



NW Natural[®]

Biennial Energy Efficiency Plan
2026-2027

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Executive Summary

In accordance with RCW 80.28.380 and Washington Utilities and Transportation Commission’s (“WUTC”) reporting requirements, Northwest Natural, dba NW Natural (“NW Natural” or the “Company”) presents this 2026-2027 Biennial Energy Efficiency Plan (“BEEP” or “Plan”).

Included within the Plan is an overview of The Company’s energy efficiency programs, and an outline of the planned activities, budgets, and savings goals for the upcoming program years.

During the 2026-27 Biennium, current program forecasts show NW Natural will exceed the conservation target established through the 2025 Conservation Potential Assessment (“CPA”). Two programs are creating a substantial difference between the CPA and NW Natural’s anticipated savings goals. One of them is the Behavioral Energy Efficiency (“BEE”) Pilot. There were very few savings attributed to the BEE program within the CPA, and moving forward the savings for the program will be incorporated into NW Natural’s baseline usage. The second program with significant variance from the CPA is the Commercial Incentive program. The program forecast is informed by custom projects that are in the pipeline as well as market insights related to Clean Buildings Performance Standards that are anticipated to drive more near-term program activity.

Table 1 - NW Natural 2026-27 EE Plan Summary

2026-2027 EE Plan Summary		Biennial Therms Goal	Biennial Cost
Incentive Programs	Commercial	404,729	\$ 3,645,140
	Residential	196,884	\$ 3,500,138
Low-Income	WA-LIEE	2,268	\$ 444,600
Market Transformation*	NEEA	81,840	\$ 443,317
Pilots & Trial Programs	Behavioral	232,353	\$ 591,320
	Industrial	35,000	\$ 1,270,000
Regional Planning	RTF	N/A	\$ 30,330
Conservation Potential Assessment	CPA	N/A	\$ 150,000
NW Natural Administration	NWN	N/A	\$ 350,000
Program Validation	Evaluation	N/A	\$ 135,000
Biennial Savings Goal (therms)			953,074
EE Plan Total		\$	10,559,845
CPA 2-year Target (therms)			571,436
CPA 10-year Target (therms)			8,415,587

*Market Transformation savings are estimates based on NEEA’s savings projection range. There is a high degree of uncertainty with savings projection.

Compared to the 2024-25 BEEP, budgets are increasing by 13.3% and savings goals have increased by 24.7%. The increase in savings over the previous biennium is largely due to the Commercial incentive program, increase in NEEA savings, and addition of Industrial EE.

Portfolio Benefit Cost Ratios

Table 2 - Anticipated Benefit Cost Ratios

Anticipated Program Performance	2026		2027		2026-27 (2-Year)	
	UCT	TRC	UCT	TRC	UCT	TRC
Total ETO (COM & RES)	1.6	1.3	1.6	1.3	1.6	1.3
Total ETO (COM & RES) & WA-LIEE & Pilots	1.5	1.3	1.5	1.3	1.5	1.3
Total ETO (COM & RES); NEEA; & WA-LIEE & Audits, Pilots, Assessments, Evaluations	1.9	1.3*	1.8	1.2*	1.9	1.3*

*NEEA activity is excluded from TRC BCRs due to the difficulty in measuring incremental costs and non-energy benefits for NEEA programs.

Table 3 - Levelized Costs

Program Year	Levelized Cost
2024 - Actual	\$ 1.06
2025 - Budgeted	\$ 1.06
2026 - Budgeted	\$ 1.01
2027 - Budgeted	\$ 1.03
2026-27 - Combined	\$ 1.02

Background

NW Natural began offering energy efficiency programs in its Washington State service territory in 2009. The direction to create and deliver energy efficiency programs came from WUTC's Order No. 04 in the Company's 2008 rate case, docketed as UG-080546.

Since the inception of NW Natural's energy efficiency programs, additional legislation has passed informing the way the programs operate today. In 2019, HB 1257 was passed and codified in RCW 80.28.380 which directs gas utilities to identify and acquire all cost-effective energy efficiency. This established a formal Conservation Potential Assessment ("CPA") requirement and the biennial reporting cycle.

History

The Company has been using Energy Trust of Oregon (“Energy Trust”) as the delivery arm for Washington since the start of the program. Energy Trust is an Oregon based entity that administers energy efficiency and renewable generation programs on behalf of Oregon’s investor-owned utilities. Since NW Natural’s Washington service territory is contiguous with its Oregon territory it made sense to extend the boundaries of Energy Trust to have consistency for the Company’s customer base.

Energy Trust implemented the Company’s incentive program for a pilot year before NW Natural made a compliance filing in 2011 within UG-080546 to allow Energy Trust to continue delivering the Company’s energy efficiency incentives programs.

Oversight

The Energy Efficiency Advisory Group (“EEAG”) is a group dedicated to reviewing the Company’s program plans, monitoring progress, and providing feedback and insights. The EEAG includes representatives from NW Natural, WUTC Staff, Public Counsel, Alliance of Western Energy Consumers (“AWEC”), The Energy Project, and NW Energy Coalition (“NVEC”).

The Company hosts quarterly calls to report on yearly progress toward savings goals and on program budgets as well as provide updates on ongoing efforts. Additional meetings are held on an ad hoc basis as needed to consult on specific topics that may be time sensitive or do not fit into a regular meeting.

Financial Audits

NW Natural has a long-standing history of program implementation with the Energy Trust of Oregon. For the first 10 years of the Washington program, the Company performed annual audits of Energy Trust expenditures. After a long-established history with no abnormal findings, it was determined that the cadence of the audits could be reduced to every other year. In June of 2026 NW Natural will perform an internal audit of the Washington Energy Trust programs for the previous two program years.

WUTC staff also conducts annual audits of all energy efficiency expenditures under NW Natural’s Schedule G. Audits were paused during COVID and resumed in 2024.

Program Delivery

NW Natural’s programs are predominantly delivered to customers through partnerships and contracts with third parties.

The Residential and Commercial incentive programs are administered through the Energy Trust of Oregon. NW Natural will be conducting a competitive bid process in 2026 for the Residential and Commercial programs, but Energy Trust will be the administrator for the entirety of the 2026-2027 biennium.

The Washington Low Income program (“WA-LIEE”) is delivered through local community action agencies. The agencies include Clark County Community Action Agency and Northwest Community Action Center.

NW Natural also funds collaborative regional efforts for energy efficiency program standards and market transformation. The Regional Technical Forum (“RTF”) is a technical advisory committee that works to develop measures and verification protocols for energy efficiency savings in the Northwest. The Northwest Energy Efficiency Alliance (“NEEA”) is a coalition of both investor and publicly owned utilities committed to transforming local markets to favor energy -efficient products and services.

Pilot offerings are delivered from time to time through third-party implementers that are selected through proposal solicitations. The Behavioral Energy Efficiency (“BEE”) Pilot is delivered by Bidgely. Bidgely specializes in energy analytics and is used by multiple utilities in the Northwest to deliver home energy report programs.

For the Industrial incentive program, the Company will explore a new delivery model where more of the administration is managed in-house. NW Natural will partner with local energy efficiency consulting firms to provide technical support, but project approvals and incentive issuance will come directly from the Company. This delivery design will be trialed in the 2026-2027 biennium.

Cost Effectiveness Standards

Cost effectiveness is measured by quantifying the benefits of an investment and comparing it to the costs associated with the project. 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”) and the Total Resource Cost Test (“TRC”). The portfolio of energy efficiency programs must have a TRC value greater than one.

Levelized costs are another metric used to assess the average cost of saving a unit of energy from the investment by looking at the present value of the total net cost relative to the total savings of a measure over its economic life. While there is no cap on levelized costs they are monitored to assess year-over-year changes and evaluate energy efficiency against other supply-side options.

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
- The larger of Washington State Carbon Policy Adder (Social Cost of Carbon as directed by HB 1257) or the cost of incremental GHG policy compliance resource
- Risk Reduction Values
- 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
- The larger of Washington State Carbon Policy Adder (Social Cost of Carbon as direction by House Bill 1257) or the cost of incremental GHG policy compliance resource
- Risk Reduction Values
- 10% Northwest Power Act Credit

Non-energy benefits as quantified by a reasonable and practical method. Examples of 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 divided by the total net savings 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 to produce the levelized cost estimate in dollars per therm saved.

Avoided Costs

Avoided costs are the estimated cost to serve an incremental unit of demand with conventional supply-side resources. This incremental cost represents the cost that is avoided if that unit of gas were not demanded. Avoided costs are calculated based on assumptions including the natural gas price and the risk reduction value associated with offsetting gas purchases on the spot market. Additional inputs include supply capacity costs based on peak-day coincident factors, distribution capacity costs based on peak-hour coincident factors, the social cost of carbon or CCA compliance resource cost, compliance risk reduction value, and the 10% conservation credit adder. Due to varying peak day and peak hour coincident factors, the avoided costs vary based on the end-use application.

The development of the avoided costs is done by the Company's Integrated Resource Planning ("IRP") team and reviewed by stakeholders through their Technical Working Groups ("TWGs"). 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.

Table 4 - NW Natural Avoided Costs

26 Year Levelized Avoided Costs

		Commodity Costs				Capacity Costs		10% Conservation Credit	Total Avoided Costs
		Natural Gas Commodity and Transport Costs	Greenhouse Gas Compliance Costs	Commodity Risk Reduction Value	Compliance Risk Reduction Value	Supply Capacity Costs Avoided	Distribution System Resources		
Washington	Residential Space Heating	\$4.00	\$10.30	\$1.18	\$0.56	\$0.54	\$8.55	\$2.51	\$27.65
	Commercial Space Heating	\$4.00				\$0.54	\$9.88	\$2.65	\$29.11
	Water Heating	\$3.62				\$0.10	\$1.71	\$1.75	\$19.22
	Cooking	\$3.57				\$0.11	\$2.55	\$1.83	\$20.10
	Process Load	\$3.57				\$0.08	\$1.06	\$1.67	\$18.43
	Interruptible Loads	\$3.57				X	X	\$1.56	\$17.17

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 outline in UG-230944 Order 1.

Biennial Energy Efficiency Plan

- On or before November 15th of every odd-numbered year, NW Natural must file their Biennial Energy Efficiency Plan with the Commission.
- 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 plans must also be defined within the plan.

Annual Energy Efficiency Report:

- On or before June 15th of each odd-numbered year, NW Natural must file with the Commission, in the same docket as its current BEEP, an annual conservation report regarding its progress toward achieving savings targets during the preceding year.

- The annual plan must include the biennial conservation target, actual savings achievement, budgeted and actual expenditures, and portfolio and program level cost-effectiveness.
- Descriptions are required for documenting key sources of variance between budgets and actuals as well as steps taken to adaptively manage the programs.

Biennial Energy Efficiency Report:

- 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 annual plan must include the biennial conservation target, actual savings achievement, budgeted and actual expenditures, and portfolio and program level cost-effectiveness.
- A third-party evaluation of the portfolio-level savings achievement and summary of steps taken to adaptively manage programs is also required.

Reporting Schedule

Table 5 - 2026-27 Reporting Schedule

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

Cost Recovery

NW Natural's Commercial and Residential EE expenses, including Energy Trust incentive programs, market transformation, evaluations, and pilots are funded by Schedule 215. The costs are forecasted on a twelve-month period basis beginning each November 1st. Funds are collected for the current program year and variance between the forecast and actual expenditures are trued up the following year through rates.

Schedule 230, which relates to low-income weatherization programming, is deferred and later amortized for recovery from applicable customers on an equal percent of margin basis as established annually in the temporary rate adjustments.

Industrial programming will be funded through a separate rate schedule. Previous work done on Industrial Pilot offering was funded through a deferral. The format for program funding moving forward will be established in coordination with the company's EEAG and WUTC staff.

Program Planning

This section includes program descriptions, planning considerations, and savings forecasts for the biennium along with a breakdown of planned activities and program budgets.

Current Landscape & Program Drivers

In the 2026-27 biennium, there are several key pieces of Washington legislation that will impact energy efficiency programs.

In 2019, the Clean Buildings Performance Standards were signed into law with the objective of lowering the energy use intensity of commercial buildings. Building owners must benchmark their building, implement an operations and maintenance ("O&M") program, create an energy management plan ("EMP"), and meeting an energy use intensity target. If the building does not meet the target they must apply for an exception or utilize the "investment criteria" pathway. 2026 will mark the first compliance reporting period for buildings over 220,000sqft. This program is anticipated to spur interest in the Company's commercial incentive programs. Energy Trust is also looking to develop tools and offerings to help customers comply with their reporting requirements.

The Climate Commitment Act ("CCA") is another driver for program development. NW Natural has the natural gas emission obligation of many large industrial facilities. Because of this obligation, the Company is planning to include transportation rate schedule customers within the new Industrial EE program.

Other market conditions that also impact programming include:

- High labor turnover and shortages
- Equipment price increases
- Long delivery timeframes

Program specific activities regarding increasing program awareness and lowering barriers for participants are included within this plan to help address some of the current market challenges.

Equity Planning & Considerations

In the 2026-27 biennium, NW Natural will look for ways to expand equity considerations throughout its energy efficiency portfolio. These are a few activities the Company is planning:

- Provide customers with information on low-income weatherization, bill discount, and bill assistance programs through community events.
- Host a workshop with stakeholders on incorporating equity into our CPA process.
- Track funds going to certified minority & and women owned business for both NW Natural and Energy Trust managed funds.
- Explore more funding options or renters and/or moderate-income households that don't qualify for free weatherization services.
- Work with Energy Trust to increase participation in underserved communities.

In 2024, NW Natural completed a detailed Energy Burden Assessment to quantify the affordability of natural gas service for income-eligible households. The study analyzed customer-level data across 27 months (January 2022–March 2024) and calculated energy burden metrics, payment behavior, and participation in assistance programs. It also identified pockets of need—including senior customers, underserved groups—including seniors, geographically and linguistically isolated households, and customers living in mobile home parks. These insights are directly informing outreach strategies, priority populations, and program enhancements.

In 2025, NW Natural increased its focus on attending community resource fairs to distribute information on utility assistance programs. In the 2026-2027 biennium the Company is setting a goal of attending 3 events annually in SW Washington. NW Natural plans to report on community events and attendance numbers in reports moving forward.

Table 6 - Equity Outreach Metrics

Category	2026	2027	Biennial Goal
Community Outreach Events	3	3	6
Attendance Targets	5,000	5,000	10,000

In addition to planned activities, the Company will also be participating and following docket A-230217 for ways to apply distributional equity in regulatory contexts.

Community Based Organizations (“CBOs”)

Energy Trust has been working to establish partnerships with CBOs as a pathway to delivering program incentives and resources to underserved or historically disadvantaged utility customers. Since 2020, the residential program team has made several concerted efforts to generate these relationships but have faced challenges due to misalignment between CBO work and Energy Trust incentive offerings as well as staff turnover.

In 2025, Energy Trust connected with Northwest Community Action Center (“NCAC”) and are anticipating the partnership to bring up to 10 projects a year for customers residing in high-priority communities in Klickitat and Skamania counties.

For 2026, the residential program team is planning on leveraging newly created incentives for income qualified and rental homes to lead discussions with CBOs. Several leads with Proud Ground and Share Vancouver have been identified as potential partners. In light of past challenges with consistent outreach, the residential program team is looking to establish an outreach schedule to ensure regular touch points with existing and emerging CBO partners.

Energy Trust Incentive Programs

The Commercial and Residential Incentive Programs are delivered by Energy Trust of Oregon (“Energy Trust” or “ETO”). Energy Trust is an independent non-profit that delivers energy efficiency on behalf of investor-owned utilities. They work with customers, community-based organizations, builders, and trade allies to provide knowledge and deliver energy solutions.

Table 7 - Energy Trust Total Budgeted Expenditures

2026-27 Efficiency Program	Budgeted Expenditures*	2026	2027	2026-27 Total
Commercial	Programs	\$1,402,170	\$1,456,199	\$2,858,369
	Energy Trust Staffing & Internal Costs	\$380,564	\$406,207	\$786,771
	Commercial Total	\$1,782,734	\$1,862,406	\$3,645,140
Residential	Programs	\$1,396,777	\$1,395,508	\$2,792,285
	Energy Trust Staffing & Internal Costs	\$344,373	\$363,480	\$707,853
	Residential total	\$1,741,150	\$1,758,988	\$3,500,138
	Total Expenditures	\$3,523,884	\$3,621,394	\$7,145,278

*Program Expenditures Include Incentives and Delivery

Table 8 - Energy Trust Incentive Budgets

Incentive Program	Incentives Budget	2026	2027	2026-27 Total
Commercial Programs	Existing Buildings - Standard	\$407,193	\$427,553	\$834,746
	Existing Buildings - Custom	\$128,316	\$133,277	\$261,593
	New Buildings - Standard	\$20,359	\$21,377	\$41,736
	Existing Buildings - Training	\$7,000.00	\$7,000.00	\$14,000
	Strategic Energy Management	\$193,459	\$195,316	\$388,775
	Commercial Total	\$756,327	\$784,523	\$1,540,850
Residential Programs	Existing Homes Retrofit	\$1,030,535	\$1,029,266	\$2,059,801
	Residential total	\$1,030,535	\$1,029,266	\$2,059,801
	Total Incentives	\$1,786,862	\$1,813,789	\$3,600,651

Table 9 - Energy Trust Savings Goals (therms)

Incentive Program	Annual Therms Goal	2026	2027	2026-27 Total
Commercial Programs	Existing Buildings - Standard	103,468	108,641	212,109
	Existing Buildings - Custom	23,518	24,694	48,212
	New Buildings - Standard	21,377	5,695	27,072
	Existing Buildings - Training	7,395	7,395	14,790
	Strategic Energy Management	46,864	55,682	102,546
	Commercial Total	202,622	202,107	404,729
Residential Programs	Existing Homes Retrofit	102,093	94,791	196,884
	Residential total	102,093	94,791	196,884
	Total savings	304,715	296,898	601,613

*Commercial Training added to EB-Standard

** Residential Multifamily added to Existing Home Retrofit

Commercial Incentive Program

Energy Trust provides incentives and technical support to NW Natural's business customers in Southwest Washington on qualifying rate schedules. Offers include incentives for energy-efficient equipment purchased through trade allies or vendors, incentives for operations and maintenance improvements, and no-cost technical studies to estimate energy savings and incentives for capital and retro-commissioning projects. The program also provides incentives for the Building Operator Certification course. Project types include upgrades and retrofits at existing commercial buildings, new construction, multifamily properties, and natural gas-heated production greenhouses.

Commercial Program Tracks

Commercial Custom Track

The Commercial Custom Track acquires gas savings through incentivizing energy efficient capital projects and operations and maintenance (“O&M”) upgrades in complex and non-standard situations. The Program Management Contractor’s account managers and engineering firms work together to identify and quantify saving opportunities at commercial facilities.

Commercial Standard Track

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

Commercial Strategic Energy Management (“SEM”)

The Commercial Program launched its 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 facility managers to save energy through operation management. SEM participants learn how their business uses energy and identify where waste is happening. Participants can share best practices with a cohort of peers, learn to increase employee engagement and monitor the progress of their energy savings work.

2026/27 Planned Program Activities

- Continue outreach to local chambers, Vancouver Business Journal, Hispanic/Latino-owned businesses, the Downtown Business Association and others to increase program awareness.
- Host quarterly targeted outreach campaigns to active and new Trade Allies in Southwest Washington to review program updates and educate allies on the project submission process.
- Promote Building Operator Certification program participation.
- Deliver targeted marketing campaigns to small business customers in rural areas that promote insulation and HVAC measures.
- Promote a simple step-by-step help guide for participants to navigate the custom project submission process.
- Increase Strategic Energy Management (“SEM”) program participation through the existing partnership with Clark Public Utilities.
- Expand lead generation and communications with NW Natural’s Major Account Managers.

- Meet with Clark Public Utilities' Commercial Account Managers quarterly to discuss customer trends, needs and leads for potential project acquisition and partnership.

Residential Incentive Program

Energy Trust helps single-family homeowners and small multifamily property owners served by NW Natural in SW Washington save energy through cash incentives for efficient space heating, smart thermostats, water heating, insulation, windows and education. Energy Trust also offers trade ally support and continues to explore opportunities to grow partnerships with Community Based Organizations ("CBOs") to deliver more benefits to customers that have historically been underserved.

In 2024, Energy Trust introduced Savings Within Reach ("SWR") to customers in SW Washington. SWR is a pathway for low-moderate income households, that do not qualify for NW Natural's low-income weatherization, to access increased incentives for energy upgrades.

Residential Program Tracks

Residential Standard Track (Existing Home Retrofit)

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

Residential Multifamily Track

Multifamily buildings are offered a specialized subset of the Residential Stand 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. Multifamily properties that are served with commercial rate schedule gas service are served through the Commercial Program.

Residential Mid-Stream Track (Supply Chain)

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. Technologies that are included in the mid-stream efforts include gas fireplaces and gas tank water heaters.

Residential Savings Within Reach ("SWR")

SWR is a program track that offers increased cash incentives to income-qualified homes. The increased incentives are delivered by Energy Trust of Oregon trade allies that are trained to deliver the program.

2026/27 Planned Program Activities

- Increase engagement with single-family and rural customers in SW Washington through expanded trade ally recruitment, targeted marketing initiatives and community events.
- Promote increased incentives for gas furnaces or other high-cost measures. Increased incentives will act as a tool for trade ally reengagement and recruitment.
- Expand marketing investments and develop marketing campaigns to both reengage past participants and acquire new customers, as well as to support the launch of increased incentives.
- Promote new window incentive resources.
- Expand engagement and recruitment of insulation installers into the trade ally network to increase insulation project and saving volumes.
- Explore collaborating with Clark County’s Planet Clark and Clark Public Utilities (“Clark PUD”) on trade ally education, recruitment and community events.

Low-Income Energy Efficiency

Program Overview

The WA-LIEE program will strive to weatherize 36 homes during program years (PY) 2026-2027. NW Natural’s primary weatherization partner in SW Washington, Clark County, continues to accelerate delivery despite uncertainty around federal funding. WA-LIEE will provide flexible support to ensure continuity and will step in to cover funding gaps for NW Natural gas customers when necessary. The estimated Biennial budget for PY 2026 and 2027 can be seen below.

Table 10 - WA-LIEE Biennial Program Goals

WA-LIEE	2026 Goal	2027 Goal	Biennial Goal
Number of Whole Homes Weatherized	9	9	18
Number of Furnace Only	9	9	18
Therms Savings - Whole Home	936	936	1872
Therms Savings - Furnace Only	198	198	396

Table 11 - WA-LIEE Biennial Budget

WA-LIEE		Budget
WA-LIEE	WA-LIEE Measures	\$252,000.0
	Health/Safety	\$18,000.0
	Flexible Funds	\$72,000.0
	WA-LIEE Agency Administration (25%)	\$85,500.0
	WA-LIEE Application Processing Admin (5%)	\$17,100.0
	WA-LIEE Total	\$444,600.0

NW Natural is currently working with Northwest Action Center (NCAC) to formalize a partnership agreement. In mid-2025, NCAC assumed responsibility for delivering low-income weatherization services in Skamania and Klickitat counties. This transition aims to improve service in a region historically underserved due to its rural setting and limited infrastructure.

While NCAC did not inherit a waitlist from the previous provider; outreach and referrals will be guided by insights from the 2024 Energy Burden Assessment.

Outreach Activities

Outreach efforts expanded significantly in 2025, with NW Natural participating in 16 community events. At each event, attendees assembled their own weatherization kits by selecting three items from the following list:

- Window insulation kits
- Door draft stoppers
- Socket sealers
- Caulk cord weatherseal
- Corner door seals
- Weatherstripping.

Two impactful events we'd like to highlight are the Race for Warmth held on January 26th, attracted approximately 1,775 participants benefiting Operation Warm Heart, a Clark PUD program benefiting low-income households. NW Natural used this opportunity to promote the Washington Bill Discount and weatherization services. Later in the year, June 7th, NW Natural participated in the Clark County Get Ready event at the Vancouver Firehouse, an emergency preparedness fair that welcomed over 1,200 attendees. The company's booth featured DIY

weatherization kits and information on energy efficiency and bill discount programs; as well as resource planning.

NW Natural will continue to expand outreach in Clark, Skamania, and Klickitat counties, cross promoting all income-based programs including weatherization and bill discount program. Event materials and program information are translated into English, Spanish, Vietnamese, Russian, and Simplified Chinese—the most commonly used languages in our territory to boost awareness and accessibility.

NW Natural and its partners will maintain active participation in LIHEAP Action Day in Washington D.C. during PY 26-27. This event provides an opportunity to engage with legislators and advocate for LIHEAP funding, which remains a critical resource for partner agencies, NW Natural recognizes that these funds are essential to delivering weatherization and bill assistance programs effectively in combination with utility funding.

Reporting

In 2025, the WALIEE program underwent its first comprehensive impact and process evaluation. Conducted by third-party evaluator ADM Associates, Inc, the evaluation assessed both the energy savings achieved and the effectiveness of program delivery strategies.

The impact evaluation utilized a combination of individual measure-level savings and whole-building billing analysis to estimate net energy savings. This included detailed analysis of monthly gas consumption data and comparisons with a matched control group to determine verified savings.

The process evaluation component included interviews with NW Natural staff, community action agencies, and contractors, as well as surveys with both program participants and non-participants.

As part of NW Natural's ongoing commitment to program accountability and improvement, impact evaluations for WALIEE will be conducted on a regular basis. The next evaluation cycle is expected to take place in 2027.

Industrial Energy Efficiency

NW Natural has been working over the past biennium on scoping out an industrial energy efficiency program for customers on sales and transportation rate schedules. Informed by the Industrial Audit Pilot that ended in 2024, NW Natural has proposed a custom incentive program to launch in early 2026.

Given the small pool of industrial customers within Washington and the variety of measures identified by the audits it was determined that a custom program would be more beneficial to

customers than a standard set of deemed savings measures. A deemed measure is easy entry for a customer; however, it is harder to track progress as the utility may not be aware of a project until it is completed and submitted. Given that this is a new program a custom approach felt more appropriate for budgeting and planning.

As the program develops, the Company may explore additional offerings. If there is strong interest from customers in standardized measures the company may look to establish deemed incentive offerings. Additionally, Strategic Energy Management is another program that was considered but is not currently within the current program proposal. Given the larger administrative lift, and extended customer engagement needed for SEM, the Company has decided not to pursue an Industrial SEM offering at this time.

Table 12 - Industrial Program Goals

Industrial Savings	2026	2027	Biennial Total
Budget	\$ 510,000	\$ 760,000	\$ 1,270,000
Savings Goal (therms)	10,000.00	25,000	35,000

Table 13 - Industrial Program Budget

Industrial Budget	2026	2027	Biennial Total
Incentive Budget	\$ 500,000	\$ 750,000	\$ 1,250,000
Marketing	\$ 10,000	\$ 10,000	\$ 20,000
Total	\$ 510,000	\$ 760,000	\$ 1,270,000

Market Transformation

NW Natural partners with NEEA to help accelerate the innovation and adoption of energy-efficient products in the region. Budgets for the 2026-2027 are based on NW Natural's share of NEEA's Cycle 7 funding. In 2026, budget has been reduced to account for an underspend in Cycle 6.

There is a large amount of uncertainty around market transformation savings. This is largely due to unpredictability with building codes and standards and in distributor and contractor practices. NW Natural uses the low end of NEEA's savings estimate range to account for some of the uncertainty.

