression using the volume and capacity data from the commercial dryers, resulted in an assumption of 3.28 lb/cu. ft.

In the dataset of 27 multifamily dryers, dry clothes capacity was missing for most models whereas drum volume data was available for all models. This is likely because these smaller dryers are sold for the residential market instead of the commercial market. An average drum volume of 7.08 cubic feet was calculated from the data. This resulted in an average dryer capacity of 21.2 lbs. of dry clothes.

For laundromats, the average dryer drum volume was calculated assuming typical full-size drum volume as 7.5 cu. ft. and typical large size drum volume as 13.0 cu. ft. This average drum volume was used in the capacity to volume ratio to estimate an average dryer capacity of 31.6 lbs. of dry clothes.

Estimation of annual baseline therms usage by facility

Annual baseline therms usage is estimated as a product of therms usage per drying cycle for a dryer and estimated number of annual drying cycles.

$$Annual\ Therms\ Usage\ per\ Dryer = Therms\ usage\ per\ drying\ cycle\ \times estimated\ number\ of\ annual\ drying\ cycles\ per\ dryer$$

Therms/drying cycle were estimated from a dryer's burner firing rate (kBtu/h) and the methodology and assumptions used are from the analysis by Southern California Gas (SCG) and Pacific Gas & Electric (PG&E). The two main assumptions used in the referenced spreadsheet analysis are:

- Average dryer cycle time is 35 minutes.
- Average time a burner is on during a drying cycle is 65% of the cycle time.

These assumptions result in an estimate an average time burner is on in each cycle of 0.38 hours. This estimate was then multiplied with kBtu/h firing rate of each of the 85 commercial gas-fired dryers identified in the California analysis to estimate the therms /cycle for each dryer. A linear regression was developed using the estimated therms/cycle data each dryer and their individual dry clothes capacity (in lbs.) to produce an estimate of 0.00936 therms/cycle/lb capacity.
The number of annual cycles data was sourced from the Illinois TRM v10, which referenced the DOE's Federal Register Notices Energy Conservation Program. For on-premises laundries, # of annual cycles is based on the average value for dryer cycles in healthcare facility, hotels, dry cleaners, and laundromats from tests conducted in Nicor Gas Emerging Technology Program's Commercial Dryer Modulation Retrofit Public Project Report. The estimated number of annual cycles are shown in Table 4.

Table 4 Number of Annual Drying Cycle and Baseline Annual Usage Estimates Per Dryer

Building/Facility Type	Average dryer capacity (lbs dry clothes)	Therms/Cycle per Dryer	Estimated Number of Annual Drying Cycles per Dryer	Annual Baseline Usage per Dryer (therms)
Laundry Rooms in Multifamily Bldgs.	21.2	0.179	1074	192.0
Coin-Operated Laundromats	31.6	0.276	1483	409.4
On-Premises Laundries	83.2	0.759	3607	2737.9

Savings

The pilot conducted by GTI in Illinois estimated 13.8% savings[4] from long-term testing and 12.4% from standardized testing for the same measure. The same measure in California eTRM used the standardized test results of 12.4% savings from the pilot conducted by GTI in Illinois. GTI Energy conducted a study for NEEA[5] to estimate savings from retrofitting this measure on existing clothes dryers in the four Pacific Northwest states- Washington, Oregon, Idaho, and Montana. The study adjusted the Illinois results for average outdoor air temperature and estimated 12.85% savings on baseline natural gas therms usage for Oregon and this savings factor was applied to baseline therms usage estimates and the resulting annual savings results are shown in Table 5.

[3] Gas Dryer Modulating Valve, Comm. & MF. Energy_Analysis_of_SCG_and_PGE_Data_Collection.xlsx
[4] Non-Modulating.pdf (nicorgas.com)
[5] Modulating Gas Valve for Commercial Dryer Study, GTI Project # 23217, Prepared for NEEA Northwest Energy Efficiency Alliance (NEEA) | Modulating Gas Valve…

Table 5 Two-stage Dryer Valve Savings

Building/Facility Type	Annual Baseline Therms Usage per Dryer	Annual Therms Savings per Dryer
Laundry Rooms in Multifamily Bldgs.	192.0	**24.7**
Coin-Operated Laundromats	409.4	**52.6**
On-Premises Laundries	2737.9	**351.8**

Measure Life

Measure life was confirmed with the manufacturer as 10 years. The manufacturer also confirmed that the measure can be removed from an existing dryer and installed on a new/replacement dryer.

Load Profile

Electric- None-ele.
Gas- Clotheswasher

Cost

Installed cost of the two-stage valve and electronic controller assembly is $875 which includes material and labor. This estimate was obtained from the manufacturer, EZ Efficiency, in April 2023.

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 dryer valve.

Follow-Up

It is recommended that data on capacity of dryers from projects (in drum volume or lbs. dry clothes) is collected by the program.

Supporting Documents

The cost effectiveness screening for these measures is number 291.1.1. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Commercial and Industrial\Process Equipment\Laundry\modulating dryers

291.1.1
CEC_2024_v1.2 dryer

Version History and Related Measures

Table 6 Version History

Date	Version	Reason for Revision
9/13/2023	291.1	Introduce two-stage valves for commercial dryers

Table 7 Related Measures

Measures	MAD ID
Ozone Laundry Systems	80
Commercial Clothes Washers	89

Approved & Reviewed by

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