Table 14 - NEEA Savings Goals & Budget

	2026	2027	Biennial Target
NEEA Funding	\$ 202,114	\$ 241,203	\$ 443,317
Savings Estimate (therms)	40,920	40,920	81,840

Strategy

NEEA's market transformation approach focuses on identifying energy efficiency opportunities along with the associated barriers, then developing and implementing market intervention strategies to accelerate adoptions and create lasting market change. Each technology falls not 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

Alongside the technology programs, NEEA also collects, analyzes, and disseminates data on behalf of the region. Primary activities include conducting evaluations of NEEA's influence and technology performance as well as regional stock assessments.

NEEA Gas Portfolio

During the 2026-27 Biennium, NEEA will be in their Cycle 7. This will be the third 5-year cycle for their gas portfolio. During this cycle the natural gas portfolio is anticipated to mature with multiple programs in the market development phase.

Initiatives in Concept Development:

- Efficient Commercial Laundry

Initiatives in Program Development:

- Advanced Commercial Gas Water Heating
- Efficient Rooftop Units
- Dual-Fuel Residential HVAC

Beyond the technology specific initiatives, NEEA will also be working on energy codes and equipment standards. NEEA works with state-level and national stakeholders to advance codes and standards for proven technologies that benefit the Northwest.

Regional Planning

The Company continues to support the work of the Northwest Power and Conservation Council's Region Technical Forum through their 2025-2029 Business Plan. The RTF works to establish standards to verify and evaluate energy efficiency savings. NW Natural incentive programs look to align with the RTF when possible.

Table 15 - RTF Biennial Budget

Regional Technical Forum	2026	2027	Biennial Total
Budget	\$14,904	\$ 15,426	\$ 30,330

Pilot & Trial Programs

NW Natural investigates and initiates opportunities to further strengthen the suite of offerings through pilot projects and temporary programs. These programs are offerings that 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 may provide feedback throughout the development process.

Behavioral Energy Efficiency (BEE)

NW Natural's BEE Pilot is a home energy report style program that provides residential customers with an energy use summary along with tips for reducing their usage. The program launched in Q4 of 2023 and will be entering its final year of the pilot run in 2026.

During 2026 NW Natural will be proposing the continuation of this program for another three-year period. Given that the program is cost-effective and a helpful tool for promoting other programs to customers it has become a valuable piece of the portfolio.

Table 16 - BEE Pilot Savings Goals & Budget

BEE Program	2026	2027*	Biennial Total
Platform Cost	\$ 100,000	\$ 100,000	\$ 200,000
Treatment Cost	\$ 96,328	\$ 115,000	\$ 211,328
Paper Report Cost	\$ 84,992	\$ 95,000	\$ 179,992
Program Budget	\$ 281,320	\$ 310,000	\$ 591,320
Program Savings Goal (therms)	112,353	120,000	232,353

*2027 numbers are estimates assuming participant refresh and mailing costs remain flat

Evaluations

NW Natural performs evaluations on the programs directly administered by the Company. The estimated expenditures for these evaluations are not inclusive of the evaluations conducted by Energy Trust for the residential and commercial incentive program.

Third-party verification is required for biennial reported savings and is captured as “Portfolio Verification”. Programs must be evaluated on a regular basis to verify savings claims. The cadence of program evaluations depends on the maturity of the program and the level of uncertainty associated with the savings.

In addition to verifying savings, evaluations may also include qualitative feedback on customer experience and program implementation. Since the Industrial Program is a new offering, budget for evaluation work is set aside in both 2026 and 2027 to support the development and refinement of the program.

Table 17 - Evaluation Budget

Evaluations	2026	2027	Biennial Total
Portfolio Verification	\$ 15,000.00	\$ -	\$ 15,000.00
Industrial Program Evaluation	\$ 20,000.00	\$ 50,000.00	\$ 70,000.00
Behavioral Program Evaluation		\$ 50,000.00	\$ 50,000.00
Low-Income Weatherization		\$ 50,000.00	
Total	\$ 35,000.00	\$ 100,000.00	\$ 135,000.00

Development Considerations

2025 Conservation Potential Assessment

In 2024, NW Natural conducted a competitive bid process to select the 2025 CPA Vendor. Lighthouse Energy Consulting was awarded the contract with Nauvoo and Anchor Blue as subcontractors on the work.

The project team developed the CPA using a combination of data provided by NW Natural, regional stock assessments, census data, and evaluations specific to NW Natural’s SW Washington service territory where available. The measures included in the assessment were developed from current program offerings from Energy Trust and the RTF.

Draft numbers were shared with the EEAG a month before filing the CPA on June 2nd. A presentation was given by Lighthouse at the May 13th EEAG meeting to walk the advisory group through the methodology and answer questions. A fully functional model was provided to

WUTC staff after the filing for their review and approval process. Additional conditions proposed by staff were adopted by the Commission and will be incorporated into the next CPA.

Table 18 - CPA Savings Summary (therms)

Sector	2-Year	5-Year	10-Year	25-Year
Residential	207,073	936,642	3,996,404	13,023,913
Commercial	295,390	864,656	2,134,553	4,828,715
Industrial	68,974	421,093	2,284,630	5,751,086
Total	571,436	2,222,391	8,415,587	23,603,714

CPA and Program Forecast Variance

Variances between the CPA and the program forecasted goals are driven by several different factors. The CPA did not reflect the same level of savings from Behavioral Energy Efficiency, and after this biennium NW Natural will assume the savings within the baseline and monitor its progress independently from the portfolio.

Within the incentive programs, saving differences are driven by the included measures and the rate of program growth in future years. For residential programs, the Furnace Tune-Up measure is available through the low-income weatherization program but is not offered broadly to all market rate customers through Energy Trust. Air and duct sealing measures are additional examples of upgrades that are available through the weatherization program but are not currently available for standard incentives.

The main difference between the commercial CPA and program forecast is the methodology used to estimate savings. Energy Trust programs use market intelligence, historical data, and custom project pipeline information to create savings estimates. The CPA used square footage estimates to estimate potential using NWPCC methodologies.

Public Engagement

NW Natural has developed this plan utilizing information provided by delivery partners. Draft budgets were shared with the EEAG on October 2nd, and the draft plan was shared on October 15th.

An overview of the plan and updates between the previous and current biennial plan were presented at the October 16th EEAG meeting. During the meeting, feedback was collected from WUTC staff on incorporating quantitative metrics in the equity section. To address this, NW Natural added attendance goals surrounding outreach activities. As this is an evolving space,

there are several tracking and planning activities included within the equity section that will help inform more quantitative goals in the future.

Comments on the plan were accepted via EEAG meeting participation and email. To ensure feedback could be incorporated into the plan prior to the filing NW Natural requested any questions or suggestions to be submitted by November 5th. No further feedback was received beyond what was heard during the EEAG meeting.

Appendices

Appendix A: List of Abbreviations

Appendix B: Unit-Energy Savings List

Appendix C: Measure Approval Documents

Appendix A: List of Abbreviations

Abbreviation	Definition
AEER	Annual Energy Efficiency Report
AEG	Applied Energy Group
AFUE	Annual Fuel Utilization Efficiency
AWEC	Alliance of Western Energy Consumers
BCR	Benefit Cost Ratio
BCR	Benefit Cost Ratio
BEE	Behavioral Energy Efficiency
BEEP	Biennial Energy Efficiency Plan
BEER	Biennial Energy Efficiency Report
BOC	Building Operator Certification
CAC	Conservation Advisory Council
CBO	Community Based Organization
CCA	Climate Commitment Act
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
EMP	Energy Management Plan
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
NCAC	Northwest Community Action Center
NEB	Non-Energy Benefit
NEEA	Northwest Energy Efficiency Alliance
NWEC	Northwest Energy Coalition
NWPCC	Northwest Power and Conservation Council
O&M	Operations and Maintenance
PUD	Public Utility District
RCW	Revised Code of Washington
RTF	Regional Technical Forum
SEM	Strategic Energy Management
SWR	Savings Within Reach
TRC	Total Resource Cost
TWG	Technical Working Group

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 B: Unit-Energy Saving List

Table 19 - Commercial UES List

MAD ID	Measure	Measure Application	Savings (therms/yr)	Max Incentive	Units
47	Door Retrofit on Refrigerated Cases	Door Retrofit - vertical med temp - Gas Heat	56.48	\$462.56	
47	Door Retrofit on Refrigerated Cases	Door Retrofit - horizontal low temp - Gas Heat	11.96	\$358.40	
47	Door Retrofit on Refrigerated Cases	Door Retrofit - horizontal med temp - Gas Heat	19.39	\$462.56	
88	Commercial and Multifamily Condensing Boilers	Condensing Boiler - Multifamily	1.28	\$7.33	kBtu/hr
88	Commercial and Multifamily Condensing Boilers	Condensing Boiler - Healthcare	4.11	\$7.33	kBtu/hr
88	Commercial and Multifamily Condensing Boilers	Condensing Boiler - Office	0.63	\$7.33	kBtu/hr
88	Commercial and Multifamily Condensing Boilers	Condensing Boiler - Restaurant	1.60	\$7.33	kBtu/hr
88	Commercial and Multifamily Condensing Boilers	Condensing Boiler - Retail	0.98	\$7.33	kBtu/hr
88	Commercial and Multifamily Condensing Boilers	Condensing Boiler - School	0.75	\$7.33	kBtu/hr
88	Commercial and Multifamily Condensing Boilers	Condensing Boiler - Hotel	1.60	\$7.33	kBtu/hr
88	Commercial and Multifamily Condensing Boilers	Condensing Boiler - Warehouse	0.74	\$7.33	kBtu/hr
137	Building Operator Certificate	BOC in Existing Buildings	1,478.56	\$2,495.00	per certificate
137	Building Operator Certificate	BOC in Multifamily	31.45	\$274.42	per certificate
235	Commercial Smart Thermostats	Smart Thermostat Grocery - Gas Heat w/ Cooling - HZ1	88.59	\$400.00	per thermostat
235	Commercial Smart Thermostats	Smart Thermostat Grocery - Gas Heat w/ Cooling - HZ2	98.58	\$400.00	per thermostat
235	Commercial Smart Thermostats	Smart Thermostat Grocery - Gas Heat NO Cooling - HZ1	88.59	\$400.00	per thermostat
235	Commercial Smart Thermostats	Smart Thermostat Grocery - Gas Heat NO Cooling - HZ2	98.58	\$400.00	per thermostat
235	Commercial Smart Thermostats	Smart Thermostat Non-Grocery - Gas Heat w/ Cooling - HZ1	30.98	\$400.00	per thermostat
235	Commercial Smart Thermostats	Smart Thermostat Non-Grocery - Gas Heat w/ Cooling - HZ2	44.52	\$400.00	per thermostat

235	Commercial Smart Thermostats	Smart Thermostat Non-Grocery - Gas Heat NO Cooling - HZ1	30.98	\$400.00	per thermostat
235	Commercial Smart Thermostats	Smart Thermostat Non-Grocery - Gas Heat NO Cooling - HZ2	44.52	\$400.00	per thermostat
110	Multifamily Insulation	HZ1 - Flat Roof Insulation - R0 to R15 - Gas Heating	1.33	\$11.06	per sq.ft
110	Multifamily Insulation	HZ2 - Flat Roof Insulation - R0 to R15 - Gas Heating	1.48	\$11.06	per sq.ft
110	Multifamily Insulation	HZ1 - Flat Roof Insulation - R0 to R30 - Gas Heating	1.38	\$14.00	per sq.ft
110	Multifamily Insulation	HZ2 - Flat Roof Insulation - R0 to R30 - Gas Heating	1.55	\$14.00	per sq.ft
110	Multifamily Insulation	HZ1 - Flat Roof Insulation - R5 or less to R30 - Gas Heating	0.38	\$14.00	per sq.ft
110	Multifamily Insulation	HZ2 - Flat Roof Insulation - R5 or less to R30 - Gas Heating	0.45	\$14.00	per sq.ft
110	Multifamily Insulation	HZ1 - Attic Insulation R11 or less - R49 Gas Heat	0.05	\$1.76	per sq.ft
110	Multifamily Insulation	HZ1 - Floor Insulation R11 or less - R30 Gas Heat	0.06	\$2.31	per sq.ft
110	Multifamily Insulation	HZ1 - Wall Insulation R6 or less - R11 Gas Heat	0.10	\$1.30	per sq.ft
110	Multifamily Insulation	HZ2 - Attic Insulation R11 or less - R49 Gas Heat	0.05	\$1.95	per sq.ft
110	Multifamily Insulation	HZ2 - Floor Insulation R11 or less - R30 Gas Heat	0.08	\$2.37	per sq.ft
110	Multifamily Insulation	HZ2 - Wall Insulation R6 or less - R11 Gas Heat	0.13	\$1.30	per sq.ft
171	Multifamily Windows	Single Pane Window to $0.22 < U \text{ value} \leq 0.30$ Window_HZ1_Gas heating	1.15	\$59.11	per sq.ft
171	Multifamily Windows	Single Pane Window to $0.22 < U \text{ value} \leq 0.30$ Window_HZ2_Gas heating	1.51	\$59.11	per sq.ft
171	Multifamily Windows	Single Pane Window to $U \text{ value} \leq 0.22$ Window_HZ1_Gas heating	1.27	\$62.82	per sq.ft
171	Multifamily Windows	Single Pane Window to $U \text{ value} \leq 0.22$ Window_HZ2_Gas heating	1.68	\$62.82	per sq.ft
171	Multifamily Windows	Storm Window for Single Pane Window (Wood Frame)_HZ1_Gas heating	0.92	\$13.79	per sq.ft
171	Multifamily Windows	Storm Window for Single Pane Window (Wood Frame)_HZ2_Gas heating	1.22	\$13.79	per sq.ft

171	Multifamily Windows	Storm Window for Single Pane Window (Metal Frame)_HZ1_Gas heating	1.18	\$13.79	per sq.ft
171	Multifamily Windows	Storm Window for Single Pane Window (Metal Frame)_HZ2_Gas heating	1.55	\$13.79	per sq.ft
171	Multifamily Windows	Double Pane Window to $0.22 < U \text{ value} \leq 0.30$ Window_HZ1_Gas heating	0.62	\$39.72	per sq.ft
171	Multifamily Windows	Double Pane Window to $0.22 < U \text{ value} \leq 0.30$ Window_HZ2_Gas heating	0.83	\$53.30	per sq.ft
171	Multifamily Windows	Double Pane Window to $U \text{ value} \leq 0.22$ Window_HZ1_Gas heating	0.75	\$47.83	per sq.ft
171	Multifamily Windows	Double Pane Window to $U \text{ value} \leq 0.22$ Window_HZ2_Gas heating	1.00	\$62.82	per sq.ft
171	Multifamily Windows	Storm Window for Double Pane Window (Metal Frame)_HZ1_Gas heating	0.60	\$13.79	per sq.ft
171	Multifamily Windows	Storm Window for Double Pane Window (Metal Frame)_HZ2_Gas heating	0.80	\$13.79	per sq.ft
New	Commercial Windows	Window Replacement Gas Hotel	0.04	\$2.36	per sq.ft
New	Commercial Windows	Window Replacement Gas Office	0.06	\$3.27	per sq.ft
New	Commercial Windows	Window Replacement Gas Restaurant	0.04	\$2.12	per sq.ft
New	Commercial Windows	Window Replacement Gas Retail	0.03	\$1.63	per sq.ft
New	Commercial Windows	Window Replacement Gas Retail - no cooling	0.03	\$1.47	per sq.ft
New	Commercial Windows	Window Replacement Gas School	0.06	\$3.45	per sq.ft
New	Commercial Windows	Window Replacement Gas School - no cooling	0.06	\$3.26	per sq.ft
New	Commercial Windows	Window Retrofit Gas Hotel	0.36	\$20.72	per sq.ft
New	Commercial Windows	Window Retrofit Gas Office	0.53	\$30.28	per sq.ft
New	Commercial Windows	Window Retrofit Gas Restaurant	0.34	\$19.15	per sq.ft
New	Commercial Windows	Window Retrofit Gas Retail	0.29	\$16.72	per sq.ft
New	Commercial Windows	Window Retrofit Gas Retail - no cooling	0.24	\$13.70	per sq.ft
New	Commercial Windows	Window Retrofit Gas School	0.32	\$18.10	per sq.ft
New	Commercial Windows	Window Retrofit Gas School - no cooling	0.29	\$16.49	per sq.ft

68	Commercial Insulation	H1 - Above Roof Deck Insulation - R0 to R30 - Gas heat Gas only	0.88	\$9.19	per sq.ft
68	Commercial Insulation	H2 - Above Roof Deck Insulation - R0 to R30 - Gas heat Gas only	1.01	\$9.19	per sq.ft
68	Commercial Insulation	H1 - Above Roof Deck Insulation - R5 or less to R30 - Gas heat Gas only	0.22	\$9.19	per sq.ft
68	Commercial Insulation	H2 - Above Roof Deck Insulation - R5 or less to R30 - Gas heat Gas only	0.27	\$9.19	per sq.ft
68	Commercial Insulation	H1 - Above Roof Deck Insulation - R0 to R15 - Gas heat Gas only	0.85	\$6.29	per sq.ft
68	Commercial Insulation	H2 - Above Roof Deck Insulation - R0 to R15 - Gas heat Gas only	0.96	\$6.29	per sq.ft
68	Commercial Insulation	H1 - Above Roof Deck Insulation - R5 or less to R15 - Gas heat Gas only	0.18	\$6.29	per sq.ft
68	Commercial Insulation	H2 - Above Roof Deck Insulation - R5 or less to R15 - Gas heat Gas only	0.22	\$6.29	per sq.ft
68	Commercial Insulation	H1 - Attic and Other Insulation - R0 to R38 - Gas heat Gas only	0.35	\$2.77	per sq.ft
68	Commercial Insulation	H2 - Attic and Other Insulation - R0 to R38 - Gas heat Gas only	0.35	\$2.77	per sq.ft
68	Commercial Insulation	H1 - Attic and Other Insulation - R5 or less to R38 - Gas heat Gas only	0.14	\$2.77	per sq.ft
68	Commercial Insulation	H2 - Attic and Other Insulation - R5 or less to R38 - Gas heat Gas only	0.14	\$2.77	per sq.ft
68	Commercial Insulation	H1 - Wall Insulation - R0 to R20 - Gas heat Gas only	0.37	\$1.98	per sq.ft
68	Commercial Insulation	H2 - Wall Insulation - R0 to R20 - Gas heat Gas only	0.42	\$1.98	per sq.ft
68	Commercial Insulation	H1 - Wall Insulation - R5 or less to R20 - Gas heat Gas only	0.11	\$1.98	per sq.ft
68	Commercial Insulation	H2 - Wall Insulation - R5 or less to R20 - Gas heat Gas only	0.14	\$1.98	per sq.ft
68	Commercial Insulation	H1 - Metal Building Roof Insulation - R0 to R30 - Gas heat Gas Only	1.02	\$3.50	per sq.ft
68	Commercial Insulation	H2 - Metal Building Roof Insulation - R0 to R30 - Gas heat Gas Only	1.16	\$3.50	per sq.ft

68	Commercial Insulation	H21 - Metal Building Roof Insulation - R5 or less to R30 - Gas heat Gas Only	0.20	\$3.75	per sq.ft
68	Commercial Insulation	H22 - Metal Building Roof Insulation - R5 or less to R30 - Gas heat Gas Only	0.26	\$3.75	per sq.ft
68	Commercial Insulation	H21 - Metal Building Roof Insulation - R0 to R20 - Gas heat Gas Only	1.01	\$3.50	per sq.ft
68	Commercial Insulation	H22 - Metal Building Roof Insulation - R0 to R20 - Gas heat Gas Only	1.15	\$3.50	per sq.ft
68	Commercial Insulation	H21 - Metal Building Roof Insulation - R5 or less to R20 - Gas heat Gas Only	0.19	\$3.75	per sq.ft
68	Commercial Insulation	H22 - Metal Building Roof Insulation - R5 or less to R20 - Gas heat Gas Only	0.24	\$3.75	per sq.ft
68	Commercial Insulation	H21 - Metal Building Wall Insulation - R0 to R20 - Gas heat Gas Only	0.20	\$1.68	per sq.ft
68	Commercial Insulation	H22 - Metal Building Wall Insulation - R0 to R20 - Gas heat Gas Only	0.25	\$1.68	per sq.ft
68	Commercial Insulation	H21 - Metal Building Wall Insulation - R5 or less to R20 - Gas heat Gas Only	0.06	\$1.68	per sq.ft
68	Commercial Insulation	H22 - Metal Building Wall Insulation - R5 or less to R20 - Gas heat Gas Only	0.08	\$1.68	per sq.ft

Table 20 - Residential UES List

Evaluation Code	Offer Type	MADId	ProductDescription	Therms/unit	MAX Incentive	Unit
OTHER	Market Rate	1	Furnace Tune Up	14	\$180.00	Per measure
GASFURNACE	CPF	22.7	CPF Gas Furnace 95%+, Gas-only	112.6	\$2,976.00	Per measure
GASFURNACE	Rental	22.7	Gas Furnace- WA Rentals	112.6	\$1,630.00	Per measure
GASFURNACE	SWR	22.7	Gas Furnace SW WA 95%+ AFUE - Savings Within Reach	112.6	\$1,630.00	Per measure
GASFURNACE	Market Rate	23	Gas Furnace SW WA 95%+ AFUE	112.6	\$1,630.00	Per measure
WINDOWS	Market Rate	28.6	ExistingCond Window Retrofit to	0.27	\$17.28	Sqft

			U-Value ≤0.30 Gas-WA			
WINDOWS	CPF	28.6	CoFunded - ExistingCond Window Retrofit to U-Value ≤0.30 Gas WA	0.27	\$17.28	Sqft
WINDOWS	NoCost	28.6	NoCost - ExistingCond Window Retrofit to U-Value ≤0.30 Gas WA	0.27	\$163.56	Sqft
GASFIRE	Market Rate	29	Gas Hearth 70-74 FE w/ ele ignition	15.36	\$150.00	Per measure
GASFIRE	Market Rate	29	Gas Hearth 75+ FE w/ ele ignition	23.22	\$250.00	Per measure
GASFIRE	Market Rate	29	New Home Gas Hearth 70+ FE w/ ele ignition	16.68	\$200.00	Per measure
CEILINGINSULATE	CPF	58	CPF Attic Insulation R0-R11, Gas Heat, Gas Only	0.11	\$7.30	Sqft
CEILINGINSULATE	CPF	58	CPF Attic Insulation R12-R18, Gas Heat, Gas Only	0.06	\$4.03	Sqft
CEILINGINSULATE	CPF	58	CPF Attic Insulation R0-R11, Gas Heat, Gas Only-XMH	0.04	\$2.81	Sqft
CEILINGINSULATE	CPF	58	CPF Attic Insulation R12-R18, Gas Heat, Gas Only-XMH	0.02	\$1.00	Sqft
CEILINGINSULATE	Market Rate	58	Attic Insulation/SQFT, Gas Only Heat R0- R11	0.11	\$2.74	Sqft
CEILINGINSULATE	Market Rate	58	Attic Insulation/SQFT, Gas Only Heat R12- R18	0.06	\$2.27	Sqft
CEILINGINSULATE	Market Rate	58	Attic Insulation/SQFT, Gas Only Heat R0- R11-XMH	0.04	\$2.31	Sqft
CEILINGINSULATE	Market Rate	58	Attic Insulation/SQFT, Gas Only Heat R12- R18-XMH	0.02	\$1.00	Sqft

CEILINGINSULATE	Rental	58	Rental Attic Insulation R0-R11, Gas Heat, Gas Only	0.11	\$7.30	Sqft
CEILINGINSULATE	Rental	58	Rental Attic Insulation R12-R18, Gas Heat, Gas Only	0.06	\$4.03	Sqft
CEILINGINSULATE	Rental	58	Rental Attic Insulation R0-R11, Gas Heat, Gas Only-XMH	0.04	\$2.81	Sqft
CEILINGINSULATE	Rental	58	Rental Attic Insulation R12-R18, Gas Heat, Gas Only-XMH	0.02	\$1.00	Sqft
CEILINGINSULATE	SWR	58	SWR Attic Insulation R0-R11, Gas Heat, Gas Only	0.11	\$7.30	Sqft
CEILINGINSULATE	SWR	58	SWR Attic Insulation R12-R18, Gas Heat, Gas Only	0.06	\$4.03	Sqft
CEILINGINSULATE	SWR	58	SWR Attic Insulation R0-R11, Gas Heat, Gas Only-XMH	0.04	\$2.81	Sqft
CEILINGINSULATE	SWR	58	SWR Attic Insulation R12-R18, Gas Heat, Gas Only-XMH	0.02	\$1.00	Sqft
FLOORINSULATE	CPF	58	CPF Floor Insulation, Gas Heat, Gas Only	0.09	\$5.93	Sqft
FLOORINSULATE	CPF	58	CPF Floor Insulation, Gas Heat, Gas Only- XMH	0.04	\$2.83	Sqft
FLOORINSULATE	Market Rate	58	Floor Insulation/SQFT, Gas Only Heat	0.09	\$2.89	Sqft
FLOORINSULATE	Market Rate	58	Floor Insulation/SQFT, Gas Only Heat - XMH	0.04	\$2.83	Sqft
FLOORINSULATE	Rental	58	Rental Floor Insulation, Gas Heat, Gas Only	0.09	\$5.93	Sqft
FLOORINSULATE	Rental	58	Rental Floor Insulation, Gas	0.04	\$2.83	Sqft

			Heat, Gas Only - XMH			
FLOORINSULATE	SWR	58	SWR Floor Insulation, Gas Heat, Gas Only	0.09	\$5.93	Sqft
FLOORINSULATE	SWR	58	SWR Floor Insulation, Gas Heat, Gas Only - XMH	0.04	\$2.83	Sqft
WALLINSULATE	CPF	58	CPF Wall Insulation, Gas Heat, Gas Only	0.08	\$5.35	Sqft
WALLINSULATE	Market Rate	58	Wall Insulation, Gas Heat, Gas Only	0.08	\$4.24	Sqft
WALLINSULATE	Rental	58	Rental Wall Insulation, Gas Heat, Gas Only	0.08	\$5.35	Sqft
WALLINSULATE	SWR	58	SWR Wall Insulation, Gas Heat, Gas Only	0.08	\$5.35	Sqft
MANUFACTUREDHOME	Market Rate	109.5	ENERGY STAR Gas Zone 1	105.91	4013.89	Per measure
MANUFACTUREDHOME	Market Rate	109.5	NEEM+ Gas Zone 1	123.77	6642.63	Per measure
MANUFACTUREDHOME	Market Rate	109.5	ENERGY STAR or NEEM+ Gas Zone 1	106.15	4049.42	Per measure
MANUFACTUREDHOME	PROMOTION	109.5	Neem+ Mfg Home Customer Incentive	0	1100	Per measure
MANUFACTUREDHOME	PROMOTION	110.5	Energy Star Mfg Home Customer Incentive	0	500	Per measure
THERMOSTAT	Market Rate	153.8	Smart Thermostat- SF & MH- Direct/ Contractor Install- gFAF	30.63	\$250.00	Per measure
THERMOSTAT	Market Rate	153.8	Smart Thermostat- Multifamily- Direct/Contractor Install- gFAF	14.12	\$239.12	Per measure
THERMOSTAT	Market Rate	153.8	Smart Thermostat- Retail/Online- gFAF	32.07	\$189.99	Per measure
THERMOSTAT	Market Rate	153.8	Smart Thermostat- New Homes- gFAF	21.74	\$250.00	Per measure
THERMOSTAT	CPF	153.8	Smart Thermostat- SF & MH- Direct/	30.63	\$518.81	Per measure

			Contractor Install- gFAF			
THERMOSTAT	CPF	153.8	Smart Thermostat- Multifamily- Direct/Contractor Install- gFAF	14.12	\$239.12	Per measure
THERMOSTAT	CPF	153.8	Smart Thermostat- Retail/Online- gFAF	32.07	\$543.14	Per measure
THERMOSTAT	CPF	153.8	Smart Thermostat- New Homes- gFAF	21.74	\$368.20	Per measure
TANKLESS	Market Rate	197	Gas Tankless Water Heater WA	60.69	\$1,025.17	Per measure
TANKLESS	Market Rate	197	Gas Tankless Water Heater WA - Gas Line Upgrade	60.69	\$1,282.52	Per measure
TANKLESS	CPF	197	Gas Tankless Water Heater WA	65.18	\$1,377.34	Per measure
TANKDHW	Market Rate	197	WA - Gas Storage WH - non-power non-cond 0.68 UEF	15.05	\$100.00	Per measure
TSTATOPT	Market Rate	217.5	Resideo Tstat Optimization - Annual - gFAF WA	15.01	\$29.50	Per measure
TSTATOPT	Market Rate	217.5	Resideo Tstat Optimization - Annual - gFAF + AC WA	15.01	\$29.50	Per measure
TSTATOPT	Market Rate	217.5	Resideo Tstat Optimization - Annual - gFAF WA w/ Control Group Cost	15.01	\$13.06	Per measure
TSTATOPT	Market Rate	217.5	Resideo Tstat Optimization - Annual - gFAF + AC WA w/ Control Group Cost	15.01	\$13.06	Per measure

Appendix C: Measure Approval Documents

Measure Approval Document for Bidgely Digital and Paper Gas and Electric Home Energy Reports

Valid Dates

July 1st, 2025, to December 31st, 2028

End Use or Description

Bidgely Home Energy Reports (HERs) delivered by email or direct mail to residential customers of Energy Trust utilities who have partnered with Bidgely. Digital report customers will receive two HERs per month--a monthly energy use summary and a comparison of energy use in similar homes--for a total of 24 communications per year. Paper report customers will receive printed HERs once per quarter for a total of 4 reports per year. Mixed delivery report customers will be delivered quarterly paper HERs and two monthly digital HERs--a monthly energy use summary and a comparison of energy use in similar homes--for a total of 28 reports per year. Home Energy Reports save energy by providing load disaggregation data, information about Energy Trust incentive offers, as well as behavior tips and recommendations for saving energy, which in turn encourage energy saving behavior and actions

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

For any Energy Trust utility providing HERs through Bidgely, all residential customers are eligible for this measure, including multifamily and manufactured homes, however most treated sites are expected to be single family homes and savings will be processed through the residential program. Customers selected to receive paper HERs are expected to meet certain criteria related to geography, income, or other factors that may limit their ability to receive digital HERs.

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

- Retrofit

Purpose of Re-Evaluating Measure

This measure is being re-evaluated due to program design needs to expand qualifications to Energy Trust utilities that partner with Bidgely to deliver HERs for electric or gas customers. To fit in with the design updates, measures for digital and paper reports delivered to gas customers have been added. Recently evaluated sources were also integrated into the analysis.

This is switching from a prescriptive measure to semi-prescriptive measure where savings will be claimed based on Bidgely's estimates, which may vary by month or by quarter.

Cost-Effectiveness

Cost-effectiveness is demonstrated for Oregon in Table 1. Co-funding scenarios are demonstrated for Oregon in Table 2. Cost-effectiveness was calculated using the tool: OR-WA-CE Calculator 2026-v1.0. The Oregon electric avoided cost year is 2026 and the Oregon gas avoided cost year is 2026. The incremental cost included in Table 1 is only for a placeholder. There is no incremental cost, and no incentive associated with this measure in cases where the sponsoring utility pays the full cost of report delivery using 838 marketing funds or other funds outside of incentive budgets. The co-funding measures represented in Table 1 are representative of the arrangement where incentive funds will pay for the delivery of the reports and the maximum remaining cost represents the highest potential incentive that can be allocated to the unit of the measure. The savings in these tables are examples used to demonstrate cost effectiveness and calculate maximum remaining cost and maximum incentives. Actual savings for this semi-prescriptive measure will be claimed based on Bidgely's regular reporting.

The values in the tables for digital reports are per treated residence per month, and the values for paper reports are per treated residence per quarter.

Table 1 Cost-Effectiveness Calculator Oregon, per residence, paid for wholly by utilities

#	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	Bidgely Electric Digital Home Energy Reports, per Month	1	3.81	0.00	0.01	\$0.00	\$0.01	57.7	57.7	100%	0%
2	Bidgely Electric Paper Home Energy Reports, per Quarter	1	13.80	0.00	0.01	\$0.00	\$0.01	208.9	208.9	100%	0%
3	Bidgely Gas Digital Home Energy Reports, per Month	1	0.00	0.37	0.01	\$0.00	\$0.01	69.3	69.3	0%	100%
4	Bidgely Gas Paper Home Energy Reports, per Quarter	1	0.00	1.10	0.01	\$0.00	\$0.01	207.9	207.9	0%	100%

Table 2 Cost-Effectiveness Calculator Oregon, per residence, paid for by Energy Trust in partnership with utilities

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Maximum Remaining Costs (\$)	Total NEB (Annual \$)	Maximum Incentive (\$)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
5	Co-funded Bidgely Electric Digital Home Energy Reports, per Month	1	3.81	0.00	0.58	\$0.00	\$0.58	1.0	1.0	100%	0%
6	Co-funded Bidgely Electric Paper Home Energy Reports, per Quarter	1	13.80	0.00	2.09	\$0.00	\$2.09	1.0	1.0	100%	0%
7	Co-funded Bidgely Gas Digital Home Energy Reports, per Month	1	0.00	0.37	0.69	\$0.00	\$0.69	1.0	1.0	0%	100%
8	Co-funded Bidgely Gas Paper Home Energy Reports, per Quarter	1	0.00	1.10	2.08	\$0.00	\$2.08	1.0	1.0	0%	100%

Requirements

- Homes must receive electric or gas services from a participating Energy Trust utility.
- Reports must be delivered through a partnership sponsoring Energy Trust utility and Bidgely.
- Reports must be delivered to residents in Oregon
- Homes that are in a comparison group for any Energy Trust utility cannot participate in a treatment group for any other Energy Trust utility.
- Homes must have at least 11 months of pre-treatment usage data available.
- “Prior AMI Opt-outs” are not eligible for this service.

- Average daily consumption (ADC) outliers are not eligible for the service.
- Homes must have a valid & active email address associated with their utility account to receive Digital HERs.
- In co-funded scenario, costs must not exceed the maximum remaining costs shown in Table 2.

Details

Digital HERs

Participating in homes receive an email report from Bidgely two times per month that contains disaggregated energy use information about their home, similar home comparisons, and behavior tips for saving energy. The digital report also directs customers to visit Bidgely’s web-based portal for further insights and recommendations. Bidgely will use the reports and portal to suggest and encourage participation in Energy Trust measures and promotional offers that participating customers may be eligible for based on their individual home characteristics. Links to Energy Trust’s incentive details pages for specific measures are embedded in the Home Energy Report emails, as well as within Bidgely’s online portal.

Paper HERs

Participating homes will receive a paper report via direct mail from Bidgely once per quarter that contains disaggregated energy use information about their home, as well as behavior tips for saving energy and comparison to similar homes. The reports will also be used to suggest and encourage participation in Energy Trust measures and promotional offers that participating customers may be eligible for based on their individual home characteristics.

Mixed Delivery HERs

Participating in homes will receive both paper and digital reports. All participating homes will receive a paper report via direct mail from Bidgely once per quarter, and participating homes with active emails available will also receive two email reports per month. The paper reports will contain disaggregated energy use information about their home, as well as behavior tips for saving energy. The digital report will contain similar disaggregated energy use information and behavioral tips for saving energy, as well as similar home energy use comparisons. Both paper and digital reports will be used to suggest and encourage participation in Energy Trust measures and promotional offers that participating customers may be eligible for based on their individual. In addition, digital reports will direct participating customers to Bidgely’s web-based portal for further insights and recommendations and contain links to Energy Trust’s incentive details pages for specific measures embedded in the report emails and web-based portal. Mixed delivery reports will be claimed as paper report measures for their respective fuel type since paper is the primary delivery mechanism for this report’s delivery method.

Comparison Group

A comparison group of homes selected at random from within the pool of homes eligible for HER enrollment will not receive HERs. The comparison group is used by Bidgely for evaluating and measuring the energy savings impact of HERs by controlling exogenous effects that may have contributed to increases/decreases in energy usage not driven by HERs. The comparison group is approximately 15% of eligible users, with the remaining eligible users being assigned to the treatment group. A comparison group is assigned for both digital and paper HERs. Due to the potential overlapping of HERs implemented with Bidgely by utilities with territories that overlap for gas and electric fuels, any customer that is selected as part of the comparison group for one utility will not be eligible to be chosen as treatment participant for any overlapping utilities reports.

Baseline

This measure uses an Existing Condition Baseline.

The baseline is a home that is not currently receiving paper or digital home energy reports from Bidgely for the utility offered fuel type, but which may have received other home energy reports and energy efficiency messaging within the previous 6-10 years or from a utility who supports an alternative fuel type.

Savings and Measure Analysis

While the measures in Table 1 and Table 2 are presented in a per treatment residence format to prove cost-effectiveness, it is recommended by DNV in the Home Energy Report Impact and Process Evaluation Final Report¹ that Energy Trust integrate performance-based savings estimates into the claims process wherever possible. This recommendation of claiming performance-based savings is a result of Bidgely’s savings claims evaluating at a 94% realization rate across treatment waves and is due to the disadvantage of crafting a deemed measure that accounts for the intricacies of different waves and years of delivery into a single or few offerings. Therefore, Bidgely HERs will not be a prescriptive measure; the savings reported by Bidgely will inform what is claimed by Energy Trust.

Electric energy savings in this analysis are from DNV’s Home Energy Report Impact and Process Evaluation Final Report which reviewed Bidgely’s electric HERs for Pacific Power in Oregon delivered between January 2021 and December 2023. DNV found an unadjusted realization rate of 99% for Bidgely’s reported savings across the 2 digital and 1 paper HERs treatment waves that have been active for 1 to 3 years. When DNV adjusted savings reported by Bidgely to remove joints savings from residential downstream programs, DNV found the resulting realization rate of 94%. DNV’s evaluation broke down savings into per treatment residence adjusted savings by treatment wave, year, and HERs report type, resulting in a weighted average adjusted annual savings per treatment residence of 45.72 kWh for digital HERs waves and 55.2 kWh for the single paper HERs wave.

To complete the cost-effectiveness testing in Table 1 and Table 2, the annual digital and paper HERs savings are divided into monthly units for digital and quarterly units for paper HERs to match the delivery cadence of the respective reports. The 3.81 kWh per monthly digital report and 13.8 kWh per quarterly paper report is a static per unit value, since these are weighted averages over multiple waves and years to account for the evaluations assertion that savings increases over a wave’s subsequent treatment years.

Gas energy savings in this analysis is from ADM’s EM&V Report: NW Natural Behavioral Energy Efficiency Program which reviewed Bidgely’s gas HERs for Northwest Natural in Southwest Washington delivered between January and December 2024. The gas reports delivered by Bidgely for Northwest Natural were a mixed wave of both digital and paper HERs and the evaluation did not break out the report types for the wave for review, so the resulting savings value is being used to inform both digital and paper reports since the report delivery type is averaged into the analysis. ADM found an unadjusted annual savings per treatment residence of 4.51 therms. When ADM adjusted savings reported by Bidgely to remove joint savings from residential downstream programs, ADM found the resulting annual savings per treatment residence of 4.4 therms.

To complete cost-effectiveness testing in Table 1 and Table 2, the annual HERs savings are divided into monthly units for digital and quarterly units for paper HERs to match the delivery cadence of the respective reports. The 0.37 therms per monthly digital report and 1.1 therms per quarterly paper report is assumed to be a static value. These static values are result of one wave and a single treatment year, while it is shown in DNV’s evaluation of Pacific Power’s HERs that savings increases over a wave with multiple years of reports

¹ [Home Energy Report Impact and Process Evaluation Final Report](#)

the percentage increase is not added to the therm savings since there are not reoccurring instances of the increase over time to establish a trend for gas.

Table 3 Digital and Paper HER Savings, per Treated Residence

Report Type	Report Cadence	Savings Per Report Cycle (kWh)	Annual Savings (kWh)	Savings Per Report Cycle (therms)	Annual Savings (therms)
Digital Home Energy Report	Monthly	3.81	45.72	-	-
Paper Home Energy Report	Quarterly	13.80	55.20	-	-
Digital Home Energy Report	Monthly	-	-	0.37	4.4
Paper Home Energy Report	Quarterly	-	-	1.1	4.4

Measure Life

A 1-year measure life is assumed for both digital and paper HERs in this analysis, which is consistent with the occurrence Bidgely reports and claims savings over. While the DNV evaluation of electric HERs for Pacific Power showed that savings increases in the later years of implementation of a wave, the savings represented in Table 1 and Table 2 weigh the increase into the result. The 1-year measure life is also consistent with prior Energy Trust Home Energy Report measures and Technical Reference Manual assumptions in other jurisdictions for behavior feedback measures.

Load Profile

The relative magnitude of heating versus cooling savings is relatively unknown for Bidgely HERs, however the last two years of monthly savings reported by Bidgely electric HERs in winter months are most often higher than the savings reported in summer months. Therefore, the electric load profile representing cooling savings in the range of 30%-74% of “Res Space Conditioning” was updated to Res Air Source HP since that profile assumes the most savings in the winter and some savings in the summer.

The average monthly savings for gas reports in the winter are approximately 3 times greater than average monthly savings in summer months as evaluated by ADM. Therefore, a gas load profile representing space heating savings was selected for the gas measure analysis- “Res Heating”.

Cost

Often a utility opts to contract directly with Bidgely to pay for some digital Home Energy Reports using SB838 marketing dollars or other funding outside of incentive budgets. Since the full cost of the measure in those cases is being covered by a complementary funder, the incremental cost is zero. A placeholder cost of \$0.01 is used in the cost effectiveness calculator to avoid dividing by zero errors.

Co-funding measure configurations are also presented in this analysis to allow for flexibility in deploying future waves of HERs under scenarios where Energy Trust pays a portion (or potentially all) of the cost of delivering either paper or digital HERs. Energy Trust has received guidance from the Oregon Public Utility Commission that Complementary Funding may be subtracted from the incremental cost of a measure, and the Remaining Cost used in cost effectiveness calculations. The *Maximum Remaining Cost* and *Maximum Incentive* columns in Table 2 above describe the maximum remaining cost and maximum Energy Trust incentives that are cost-effective for each measure configuration. The remaining cost is calculated according to the following formulas:

Total Cost = Complimentary Funding + Energy Trust Incentive

Remaining Cost = Total Cost - Complimentary Funding = Energy Trust Incentive

In both cases, the customer is not expected to be charged for the service.

Non-Energy Benefits

This analysis does not currently quantify any non-energy benefits (NEBs) for electric or gas HERs. The DNV evaluation of electric HERs did show an incremental amount of gas savings, but due to the inability of Bidgely to distinguish between treatment group homes with and without gas service, and the potential overlap of treatment homes receiving gas and electric HERs, the gas savings for electric HERs was excluded from the analysis. There is currently no source proving electric savings for HERs for gas.

Incentive Structure

The maximum incentives listed in Table 2 are for reference only and are not suggested incentives. Incentives will be structured per report per month or quarter per residence, when a portion of the report cost is paid for by Energy Trust.

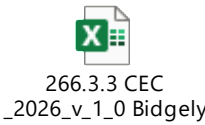
In cases where the funding utility pays for the full cost of report delivery there will be no incentive.

Follow-Up

- Updated evaluation results for digital, paper, and mixed delivery HERs should inform future updates to this measure.
- Updated evaluation results for electric and gas HERs should inform future updates to this measure.
- If it becomes possible to account for customers who receive electric or gas HERs and also have the alternative fuel source usage, while being able to isolate those customers who don’t have the alternative fuel source or receive both report types becomes possible, accounting for that alternative fuel source in the future should be considered.
- The impact of treatment customers who receive both electric and gas HERs should be considered if reliable information becomes available.

Supporting Documents

The cost effectiveness screening for these measures is number 266.3.3. It is attached and can be found along with supporting documentation at: \\Etoo.org\home\Groups\Planning\Measure Development\Residential\Whole Home\Home Energy Reviews\Bidgely HERs



References

- [Home Energy Report Impact and Process Evaluation Final Report | DNV submitted to Energy Trust of Oregon | December 5, 2024](#)
- EM&V report: NW Natural Behavioral Energy Efficiency Program | ADM Associates submitted to NW Natural | March 10, 2025

Version History and Related Measures

Table 4 Version History

Date	Version	Reason for revision
2/3/2021	266.1	Initial Digital HER MAD publication
1/24/2022	277.1	Initial Paper HER MAD publication
7/13/2022	266.2	Merge MADs 266 & 277. 277 will be retired. Updated savings. Add co-funded or Energy Trust paid measure applications
7/3/2025	266.3	Addition of measures for gas HERs, changing to semi-prescriptive savings, and expansion of potential utility report delivery to utilities that partner with Bidgely

Approved & Reviewed by

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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.
- Additional Washington New Home Requirements:

¹ RTF Residential Gas Fireplace [Presentation](#).

² Natural Resources Canada [gas fireplace energy efficiency ratings search](#).

- 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		
75+ FE	76%	684	70+ FE	72.1%

Measure Analysis and Savings

The RTF Savings calculations are based on the following formulas:

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

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

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.

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

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](#).

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.

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

⁶ Energy Trust [Technical Guidelines for Energy Efficiency Measures](#).

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 requirements

Table 9 Related Measures

Measures	MAD ID
New Homes EPS	181

Approved & Reviewed by
Kenji Spielman
Planning Engineer

Disclaimer

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Measure Approval Document for Manufactured Home Replacement

Valid Dates

January 1, 2025 – December 31, 2027, or 6 months after new code is implemented.

End Use or Description

Early retirement of existing pre-1995 vintage single-wide or double-wide manufactured homes, or homes destroyed by natural disasters such as wildfires and flooding, and replacement with new Northwest Energy Efficiency Manufactured Housing Program, NEEM, certified ENERGY STAR® or NEEM+ single-wide or double-wide 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:

- 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:

- Customer qualifications:
 - Income qualified
 - Natural disaster rebuilding
- Homes may be Owner financed and/or co-funded
- Incentives paid to retailers and/or customers

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

- Retrofit, early replacement

Purpose of Re-Evaluating Measure

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

We anticipate updating this early replacement measure and the new manufactured homes measure in 2026 when pending Federal Housing and Urban Development, HUD, building codes for manufactured homes and specifications for ENERGY STAR and NEEM are finalized and implemented.

Cost-Effectiveness

Cost-effectiveness is demonstrated for Oregon in Table 1. Co-funded measure shown in Table 2 demonstrates the maximum remaining cost that yields a cost-effective project. Cost-effectiveness was calculated using the tool: OR-WA-CE Calculator 2025-v2.1. The Oregon electric avoided cost year is 2025 and the Oregon gas avoided cost year is 2025. The values in these tables are per manufactured home.

Table 1 Cost-Effectiveness Calculator Oregon per manufactured 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	Manufactured Home Replacement ENERGY STAR 2.0 - SW - Any Zone - Electric	45	15,228.18	0.00	\$102,411.27	\$2,275.81	\$41,793.33	1.0	0.9	100%	0%
2	Manufactured Home Replacement ENERGY STAR 2.0 - DW - Any Zone - Electric	45	18,362.03	0.00	\$133,583.03	\$2,968.51	\$50,394.10	1.0	0.8	100%	0%
3	Manufactured Home Replacement NEEM+ - SW - Any Zone - Electric	45	15,639.49	0.00	\$134,493.79	\$2,988.75	\$42,922.17	1.0	0.8	100%	0%
4	Manufactured Home Replacement NEEM+ - DW - Any Zone - Electric	45	18,947.66	0.00	\$175,430.78	\$3,898.46	\$52,001.35	1.0	0.7	100%	0%
5	Manufactured Home Replacement ENERGY STAR 2.0 - SW - Any Zone - Gas	45	678.85	387.88	\$102,411.27	\$2,275.81	\$19,396.56	1.0	0.6	10%	90%
6	Manufactured Home Replacement ENERGY STAR 2.0 - DW - Any Zone - Gas	45	690.38	532.80	\$133,583.03	\$2,968.51	\$25,978.96	1.0	0.6	7%	93%
7	Manufactured Home Replacement NEEM+ - SW - Any Zone - Gas	45	696.89	407.60	\$134,493.79	\$2,988.75	\$20,337.40	1.0	0.6	9%	91%
8	Manufactured Home Replacement NEEM+ - DW - Any Zone - Gas	45	696.96	561.06	\$175,430.78	\$3,898.46	\$27,274.30	1.0	0.6	7%	93%
9	Manufactured Home Replacement ENERGY STAR 2.0 - SW - Any Zone - Gas Only	45	0.00	387.88	\$102,411.27	\$2,386.05	\$17,533.48	1.0	0.6	0%	100%
10	Manufactured Home Replacement ENERGY STAR 2.0 - DW - Any Zone - Gas Only	45	0.00	532.80	\$133,583.03	\$3,080.62	\$24,084.22	1.0	0.7	0%	100%
11	Manufactured Home Replacement NEEM+ - SW - Any Zone - Gas Only	45	0.00	407.60	\$134,493.79	\$3,101.92	\$18,424.82	1.0	0.6	0%	100%
12	Manufactured Home Replacement NEEM+ - DW - Any Zone - Gas Only	45	0.00	561.06	\$175,430.78	\$4,011.64	\$25,361.52	1.0	0.6	0%	100%

Exceptions

On 12/10/2024 the Oregon Public Utility Commission granted an exception to the TRC for manufactured home replacements. Order number 24-443 allows Energy Trust to offer this measure through December 31, 2027. The exception was granted under Categories A, C, G and H:

A. Measure produces significant non-quantifiable nonenergy benefits.

Energy Trust recognizes that while it can quantify certain non-energy benefits, significant advantages exist beyond energy savings. Replacing aging manufactured housing enhances comfort, health, safety, and durability for residents.

C. Measure is included for consistency with other DSM programs in the region.

Several regional DSM programs align with this initiative. OHCS operates a Manufactured Housing Replacement Program, supported by funding from HB 2896, which can potentially co-fund Energy Trust's program. Both Energy Trust and OHCS are committed to a coordinated customer service approach, aided by a Navigator model to streamline the process for clients navigating multiple programs. Additionally, the Bonneville Power Administration (BPA) offers a similar program for homes built before 1976. The Regional Technical Forum (RTF) Manufactured Home Replacement measure is available through May 31,2027. Northwest Energy Efficiency Alliance (NEEA) has historically supported energy-efficient manufactured homes and is collaborating with the Department of Energy and ENERGY STAR on relevant certifications.

G. The measure is required by law or is consistent with the Commission Policy.

The Commission's approval of DEI-specific performance metrics for Energy Trust through Order No. 21-068 emphasizes partnerships with organizations advocating for affordable housing and services for low-income customers. Collaboration with OHCS enhances the effectiveness of both programs. These exceptions also support Executive Order No. 20-04 (2021) by reducing greenhouse gas emissions and alleviating energy burdens for low-income customers, as well as House Bill 2475 (2021).

H. Inclusion of the measure mitigates energy burden

Staff thinks that the exception request also qualifies under category H resulting in the reduction of energy burden due to lower bills.

Co-funding

Energy Trust has received guidance from the Oregon Public Utility Commission that Complimentary Funding may be subtracted from the incremental cost of a measure, and the Remaining Cost used in cost effectiveness calculations. The Max Remaining Cost column in Table 2 describes the maximum remaining cost that is cost effective for each measure configuration.

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

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

The measures approved in Table 2 are for use for projects where qualifying complementary funding reduces the remaining cost to less than or equal to the max remaining costs. These projects are cost effective and are not bound by any limitations imposed by the exception.

Table 2 Cost-Effectiveness Calculator Oregon, with cost effective Co-Funding levels, per manufactured home

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Maximum Remaining Costs (\$)	Total NEB (Annual \$)	Maximum Incentive (\$)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
14	Manufactured Home Replacement ENERGY STAR 2.0 - SW - Any Zone - Electric - CoFunded	45	15,228.18	0.00	\$88,200.22	\$2,275.81	\$41,793.33	1.0	1.0	100%	0%
15	Manufactured Home Replacement ENERGY STAR 2.0 - DW - Any Zone - Electric - CoFunded	45	18,362.03	0.00	\$110,926.24	\$2,968.51	\$50,394.10	1.0	1.0	100%	0%
16	Manufactured Home Replacement NEEM+ - SW - Any Zone - Electric - CoFunded	45	15,639.49	0.00	\$103,867.02	\$2,988.75	\$42,922.17	1.0	1.0	100%	0%
17	Manufactured Home Replacement NEEM+ - DW - Any Zone - Electric - CoFunded	45	18,947.66	0.00	\$131,496.49	\$3,898.46	\$52,001.35	1.0	1.0	100%	0%
18	Manufactured Home Replacement ENERGY STAR 2.0 - SW - Any Zone - Gas - CoFunded	45	678.85	387.88	\$65,803.45	\$2,275.81	\$19,396.56	1.0	1.0	10%	90%
19	Manufactured Home Replacement ENERGY STAR 2.0 - DW - Any Zone - Gas - CoFunded	45	690.38	532.80	\$86,511.10	\$2,968.51	\$25,978.96	1.0	1.0	7%	93%
20	Manufactured Home Replacement NEEM+ - SW - Any Zone - Gas - CoFunded	45	696.89	407.60	\$81,282.25	\$2,988.75	\$20,337.40	1.0	1.0	9%	91%
21	Manufactured Home Replacement NEEM+ - DW - Any Zone - Gas - CoFunded	45	696.96	561.06	\$106,769.43	\$3,898.46	\$27,274.30	1.0	1.0	7%	93%
22	Manufactured Home Replacement ENERGY STAR 2.0 - SW - Any Zone - Gas Only - CoFunded	45	0.00	387.88	\$66,188.31	\$2,386.05	\$17,533.48	1.0	1.0	0%	100%
23	Manufactured Home Replacement ENERGY STAR 2.0 - DW - Any Zone - Gas Only - CoFunded	45	0.00	532.80	\$86,902.49	\$3,080.62	\$24,084.22	1.0	1.0	0%	100%
24	Manufactured Home Replacement NEEM+ - SW - Any Zone - Gas Only - CoFunded	45	0.00	407.60	\$81,677.33	\$3,101.92	\$18,424.82	1.0	1.0	0%	100%
25	Manufactured Home Replacement NEEM+ - DW - Any Zone - Gas Only - CoFunded	45	0.00	561.06	\$107,164.55	\$4,011.64	\$25,361.52	1.0	1.0	0%	100%

Requirements

- Must be replacing existing manufactured homes built prior to 1995.
 - 1. Units replacing manufactured homes that have been destroyed or damaged by natural disaster may qualify regardless of original year or construction.
- New manufactured homes must be certified ENERGY STAR or NEEM+.
- New manufactured homes must be a single or double wide manufactured home, triple-wide home configurations are excluded.
- Prefabricated, modular homes built in compliance with Oregon Residential Specialty Code are eligible for this measure where such dwellings are allowed in manufactured home parks as detailed by HB 3219¹.
 - 1. Modular homes must use a central heat pump or ductless heat pump as the primary heating source to qualify.
- Electrically heated homes must be served by Portland General Electric or Pacific Power.

¹ <https://olis.oregonlegislature.gov/liz/2021R1/Measures/Overview/HB3219>

- Gas-heated homes must be served by Northwest Natural, Cascade Natural Gas or Avista.
- Oregon only.
- If using the measure applications shown in Table 2, the program will document known co-funding and provide to Planning for use in calculating program-level BCRs.

Details

The new (replacement) manufactured homes included in the program will meet ENERGY STAR 2.0 or NEEM+ specifications. Homes must be certified by Northwest Energy Works to qualify. The assumed building components to achieve each specification are listed in Table 3.

Table 3 Measure Specifications and SEEM Inputs

Component	Market Practice, HUD Home	ENERGY STAR 2.0	NEEM+
Heating System (Electric)	Electric Resistance Furnace or 7.7 HSPF Heat Pump	Electric Resistance Furnace or 7.7 HSPF Heat Pump	Electric Resistance Furnace or 7.7 HSPF Heat Pump
Heating System (Gas)	78% AFUE Gas FAF	78% AFUE Gas FAF	NA
Floors	R-25 Nominal	R-33	R-33
		(longitudinal framing)	(transverse framing)
Walls	R-13 Nominal (Modified to get a target U of 0.0647)	R-21	R-21 batt; R-1 foam sheathing; 2.5-stud corners; R-5 insulated headers
Ceilings	Avg. R-33 Nominal	Flat: R-49 Nominal	Vaulted: R-49 nominal blown cellulose; truss w/6 1/8" heel & 17" King post
		Vaulted: R-40 Nominal	
Glazing	Avg. U = 0.40	U = 0.35	U = 0.28, SHGC ≥ 0.27
		(SHGC assumed at 0.32)	
Envelope Tightness	4.8 ACH ₅₀	5.0 ACH ₅₀	4.0 ACH ₅₀
Ventilation	32 Watt fan	32 Watt fan	17 Watt fan
Duct Leakage	13%	5% supply leakage fraction	5% supply leakage fraction
Lighting	33 watt lamps	33 watt lamps	100% of fixtures with LEDs (5.6 watt lamps)
Appliances	Standard Dishwasher and Refrigerator	ENERGY STAR Dishwasher and Refrigerator	ENERGY STAR Dishwasher and Refrigerator

Baseline

This measure uses an Early Replacement Baseline which is a hybrid of an existing condition and a market baseline.

- Remaining Useful Life - The existing condition baseline is a manufactured home built before 1995
- Balance of Measure Life - The market baseline is a new manufactured home built to HUD minimum standards

The remaining useful life (RUL), also referred to as Period 1, is the length of time the existing condition would still be effective and in use in the absence of the program. An existing condition baseline is assumed for the RUL. The existing condition is assumed to be a manufactured home built before 1995. The balance of measure life (BML), also referred to as Period 2, is the efficient measure’s life minus the RUL. The market baseline is assumed to be a new non-NEEM home built to current HUD standards.

Length of remaining useful life

Industry stakeholders surveyed in 2021 believe manufactured homes occupied by low-moderate income residents stay in service indefinitely and are not decommissioned at the end of the assumed 45-year measure life. Specifically, when asked how long pre-1995 homes would remain occupied without Energy Trust intervention, five out of eight respondents answered “45 or more” additional years, one respondent indicated an additional 15-24 year, and two respondents didn’t know, see Table 4. Energy Trust technical guidelines align with the Regional Technical Forum, RTF, methodology of calculating Remaining Useful Life, RUL, as one-third of measure life and Balance of Measure Life, BML, as remaining measure life. The guidelines would indicate a 15-year RUL and 30 year BML. However, given the long lifetime of this measure and feedback from stakeholders, this analysis uses a RUL of 40 years and a corresponding BML of 5 years. The program believes that without intervention, manufactured homes would not be replaced.

Table 4 Stakeholder survey response to additional life without program intervention

Considering the population of low to moderate income households residing in manufactured homes constructed prior to 1995, what do you believe is the average number of years an older home would continue to remain occupied without Energy Trust's program?		
Response	Response Count	Percent
I don't know	2	25%
15 to 24 years	1	13%
45 years or more	5	63%

Measure Analysis – Electric heated manufactured homes

The existing condition RBSA consumption and RTF market, and improved consumption are consolidated based on distribution and weights from RBSA and program participation. For each efficiency level consumption data were consolidated to generate single consumption amounts for each home size, efficiency level, and heating fuel type.

Data sources for analysis:

- RTF
 - Energy consumption modeling for federal minimum HUD and efficient measures cases
- Program participation data
 - Climate zone weighting
 - Energy Trust CRP impact evaluation results energy consumption adjustments and evaluation adjustment values
- RBSA
 - Existing condition annual consumption
 - Heating zone multiplier used to determine energy consumption in Zone 2, existing condition home
 - Home configuration distribution (single versus doubles wide)
 - Average home sizes
 - Vintage distribution for existing condition energy consumption weighting

Existing condition energy consumption calculation methodology – electric heated homes

- Electric heated manufactured home sites in the RBSA data were categorized per home configuration, climate zone, and vintage
 - Twenty-eight discrete categories were defined, but only eighteen categories had homes that met the combined requirements
 - Two home configurations of single versus double wide, seven heating/cooling zone combinations, and two vintage categories pre-1976 or 1976-1994
- For each category, the number of homes, square footage, and annual consumption for all homes in each category were summed to provide total number of homes, 'collective square footage' and 'collective consumption' per category
- Average per home annual consumption for each category was calculated by dividing collective consumption by total number of home homes in each category (total kWh / total number homes = kWh per home)
 - Heating zone 2 sites were limited, with only 13 sites in 6 categories, there were no heating zone 3 sites
- A heating zone multiplier was determined by combining the average Energy Usage Intensity, EUI, of HZ 2 homes to the HZ 1 homes
 - EUI were calculated dividing the cumulative annual electric consumption and cumulative square footage for HZ 1 and HZ 2 for each of the two vintage bins.
 - The heating zone multipliers were calculated by dividing HZ2 EUI by HZ 1 EUI for each vintage
- These heating zone multipliers were applied to HZ 1 average annual consumption value to serve as a Combined HZ 2 and HZ 3 consumption values
- Annual consumption for the resulting configurations were weighted by RBSA vintage and program climate zone distribution to produce two final existing condition configurations:
 - Single Wide Pre-1995, any HZ
 - Double Wide Pre-1995, any HZ
- An EUI for each configuration was determined by dividing the weighted average annual consumption by the RBSA regional median home sizes for single and double wide homes
 - Median home size per single and double wide configuration were calculated based on RBSA square footage and home configuration details for all Oregon and Washington manufactured homes
- These EUI were then calibrated to evaluation results to determine an Adjusted EUI
- Final existing conditions annual consumption was determined by multiplying the Adjusted EUI by the RBSA regional square footages for single and double wide homes
- Savings for Remaining Useful Life were calculated by subtracting the improved case annual consumption from these existing condition consumption values

New home baseline and measure case consumption calculation methodology – electric heated homes

- RTF annual consumption for Federal HUD, ENERGY STAR, and NEEM+ homes was available for each of 9 climate zone combinations for single and double wide homes heated with electric forced air furnaces and heat pumps
- For each climate zone, annual consumption was weighted by RTF assumption of heating equipment types per efficiency level to provide a single 'any electric HVAC' electric heating consumption value for each climate zone
 - For market baseline HUD homes, annual consumption values were blended assuming 90% electric furnaces and 10% heat pumps
 - For ENERGY STAR and NEEM+ homes, annual consumption values were blended assuming 60% electric furnaces and 40% heat pumps
- Individual climate zones were weighted based on program participation data to yield a single and double wide annual consumption value for each of the efficiency levels
- An EUI for each configuration was determined by dividing the annual consumption values by the RTF modeled square footages for single and double wide homes
- This EUI was then calibrated to evaluation results to determine an Adjusted EUI
- Final market baseline and measure case annual consumption was determined by multiplying the Adjusted EUI by the RBSA regional square footages for single and double wide homes
- Savings for Remaining Useful Life were calculated by subtracting the measure case annual consumptions from the existing condition annual consumption.
- Savings for the Balance of Measure Life were calculated by subtracting the measure case annual consumption from the market baseline HUD annual consumption.

Remaining Useful Life – Energy consumption sources and adjustments

The whole existing condition energy use was determined using a combination of Energy Trust CRP impact evaluation results, NEEA Residential Building Stock Assessment (RBSA) utility bill analysis data, and RTF New Manufactured Homes & HVAC measure analysis. For this analysis RBSA data was limited to Oregon and Washington, single and double wide homes, heated by electricity or natural gas; other configurations were removed from the working data.

Annual electric consumption in electric heated, existing manufactured homes from RBSA II billing data were normalized to the RBSA median size of 845 sq. ft. for a single wide home, then adjusted to align with CRP evaluation results which found 145 percent higher pre-replacement electric usage when compared to RBSA billing data. This 145 percent adjustment factor was applied to RBSA II consumption data to determine existing condition consumption.

RTF analysis provides modeled consumption for each home configuration, climate zone, and for electric furnaces and heat pumps. The RTF analysis assumes that for electric heated HUD homes 10% are heated by a heat pump and 90% are heated by a forced air furnace. For the improved electric heated ENERGY STAR and NEEM+ homes, the percentage of heat pump homes increases to 40% with electric furnaces is reduced to 60%. Energy consumption for the electric furnace and heat pump home were blended using these rates for the market HUD homes, ENERGY STAR and NEEM+ homes. The electric home consumption was then further weighted across climate zone as noted above in .

Balance of Measure Life – Energy consumption sources and adjustments

Annual electric consumption for market baseline and measure case homes are based on RTF analysis of new construction HUD, ENERGY STAR, and NEEM+ homes as described in their New Manufactured Homes and HVAC measure² and supporting analysis in the MHNNewConstructionSEEMWorkbookV10³ workbook. The RTF values are adjusted to align with Energy Trust CRP evaluation results in the same manner as the RBSA consumption data. The adjustment factor for the improved measure cases was calculated by comparing RTF HUD consumption for electric heated, single wide homes, in Heating Zone 1 to the newly installed, post-replacement consumption from the CRP evaluation results. When comparing the post-replacement consumption to RTF modeled consumption, evaluation results were 164 percent higher than modeled consumption. This 164 percent adjustment factor is applied to RTF consumption to determine market baseline, ENERGY STAR, and NEEM+ consumption.

² Regional Technical Forum, New Manufactured Homes and HVAC UES: <https://rtf.nwcouncil.org/measure/new-manufactured-homes/>

³ Regional Technical Forum, New MH SEEM Workbook v10, 05/19/2020: <https://nwcouncil.box.com/v/20200519NewMHSEEM>

RBSA billing data was not evenly distributed across all climate combinations, therefore a heating zone multiplier was determined by comparing consumption in Heating Zone 1 homes to the consumption in all other heating zones, based on the average Energy Usage Intensity, EUI, in kWh per conditioned area, per heating zone. This multiplier was then applied to RBSA consumption in heating zone 1 to represent consumption in heating zones 2 and 3, as shown in Table 5. These values were further weighted to single ‘Any Zone’ consumption value based on program climate distribution. RBSA consumption was further consolidated across home vintage, 34% Pre-1976 and 66% 1976-1994, based on number of sites in the RBSA dataset.

Table 5 Heating zone multiplier

RBSA Annual Electric Consumption - Manufactured Homes OR & WA				
Manufactured Home Vintage	Quantity	Avg Sq. Ft.	Annual Electric Consumption	Avg Annual EUI
Heating Zone 1				
Pre-1976, pre-HUD	35	1,039	14,428	13.9
1976-1994, HUD	65	1,346	13,461	10.0
Heating Zones 2 & 3				Heating Zone Multiplier
Pre-1976, pre-HUD	4	1,271	24,799	19.5
1976-1994, HUD	9	1,343	18,766	14.0
				141%
				140%

Final adjusted consumption – electric heated homes

After heating system, climate, and vintage weightings were applied, annual electric consumption was normalized to RBSA median square footage of 845 sq. ft. for single-wide and 1,424 sq. ft. for double-wide homes. Climate zone specific consumption results were blended for an ‘any zone’ measure to provide a single incentive value to minimize market confusion and ensure customer incentives are consistent across the state.

Consumption results were calibrated to evaluation results as noted above and summarized below in Table 6. Evaluation adjustments are applied to both electric and gas heated homes.

Table 6 Electric manufactured home EUI and consumption pre- and post-evaluation adjustments

Efficiency level and size configuration	Any HZCZ – Consumption pre-calibration		Calibrating annual consumption to Energy Trust CRP evaluation results		
	Normalized Electric EUI	Annual Normalized Consumption kWh	Evaluation Adjustment	Electric EUI Adj	Annual Electric Consumption Adj kWh
Existing Condition - Single Wide (Pre-1995)	17.6	14,876	145%	25.6	21,603
Existing Condition - Double Wide (Pre-1995)	13.2	18,831	145%	19.2	27,346
Market Baseline-Single Wide	6.3	5,327	164%	10.3	8,735
Market Baseline-Double Wide	5.3	7,554	164%	8.7	12,387
ENERGY STAR 2.0-Single Wide	3.6	3,015	164%	5.9	4,945
ENERGY STAR 2.0-Double Wide	3.1	4,465	164%	5.1	7,322
NEEM+ Single Wide	3.3	2,765	164%	5.4	4,533
NEEM+ Double Wide	2.9	4,108	164%	4.7	6,736

Measure Analysis – Gas heated manufactured homes

RBSA data for gas manufactured homes is quite rare, making estimates of normalized gas loads difficult to determine. Therefore, billing analysis of past Energy Trust participants was used for existing condition analysis. For market and improved cases, RTF analysis includes consumptions models for HUD, ENERGY STAR, NEEM+ homes with gas furnaces.

Existing condition energy consumption calculation methodology – gas heated homes

- Energy Usage Intensities were available for 201 single wide, gas heated, manufactured homes that participated in Energy Trust free home and air sealing.
 - EUI results were broken into two vintage bins and climate zones based on participant home details
 - Of these homes, 91 percent were in heating zone 1
 - Heating zone 2 values from program data were not used, instead a heating zone multiplier was calculated
- A heating zone multiplier was determined by comparing the annual consumption of RTF gas manufactured homes in heating zones 1 and a combined heating zone 2 & 3
 - Annual gas consumption for single wide, gas heated, federal HUD homes from RTF were used
 - Consumption from heating zones 2 and 3 were weighted together based on climate zone distribution from program data
 - Combined HZ 2&3 consumption was divided by HZ 1 consumption to determine a heating zone multiplier
- The heating zone multiplier was applied to the HZ1 EUI of each vintage bin to estimate the EUI for HZ 2 & 3
- The climate specific values were then weighted by participant climate zone distribution to create a single ‘any climate’ EUI for each vintage bin
- As the program source EUI data did not contain double wide homes, a double wide scaler was calculated based on RTF consumption
 - Annual consumption from RTF federal HUD gas heated homes was converted to EUI by dividing the annual consumption by the RTF square footage for single and double wide homes
 - For each climate zone, a Double Wide scaler was calculated by dividing the single wide EUI by the double wide EUI, these were weighted into a single double wide scaler for any heating zone
 - For each vintage bin, the single wide EUI were multiplied by the double wide scaler
- Vintage specific EUI were then weighted based on RBSA vintage distribution to create two existing condition scenarios
 - Single Wide Pre-1995, any HZ
 - Double Wide Pre-1995, any HZ
- These EUI were then calibrated to evaluation results to determine an Adjusted EUI
- Final existing conditions annual consumption was determined by multiplying the Adjusted EUI by the RBSA regional square footages for single and double wide homes
- Savings for Remaining Useful Life are calculated by subtracting the improved case annual consumption from these existing condition consumption values

New home baseline and measure case consumption calculation methodology – gas heated homes

- RTF annual consumption for Federal HUD, ENERGY STAR, and NEEM+ homes was available for each of 9 climate zone combinations for single and double wide homes heated with gas furnaces
- The methodology for these cases is the same as for electric heated homes with the following variations:
 - There is only one gas heating equipment type, so no equipment weighting is applied to gas homes
 - The same evaluation adjustment is made to gas homes as is made to electric homes; the evaluation adjustment is applied before furnace fan calculations are made
 - The RTF analysis does not break out electric consumption related to the gas furnace fan; however, furnace capacity and fan power are provided within the RTF analysis.
 - Furnace fan energy is calculated according to Equation 1 where:

Equation 1 Gas furnace fan energy calculation

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

- *Therm usage* = annual therm consumption (after evaluation adjustments applied) from RTF or per existing condition calculations
- *Input Btu/h* = furnace capacity
 - For market and measure cases, capacity is specified in RTF per home size and efficiency level
 - For existing condition furnace capacity, RTF federal HUD capacity is scaled by increased fan efficiency as a proxy for larger furnace estimates in existing homes with higher heating loads
 - Existing Condition Capacity = RTF Capacity * (84.4 HUD AFUE / 78.4 existing AFUE)
- *Fan input* = RTF fan kW per home size and efficiency level
 - Fan kW is assumed to be the same 0.40 kW in the new and existing conditions
- Annual gas therm and electric kWh consumption are converted to EUI by dividing the consumption values by RTF modeled square footages for single and double wide homes
- Final market baseline and measure case annual consumption was determined by multiplying the Adjusted EUI by the RBSA regional square footages for single and double wide homes
- Savings for Remaining Useful Life are calculated by subtracting the measure case annual consumptions from the existing condition annual consumption.
- Savings for the Balance of Measure Life are calculated by subtracting the measure case annual consumption from the market baseline HUD annual consumption.

Existing condition – gas heated homes

Existing Condition baseline energy use for gas heated homes was calculated based on billing data from past participants in Energy Trust’s free air and duct sealing measure for manufactured homes. Customer billing data from the year prior to the free treatment was analyzed using the Open Energy Efficiency Meter (aka Recurve) platform to estimate weather normalized annual consumption. Results from HZ2 were not used as the sample was small (19 sites) with high variance. A heating zone multiplier was calculated based on ratio of HZ2 to HZ1 gas consumption in RTF gas heated HUD homes. These heating zone specific gas EUI results were weighted based on RBSA II vintage distribution and program climate distribution. Additionally, the participant billing data was assumed to be single wide homes, therefore a single-wide to double-wide multiplier of 85 percent was applied to the single wide gas EUI. The single wide to double wide scaler is based on ratio of double wide gas EUI to single wide gas EUI from RTF gas heated HUD homes. See Table 7 for initial gas EUI, weightings and consolidated gas EUI values for existing condition gas homes.

Table 7 Existing condition gas EUI weightings

	HZ1 OEEM Gas EUI	RTF Gas HZ2 to HZ1 Multiplier	HZ 2&3 Calculated Gas EUI	Single Wide - Any HZ - Gas EUI	Single to Double Wide Scaler	Double Wide - Any HZ - Gas EUI
Pre-1976, pre-HUD	0.55	153%	0.84	0.59	85%	0.50
1976-1994, HUD	0.46		0.71	0.50		0.42
HZ Distribution	86%		14%			
	Single Wide Gas EUI	Double Wide EUI	RBSA Vintage Distribution			
Pre-1976, pre-HUD	0.59	0.50	34%			
1976-1994, HUD	0.50	0.42	66%			
Pre-1995 - Any Heating Zone	0.53	0.45				

These EUI results were normalized to the RBSA median home sizes of 845 sq. ft. single wide home and a 1,424 sq. ft. double-wide home and adjusted by 145 percent according to the CRP evaluation findings.

Market and improved cases – gas heated homes

Market baseline, ENERGY STAR, and NEEM+ energy use for gas homes was sourced from the same RTF analysis as the electric homes. As with electric homes, RTF consumption for gas homes were weighted by program climate distribution, normalized to RBSA median home sizes, and then adjusted by 165 percent according to the CRP findings of post-replacement energy use for single-wide electric homes in HZ1.

Electric consumption and savings in gas heated homes

In gas heated homes, electric fan energy is calculated using Equation 2, where fan input energy of 0.40 kW is based on RTF SEEM modeling of electric forced air furnaces⁴ and furnace input capacity assumptions (which vary by home size, specification, and climate zone) are taken from the RTF’s supplemental SEEM workbook v10⁵. The fan energy calculation is applied to therm usage of all cases, after evaluation adjustments have been applied to therm usage. See Table 8 for a summary of EUI, therm usage, evaluation adjustments, and fan energy consumption for gas heated homes.

Equation 2 Gas furnace fan energy calculation

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

⁴ RTF Single Family Existing HVAC and Weatherization SEEM runs - February 2016 – Tab ‘SEEMOutput’

⁵ <https://rtf.nwcouncil.org/measure/new-manufactured-homes-> Tab “SEEMinput”

Table 8 Gas manufactured home EUI and consumption pre- and post-evaluation adjustments

	Any HZCZ Gas Heated Homes		Calibrating annual consumption to Energy Trust CRP evaluation results				
Gas Heated Homes	Normalized Gas Therms	Annual Normalized Consumption therms	Evaluation Adjustment	Annual Gas Consumption Adj therms	Annual Electric Fan Consumption Adj kWh	Gas EUI Adj	Electric Fan EUI Adj
Existing Condition - Single Wide (Pre-1995)	0.53	446	145%	648	1,629	0.77	1.9
Existing Condition - Double Wide (Pre-1995)	0.45	635	145%	923	1,755	0.65	1.2
Market Baseline-Single Wide	0.26	219	164%	359	971	0.42	1.1
Market Baseline-Double Wide	0.22	311	164%	511	1,045	0.36	0.7
ENERGY STAR 2.0-Single Wide	0.16	139	164%	228	877	0.27	1.0
ENERGY STAR 2.0-Double Wide	0.15	210	164%	344	986	0.24	0.7
NEEM+ Single Wide	0.15	127	164%	208	859	0.25	1.0
NEEM+ Double Wide	0.14	193	164%	316	979	0.22	0.7

Measure Analysis – Appliance and other electric savings – all heating fuels

Additional electric consumption and savings from ENERGY STAR appliances and lighting in ENERGY STAR and NEEM+ homes are not included in this analysis as SEEM modeling does not account for these savings. Additionally, appliances and lighting in existing condition are likely to have been replaced over the lifetime of the existing manufactured home, likely near efficient market baseline conditions. Accounting for these small savings with varying lifetimes was deemed unnecessary.

Savings

Energy savings are calculated in two parts as per technical guidelines for Early Replacement measures as described in Equation 3.

Equation 3 Early replacement savings calculation

Early Replacement Savings =
$$\frac{(Savings_{RUL} * Years_{RUL}) + (Savings_{BML} * Years_{BML})}{Meausre Life}$$

Where:

- Period 1 Remaining Useful Life:
- Savings_{RUL} are the difference in annual consumption between the existing condition and the improved ENERGY STAR or NEEM+ home.
- Years_{RUL}= 40 years
- Period 2 Balance of Measure Life
- Savings_{BML} are the difference in annual consumption between the market baseline new HUD home and the improved ENERGY STAR or NEEM+ home.
- Years_{BML} = 5 years

Electric heated home savings are shown below in Table 9 and gas heated home savings are shown in Table 10. Energy savings for gas homes includes both heating energy savings (therms) and fan energy savings (kWh).

Table 9 Electric manufactured home early replacement savings

Period 1 - Remaining Useful Life Savings (RUL)	kWh RUL Savings	therm RUL Savings	RUL Years
Existing MH to ESTAR 2.0 MH - Single Wide	16,658	-	40.0
Existing MH to ESTAR 2.0 MH - Double Wide	20,024	-	40.0
Existing MH to NEEM+ MH - Single Wide	17,069	-	40.0
Existing MH to NEEM+ MH - Double Wide	20,610	-	40.0
Period 2 - Balance of Measure Life (BML)	kWh BML Savings	therm BML Savings	BML Years
Market Baseline MH to ESTAR 2.0 MH - Single Wide	3,790	-	5.0
Market Baseline MH to ESTAR 2.0 MH - Double Wide	5,065	-	5.0
Market Baseline MH to NEEM+ MH - Single Wide	4,202	-	5.0
Market Baseline MH to NEEM+ MH - Double Wide	5,651	-	5.0
Early Replacement Savings	kWh Early Replacement Savings	therms Early Replacement Savings	Total Measure Life Years
ENERGY STAR 2.0-Single Wide	15,228	-	45.0
ENERGY STAR 2.0-Double Wide	18,362	-	45.0
NEEM+ Single Wide	15,639	-	45.0
NEEM+ Double Wide	18,948	-	45.0

Table 10 Gas manufactured home early replacement savings

Period 1 - Remaining Useful Life Savings (RUL)	kWh RUL Savings	therm RUL Savings	RUL Years
Existing MH to ESTAR 2.0 MH - Single Wide	752	420	40.0
Existing MH to ESTAR 2.0 MH - Double Wide	769	579	40.0
Existing MH to NEEM+ MH - Single Wide	770	440	40.0
Existing MH to NEEM+ MH - Double Wide	776	607	40.0
Period 2 - Balance of Measure Life (BML)	kWh BML Savings	therm BML Savings	BML Years
Market Baseline MH to ESTAR 2.0 MH - Single Wide	94	131	5.0
Market Baseline MH to ESTAR 2.0 MH - Double Wide	59	166	5.0
Market Baseline MH to NEEM+ MH - Single Wide	112	151	5.0
Market Baseline MH to NEEM+ MH - Double Wide	66	195	5.0
Early Replacement Savings	kWh Early Replacement Savings	therm Early Replacement Savings	Total Measure Life Years
ENERGY STAR 2.0-Single Wide	679	388	45.0
ENERGY STAR 2.0-Double Wide	690	533	45.0
NEEM+ Single Wide	697	408	45.0
NEEM+ Double Wide	697	561	45.0

Comparison to RTF or other programs

- Previous analysis for this MAD and for RTF included other product names that have evolved over time but are equivalent specifications and efficiencies; specifically, NEEM 1.1 is retired but is equivalent to the current ENERGY STAR 2.0 while NEEM 2.0 is retired but is equivalent to the current NEEM+. The EcoRated product has been retired but remains in RTF analysis, though it is not used in this analysis.
- This measure analysis is based on consumption data from both NEEA RBSA and RTF SEEM, both data sources have been adjusted to align with Energy Trust CRP evaluation results.
- Energy Trust New Homes, MAD 109, references the same RTF New Manufactured Homes analysis.

Measure Life

The measure life of a replacement home is 45 years, as published by the RTF for new manufactured homes and in alignment with Energy Trust’s New Manufactured Homes measure. As explained in the Baseline section, early replacement RUL and BML are sourced from 2021 stakeholder surveys.

- RUL: 40 years
- BML: 5 years

Load Profile

The electric load profile “Res Ele Resistance Heat” is used to value electric savings for both gas and electrically heated homes, since cooling savings account for less than 1% of annual electric savings in both cases.

The load profile “Res- Heating” is used to value gas savings for gas heated homes.

Cost

As per Technical Guidelines for early replacement measures, the full cost of the measure is used for cost effectiveness screening. Costs are based on Energy Trust total installed project cost reported for manufactured homes installed 2019-May 2024.

From project data where both square footage and installation costs were available, a dollar per square foot for single wide homes was calculated based on the cumulative project cost and cumulative square footage of single wide ENERGY STAR and NEEM+ homes. This value was multiplied by the RBSA median 845 sq. ft. to determine a normalized single wide installation cost of \$102,411 for ENERGY STAR and \$134,494 for NEEM+ homes.

Table 11 Single wide total install costs from program data

Efficiency Level	Quantity	Cumulative Install Cost	Cumulative SQFT	Calculated \$/Sq. Ft.	845 Sq Ft Total Cost
ENERGY STAR Single Wide	123	\$16,127,169.02	133,066.00	\$121.20	\$102,411.27
NEEM+ Single Wide	13	\$1,802,535.15	11,325.00	\$159.16	\$134,493.79

Recreating this analysis for double wide home yielded counterintuitive total installation cost results, due to a limited number of NEEM+ double wide homes. Instead, a multiplier was calculated based on the ratio of median costs of double wides compared to median cost of single wide in the data set, see Table 12.

Table 12 Single to double wide cost comparison and scaler

Configuration and Efficiency	Quantity	Median Install Cost
Single Wide	145	\$114,384
ENERGY STAR	123	\$114,262
NEEM+	13	\$149,116
ESTAR or NEEM+	9	\$114,724
Double Wide	106	\$149,200
ENERGY STAR	98	\$149,200
NEEM+	3	\$158,445
ESTAR or NEEM+	5	\$147,744
Single to Double Scaler Any Efficiency		130%
ENERGY STAR		131%
NEEM+		106%
ESTAR or NEEM+		129%

The resulting 130 percent single to double wide cost scaler was applied to the calculated single wide installation costs to get double wide installation costs of \$133,583 for ENERGY STAR and \$175,431 for NEEM+ homes. Individual scalers for ENERGY STAR and NEEM+ were not used due to the limited number of NEEM+ homes. Final costs are shown below in Table 13.

Table 13 Manufactured home full installation costs

Manufactured Home Efficiency and Size	Full Install Cost
ENERGY STAR 2.0-Single Wide	\$102,411.27
ENERGY STAR 2.0-Double Wide	\$133,583.03
NEEM+ Single Wide	\$134,493.79
NEEM+ Double Wide	\$175,430.78

Non-Energy Benefits

An early replacement, prevented future cost of replacement is included for all the measures in this MAD. This NEB is calculated using the simple calculation shown in Equation 4 and described in the Technical Guidelines as Method 1, Equation 3-2. Calculated NEBs are shown below in Table 14

Equation 4 Early replacement prevented future cost NEB

$$Early\ Replacement\ NEB = \frac{Baseline\ Cost_{BML}}{Measure\ Life}$$

- Where:
- Baseline Cost is the Full Cost of the measure
 - Measure Life is 45 years

Table 14 Early replacement prevented future cost non-energy benefits

Manufactured Home Efficiency and Size	Full Install Cost	Early Replacement NEB \$
ENERGY STAR 2.0-Single Wide	\$102,411.27	\$2,275.81
ENERGY STAR 2.0-Double Wide	\$133,583.03	\$2,968.51
NEEM+ Single Wide	\$134,493.79	\$2,988.75
NEEM+ Double Wide	\$175,430.78	\$3,898.46

For homes in gas-only territory, NEBs for non-participating fuel savings are calculated based on the annual unclaimed electric savings and the blended electric utility rate defined in the 2025 CEC calculator. These NEBs are added to Early replacement NEBs for homes in Gas-Only territory, as shown in Table 15.

Table 15 Non-energy benefits in gas only territory

Gas Only Territory	Electric Savings kWh	Blended Electric Utility Rate \$/kWh	Electric Bill Savings NEB \$	Early Replacement NEB \$	Total NEB \$ Gas Only Territory
ENERGY STAR 2.0-Single Wide	679	\$0.162	\$110.24	\$2,275.81	\$2,386.05
ENERGY STAR 2.0-Double Wide	690	\$0.162	\$112.11	\$2,968.51	\$3,080.62
NEEM+ Single Wide	697	\$0.162	\$113.17	\$2,988.75	\$3,101.92
NEEM+ Double Wide	697	\$0.162	\$113.18	\$3,898.46	\$4,011.64

The program also expects that participants will experience significant non-energy benefits such as improved comfort, health and safety and housing security. These difficult to quantify NEBs are not included in the cost benefit 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 limited by the maximum incentives per replaced home.

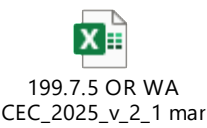
Follow-Up

Measures should be reviewed on a regular basis. Describe in this section the parts of this measure most likely to change and actions or research that are required in the meantime. If there are required attributes needed to inform future updates, include here.

- Federal HUD code, ENERGY STAR and NEEM specifications are expected to be updated and implemented at the end of- 2026, 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.
- At the next edit of this MAD, program design should consider options for Heat Pump Ready home design and review of the heat pump in existing manufactured homes measure from MAD 50.5⁶.
- Existing condition usage assumptions should continue to be monitored, particularly for double-wide homes, as more participant sites are accrued.
- This analysis assumes that single wide homes being replaced are on average 845 sq. ft., despite much smaller participating home sizes in the pilot. Existing home size should continue to be monitored and normalization updated if different.
- If program participation grows (to greater than 5% of program savings), a study should be pursued to verify RUL and BML assumptions.
- Modular homes in manufactured home parks are included in this MAD based on the understanding that the ORSC code requires similar or better energy characteristics than the NEEM 2.0 specification, although the analysis team was unable to verify this exactly. The prevalence of modular homes utilizing this measure should be monitored, and if significant, this home type should be evaluated separately to verify their energy performance.

Supporting Documents

The cost effectiveness screening for these measures is number 199.7.5. It is attached and can be found along with supporting documentation at: \\Etoo.org\home\Groups\Planning\Measure Development\Residential\Manufactured homes\manufactured home replacement



⁶ Energy Trust Residential Heat Pump Conversions, MAD 50.5, expiring 12/31/26: [MAD 50.5 Residential Heat Pump Conversions](#)

Version History and Related Measures

Energy Trust has been offering manufactured home replacements for many years. These predate our measure approval documentation process and record retention requirements. Table 16 may be incomplete.

Table 16 Version History

Date	Version	Reason for revision
5/1/2017	199.1	Pilot Approval- Electrically heated single wide only.
11/14/2017	199.2	Corrects formula error in previous analysis. Expands scope of pilot to include double-wides and vintage up to 1994. Adopts costs from RTF analysis.
11/29/2018	199.3	Extension of pilot through 2020
11/29/2018	225.1	Approve gas heated homes in manufactured homes replacement pilot
5/6/2020	199.4	Extension of pilot through 2022. Merges electrically heated and gas heated homes into one MAD. MAD 225 to be retired.
10/16/2020	199.5	Correct typo in CEC to allow correct pilot designation in database and to extend expiration date
11/22/2021	199.6	Transition from pilot to standard offer, update baseline type and all measure characteristics
12/20/2024	199.7	Updated savings and costs

Table 17 Related Measures

Measures	MAD ID
Gas heated manufactured homes early retirement pilot (inactive)	225
New manufactured homes	109

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Measure Approval Document for Multifamily Pipe Insulation

Valid Dates
1/1/2026-12/31/2028

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

Measure costs were updated, electric measures were added, and a 6” pipe diameter was included to reflect conditions that may be present in older buildings. Additionally, the minimum insulation thickness was reduced to 1” to ensure consistency and broaden applicability for customers.

Cost-Effectiveness

Cost-effectiveness is demonstrated for Oregon in Table 1Table 1 and Washington in Table 2Table 2. Cost-effectiveness was calculated using the tool: OR-WA-CE Calculator 2026-v1.0. The Oregon electric avoided cost year is 2026 and the Oregon gas avoided cost year is 2026. The Washington gas avoided cost year is 2026. 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	MF Pipe Insulation, 1" DHW pipe, Gas	15	0.00	2.15	30.00	\$0.00	\$30.00	1.2	1.2	0%	100%
2	MF Pipe Insulation, 2" DHW pipe, Gas	15	0.00	3.67	34.00	\$0.00	\$34.00	1.8	1.8	0%	100%
3	MF Pipe Insulation, 3" DHW pipe, Gas	15	0.00	5.19	37.00	\$0.00	\$37.00	2.4	2.4	0%	100%
4	MF Pipe Insulation, 4" DHW pipe, Gas	15	0.00	6.49	41.00	\$0.00	\$41.00	2.7	2.7	0%	100%
5	MF Pipe Insulation, 6" DHW pipe, Gas	15	0.00	9.14	48.00	\$0.00	\$48.00	3.2	3.2	0%	100%
6	MF Pipe Insulation, 1" HHW pipe, Gas	15	0.00	1.96	30.00	\$0.00	\$30.00	1.4	1.4	0%	100%
7	MF Pipe Insulation, 2" HHW pipe, Gas	15	0.00	3.67	34.00	\$0.00	\$34.00	2.4	2.4	0%	100%
8	MF Pipe Insulation, 3" HHW pipe, Gas	15	0.00	5.19	37.00	\$0.00	\$37.00	3.1	3.1	0%	100%
9	MF Pipe Insulation, 4" HHW pipe, Gas	15	0.00	6.49	41.00	\$0.00	\$41.00	3.4	3.4	0%	100%
10	MF Pipe Insulation, 6" HHW pipe, Gas	15	0.00	9.14	48.00	\$0.00	\$48.00	4.1	4.1	0%	100%
11	MF Pipe Insulation, 1" LPS pipe, Gas	15	0.00	3.85	30.00	\$0.00	\$30.00	2.8	2.8	0%	100%
12	MF Pipe Insulation, 2" LPS pipe, Gas	15	0.00	6.53	34.00	\$0.00	\$34.00	4.2	4.2	0%	100%
13	MF Pipe Insulation, 3" LPS pipe, Gas	15	0.00	9.20	37.00	\$0.00	\$37.00	5.4	5.4	0%	100%
14	MF Pipe Insulation, 4" LPS pipe, Gas	15	0.00	11.49	41.00	\$0.00	\$41.00	6.1	6.1	0%	100%
15	MF Pipe Insulation, 6" LPS pipe, Gas	15	0.00	16.19	48.00	\$0.00	\$48.00	7.4	7.4	0%	100%
16	MF Pipe Insulation, 1" DHW pipe, Electric Resistance	15	53.14	0.00	30.00	\$0.00	\$30.00	2.6	2.6	100%	0%
17	MF Pipe Insulation, 2" DHW pipe, Electric Resistance	15	90.60	0.00	34.00	\$0.00	\$34.00	3.9	3.9	100%	0%
18	MF Pipe Insulation, 3" DHW pipe, Electric Resistance	15	128.00	0.00	37.00	\$0.00	\$37.00	5.1	5.1	100%	0%
19	MF Pipe Insulation, 4" DHW pipe, Electric Resistance	15	160.04	0.00	41.00	\$0.00	\$41.00	5.7	5.7	100%	0%
20	MF Pipe Insulation, 6" DHW pipe, Electric Resistance	15	225.51	0.00	48.00	\$0.00	\$48.00	6.9	6.9	100%	0%
21	MF Pipe Insulation, 1" HHW pipe, Electric Resistance	15	50.05	0.00	30.00	\$0.00	\$30.00	3.1	3.1	100%	0%
22	MF Pipe Insulation, 2" HHW pipe, Electric Resistance	15	90.60	0.00	34.00	\$0.00	\$34.00	5.0	5.0	100%	0%
23	MF Pipe Insulation, 3" HHW pipe, Electric Resistance	15	128.00	0.00	37.00	\$0.00	\$37.00	6.5	6.5	100%	0%
24	MF Pipe Insulation, 4" HHW pipe, Electric Resistance	15	160.04	0.00	41.00	\$0.00	\$41.00	7.4	7.4	100%	0%
25	MF Pipe Insulation, 6" HHW pipe, Electric Resistance	15	225.51	0.00	48.00	\$0.00	\$48.00	8.9	8.9	100%	0%
26	MF Pipe Insulation, 1" LPS pipe, Electric Resistance	15	94.97	0.00	30.00	\$0.00	\$30.00	6.0	6.0	100%	0%
27	MF Pipe Insulation, 2" LPS pipe, Electric Resistance	15	161.00	0.00	34.00	\$0.00	\$34.00	8.9	8.9	100%	0%
28	MF Pipe Insulation, 3" LPS pipe, Electric Resistance	15	227.00	0.00	37.00	\$0.00	\$37.00	11.6	11.6	100%	0%
29	MF Pipe Insulation, 4" LPS pipe, Electric Resistance	15	283.62	0.00	41.00	\$0.00	\$41.00	13.0	13.0	100%	0%
30	MF Pipe Insulation, 6" LPS pipe, Electric Resistance	15	399.50	0.00	48.00	\$0.00	\$48.00	15.7	15.7	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	MF Pipe Insulation, 1" DHW pipe, Gas	15	2.15	30.00	0.00	\$30.00	1.5	1.5	0%	100%
2	MF Pipe Insulation, 2" DHW pipe, Gas	15	3.67	34.00	0.00	\$34.00	2.2	2.2	0%	100%
3	MF Pipe Insulation, 3" DHW pipe, Gas	15	5.19	37.00	0.00	\$37.00	2.9	2.9	0%	100%
4	MF Pipe Insulation, 4" DHW pipe, Gas	15	6.49	41.00	0.00	\$41.00	3.2	3.2	0%	100%
5	MF Pipe Insulation, 6" DHW pipe, Gas	15	9.14	48.00	0.00	\$48.00	3.9	3.9	0%	100%
6	MF Pipe Insulation, 1" HHW pipe, Gas	15	1.96	30.00	0.00	\$30.00	2.1	2.1	0%	100%
7	MF Pipe Insulation, 2" HHW pipe, Gas	15	3.67	34.00	0.00	\$34.00	3.5	3.5	0%	100%
8	MF Pipe Insulation, 3" HHW pipe, Gas	15	5.19	37.00	0.00	\$37.00	4.6	4.6	0%	100%
9	MF Pipe Insulation, 4" HHW pipe, Gas	15	6.49	41.00	0.00	\$41.00	5.2	5.2	0%	100%
10	MF Pipe Insulation, 6" HHW pipe, Gas	15	9.14	48.00	0.00	\$48.00	6.2	6.2	0%	100%
11	MF Pipe Insulation, 1" LPS pipe, Gas	15	3.85	30.00	0.00	\$30.00	4.2	4.2	0%	100%
12	MF Pipe Insulation, 2" LPS pipe, Gas	15	6.53	34.00	0.00	\$34.00	6.3	6.3	0%	100%
13	MF Pipe Insulation, 3" LPS pipe, Gas	15	9.20	37.00	0.00	\$37.00	8.2	8.2	0%	100%
14	MF Pipe Insulation, 4" LPS pipe, Gas	15	11.49	41.00	0.00	\$41.00	9.2	9.2	0%	100%
15	MF Pipe Insulation, 6" LPS pipe, Gas	15	16.19	48.00	0.00	\$48.00	11.1	11.1	0%	100%

Requirements

- 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.
- Pipe insulation must be a minimum of 1” thick.
- Steam systems must be low pressure (≤15 psig).
- Heating for gas measures must be provided by a central gas-fired system.

Program Requirements

- Project invoices must be checked for ineligible or unassociated costs (such as for fittings or non-installation labor).

Baseline

This measure uses an Existing Condition Baseline. The baseline is assumed to be existing, uninsulated schedule of 40 steel pipe.

Measure and Savings Analysis

Savings were based on a 2010 ICF study¹ performed on behalf of Energy Trust of Oregon that analyzed the impact of pipe insulation in commercial and industrial applications. Various process applications and their associated fluid temperatures and operating hours were used in the calculations. The assumptions for the analysis are listed in Table 3 and Table 4. The steam and HHW operating hours were adjusted to align with ETO steam trap measures’ hourly estimates from MAD 42 while the other operating hours were calculated from RTF model flow rates for apartment buildings and water usage from a NY study.^{2,3}

Table 3 Estimated Operating Hours

Application	Operating Hours
Domestic Hot Water (DHW)	4,825
Heating Hot Water (HHW)	2,209
Low Pressure Steam (LPS)	2,209

Table 4 Input Parameter Summary

Input Parameter	Value	Units
DHW Heater & LPS Boiler Efficiency	80%	N/A
HHW Boiler Efficiency	83%	N/A
Electric Resistance Efficiency	95%	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
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
Pipes Located indoors	90%	N/A
Pipes Located outdoors	10%	N/A

Savings were determined using heat transfer equations to model a horizontal pipe with internal fluid flow and the calculated savings estimates were averaged for supply and return piping. The heat losses were calculated to establish incremental heat loss per hour. Using this heat loss rate, savings were determined by multiplying heat loss and operating hours and then dividing by the assumed efficiency.

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.

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.
² <https://cleanheat.ny.gov/assets/pdf/category-6-energy-calculations-guidance-assumptions.pdf>
³ [RTF Commercial EnergyPlus Model Alignment MASTER FILE - PUBLIC VERSION.xlsx | Powered by Box](#)

The following equation was used to determine heat loss from the pipe:

$$q = \frac{Q}{L} = \frac{\pi \cdot \Delta T}{R_1 + R_{pipe} + R_{ins} + R_2}$$

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 may be solved with physical properties and heat transfer coefficients.

- R₁* = 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
- R₂* = Thermal resistance due to convection and radiation at the exterior insulation surface.

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 processing heating water (PHW) applications up to 200 psi(g) and 388°F. 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 are DHW and Residential Heating for DHW and LPS or HHW applications respectively. The electric load profiles are Res Hot Water and Electric Resistance Heating for DHW and LPS or HHW applications respectively.

Cost

All installation costs were sourced from historical PT data. Outlier data was removed when costs or age of data were determined to be outside the typical range. PT data was categorized into bins by pipe diameter and associated process. To apply costs for pipes of unknown diameter, costs were then consolidated using a weighted average based on the number of PT data projects per process. Costs were then distributed evenly from 1" to 4" pipe diameters and forecast for the 6" pipe diameter addition. Lastly, all costs per pipe diameter were averaged and rounded up for programmatic ease and based on the assumption that the cost of pipe insulation installation is not influenced by the process the pipes are serving.

Table 5: PT Data Costs

Pipe Dia.	Count			Costs			Adjusted Costs*		
	HHW	Comm LPS/MPS	Comm DHW	HHW	Comm LPS/MPS	Comm DHW	HHW	Comm LPS/MPS	Comm DHW
unknown	3	3	5	\$52.62	\$19.72	\$30.76			
1"	5	6	4	\$20.34	\$27.82	\$53.02	\$32.45	\$25.12	\$40.66
2"	4	7	1	\$35.18	\$38.25	\$45.17	\$42.65	\$32.69	\$33.16
3"	1	2	1	\$14.14	\$50.32	\$45.17	\$43.00	\$31.96	\$33.16
4"	6	7	0	\$47.21	\$39.28		\$49.01	\$33.41	
Total/Avg	19	25	11	\$33.90	\$35.08	\$43.53	\$41.78	\$30.80	\$35.66

*Adjusted costs are the weighted costs of projects with and without defined pipe diameters

Table 6: Final cost adjustments

Costs Evenly Distributed per 1" pipe thickness					
Pipe Dia.	HHW	Comm LPS/MPS	Comm DHW	Average	Rounded avg
1"	\$32.45	\$25.12	\$33.16	\$30.25	\$30.00
2"	\$37.97	\$27.89	\$35.66	\$33.84	\$34.00
3"	\$43.49	\$30.65	\$38.16	\$37.43	\$37.00
4"	\$49.01	\$33.41	\$40.66	\$41.03	\$41.00
6"	\$60.05	\$38.93	\$45.65	\$48.21	\$48.00

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

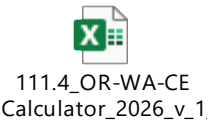
Costs, particularly the inclusion of fittings into cost estimates, and operational hours for LPS and HHW measures should be reviewed during the next update. Fluids in LPS or HHW systems will most likely be always circulating whenever there is heating load and not only for a reduced time equivalent to a fully loaded situation, therefore the program should consider using total heating hours rather than EFLH for savings estimates.

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.

Also, any feedback from the Program Operations or Energy Advisor team must be considered.

Supporting Documents

The cost effectiveness screening for these measures is number 111.4.3. It is attached and can be found along with supporting documentation at:



Version History and Related Measures

Energy Trust has been offering pipe insulation 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
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
09/16/2022	111.3	Updated measure costs, removed fitting savings, expanded exterior jacketing options, added HHW application.
09/26/2025	111.4	Updated measure costs, insulation thickness, max pipe diameter, operational hours, and fuel source options.

Table 8 Related Measures

Measures	MAD ID
Commercial and Industrial Pipe Insulation	91
Industrial DI Pipe Insulation	249
Commercial and Multifamily Steam Traps	42

Approved & Reviewed by

Akanksha Rawal
Engineer- Planning & Evaluation

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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 Code¹ 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 ENERGY 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+ specifications² 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 2023³.

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 MHNewCosntructionSEEMWorkBookv10⁴. 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_v8.2⁶, 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 2022⁷, 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 Gas Water Heaters in Washington

Valid Dates

January 1, 2024 to December 31, 2026

End Use or Description

Qualified residential gas water heaters in Washington used for residential domestic hot water.

Program Applicability

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

- Products
- Existing Homes
- Manufactured Homes, New and Existing
- New Homes, non-EPS
- Existing Buildings, Small Multifamily (2-4 side-by-side units)

Within these programs, applicability to the following customer qualifications, delivery methods, building types, market segments are expected or will be developed during the MAD lifetime:

- Retail delivery (midstream)
- Distributor delivery (midstream)
- Complementary Funding (Co-funding)
- Promotions and engagements for complementary funding, early replacement, and other equity engagements may be qualified based on one or more of the following:
 - Mid and lower income qualified customers, owners and renters
 - Utility rate assistance qualified customers, owners and renters
 - Community partner identified customers, owners and renters
 - Customers in rural and underserved communities
 - Single family and small-multifamily rentals
 - Existing manufactured home customers

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

- Replacement
- Early Replacement
- New

Purpose of Re-Evaluating Measure

This update combines storage and tankless gas water heaters into a single Washington MAD, with updated market assumptions and analysis This MAD replaces and combines the following gas water heater MADs:

- 102.4 Gas Storage Water Heaters, OR and WA
- 197.3 Residential Tankless Water Heaters in SW WA

An early replacement, direct installation configuration for tankless water heaters is included as a new offering and is limited to program identified/qualified customers replacing existing gas storage water heaters.

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 water heater.

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	WA - Gas Storage WH - non-power non-cond 0.68 UEF	13	15.05	\$0.01	\$0.52	\$100	2.1	20690	0%	100%
2	WA - Gas Tankless WH - ESTAR	20	60.69	\$1,025.17	-\$1.84	\$1,025.17	1.3	1.2	0%	100%
3	WA - Gas Tankless WH - ESTAR - Gas Line Upgrade	20	60.69	\$2,225.17	-\$1.84	\$1,282.52	1.0	0.6	0%	100%
4	WA – EarlyReplacement - Gas Tankless WH - ESTAR - Cofunding	20	65.18	\$4,878.48	\$243.90	\$1,377.34	1.0	1.0	0%	100%

The incremental cost for Measure 1 is negative \$220.85 compared to the market baseline cost, this negative cost is represented as \$0.01 in the cost effectiveness calculator as the tool requires positive incremental costs. Maximum Incentives for Measures 1 and 4 differ from the standard Maximum Incentive calculation, the adjusted formulas remove the incentive cap set by the incremental cost.

Requirements

- Used for domestic hot water only, combination space-water heating equipment are excluded from this measure.
- Washington Northwest Natural Gas residential customers only

Existing Condition Requirements

- For new and replacement gas storage and gas tankless water heater measures (#1-3), there is no requirement for existing fuel or equipment types
- For early replacement measures (#4), tankless water heaters must be replacing a gas storage water heater

Gas Storage Water Heater Requirements

- Storage water heater capacity less than 56 gallons
- Minimum of 0.68 UEF
- Non-condensing and non-powered equipment only (no electronic ignition nor power venting)
- Existing construction only

Gas tankless water heater requirements

- ENERGY STAR qualified at time of purchase
- Input less than 200 kBtu/hr
- Equipment that has a tank capacity over two gallons with a burner rating greater than 75 kbtu/hr are not approved

- May not be combined with any new home or new multifamily offer where water heat savings are included in whole building savings analysis such as EPS or market solutions.

Early Replacement Requirements:

- Measure #4 is limited to applications where the program and/or direct install partner is able to verify that the qualified tankless water heater is replacing a functional gas storage water heater before the end of it’s useful life.
- Early Replacement measures are intended for use in program designs that influence customers before they would have naturally been in the market for equipment. It is likely that complementary funding would be necessary for that influence given the maximum incentive is a relatively small portion of expected project costs.
- Measure #4 is limited to qualifying customers as defined by the Program and within approved Energy Trust practices.

Details

In April 2023 ENERGY STAR criteria was updated to version 5.0¹ specifications with increased efficiency requirements for gas water heaters, as shown in Table 2. Storage water heater efficiency increases were particularly significant, increasing from 0.68 to 0.86 UEF (uniform energy factor), there are few to no storage water heaters on the market that meet these new requirements. The previous ENERGY STAR v4.0 non-condensing, and non-power vented equipment remain available, though new to the market. Rather than specify ENERGY STAR certification for storage water heaters, the program will maintain the minimum 0.68 UEF requirement and will limit qualifying products to storage units that are non-condensing and that do not require electric connections for electronic ignition or power venting. Currently, there is one manufacturer producing this equipment type. Gas storage water heaters with more advanced efficiency features are cost prohibitive.

Table 2 ENERGY STAR Product Criteria Version 4.0 Compared to Version 5.0

Criteria			ENERGY STAR Requirements	
Storage Gas Water Heaters			v4.0	v5.0
Uniform Energy Factor (UEF)	≤ 55 gallons	Medium Draw	≥ 0.64	≥ 0.81
		High Draw	≥ 0.68	≥ 0.86
	> 55 gallons	Medium Draw	≥ 0.78	≥ 0.86
		High Drawl	≥ 0.8	≥ 0.86
First Hour Rating (FHR, gallons per hour)			≥ 51 gph	
Warranty			Warranty ≥ 6 years on system (including parts)	
Safety			ANSI Z21.10.1/CSA 4.1	
Tankless Gas Water Heaters			v4.0	v5.0
Uniform Energy Factor			≥ 0.87	≥ 0.95
Maximum Gallons Per Minute			Max GPM ≥ 2.9 over a 67° rise	
Warranty			Warranty ≥ 6 years on heat exchanger and ≥ 5 years on parts	
Safety			ANSI Z21.10.3/CSA 4.3	
Effective Date			1/5/2022	4/18/2023

The ENERGY STAR v5.0 tankless water heater efficiency improvements do not appear to limit availability of qualifying tankless products. Tankless water heater equipment installed in the region and within the program are able to meet the new ENERGY STAR requirements of 0.95 UEF, therefore ENERGY STAR remains a qualification for tankless water heaters. From 2019 through March 2023, seventy percent of tankless water heaters in the program meet the ENERGY STAR v5.0 minimum of 0.95 UEF.

This analysis reflects the market baseline and savings analysis from the Regional Technical Forum, RTF, Residential Gas Water Heaters v2.0 measure updated April 18, 2022², built on ENERGY STAR v4.0 product qualification. The RTF analysis remains suitable for these measures as the UEF ratings for the various efficiency tiers used by RTF align with the measures in this MAD, see Table 3.

Table 3 RTF Equipment Efficiencies by Type

RTF Equipment Type, ENERGY STAR v4.0	RTF UEF	Measure UEF
Storage non-ENERGY STAR	0.62	
Storage ENERGY STAR non-condensing, non-Powered	0.68	0.68
Storage ENERGY STAR non-condensing, powered	0.70	
Storage ENERGY STAR non-condensing	0.70	
Storage ENERGYS STAR condensing	0.83	
Tankless non-ENERGY STAR	0.82	
Tankless ENERGY STAR	0.94	0.95

Baseline

These measures use Full Market and Early Replacement Baselines.

- A full market baseline is used for new and replacement gas water heater applications (#1-3) to reflect the market mix of gas water heaters available to customers.
- An early replacement baseline is used for the direct install, co-funded measure application (#4) when the customer would not have participated without program intervention and the water heater being replaced is gas storage water heater.

Full Market Baseline – New & Replacement Measures

The full market baseline reflects the market blend of storage and tankless gas water heaters in the region. The baseline blends water heater storage volume, market share, installation locations, and climate zones to represent the average newly purchased gas water heater. This full market baseline is used for Replacement and New water heaters.

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 tankless units and storage water heaters of various capacity is appropriate.

¹ ENERGY STAR v5.0 Residential Water Heater Specifications: <https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Residential%20Water%20Heaters%20Version%205.0%20Specification%20and%20Partner%20Commitments.pdf>
² Regional Technical Forum, Residential Gas Water Heater v2.0 Measure Analysis workbook, 4/18/2022: <https://nwcouncil.box.com/v/ResGasWH-v2-0>

Per the RTF measure analysis³ 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. ENERGY STAR non-condensing storage water heaters accounts for 2.7% of the market and ENERGY STAR tankless water heaters account for 11.9%, as summarized below in Figure 1 and Table 4 from the RTF measure analysis.

Figure 1 RTF Residential Gas Water Heaters - Baseline Configuration

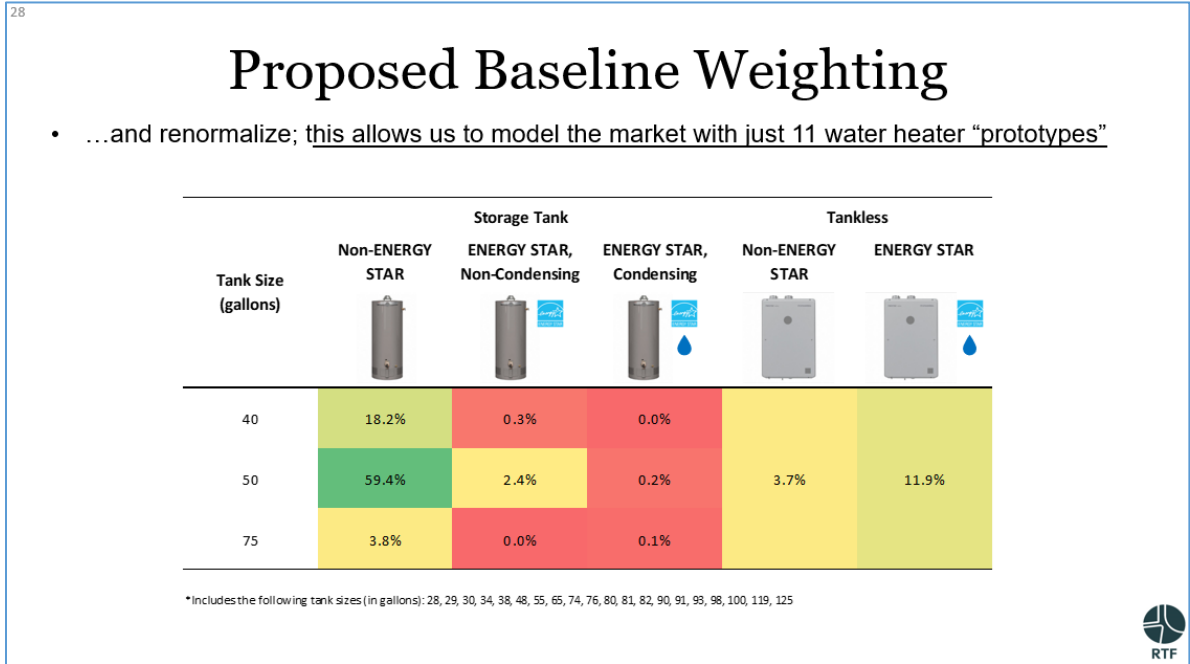


Table 4 RTF Residential Gas Water Heaters – Market Share Equipment Distribution

Current Practice Baseline	Distribution Across Market	Distribution Within Equipment Type
40-gal non-ENERGY STAR	18%	22%
50-gal non-ENERGY STAR	59%	73%
75-gal non-ENERGY STAR	4%	5%
40-gal ENERGY STAR, non-condensing*	0.3%	10%
50-gal ENERGY STAR, non-condensing*	2.4%	90%
75-gal ENERGY STAR, non-condensing*	0.0%	0%
40-gal ENERGY STAR, condensing	0.0%	0%
50-gal ENERGY STAR, condensing	0.2%	70%
75-gal ENERGY STAR, condensing	0.1%	30%
Tankless, non-ENERGY STAR*	4%	24%
Tankless, ENERGY STAR*	12%	76%

*ENERGY STAR, non-condensing reflects powered and non-powered units in this table

* Gas line additions are assumed to occur 50% of the time in tankless installations, per RTF analysis

In new homes we assume a full market baseline as the market baseline efficiency of 0.67 UEF is higher than the federal code minimum of 0.63 UEF. There is considerable difficulty knowing precisely what builders are choosing for code compliance. With updates to 2021 Washington State Energy Code, Residential⁴ (WSEC) focusing on meeting State electrification, energy efficiency, and fuel normalization goals the installation and qualification of gas fueled space and/or water heating equipment is difficult and highly unlikely in new construction. The 2021 WSEC code requires heat pump water heaters (HPWH) in most scenarios, though several exceptions do exist. In particular, dwellings 1,000 square feet or less are excluded from HPWH requirements. This exception acknowledges barriers to HPWH installation due to unit layout, additional space, venting, and access to heat needed for HPHW in smaller multifamily, ADUs and tiny houses, as noted in the code proposal details and notes from June 3, 2022⁵. This exception means that builder could install gas water heaters in dwelling under 1,000 square feet. As the energy code does not include energy code compliance points for gas water heater efficiency or equipment upgrades, builders can install gas water heaters of their choice. For this small group of new construction projects, builders would likely be making equipment selections in line with the RTF market mix.

Early Replacement Baseline – Early Replacement Measures

Savings for the early-replacement, direct-install measures include savings from upgrading from existing gas storage water heater to to an ENERGY STAR gas tankless water heater where the customer would not have replaced functioning equipment without program engagement. The measure analysis is broken into two periods, Period 1 reflects the time when the Remaining Useful Life, RUL, of the existing storage water heater. assumed to be 1/3 of the equipment measure life. Period 2 reflects savings from market baseline to the tankless water heater over the time period after the existing equipment would have been replaced, also called Balance of Measure Life, BML.

Remaining Useful Life (Period 1) - Existing Condition Baseline

An existing condition baseline is assumed for program implementations where the customer would not have participated without program engagement. In these cases, the efficiency of the existing gas storage water heater is the baseline for savings and costs. Existing water heater age was determined by reviewing Northwest Energy Efficiency Alliance (NEEA), Regional Building Stock Assessment II⁶ (RBSA II) distribution of water heaters by vintage, as shown in Table 5. Efficiency for each vintage was determined based on alignment with federal minimum efficiency levels for the period, based Department of Energy, Energy Conservation Standards for Water Heaters from 1990 onwards. For this measure, the 2nd Federal Standard 2001, Effective 2004, was chosen as the baseline code period, yielding an efficiency level of 0.58 EF. This vintage was selected as it covers the years when existing water heaters may be at end of expected life and water heaters older than this range would be near or beyond end of life.

³ RTF Residential Gas Water Heaters Presentation, April 14, 2021: <https://nwcouncil.app.box.com/v/20210414GasWaterHeaterPres>

⁴ Washington State Energy Code, Residential, 2021 Edition: https://sbcc.wa.gov/sites/default/files/2023-03/2021_WSEC_R_1stPrint_033123.pdf

⁵ Washington State, Building Code Council, 2021 Energy Technical Advisory Group, Standard Energy Code Proposal Form dated 6/3/2022: https://sbcc.wa.gov/sites/default/files/2022-06/066_TM_HP_WH_060322.pdf

⁶ Northwest Energy Efficiency Alliance, Regional Building Stock Assessment II Single Family Report 2016-2017: <https://neea.org/data/residential-building-stock-assessment>

Table 5 RBSA II water heater vintage distribution and federal minimum efficiency

Water Heater Vintage		Distribution	Fed Min EF	Efficiency Requirement & Effective Year
Pre 1990		3%	0.53	
1990	1999	17%	0.53	1st DOE Federal Standard, Effective 1990
2000	2004	18%	0.53	
2005	2009	28%	0.58	2nd Federal Standard 2001, Effective 2004 ⁷
2010	2014	24%	0.58	
Post 2014		10%	0.60	3rd Federal Standard 2010, Effective 2015 ⁸

Using the RESNET water heater efficiency rating conversion tool, RESNET-EF-Calculator-2017⁹, a 0.58 EF storage gas water heater would be equivalent to a 0.56 UEF unit. This 0.56 UEF is used as our existing condition baseline equipment efficiency.

Balance of Measure Life – Market Baseline

The balance of measure life baseline is assumed to be the same as the market baseline used for replacement measures. This does not reflect changes in the market over the next 4-10 years. We cannot predict future market shares so current are used.

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)¹⁰. 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.

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

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.

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

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.

⁷ US Department of Energy, Energy Conservation Standards for Water Heaters 2001: <https://www.federalregister.gov/documents/2001/01/17/01-1081/energy-conservation-program-for-consumer-products-energy-conservation-standards-for-water-heaters>

⁸ US Department of Energy, Energy Conservation Standards for Water Heaters 2010: <https://www.federalregister.gov/documents/2010/04/16/2010-7611/energy-conservation-program-energy-conservation-standards-for-residential-water-heaters-direct>

⁹ RESNET water heater efficiency rating conversion calculator <https://www.resnet.us/wp-content/uploads/RESNET-EF-Calculator-2017.xlsx>

¹⁰ 2010 DOE Technical Support Document Appendix, "2010-04-08_Final_Rule_Technical_Support_Document_Appendices." <https://www.regulations.gov/document?D=EERE-2006-STD-0129-0149>

The resulting equation is:

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

Where:

- Q_{in} = total water heater energy consumption, Btu/day,
- vol = daily draw volume, gal/day,
- den = density of water, lb/gal,
- C_p = specific heat of water, Btu/lb-°F,
- T_{tank} = set point of tank thermostat, °F,
- T_{in} = inlet water temperature, °F,
- RE = recovery efficiency, %,
- PA_{iwh} = performance adjustment factor,
- Q_p = pilot input rate, Btu/h,
- P_{ON} = rated input power, Btu/h.

Savings are determined by subtracting the annual consumption of the weighted measure case from the weighted average annual consumption of the market baseline.

Replacement and New Measures

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. The market baseline includes some equipment with power venting and electric ignitions, reflected by 6 kWh annual electric consumption. The market baseline consumption is 162 therms and 6 kwh.

Baseline and efficient case gas and electric consumption and savings from the RTF analysis are provided in Table 6, these measures use the analysis and savings for the RTF measures:

- Tank, ENERGY STAR, non-condensing, non-powered
- Tankless, ENERGY STAR, No Gas Line Upgrade
- Tankless, ENERGY STAR, With Gas Line Upgrade

Table 6 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)

Early Replacement Measures

The savings analysis for the early replacement measures is broken into two periods, Period 1 reflects savings from the existing condition to the tankless water heater over the Remaining Useful Life, RUL, of the existing equipment, assumed to be 1/3 of the equipment measure life.

To determine Period 1 savings, a regression formula was determined to calculate energy savings based on the savings per UEF in the RTF analysis. Water heat savings were plotted against the UEF for each type of gas water heater in the RTF analysis. The difference in energy use between the existing condition 0.56 UEF to the market baseline was calculated as an additional 20.71 therms. Additional electric penalties were not calculated as the existing equipment is assumed to not require power and there will be 0 additional electric savings. This indicates that without program intervention, a new water heater on average will save about 21 therms compared to a gas tank water heater installed between 2001-2010.

Methodology for calculating the total early replacement savings follows Energy Trust Technical Guidelines 2023, incorporating remaining useful life, RUL, and balance of measure life, BLM, where the savings are calculated independently for each period and weighted across the whole measure life, as defined in Equation 3 with terms and savings summarized in Table 7.

Equation 3 Early Replacement Savings Formula

Early Replacement Savings =
$$\frac{(Savings_{RUL} * Years_{RUL}) + (Savings_{BML} * Years_{BML})}{Measure Life}$$

Where:

- Remaining Useful Life (RUL) Years are one third of the lifetime of the existing equipment
 - Gas Storage Water Heater Life = 13 years.
 - RUL = 13 / 3 = 4.3 years
- Balance of Measure Life (BML) Years are the efficient measure life years minus the RUL
 - Gas Tankless Water Heater Life = 20 years.
 - BML = 20 – 4.3 = 15.7 years
- Savings BML are the savings over the market baseline
 - Market baseline savings of 60.7 kWh and -23 kWh are described above and summarized in Table 9
- Savings RUL reflects the market baseline savings plus the savings generated by replacing the existing equipment.
 - Market baseline savings 60.7 kWh and -23 kWh
 - Additional savings of 20.7 therms and 0 kWh, from upgrading from 0.56 UEF to Market Baseline
 - Total RUL Savings = 81.4 therms and -23 kWh

Table 7 Early replacement savings summary

Period	Years	kWh	therms
Balance of measure life – Period 1	4.3	-23	60.7
Remaining useful life – Period 2	15.7	-23	81.4
Early Replacement Total	20	-23	65.2

Comparison to RTF or other programs

These measures align with RTF “Tank, ENERGY STAR, non-condensing, non-powered”, “Tankless, ENERGY STAR, No Gas Line Upgrade”, and “Tankless, ENERGY STAR, With Gas Line Upgrade” measures within the Residential Gas Water Heaters measure approved by the RTF 4/13/2021 and updated 4/18/2022. While the RTF analysis has other gas water heater configurations, these configuration are the only three approved as they are the only cost-effective options.

Cost used in this MAD and analysis do not align with RTF installation/labor costs which appear to be out of date.

This analysis includes an early replacement measure which is not part of the RTF analysis.

Measure Life

Gas storage and tankless water heater have equipment specific measure lives listed below. These measure lives are sourced from RTF, align with the DOE Technical Support Document for the 2015 federal standards change and align with past measure lives used by Energy Trust:

- Gas storage water heater measure life: 13 years
- Gas tankless water heater measure life: 20 years

Load Profile

The following load profiles were used in this analysis:

- Gas Load Profile: DHW
- Electric Load Profile: Res Water Heat

Cost

RTF equipment cost data is sourced from 2019-2020 NEEA distributor data which is considered to be reliable and recent. Some limited water heater equipment pricing was available from program data, based on retail and distributor prices from 2022, and is provided for comparison with RTF values in Table 8. Given the low volume and limited equipment types in the program data, RTF equipment costs were used.

Table 8 RTF and Program Water Heater Equipment Pricing

Water Heater Type		RTF UEF	RTF Equipment Cost	Program Equipment Cost
Tank	non-ENERGY STAR	0.62	\$529.78	\$645.31
	ENERGY STAR, non-condensing, non-powered	0.68	\$672.00	\$652.00
	ENERGY STAR, non-condensing, powered	0.70	\$1,299.78	\$1,060.39
	ENERGY STAR, non-condensing	0.70	\$1,299.78	n/a
	ENERGY STAR, condensing	0.83	\$2,235.80	n/a
Tankless	non-ENERGY STAR	0.82	\$662.17	n/a
	ENERGY STAR	0.94	\$1,107.36	n/a

Energy Trust past project cost data was used to adjust RTF installation cost assumptions, as RTF install cost was sourced from the 2009 Department of Energy, DOE, Technical Support Document (TSD) for Water Heater Standards, Appendix 8-A ¹¹, which is quite old. Gas tankless water heater program cost data was sourced from 2019-March 2023 installed projects, these costs reflect the full invoice cost of equipment and installation for non-gas line tankless water heater measures. Inferred installation cost serves as a basis to scale the RTF installation costs to other equipment types. Install costs for non-ENERGY STAR and ENERGY STAR tankless water heaters were weighted by their market share of the tankless equipment type to determine an average installation scaling factor of 344%. See Table 9 for a breakdown of RTF costs, install costs and scaling factors.

Table 9 RTF versus program installation costs of tankless water heaters, no gas line upgrades

Water Heater Type & Efficiency		RTF UEF	RTF Equipment Cost	RTF Install Cost	RTF Full Cost	Program Full Cost	Inferred Install Cost (Program Full Cost - RTF Equipment Cost)	Installation Scaling Factor	Tankless Market Share
Tankless	non-ENERGY STAR	0.82	\$662.17	\$1,222.04	\$1,884.22	\$5,761.00	\$5,098.83	417%	24%
	ENERGY STAR	0.94	\$1,107.36	\$1,102.16	\$2,209.52	\$4,638.44	\$3,531.08	320%	76%
Inferred scaling factor								344%	

In 2022, the program saw three tankless water heaters with gas line upgrades, invoices for these projects range from \$3,624-\$8,000. Given this high variability and limited invoice details, this analysis uses the \$1,200 gas line costs from RTF. Gas line costs are added to the cost of the tankless water heaters as a flat \$1,200. Final equipment, install, and full costs are shown below in Table 10.

¹¹ Department of Energy, Technical Support Document, Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters, Nov. 23, 2009: <https://www.regulations.gov/document/EERE-2006-STD-0129-0170>

Table 10 Adjusted installation and total costs

Water Heater Type & Efficiency		RTF Equipment Cost	Original RTF Install Costs	Adjusted RTF Install Cost	Gas Line Cost	Install Adjusted Total Cost
Tank	non-ENERGY STAR	\$529.78	\$578.13	\$1,985.95	n/a	\$2,515.73
	ENERGY STAR, non-condensing, non-powered	\$672.00	\$578.13	\$1,985.95	n/a	\$2,657.95
	ENERGY STAR, non-condensing, powered	\$1,299.78	\$1,190.05	\$4,087.99	n/a	\$5,387.78
	ENERGY STAR, non-condensing	\$1,299.78	\$1,190.05	\$4,087.99	n/a	\$5,387.78
	ENERGY STAR, condensing	\$2,235.80	\$1,292.03	\$4,438.32	n/a	\$6,674.12
Tankless	Non-ENERGY STAR	\$662.17	\$1,222.04	\$4,197.90	n/a	\$4,860.07
	ENERGY STAR	\$1,107.36	\$1,102.16	\$3,786.08	n/a	\$4,893.44
Tankless	Non-ENERGY STAR – With Gas Line	\$662.17	\$1,222.04	\$4,197.90	\$1,200.00	\$6,060.07
	ENERGY STAR – With Gas Line	\$1,107.36	\$1,102.16	\$3,786.08	\$1,200.00	\$6,093.44

Baseline costs reflect the weighted average cost of the RTF equipment types. 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. See Table 11 for measure life adjusted costs and market baseline costs.

Table 11 Measure life adjusted individual and market baselines costs

WH Type and Efficiency		Install Adjusted Total Cost	Install Adjusted Total Costs, 13-yr Life	Install Adjusted Total Costs, 20-yr Life	Market Distribution of Equipment
Tank	non-ENERGY STAR	\$2,515.73	\$2,515.73	\$3,423.87	81.4%
	ENERGY STAR, non-condensing, non-powered*	\$2,657.95	\$2,657.95	\$3,617.43	
	ENERGY STAR, non-condensing, powered*	\$5,387.78	\$5,387.78	\$7,332.69	
	ENERGY STAR, non-condensing*	\$5,387.78	\$5,387.78	\$7,332.69	2.7%
	ENERGY STAR, condensing	\$6,674.12	\$6,674.12	\$9,083.38	0.3%
Tankless	Non-ENERGY STAR	\$4,860.07	\$3,777.50	\$4,860.07	1.9%
	ENERGY STAR	\$4,893.44	\$3,803.44	\$4,893.44	6.0%
Tankless	Non-ENERGY STAR – With Gas Line	\$6,060.07	\$4,710.21	\$6,060.07	1.9%
	ENERGY STAR – With Gas Line	\$6,093.44	\$4,736.15	\$6,093.44	6.0%
Market Baseline per 13 or 20 year lifetime			\$2,878.80	\$3,868.27	
*ENERGY STAR, non-condensing distribution includes powered and non-powered equipment					

Incremental costs are calculated as Install Adjusted Total Cost minus the Baseline Cost, specific to the measure life of the measure equipment. For the storage water heater measure, the 13-year Market Baseline and 13-year Install Adjusted Total Cost are used. For the tankless water heater measure, the 20-year Market Baseline and 20-year Install Adjusted Total Cost are used. Table 12 is a summary of the baseline, measure and incremental costs.

Table 12 Baseline, measure and incremental costs

WH Type and Efficiency		Baseline Cost	Install Adjusted Total Cost	Incremental Cost
Tank	non-ENERGY STAR	\$2,878.80	\$2,515.73	(\$363.07)
	ENERGY STAR, non-condensing, non-powered*	\$2,878.80	\$2,657.95	(\$220.85)
	ENERGY STAR, non-condensing, powered*	\$2,878.80	\$5,387.78	\$2,508.98
	ENERGY STAR, non-condensing*	\$2,878.80	\$5,387.78	\$2,508.98
	ENERGY STAR, condensing	\$2,878.80	\$6,674.12	\$3,795.32
Tankless	Non-ENERGY STAR	\$3,868.27	\$4,860.07	\$991.80
	ENERGY STAR	\$3,868.27	\$4,893.44	\$1,025.17
Tankless	Non-ENERGY STAR – With Gas Line	\$3,868.27	\$6,060.07	\$2,191.80
	ENERGY STAR – With Gas Line	\$3,868.27	\$6,093.44	\$2,225.17

The storage water heater has a negative \$220.85 incremental cost based on a blend of the inefficient and efficient gas water heaters available. It is important to note that this measure has a total cost of \$2,658 while a code storage water heater is \$2,516. Thus, there is a \$142 price difference from a federal minimally compliant unit, which represents 81% of the market

Non Energy Benefits

Past gas water heater measures have referenced financial benefits related to extended warranty coverage for higher efficiency equipment. As this measure savings analysis incorporates blended measure life across the market, differences in warranty are not clear. Additionally, the ENERGY STAR v5.0 specifications no longer cover the previously ENERGY STAR certified storage water heater measure, which has not been in the market long enough to establish the confidence to claim extended lifetime/warranty NEBs.

The early replacement, direct-install measure includes non-energy benefits for avoided future equipment cost. The avoided future equipment replacement was calculated using the second method outlined within the Technical Guidelines using excel financial function, Equation 4, and resulting in \$245.74 annualized.

Equation 4 Early replacement, avoided replacement NEB calculation

NEB = PMT(Disountrate, MeasureLife, PV(Disountrate, YearsRUL, 0, BaselineCostBML))

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 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 maximum incentives for gas storage water heaters exceed incremental costs. The technology is new to the market, is currently only made by one company and exceed federal minimum efficiency while producing savings relative to the market baseline, while continuing to be less expensive than the market baseline water heater. 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 to align with the approved incentive levels for the Oregon measure (MAD 102).

Follow-Up

- Review of market uptake/adoption of qualified gas storage non-condensing, non-powered equipment for cost and market penetration
- Review of RTF measure analysis if updates/revisions have been made, the RTF measures is approved through 4/30/2026
- Review of ENERGY STAR versions and specifications
- Review of equipment cost from retail, NEEA, and program data
- Review of gas line upgrade prevalence and pricing would be helpful to assess the weighting used for these measures in the market
- Review of Washington code updates and compliance methods as available in the future
- Change analysis so avoided future replacement is a NEB instead of a baseline cost adjustment.
- Consider differential baseline for customers unlikely to afford an upgrade to tankless.

Supporting Documents

The cost effectiveness screening for these measures is number 197.4.4. It is attached and can be found along with supporting documentation at: \\Etoo.org\home\Groups\Planning\Measure Development\Residential\Res Water Heating\gas tank and tankless\either tank or tankless\wa only



Version History and Related Measures

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

Table 13 Version History

Date	Version	Reason for revision
2007	x	Tankless in existing homes approved
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.
12/31/2011	x	Tankless measure canceled for existing homes
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.
04/24/2017	197.1	Re-introduce tankless water heaters to existing homes in SW Washington
11/8/2017	102.2	Updated costs, NEBs. Change qualifying criteria to ENERGY STAR. Clarifies mid-stream program design.
12/4/2018	197.2	Update expected efficiency rating to 0.92 EF. Include UEF specification.
4/2/2019	178.2	New Home OR Tankless. Reactivated MAD with updated measure costs and savings using new UEF tiers
9/8/2020	259.1	Res Tankless in OR. Approval of Tankless in Oregon existing home retrofits limited to homes that do not require a gas line upgrade
9/16/2020	102.3	Updated requirements and analysis for new UEF test method, differentiated volumes
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.
12/15/2021	178.3	New Home OR Tankless. Update savings and costs
12/6/2023	197.4	Combining storage and tankless equipment into single MAD using RTF analysis. ENERGY STAR v5.0 impacts storage WH availability, remove ENERGY STAR qualification for storage measure, maintain tankless ESTAR certification. Inclusion of a direct-install, early replacement measure.

Table 14 Related Measures

Measures	MAD ID
Residential and existing small multifamily heat pump water heaters	52
New small multifamily heat pump water heaters	176
Commercial condensing tank water heaters	21
Commercial tankless water heaters	72
Residential Tankless Oregon	259
Residential Tankless Water Heaters in SW WA	197
New homes and small multifamily tankless water heaters (OR only)	178
Residential Gas Water Heaters (OR)	102

Approved & Reviewed by

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Planning Engineer

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Measure Approval Document for Residential ENERGY STAR Front Load Clothes Washers & Laundry Centers

Valid Dates

January 1, 2025 to December 31, 2027

End Use or Description

Residential ENERGY STAR® Front Load (FL) Clothes Washers and Laundry Centers in Oregon.

A Laundry Center is a consumer product that meets the definition of a Residential Clothes Washer and Electric Clothes Dryer, which cleans and dries clothes in separate, stacked drums.

Applicability

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

- EHP – Residential Products
- HES – Existing Homes
- BEM – Existing Multifamily

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

- Residential – Midstream, downstream, retail
- Existing Multifamily In-unit Installations – Midstream, downstream, retail

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

- New
- Replacement

Purpose of Re-Evaluating Measure

Updates include fuel weights for dryers and domestic water heaters. Measure analysis reflects Regional Technical Forum, RTF, Clothes Washer measure analysis v8.1 update. Cost data updated with program data and online retail costs.

Cost-Effectiveness

Cost-effectiveness is demonstrated for Oregon in Table 1. Cost-effectiveness was calculated using the tool: OR-WA-CE Calculator 2025-v2.1. The Oregon electric avoided cost year is 2025 and the Oregon gas avoided cost year is 2025. The values in these tables are per washer and/or per laundry center.

Table 1 Cost-Effectiveness Calculator Oregon, per washer/laundry center

#	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 FL Washer - Electric DHW	14	166.57	0.18	\$131.40	\$30.22	\$131.40	1.8	4.2	99%	1%
2	ENERGY STAR FL Washer - Electric DHW - Elec Only	14	166.57	0.00	\$131.40	\$30.22	\$131.40	1.7	4.1	100%	0%
3	ENERGY STAR FL Washer - Gas DHW	14	54.80	5.51	\$131.40	\$30.22	\$131.40	1.2	3.6	47%	53%
4	ENERGY STAR FL Washer - Gas DHW - Gas Only	14	0.00	5.51	\$131.40	\$39.82	\$83.97	1.0	3.8	0%	100%
5	ENERGY STAR FL Washer - Any DHW	14	120.87	2.36	\$131.40	\$30.22	\$131.40	1.5	3.9	82%	18%
6	FL Laundry Center Elec Dryer - Electric DHW	12	225.57	0.00	\$386.70	\$30.22	\$252.75	1.1	1.5	100%	0%
7	FL Laundry Center Elec Dryer - Electric DHW - Elec Only	12	225.57	0.00	\$386.70	\$30.22	\$252.75	1.1	1.5	100%	0%
8	FL Laundry Center Elec Dryer - Gas DHW	12	113.80	5.33	\$386.70	\$30.22	\$252.75	0.8	1.3	66%	34%
9	FL Laundry Center Elec Dryer - Gas DHW - Gas Only	12	0.00	5.33	\$386.70	\$49.40	\$252.75	0.3	1.4	0%	100%
10	FL Laundry Center Elec Dryer - Any DHW	12	179.88	2.18	\$386.70	\$30.22	\$252.75	1.0	1.4	88%	12%

Exceptions

The OPUC provided an exception on September 2, 2015 for higher incentives on clothes washers in gas only service territory that are not cost-effective on the basis of the established exceptions listed in UM-551, Criteria C: “The measure is included for consistency with other demand side management (DSM) programs in the region.” The OPUC directed Energy Trust to consider cost-effectiveness for clothes washer measures based on efficiency rating as a group, rather than separating them into different results based on fuel type or restricting participation based on territory.

The weighted savings and cost effectiveness are rows 5 and 10, in bold, in Table 1. The water heating fuel weighting is based on RBSA III distribution of water heat fuels indicating 59% electric and 41% gas hot water system in Oregon, Energy Trust territory. This guidance would have allowed our gas-only washer measure application (4) to use higher incentives than is shown, however the program does plan to use that higher rate. The exception is being applied to measure applications for laundry centers with gas water heat (8 & 9) only.

Requirements

- Oregon Only
- Clothes washers must be front loading and ENERGY certified.
- Laundry centers must be front load washers with electric dryers and be ENERGY STAR certified. Gas dryer configurations do not qualify.
- Clothes washers and laundry centers must have washer capacities of 2.5 cubic feet or greater
- Residential Single Family or Existing Multifamily in-unit installations only
- Overlap of incentives and savings with MAD 152 Multifamily In-Unit Clothes Washers on individual clothes washers is not allowed, eligible programs will develop mechanisms to ensure savings and incentives are booked under one MAD or the other.

Details

Midstream sales will be allocated to electric utility providers based on the most current version of the Regional Sales Allocation Tool (“RSAT”) or Distributor Sales Allocation Tool (“DSAT”). The programs will only claim savings for units allocated to Energy Trust electric and gas utilities.

Distribution of completed projects between Residential and Existing Buildings (multifamily) programs is allocated according to the Residential Program’s Retail Appliance Allocation Methodology.

Baseline

These measures use a Full Market Baseline.

The full market baseline for clothes washer includes top-loading, front-loading, non-ENERGY STAR, and ENERGY STAR clothes washers based on market data provided by NEEA for the RTF Residential Clothes Washer measure analysis, see Table 2 for market shares. This full market baseline assumes that consumers who shop for a clothes washer are able and willing to replace a top-loading washer with a front-loading washer.

Table 2 Clothes washer market shares from NEEA

Clothes Washer Configurations and Efficiency Ratings	NEEA Market Share
Top - non-ENERGY STAR	44%
Top - ENERGY STAR	22%
Top - CEE Tier 1	6%
Front - non-ENERGY STAR	0%
Front - CEE Tier 1	10%
Front - CEE Tier 2	18%
Front - CEE Advanced Tier	0%

Laundry centers are expected to retain low market share measures compared to conventional stand-alone washer and dryer sets. The program is assuming that laundry centers are competing with the mixed market of stand-alone washer and stand-alone dryers, therefore the market baseline of washer and dryers are used as the baseline for laundry centers. The washer baseline is described above. The full market baseline for dryers includes a blend of conventional non-ENERGY STAR, conventional ENERGY STAR and hybrid/heat pump ENERGY STAR electric dryers. Full market baseline represents all the electric dryer types based on their market share as described in the RTF Clothes Dryer workbook and Energy Trust Measure Approval Document, MAD, 231.3 Residential Clothes Dryers as shown in Table 3.

Table 3 Clothes dryer market share

Electric Clothes Dryer Type	Market Share
Conventional, non-ENERGY STAR	56.8%
Conventional, ENERGY STAR (vented & ventless)	42.9%
Super-efficient (heat pump and hybrid heat pump)	0.3%

Clothes Washer Savings

This clothes washer savings analysis is based on RTF measure analysis methodology, parameters and market data. The RTF measure analysis for clothes washers and dryers was approved July 18, 2023¹ including associated workbooks Residential Clothes Washers v8.1² and Residential Clothes Dryers v5.1³. The RTF analysis reflects lab and market research and includes updates to Remaining Moisture Content (RMC), hot water use, machine energy and standby energy, market share, cost data, dryer efficiency, updates to the RTF Standard Information Workbook v4.8⁴ and fuel mixes for water heaters and dryers based on updated NEEA 2022 Residential Building Stock Assessment III⁵ (RBSA III) data.

Washing Machine Energy

Energy use is determined from the energy used per cycle multiplied by 311 cycles per year. Energy per cycle is a function of configuration (front vs top load) and IMEF and calculated using DOE methods modified by the RTF. ENERGY STAR washers use more electricity than market baseline washers do. The energy penalty is an increase of 9 kWh per year, which is more than made up for in decreased dryer energy and hot water savings.

Dryer Energy

Dryer savings associated with clothes washers are determined by the difference in rated Remaining Moisture Content (RMC) between the efficient and baseline washing machines. This difference in moisture content is multiplied by the annual clothing weight and typical dryer energy usage per pound of moisture to determine the annual dryer energy savings. For electric dryers, this is a savings of 62.8 kwh. For gas dryers, the dryer savings is 2.4 therms.

Energy Trust assumes that 92.5% of customers have electric dryers and only 7.5% have gas dryers, based on RBSA III data for Oregon Energy Trust territory; dryer energy savings are weighted accordingly.

DHW Energy

Domestic Hot Water (DHW) savings are the reduction in energy used to heat water based on the lower amount of water used by machines with lower Integrated Water Factor (IWF). The RTF Clothes Washer DHW savings are calculated using 105% and 75% recovery efficiency for electric and gas water heaters, respectively. The energy savings for electric water heaters is 112 kWh and 5.3 therms for gas water heaters.

For weighted water heater measure configurations, we assume 59% electric and 41% gas water heaters based on RBSA III data for Oregon Energy Trust territory. Additionally, electric water heater recovery efficiency includes electric resistance and heat pump water heater weighted by RBSA III market share data.

Water Embedded Energy

Annually, an ENERGY STAR front-loading clothes washer is expected to save 1,444 gallons of water. Water transportation energy savings result from less energy needed to transport water. Water treatment energy savings result from less energy needed to treat water. The combined freshwater and wastewater embedded energy savings is 5.32 kWh using the Energy Trust’s embedded energy value of 3.68 kWh/1000 gallons for the embedded energy from wastewater.

¹ RTF Residential Clothes Washers: <https://rtf.nwccouncil.org/measure/clothes-washers-0>
² RTF Residential Clothes Washers v8.1 measure analysis workbook: <https://nwccouncil.box.com/v/resclotheswasher-8-1>
³ RTF Residential Clothes Dryers v5.1 measure analysis workbook: <https://nwccouncil.box.com/v/resclothesdry-5-1>
⁴ RTF Standard Information Workbook v4.8: <https://nwccouncil.box.com/v/RTF-SIW-v4-8>
⁵ NEEA Residential Building Stock Assessment 2022: <https://neea.org/data/residential-building-stock-assessment>

Comparison to RTF or other programs

Savings analysis and assumptions are sourced from the RTF clothes washer measure analysis and RBSA III fuel splits for hot water fuel and clothes dryer fuels. Cost data used for this measure is based on online cost research of models reviewed by RTF and program reported models.

Laundry Centers Savings

Laundry center savings are a combination of stand-alone clothes washer and stand-alone electric clothes dryer savings. ENERGY STAR laundry center washers must meet both ENERGY STAR washer and ENERGY STAR dryer specification to qualify as ENERGY STAR units. As such, saving and cost analysis assume that the washer and dryer portion of the laundry center behave the same as individual stand-alone units and compete in the same market.

Savings associated with the washer technology are the same as for the stand-alone clothes washer as this measure specifies front load washers. As ENERGY STAR laundry center washers have the same requirements as stand-alone clothes washers, the motor and other efficiency requirements and savings are the same. Laundry centers have the same front-load requirement as the stand-alone washer, we are assuming the same functionality and performance between the equipment, therefore savings associated with front load remaining moisture content are transferrable to these laundry center washers.

For the clothes dryer portion of the laundry centers, savings associated with the dryer technology are the same as for the stand-alone clothes dryer and are drawn directly from the latest RTF’s analysis for each clothes dryer type, approved July, 2023⁶ and the associated workbooks Residential Clothes Dryers v5.1⁷. The RTF analysis reflects lab and market research for washers and dryers. There were very minor updates between v5.1 and the previous v4.1 used for this measure analysis.

RTF calculated annual consumption for various dryer types, which were then blended into a market average using 2020 NEEA market data. Blending the efficient unit market shares for conventional ENERGY STAR and heat pump ENERGY STAR dryers together and subtracting their weighted annual consumption estimate, 702 kWh, from the market average annual consumption, 756 kWh, results in an estimated savings of 54 kWh for any electric ENERGY STAR dryer and 185 kWh for Heat Pump dryers (heat pump dryer savings are not included in the laundry center measure). See Table 4 below for dryer market shares, consumption and savings. Annual dryer energy consumption was calculated using standardized dryer loads, usage per year, dryer UCEF and additional parameters defined in the RTF measure workbook, the basic calculation is as follows:

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

Table 4 RTF Clothes dryer market share, annual consumption and savings

Electric Dryer Type	Market Share	Dryer Consumption kWh/year
non-ENERGY STAR Dryer	56.8%	797
ENERGY STAR – Conventional electric dryer	42.8%	703
ENERGY STAR – Heat Pump dryer	0.4%	571
ENERGY STAR – Any electric		702
Market Baseline Consumption		756
Dryer Savings		
ENERGY STAR – Any Electric		54
ENERGY STAR – HP Dryer		185

Comparison to RTF or other programs

Laundry centers are not currently offered in other regional programs. Methodology and data for laundry centers is based on the RTF clothes washer and dryer measure analysis.

Energy Trust’s Multifamily offering for residential clothes washers now includes a laundry center offering based on this same methodology.

Measure Life

- Clothes washers use a measure life 14 years, rounded from 14.2 years based on the RTF’s review of the DOE Residential Clothes Washers Technical Support Document⁸.
- Laundry centers use a measure life of 12 years, based on based on RTF’s review of the US Department of Energy’s Technical Support Document on clothes dryers⁹. The lower 12-year measure life is used for these laundry centers as we expect that the combined unit will be replaced when either portion fails.

Load Profile

Clothes washers and laundry centers use the same load profiles as the bulk of laundry center savings come from the clothes washer:

- Electric Load Profile: Res Clotheswasher
- Gas Load Profile: Clotheswasher

Cost

Cost for clothes washers and laundry centers were sourced from online price research.

For efficient clothes washers, individual model numbers were grouped into Model Families by manufacturer, capacity and efficiency level to remove noise associated with model variables such as color, display, and feature sets. Twenty-five individual Model Families were identified, with the top 10 model families accounting for 91 percent of program volume. For these top Model Families online costs were found for model numbers reported by the program retail partner. The MSRP for these model families were weighted by program volume to determine a weighted average efficient clothes washer cost of \$1,144, see Table 5. At the time of cost research many units were available at reduced prices, with an average discount of 24 percent. Consumer are expected to purchase items at the lower discounted price when available, per program discussion, MSRP was reduced by the average price reduction, yielding a final ENERGY STAR front load clothes washer price of \$871.

⁶ RTF Clothes Dryers – SF, MH, and MF in-unit: <https://rtf.nwccouncil.org/measure/clothes-dryers-sf-mh-and-mf-unit>

⁷ RTF Residential Clothes Dryers v5.1 measure analysis: <https://nwccouncil.box.com/v/resclothesdry-5-1>

⁸ DOE, 2012-2014 Direct Final Rule Technical Support Document: <https://www.regulations.gov/document?D=EERE-2008-BT-STD-0019-0047>

⁹ US DOE 2011-04 Technical Support Document: [Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment. Residential Clothes Dryers and Room Air Conditioners.](https://www.energy.gov/eere/energy-efficiency-program-for-consumer-products-and-commercial-and-industrial-equipment)

Table 5 Clothes washer efficient case pricing

Model Family	Program Volume	Percent of Program Volume	Average MSRP
Whirlpool - 4.3 - 2.76	2,783	22%	\$1,049
LG - 4.5 - 2.92	2,142	17%	\$1,053
Electrolux - 4.5 - 2.92	1,972	16%	\$1,345
GE - 4.8 - 2.76	1,554	12%	\$1,133
GE - 5 - 2.76	1,094	9%	\$1,221
Samsung - 4.5 - 2.95	577	5%	\$937
Maytag - 5 - 2.76	426	3%	\$1,399
Whirlpool - 4.5 - 2.76	381	3%	\$1,049
Maytag - 4.5 - 2.76	204	2%	\$999
LG - 5 - 3.1	192	2%	\$1,499
Program Quantity	11,325	91%	Weighted Average Price \$1,144

For non-qualified washers, online costs for fifty-three model numbers from the RTF Clothes Washer analysis were used. Washers were grouped according to loading configuration and efficiency level, a median price for each category was determined from the online cost data. As with the ENERGY STAR models, the MSRP was reduced by the price reduction observed online at time of data collection, 25 percent, for final top load washer price of \$598 and front load price of \$1,179. See Table 6Error! Reference source not found. for MSRP, price reduction, and final prices for each washer category.

A market baseline cost of \$740 was determined by weighting the non-qualified median costs and program qualified weighted average cost, by NEEA market shares, as shown in Table 6. The same weighted average \$871 price was used for both Front-Load CEE Tier 1 and CEE Tier 2 as qualified products could be either of these efficiency levels. Subtracting the program weighted average cost from the market baseline results in an incremental cost of \$131 for clothes washers.

Table 6 Clothes washer current practice market baseline and incremental cost

Clothes Washer Configuration & Efficiency		NEEA Market Share	MSRP	Price Reduction	Final Price	Price Source
Top Load	NQ	44%	\$799.00	25%	\$598.26	Median retail pricing RTF models
	ES	22%	\$1,099.00	24%	\$837.06	
	CEE Tier 1	6%	\$1,024.50	24%	\$780.32	
Front Load	NQ	0%	\$1,574.00	25%	\$1,178.56	Program partner weighted avg price
	CEE Tier 1	10%	\$1,143.84	24%	\$871.22	
	CEE Tier 2	18%	\$1,143.84	24%	\$871.22	
Current Practice Market Baseline					\$739.81	
ENERGY STAR Front Load Washer					\$871.22	
Incremental Cost					\$131.40	

For efficient laundry centers, the same model family analysis was performed, five model families were determined with one single model family representing 87 percent of laundry center volume. Of this single model family, there were only two distinct laundry center models reported. To expand the cost survey, online cost were found for the 8 distinct models reported through the program. These online costs were weighted by program volume for a weighted average of \$2,521. The average price reduction for laundry centers was found to be 28%, yielding a final cost of \$1,819. See Table 7 for individual model numbers, program weight, price reductions, and weighted average cost.

Table 7 Laundry center cost details

Laundry Center Model Number	Quantity	Weight	Online MSRP	Final Laundry Center Cost
WKEX200H	578	61%	\$2,564	\$1,849
WKE100H	240	25%	\$2,354	\$1,698
ELTE7600	72	8%	\$2,499	\$1,803
WSEX200H	21	2%	\$2,599	\$1,875
ELTE7300	16	2%	\$2,499	\$1,803
WKEX300HBA	14	1%	\$2,899	\$2,091
WKHC202H	11	1%	\$3,400	\$2,453
WSEX200HNA	2	0%	\$2,797	\$2,018
Weighted Average	954	100.0%	\$2,521	\$1,818.53

The baseline cost for laundry centers is assumed to be the cost of a stand-alone washer and a stand-alone dryer. From the Clothes Dryer MAD 231.3, the market baseline dryer cost is \$692 and reflects non-ENERGY STAR, ENERGY STAR conventional dryers and heat pump dryers weighted by NEEA market share, as shown Table 8. Combing the market baseline clothes washer cost of \$740 and the market baseline dryer cost yields a washer and dryer set cost of \$1,432 and an incremental cost of \$387 for a qualified laundry center, see Table 9.

Table 8 Clothes dryer cost details

Electric Dryer Type	NEEA Market Share	Electric dryer cost
non-ESTAR Dryer	56.8%	\$648.22
ESTAR - Conventional electric dryer	42.8%	\$746.16
ESTAR - HP dryer	0.4%	\$1,130.84
Market Baseline Dryer Cost:		\$692.02

Table 9 Laundry set and laundry center incremental costs

Laundry Center Cost Comparison	Market Baseline Cost
Dryer Market Baseline Cost	\$692.02
Washer Market Baseline Cost	\$739.81
Washer & Dryer Set - Current Practice Market Cost	\$1,431.83
Front Load Laundry Center Elec Dryer	\$1,818.53
Laundry Center Incremental Cost	\$386.70

Non-Energy Benefits

Significant non-energy benefits are achieved through reduced water use and reduced wastewater volume and treatment, resulting in lower water bills. Water bill reduction is valued at \$20.92/1000 gallons, ENERGY STAR clothes washer savings of 1,444 gallons results in water bill savings of \$30.22 in Oregon gas and electric territory. In gas only territory water bill reduction and embedded energy is valued at \$21.41/1000 gallons for a total of \$30.92 of bill savings in Oregon. Water/Wastewater NEBs for clothes washers and laundry centers are the same as there are no additional water savings associated with ENERGY STAR clothes dryers.

Gas-only customer electric bill savings are considered non-energy benefit because they cannot be claimed by the program. Electric water heating savings are claimed as electric bill reductions at \$0.162/kWh. Laundry center dryer savings can also be claimed at the same \$0.162/kWh for gas-only customers. The electric bill savings NEBs in gas-only territory are an additional \$8.90 for clothes washers and \$18.48 for laundry centers. Total combined water and electric NEBs in gas only territory is \$39.82 for clothes washers and \$49.40 for laundry centers.

Incentive Structure

The maximum incentives listed in Table 1 are for reference only and are not suggested incentives. Incentives will be structured per clothes washer or laundry center sold via midstream instant discount at retailer, distributors or downstream, depending on the program and design. Incentives will not exceed the max cost-effective incentive per CEC.

Follow-Up

- Federal minimum and ENERGY STAR washer and dryer specification updates are in development in 2024; implementation timing of new specifications is not clear but are not expected before Spring 2028. Specifications should be reviewed in conjunction with NEEA dryer testing and qualification.
- Laundry center program data should continue to be reviewed to better understand volume, cost and other relevant information. Input from manufacturers/distributors may be helpful, particularly to understand if more affordable qualified units are in the production pipeline.
- Changes to the analysis for Residential Clothes Dryers will impact laundry center measure and should be reviewed and incorporated as needed.
- Consider combining the multifamily and residential clothes washers MADs at the next update of these measures.

Supporting Documents

The cost effectiveness screening for these measures is number 4.6.4 It is attached and can be found along with supporting documentation at: \\Etoo.org\home\Groups\Planning\Measure Development\Residential\Res Appliances\clothes washer



4.6.4 OR-WA-CE
Calculator_2025_v_2

Version History and Related Measures

Energy Trust has been offering clothes washer 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
7/9/2004	x	Residential Clothes washer measure for 1.26 and 1.42 MEF.
1/14/2005	x	Residential Clothes washer measure for MEF 1.8.
2006	x	Residential Clothes washer measure for MEF 1.8, updated federal standard.
6/27/2007	x	Residential Clothes washer measure for MEF 2.0.
12/3/2007	x	Products program clothes washers for tiers at 2.0 and 2.2 MEF.
11/24/2010	4.x	Include separate savings for multifamily applications. Weighted dryer fuel type. Tiers at 2.2 and 2.46 MEF.
6/22/2011	x	Approve Washington only clothes washers.
11/21/2012	4.x	Update savings due to increasing market for more efficient clothes washers. Baseline and efficiency case updated. Tiers at 2.4 and 2.6 MEF. Dryer fuel type split as separate measures. Multifamily applications removed from MAD 4.
7/29/2015	4.x	Updated savings based on April 14, 2015 RTF decisions. Split clothes washer measures by DHW fuel. Use ENERGY STAR and IMEF metrics for minimum criteria.
9/24/2015	4.x	Set max incentives based on UCT exception. Weighted dryer fuel type.
10/27/2015	4.1	Removed top-loading units. Clarified single fuel territory situations.
8/7/2017	4.2	Update non-energy benefits and use 2018 avoided costs.
8/2/2018	4.3	Update savings to account for new ENERGY STAR specification IMEF ≥ 2.76 and IWF ≤ 3.7, update incremental costs, non-energy benefits, requirements and 2019 avoided costs.
4/1/2019	4.4	Amend program applicability to allow midstream instant discount delivery without collecting address information
8/23/2021	4.5	Updated analysis to reflect updated RTF Clothes Washer and Clothes Dryer measure analysis. Addition of laundry center measures
10/11/2024	4.6	Update cost data to program data and online cost research. 2022 RBSA III data for fuel weighting updated. RTF measure analysis mostly unchanged.

Table 11 Related Measures

Measures	MAD ID
Residential Clothes Dryers	231
Residential style in-unit multifamily clothes washers	152
Shift-model top loading clothes washers (no longer offered)	218
Commercial clothes washers (coin-op laundry, commercial laundry, multifamily shared laundry)	89

Approved & Reviewed by

Jackie Goss, PE
Sr. Engineer – Planning & Evaluation

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Measure Approval Document for Resideo Thermostat Optimization

Valid Dates

January 1, 2026 through December 31, 2028

End Use or Description

Thermostat optimization is a service where a company applies optimization algorithms to internet-connected thermostats on central heating and cooling systems to reduce energy consumption. This approval is for Resideo optimization service to be applied continuously for one year to households with enrolled eligible devices.

Details

Resideo is paid for each device they enrolled in the optimization program and provides data about each enrolled device including street address, and heating (gas or electric forced air furnace, or heat pump) and cooling systems (central air conditioning, heat pump, none).

Participants are notified of their enrollment and can opt-out of the service once enrolled. Participant attrition reasons include customer opt outs, disconnected devices, and move-outs.

Applicability

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

- Residential

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

- Retrofit

Purpose of Re-Evaluating Measure

Update savings and add participant incentives

Cost-Effectiveness

Cost-effectiveness is demonstrated for Oregon in Table 1 and Table 2 and Washington in Table 3 and Table 4. Cost-effectiveness was calculated using the tool: OR-WA-CE Calculator 2026-v1.0. The Oregon electric avoided cost year is 2026 and the Oregon gas avoided cost year is 2026. The Washington gas avoided cost year is 2026. The values in these tables are per unit. Tables 2 and 4 show cost effectiveness when considering the additional program cost of paying for control group participants. These are shown for information only.

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	Resideo Tstat Optimization - Annual - gFAF	1	45.96	15.01	\$12.00	\$0.00	\$29.50	1.2	2.9	18%	82%
2	Resideo Tstat Optimization - Annual - gFAF GOT	1	0.00	15.01	\$12.00	\$7.98	\$29.50	1.0	3.0	0%	100%
3	Resideo Tstat Optimization - Annual - gFAF + AC	1	75.04	15.01	\$12.00	\$0.00	\$29.50	1.5	3.7	37%	63%
4	Resideo Tstat Optimization - Annual - gFAF + AC GOT	1	0.00	15.01	\$12.00	\$13.04	\$29.50	1.0	3.4	0%	100%
5	Resideo Tstat Optimization - Annual - eFAF	1	434.32	0.00	\$12.00	\$0.00	\$29.50	2.0	5.0	100%	0%
6	Resideo Tstat Optimization - Annual - eFAF + AC	1	463.40	0.00	\$12.00	\$0.00	\$29.50	2.4	5.8	100%	0%
7	Resideo Tstat Optimization - Annual - Heat Pump	1	195.11	0.00	\$12.00	\$0.00	\$29.50	1.0	2.5	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	% Ele	% Gas
8	Resideo Tstat Optimization - Annual - gFAF w/ Control Group Cost	1	45.96	15.01	\$13.06	\$0.00	\$29.50	1.2	2.7	18%	82%
9	Resideo Tstat Optimization - Annual - gFAF GOT w/ Control Group Cost	1	0.00	15.01	\$13.06	\$7.98	\$29.50	1.0	2.8	0%	100%
10	Resideo Tstat Optimization - Annual - gFAF + AC w/ Control Group Cost	1	75.04	15.01	\$13.06	\$0.00	\$29.50	1.5	3.4	37%	63%
11	Resideo Tstat Optimization - Annual - gFAF + AC GOT w/ Control Group Cost	1	0.00	15.01	\$13.06	\$13.04	\$29.50	1.0	3.1	0%	100%
12	Resideo Tstat Optimization - Annual - eFAF w/ Control Group Cost	1	434.32	0.00	\$13.06	\$0.00	\$29.50	2.0	4.6	100%	0%
13	Resideo Tstat Optimization - Annual - eFAF + AC w/ Control Group Cost	1	463.40	0.00	\$13.06	\$0.00	\$29.50	2.4	5.4	100%	0%
14	Resideo Tstat Optimization - Annual - Heat Pump w/ Control Group Cost	1	195.11	0.00	\$13.06	\$0.00	\$29.50	1.0	2.3	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	% Ele	% Gas
1	Resideo Tstat Optimization - Annual - gFAF WA	1	15.01	\$12.00	\$4.04	\$29.50	1.4	3.8	0%	100%
2	Resideo Tstat Optimization - Annual - gFAF + AC WA	1	15.01	\$12.00	\$6.60	\$29.50	1.4	4.0	0%	100%

Table 4 Cost-Effectiveness Calculator Washington w/ 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	% Ele	% Gas
3	Resideo Tstat Optimization - Annual - gFAF WA w/ Control Group Cost	1	15.01	\$13.06	\$4.04	\$29.50	1.4	3.5	0%	100%
4	Resideo Tstat Optimization - Annual - gFAF + AC WA w/ Control Group Cost	1	15.01	\$13.06	\$6.60	\$29.50	1.4	3.7	0%	100%

Requirements

- Household must have an eligible internet-connected thermostat compatible with Resideo’s optimization 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.
- Savings are not claimed for sites enrolled as control sites.

Baseline

This measure uses an Existing Condition Baseline.

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

Measure Analysis

This measure analysis is based on the Connected Savings pilot program in 2018 and 2019, which Energy Trust hired Apex Analytics (Apex) to evaluate 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.

Key findings of Resideo Thermostat Optimization Pilot Report¹:

- Reduction of 3.2% primary heating fuel savings for thermostats connected to furnaces and 5.1% fan electric savings.
- Reduction of 4% of heating electric use for thermostats connected to heat pumps (high uncertainty).
- Reduction of 3.9% of cooling electric use for thermostats connected to central air conditioning systems (high uncertainty).

Reductions are shown in absolute and percentage savings in Table 5.

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

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

Apex calculated electric furnace values using gas furnace values converted to kWh. Furnace fan savings were calculated from 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 to the savings. Annual treatment attrition rates are calculated by dividing the annual treatment cancellation total by yearly active treatment participants, and each year’s attrition rate is averaged into the average treatment attrition rate. The average treatment attrition rate from Table 6 was applied to estimated savings from Table 5 and the final values are represented in the savings columns of Tables 1 through 4.

Table 6 Summary of Treatment Approvals and Cancellation 2020-2025

Distinct Count of Account Approvals and Cancellations by Year								
Group	Enrollment Status	2020	2021	2022	2023	2024	2025	Total
Annual Treatment Cancellation Total		15	42	39	28	23	29	176
Active Treatment Participants		250	404	481	565	671	677	
Annual Treatment Attrition Rates		6%	10%	8%	5%	3%	4%	21%
Average Treatment Attrition Rate		6.2%						

Comparison to RTF or other programs

- Currently this is the only Energy Trust approved standalone thermostat optimization service. Other thermostat offers have experienced a decline in savings since their initial pilots, with much lower electric savings, especially for thermostats on heat pumps.
- RTF does not currently have approved UES for thermostat optimization services.

Measure Life

A one-year measure life is used in this analysis based on the Resideo Optimization Pilot Report evaluation representing one year and Resideo optimization service being annually renewed and funded.

Load Profile

Based on the portion of savings from heating and/or cooling the following load profiles are used.

- The Res Heating gas load profile is used for all measures with gas heat, where central air conditioning is present Res Space Conditioning is used as the electric profile.
- Res Ele Resistance Heat electric load profile is used for electric forced air furnace measures without central cooling.
- Res Air Source Heat Pump electric load profile is used for electric forced air furnace with central air conditioning and heat pump.

¹ [Energy Trust of Oregon Resideo Thermostat Optimization Pilot Report](#)

Table 7 Electric Load Profile Selection

Measure	Electric Load Profile	Gas Load Profile	Total Savings (kWh)	Cooling Savings (kWh)	Percent Cooling
Resideo Tstat Optimization - Annual - gFAF	Res Ele Resistance Heat	Res Heating	45.96	0.00	0%
Resideo Tstat Optimization - Annual - gFAF GOT	None - ele	Res Heating	0.00	0.00	0%
Resideo Tstat Optimization - Annual - gFAF + AC	Res Space Conditioning	Res Heating	75.04	29.08	39%
Resideo Tstat Optimization - Annual - gFAF + AC GOT	None - ele	Res Heating	0.00	0.00	0%
Resideo Tstat Optimization - Annual - eFAF	Res Ele Resistance Heat	None - gas	434.32	0.00	0%
Resideo Tstat Optimization - Annual - eFAF + AC	Res Air Source HP	None - gas	463.40	29.08	6%
Resideo Tstat Optimization - Annual - Heat Pump	Res Air Source HP	None - gas	195.11	29.08	15%

Cost

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

A target of ten percent of enrollees are designated as ‘control’ sites and do not receive thermostat optimization. The total amount of approved control group customers at time of measure development is 8.86% of treatment customers, seen in Table 8. This 8.86% results in a control group site cost of \$1.06 per treatment site. Cost effectiveness calculations including control site costs as portion of treatment site costs, for a total of \$13.06, is demonstrated in Table 2 and Table 4.

Table 8 Control Group Percentage of Total

Group	n
Control	63
Treatment	648
Total	711
Control % of Total	8.86%

Non Energy Benefits

Electric bill savings for Energy Trust gas only customers are incorporated as a non-energy benefit.

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. Maximum incentives are above incremental costs to allow for the program to consider program design strategies to boost enrollment by offering additional annual incentives to customers above the cost of the Resideo optimization service. Energy Trust notified the OPUC of this possibility on 9/26/2025.

Table 2 and Table 4 represent the maximum incentive when incorporating control group costs into treatment group customer costs to represent incremental costs.

Follow-Up

A new evaluation is recommended based on dramatic changes in realized savings for other thermostat measures.

- Using the approved control and treatment groups that are enrolled in Resideo optimization to conduct randomized control trials could inform future updates to this measure.
- Future evaluations may look for persistence of savings beyond one year which could be incorporated into the measure.

Opt-out rates and proportion of participants in the control group should be updated with the most recent data at each update.

Supporting Documents

The cost effectiveness screening for these measures is number 217.5.5. 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\optimization\Resideo



217.5.5 OR-WA-CEC
2026_v_1_0 Resideo.

Version History

Table 9 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.
10/14/2025	217.5	Update to opt-out savings adjustment, increase max incentive

Table 10 Related Measures

Measures	MAD ID
Residential Smart Thermostats (Nest and Ecobee only)	153
Commercial Smart Thermostats (Various manufacturers, including Honeywell)	235

Approved & Reviewed by

Jackie Goss, PE

Lead Engineer – Planning & Evaluation

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Measure Approval Document for Building Operator Certificate

Valid Dates
1/1/2026 – 12/31/2028

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 - Assisted Living
- Existing Multifamily - Market Rate
- Large 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 and updated energy use intensities from CBSA and RBSA.

Multifamily Electric is cost effective and added as a 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 2026-v1.0. In Oregon the electric avoided cost year is 2026 and the gas avoided cost year is 2026. In Washington the gas avoided cost year is 2026. 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	27,713.84	1,478.56	2,495.00	\$0.00	\$2,495.00	6.7	6.7	52%	48%
2	BOC - Multifamily	3	11,249.04	31.45	2,495.00	\$0.00	\$2,495.00	1.4	1.4	95%	5%
3	BOC - Existing Buildings - Electric Heat	3	27,713.84	0.00	2,495.00	\$0.00	\$2,495.00	3.5	3.5	100%	0%
4	BOC - Existing Buildings - Gas Only Territory	3	0.00	1,478.56	2,495.00	\$4,595.38	\$2,495.00	3.2	8.2	0%	100%
5	BOC - Multifamily - Electric Heat	3	11,249.04	0.00	2,495.00	\$0.00	\$2,495.00	1.4	1.4	100%	0%
6	BOC - Multifamily - Gas Only Territory	3	0.00	31.45	2,495.00	\$1,954.10	\$168.55	1.0	2.2	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	1,478.56	2,495.00	0.00	\$2,495.00	5.2	7.6	0%	100%
2	BOC in Multifamily	3	31.45	2,495.00	0.00	\$274.42	1.0	1.1	0%	100%

Requirements
Participation Requirements

- Participants 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
- Total square footage of buildings under operator supervision must be greater than 70,000 sq. ft.

Program Tracking Requirement

- Building square footage will be tracked
- Building a primary heating system will be tracked

Details
Savings may be captured for additional building operators in the same building where each is responsible for separate areas. Where areas of responsibilities 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 (NEEA) 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 (CBSA). The EUIs in the table were updated to the values published in the 2019 CBSA² for this MAD.

The total annual savings for each fuel type is the product of building square footage, 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, ft²
- EUI_{elec} = Energy Use Intensity, kWh/ft²
- EUI_{gas} = Energy Use Intensity, therm/ft²
- $Savings_{elec}$ = Electric Savings, %
- $Savings_{gas}$ = Gas Savings, %

The multifamily energy intensities were sourced from the *Residential Building Stock Assessment III (RBSA III) - Multifamily Homes Report 2022*.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/ft²
- EUI_{gasMF} = Multifamily Energy Use Intensity, therm/ft²
- $EUI_{elecComm}$ = Commercial Energy Use Intensity, kWh/ft²
- $EUI_{gasComm}$ = Commercial Energy Use Intensity, therm/ft²

Project Tracker (PT) data were used to calculate typical project square footage (114,724 square feet) for the Existing Buildings measure applications. The average multifamily building area is assumed to be 77,721 square feet, which is the average square footage per operator reported from MPER #3.

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	27,714	1,479
BOC in Multifamily	11,249	31

The reported electric EUI in the CBSA includes both electric and gas heated buildings. Therefore, the dual-fuel measure applications likely overestimate electric 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 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.

Comparison to RTF or other programs

This measure is not offered by the RTF. However, Programs are required to track participants and savings for reporting to NEEA to avoid regional double counting.

Measure Life

Measure life is three years, consistent with other operations and maintenance measures and participation requirements.

Load Profile

Dual Fuel Measure Applications:

- Electric: Ventilation

¹ [BOC-Expansion Initiative Market Progress Evaluation Report #3](#)
² [CBSA 4 2019 Final Report.pdf](#)
³ [2022-Residential-Building-Stock-Assessment](#)

- Gas: Com-Heating
- Electric Heat Measure Applications:
1. Electric: Ventilation
 2. Gas: Non - gas
- Gas-only territory
3. Electric: None – ele
 4. Gas: Com-Heating

Cost

The full BOC training cost is currently \$2,495 per level – sourced from the Building Operator Certification (BOC) website.⁴

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 Stock Assessment EUIs or BPS benchmarking if available. Updated program data should be included to update typical project square footage and primary heating type. Next update should investigate if this measure is applicable for the New Buildings program.

Supporting Documents

The cost-effective screening for these measures is number 137.6.4. It is attached and can be found along with supporting documentation at: \\Etoo.org\home\Groups\Planning\Measure Development\Commercial and Industrial\Whole Building and Controls\Builder Operator Certificate



137.6.4 OR-WA-CE
Calculator_2026_v_1

Version History

Energy Trust has been offering the building operator certificate 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
8/2/2022	137.5	Updated savings
7/29/2025	137.6	Updated savings and costs

Approved & Reviewed by

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⁴ [Building Operator Certification Northwest](#)

Measure Approval Document for Commercial & Industrial Pipe Insulation

Valid Dates
1/1/2025 to 12/31/2027

End Use or Description

This measure incentivizes energy savings associated with the purchase and installation of insulation on previously uninsulated hot water and steam piping. This measure is available for low/medium pressure steam systems (LPS/MPS), domestic hot water (DHW), and heating hot water (HHW) in 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, applicability to the following classes:

- Retrofit

Purpose of Re-Evaluating Measure

91.5 This update reevaluated costs, updated insulation thickness minimums, consolidated LPS and MPS measures for commercial applications, and added additional pipe diameters to commercial measures and electric fuel sources for commercial hot water measures.

91.6 Corrects an error in the CEC that prevented some rows from uploading to PT. 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 2025_v_2_1. The Oregon electric avoided cost year is 2025 and the Oregon gas avoided cost year is 2025. The Washington gas avoided cost year is 2025. 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 (\$)	Maximum Incentive (\$)	UCT BCR at Max Incentive	TRC BCR	% Electric Allocation	% Gas Allocation
1	Commercial Insulation, 1" DHW pipe, Gas	15	0.00	2.12	\$36.00	\$35.01	1.0	1.0	0%	100%
2	Commercial Insulation, 2" DHW pipe, Gas	15	0.00	3.59	\$39.50	\$39.50	1.5	1.5	0%	100%
3	Commercial Insulation, 3" DHW pipe, Gas	15	0.00	5.10	\$43.00	\$43.00	2.0	2.0	0%	100%
4	Commercial Insulation, 4" DHW pipe, Gas	15	0.00	6.34	\$46.50	\$46.50	2.3	2.3	0%	100%
5	Commercial Insulation, 6" DHW pipe, Gas	15	0.00	8.93	\$53.50	\$53.50	2.8	2.8	0%	100%
6	Commercial Insulation, 8" DHW pipe, Gas	15	0.00	11.27	\$60.50	\$60.50	3.1	3.1	0%	100%
7	Commercial Insulation, 1" HHW pipe, Gas	15	0.00	2.70	\$36.00	\$36.00	1.7	1.7	0%	100%
8	Commercial Insulation, 2" HHW pipe, Gas	15	0.00	4.57	\$39.50	\$39.50	2.7	2.7	0%	100%
9	Commercial Insulation, 3" HHW pipe, Gas	15	0.00	6.47	\$43.00	\$43.00	3.5	3.5	0%	100%
10	Commercial Insulation, 4" HHW pipe, Gas	15	0.00	8.04	\$46.50	\$46.50	4.0	4.0	0%	100%
11	Commercial Insulation, 6" HHW pipe, Gas	15	0.00	11.31	\$53.50	\$53.50	4.9	4.9	0%	100%
12	Commercial Insulation, 8" HHW pipe, Gas	15	0.00	14.26	\$60.50	\$60.50	5.5	5.5	0%	100%
13	Commercial Insulation, 1" LPS/MPS pipe, Gas	15	0.00	6.79	\$36.00	\$36.00	4.4	4.4	0%	100%
14	Commercial Insulation, 2" LPS/MPS pipe, Gas	15	0.00	11.54	\$39.50	\$39.50	6.8	6.8	0%	100%
15	Commercial Insulation, 3" LPS/MPS pipe, Gas	15	0.00	16.30	\$43.00	\$43.00	8.8	8.8	0%	100%
16	Commercial Insulation, 4" LPS/MPS pipe, Gas	15	0.00	20.26	\$46.50	\$46.50	10.1	10.1	0%	100%
17	Commercial Insulation, 6" LPS/MPS pipe, Gas	15	0.00	28.49	\$53.50	\$53.50	12.3	12.3	0%	100%
18	Commercial Insulation, 1" DHW pipe, Electric Resistance	15	47.16	0.00	\$36.00	\$36.00	1.5	1.5	100%	0%
19	Commercial Insulation, 2" DHW pipe, Electric Resistance	15	80.00	0.00	\$39.50	\$39.50	2.4	2.4	100%	0%
20	Commercial Insulation, 3" DHW pipe, Electric Resistance	15	113.53	0.00	\$43.00	\$43.00	3.1	3.1	100%	0%
21	Commercial Insulation, 4" DHW pipe, Electric Resistance	15	141.15	0.00	\$46.50	\$46.50	3.6	3.6	100%	0%
22	Commercial Insulation, 6" DHW pipe, Electric Resistance	15	198.98	0.00	\$53.50	\$53.50	4.4	4.4	100%	0%
23	Commercial Insulation, 8" DHW pipe, Electric Resistance	15	250.92	0.00	\$60.50	\$60.50	4.9	4.9	100%	0%
24	Commercial Insulation, 1" HHW pipe, Electric Resistance	15	82.23	0.00	\$36.00	\$36.00	2.9	2.9	100%	0%
25	Commercial Insulation, 2" HHW pipe, Electric Resistance	15	138.89	0.00	\$39.50	\$39.50	4.5	4.5	100%	0%
26	Commercial Insulation, 3" HHW pipe, Electric Resistance	15	196.71	0.00	\$43.00	\$43.00	5.8	5.8	100%	0%
27	Commercial Insulation, 4" HHW pipe, Electric Resistance	15	244.33	0.00	\$46.50	\$46.50	6.7	6.7	100%	0%
28	Commercial Insulation, 6" HHW pipe, Electric Resistance	15	344.02	0.00	\$53.50	\$53.50	8.2	8.2	100%	0%

29	Commercial Insulation, 8" HHW pipe, Electric Resistance	15	433.55	0.00	\$60.50	\$60.50	9.2	9.2	100%	0%
31	Industrial Insulation, 0.5-1" LPS pipe	10	0.00	10.48	\$35.00	\$35.00	3.4	3.4	0%	100%
32	Industrial Insulation, 1.25-2" LPS pipe	10	0.00	21.79	\$40.00	\$40.00	6.1	6.1	0%	100%
33	Industrial Insulation, 2.5-3.5" LPS pipe	10	0.00	34.50	\$45.00	\$45.00	8.6	8.6	0%	100%
34	Industrial Insulation, 4-6" LPS pipe	10	0.00	56.07	\$50.00	\$50.00	12.6	12.6	0%	100%
35	Industrial Insulation, 8-10" LPS pipe	10	0.00	82.55	\$55.00	\$55.00	16.9	16.9	0%	100%
36	Industrial Insulation, 0.5-1" MPS pipe	10	0.00	13.91	\$35.00	\$35.00	4.5	4.5	0%	100%
37	Industrial Insulation, 1.25-2" MPS pipe	10	0.00	27.97	\$40.00	\$40.00	7.9	7.9	0%	100%
38	Industrial Insulation, 2.5-3.5" MPS pipe	10	0.00	46.95	\$45.00	\$45.00	11.7	11.7	0%	100%
39	Industrial Insulation, 4-6" MPS pipe	10	0.00	76.94	\$50.00	\$50.00	17.3	17.3	0%	100%
40	Industrial Insulation, 8-10" MPS pipe	10	0.00	125.54	\$55.00	\$55.00	25.6	25.6	0%	100%
41	Industrial Insulation, 0.5-1" PHW pipe	10	0.00	6.43	\$35.00	\$35.00	2.1	2.1	0%	100%
42	Industrial Insulation, 1.25-2" PHW pipe	10	0.00	11.20	\$40.00	\$40.00	3.1	3.1	0%	100%
43	Industrial Insulation, 2.5-3.5" PHW pipe	10	0.00	18.42	\$45.00	\$45.00	4.6	4.6	0%	100%
44	Industrial Insulation, 4-6" PHW pipe	10	0.00	28.10	\$50.00	\$50.00	6.3	6.3	0%	100%
45	Industrial Insulation, 8-10" PHW pipe	10	0.00	46.19	\$55.00	\$55.00	9.4	9.4	0%	100%

Table 2 Cost Effectiveness Calculator Washington, per linear foot

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs (\$)	Maximum Incentive (\$)	UCT BCR at Max Incentive	TRC BCR	% Electric Allocation	% Gas Allocation
1	Commercial Insulation, 1" DHW pipe, Gas	15	0.00	2.12	\$36.00	\$36.00	1.0	1.0	0%	100%
2	Commercial Insulation, 2" DHW pipe, Gas	15	0.00	3.59	\$39.50	\$39.50	1.6	1.6	0%	100%
3	Commercial Insulation, 3" DHW pipe, Gas	15	0.00	5.10	\$43.00	\$43.00	2.1	2.1	0%	100%
4	Commercial Insulation, 4" DHW pipe, Gas	15	0.00	6.34	\$46.50	\$46.50	2.4	2.4	0%	100%
5	Commercial Insulation, 6" DHW pipe, Gas	15	0.00	8.93	\$53.50	\$53.50	2.9	2.9	0%	100%
6	Commercial Insulation, 8" DHW pipe, Gas	15	0.00	11.27	\$60.50	\$60.50	3.2	3.2	0%	100%
7	Commercial Insulation, 1" HHW pipe, Gas	15	0.00	2.70	\$36.00	\$36.00	2.2	2.2	0%	100%
8	Commercial Insulation, 2" HHW pipe, Gas	15	0.00	4.57	\$39.50	\$39.50	3.4	3.4	0%	100%
9	Commercial Insulation, 3" HHW pipe, Gas	15	0.00	6.47	\$43.00	\$43.00	4.4	4.4	0%	100%
10	Commercial Insulation, 4" HHW pipe, Gas	15	0.00	8.04	\$46.50	\$46.50	5.1	5.1	0%	100%
11	Commercial Insulation, 6" HHW pipe, Gas	15	0.00	11.31	\$53.50	\$53.50	6.2	6.2	0%	100%
12	Commercial Insulation, 8" HHW pipe, Gas	15	0.00	14.26	\$60.50	\$60.50	6.9	6.9	0%	100%
13	Commercial Insulation, 1" LPS/MPS pipe, Gas	15	0.00	6.79	\$36.00	\$36.00	5.6	5.6	0%	100%
14	Commercial Insulation, 2" LPS/MPS pipe, Gas	15	0.00	11.54	\$39.50	\$39.50	8.6	8.6	0%	100%
15	Commercial Insulation, 3" LPS/MPS pipe, Gas	15	0.00	16.30	\$43.00	\$43.00	11.2	11.2	0%	100%
16	Commercial Insulation, 4" LPS/MPS pipe, Gas	15	0.00	20.26	\$46.50	\$46.50	12.8	12.8	0%	100%
17	Commercial Insulation, 6" LPS/MPS pipe, Gas	15	0.00	28.49	\$53.50	\$53.50	15.7	15.7	0%	100%
19	Industrial Insulation, 0.5-1" LPS pipe	10	0.00	10.48	\$35.00	\$35.00	3.4	3.4	0%	100%
20	Industrial Insulation, 1.25-2" LPS pipe	10	0.00	21.79	\$40.00	\$40.00	6.1	6.1	0%	100%
21	Industrial Insulation, 2.5-3.5" LPS pipe	10	0.00	34.50	\$45.00	\$45.00	8.7	8.7	0%	100%
22	Industrial Insulation, 4-6" LPS pipe	10	0.00	56.07	\$50.00	\$50.00	12.7	12.7	0%	100%
23	Industrial Insulation, 8-10" LPS pipe	10	0.00	82.55	\$55.00	\$55.00	16.9	16.9	0%	100%
24	Industrial Insulation, 0.5-1" MPS pipe	10	0.00	13.91	\$35.00	\$35.00	4.5	4.5	0%	100%
25	Industrial Insulation, 1.25-2" MPS pipe	10	0.00	27.97	\$40.00	\$40.00	7.9	7.9	0%	100%
26	Industrial Insulation, 2.5-3.5" MPS pipe	10	0.00	46.95	\$45.00	\$45.00	11.8	11.8	0%	100%
27	Industrial Insulation, 4-6" MPS pipe	10	0.00	76.94	\$50.00	\$50.00	17.4	17.4	0%	100%
28	Industrial Insulation, 8-10" MPS pipe	10	0.00	125.54	\$55.00	\$55.00	25.8	25.8	0%	100%
29	Industrial Insulation, 0.5-1" PHW pipe	10	0.00	6.43	\$35.00	\$35.00	2.1	2.1	0%	100%
30	Industrial Insulation, 1.25-2" PHW pipe	10	0.00	11.20	\$40.00	\$40.00	3.2	3.2	0%	100%
31	Industrial Insulation, 2.5-3.5" PHW pipe	10	0.00	18.42	\$45.00	\$45.00	4.6	4.6	0%	100%
32	Industrial Insulation, 4-6" PHW pipe	10	0.00	28.10	\$50.00	\$50.00	6.34	6.34	0%	100%
33	Industrial Insulation, 8-10" PHW pipe	10	0.00	46.19	\$55.00	\$55.00	9.48	9.48	0%	100%

Requirements

- Existing condition must be either bare pipe with no insulation or insulation that is aged, wet, or damaged/torn in multiple locations (is also typically beyond useful life). Aged, wet, or damaged/torn existing insulation claimed as ineffective or providing no insulating value must be pre-qualified and documented as such by the installation contractor.
- Minimum insulation thickness of 1 inch.
- Jacketing that provides appropriate protection for the insulation under the given environmental conditions will be required for pipe insulation projects to maintain the insulation's life. This will commonly be All Service Jacketing (ASJ) or PVC in indoor applications and aluminum or stainless-steel jacketing for outdoor projects.
- 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.

Baseline

This measure uses an existing condition baseline. The baseline is assumed to be an uninsulated schedule 40 steel pipe.

Measure and Savings Analysis

Analysis was based on the impact of pipe insulation in commercial and industrial applications presented in a 2010 ICF study conducted on behalf of the Energy Trust of Oregon.¹ A bare pipe baseline is assumed and applied to describe sites that had missing, severely deteriorated, or uninsulated piping. Savings are based on straight linear feet of pipe, not equivalent length. Fittings and pipe bends are not accounted for in savings calculation.

Savings were determined using heat transfer equations to model a horizontal pipe with internal fluid flow. Additionally, empirical quantifiers were used for the necessary heat transfer coefficients. The heat losses of bare and insulated pipes were calculated to establish the incremental heat loss per hour. Using this heat loss rate, savings were determined by multiplying heat loss and operating hours and then dividing by the assumed efficiency. The following equation was used to determine heat loss from the pipe:

q = Q / L = (pi * Delta T) / (R1 + Rpipe + Rins + R2)

Where,

q = Energy loss per length of pipe (Btu/hr/ft)

Q = Energy loss (Btu/hr)

L = Pipe length (ft)

Delta T = Temperature difference between fluid and air (Tfluid - Tair,) (°F)

The R values in the denominator represent the thermal resistance factors that impede the flow of heat. R values vary and may be solved 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.

For commercial measures, savings were calculated for pipe diameters of 1", 2", 3", 4", and 6" for each application with an additional 8" pipe diameter added for hot water measures. 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. Additionally, small and large commercial building values were averaged for each pipe diameter so that the program will not have to discern what constitutes a small versus a large commercial building. Lastly, to reduce the number and complexity of measures and based on the similarity in savings and systems, low and medium pressure steam measures were combined using a weighted average based on historical PT data.

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 where 75% of these projects are expected to be 1" pipe, 20% to be 0.75" and 5% to be 0.5". These percentages were estimated based on experience delivering the measure, 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 is expected to be a conservative estimate of savings.

Various process applications and their associated fluid temperatures and operating hours were used in the calculations. The assumptions for the analysis are listed in Table 3 and Table 4. The commercial steam operating hours were adjusted to align with ETO steam trap measures' hourly estimates while the other operating hours were provided by the ICF study.

Table 3 Estimated Operating Hours

Application	Operating Hours
Small Commercial DHW	2,500 hours
Small Commercial Medium Pressure Steam	2,425 hours
Large Commercial DHW	6,500 hours
Large Commercial Heating	2,900 hours
Large Commercial Low-Pressure Steam	4,380 hours
Industrial Low-Pressure Steam	8,400 hours
Industrial Medium Pressure Steam	8,400 hours
Industrial Process Hot Water	8,400 hours

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
Electric Resistance Efficiency	95%	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
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
Pipes Located indoors	90%	N/A
Pipes Located outdoors	10%	N/A

¹ [Pipe Insulation Report \(20902D, Apr 10\)-Apr29.doc](#)

The assumed efficiency for HHW boilers was updated based on the findings in the ‘Oregon Commercial and Industrial Boilers Market Characterization Memo’ (Dec 2020)². 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
- 90% of condensing boilers are not operating in condensing mode, therefore efficiency of a condensing boiler operating in non-condensing mode is less than 94% and is assumed to be approx. 84%³.

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 2020 memo does not mention the efficiency of steam boilers and therefore the assumed efficiency for steam boilers was unchanged and remains 80%.

The assumed efficiency from the EnergyStar report for electric-resistance water heaters is 95-99%.⁴ An efficiency of 95% was used for conservative calculations of DHW and HHW processes.

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

Small office ‘DHW’ and ‘Hot Water’ load profiles are used for gas and electric DHW measures respectively.
Large office ‘Com Heating’ and ‘Heating’ load profiles are used for gas and electric HHW measures respectively.
Small office ‘Com Heating’ and ‘Flat-gas’ load profiles are used for commercial and industrial steam measures respectively.

Cost

All installation costs were sourced from historical PT data. Outlier data was removed when costs were determined to be outside the typical range. Commercial and Industrial PT data was categorized into bins by pipe diameter and associated process. For Industrial projects where pipe diameter descriptions did not match an existing measure, the data was allocated to the nearest existing measure bin. Process bins were then consolidated using a weighted average based on the number of PT data projects per process. The consolidation of the processes assumes that the costs of pipe insulation installation is not influenced by the process the pipes are serving.

For final cost estimations, an average cost difference method was employed to distribute the expected costs. An average cost difference of \$3.50 per 1” pipe diameter for commercial measures as seen in Table 8 and \$5.00 per pipe bin for industrial measures as seen in Table 6 was calculated and used for cost allocation. This method addressed the challenge of determining direct costs in cases where bins derived results from insufficient data points. Additionally, new larger diameter bins for commercial measures lacked data, requiring a method to estimate their costs. By utilizing the average cost difference approach, costs were distributed more evenly and reliably, addressing gaps for both bins with limited data and new larger bins by referencing average values derived from existing data. The consolidated vs final distributed costs can be seen in Table 5Table 5 and Table 7 for Industrial and Commercial measures respectively.

Table 5: Industrial Bin Costs

Pipe Dia.	Consolidated Processes	Final Costs
0.5-1"	\$ 35.00	\$ 35.00
1.25-2"	\$ 38.99	\$ 40.00
2.5-3.5"	\$ 42.08	\$ 45.00
4-6"	\$ 46.70	\$ 50.00
8-10"	\$ 55.89	\$ 55.00

Table 6: Industrial Cost Differences

Bin Difference	Cost Difference
Small to SmMed	\$ 3.99
SmMed to Med	\$ 3.09
Med to MdLrg	\$ 4.61
MdLrg to Large	\$ 9.20
Average	\$ 5.00

Table 7: Commercial Bin Costs

Pipe Dia.	Consolidated Processes	Final Costs
1"	\$ 35.71	\$ 36.00
2"	\$ 42.16	\$ 39.50
3"	\$ 45.07	\$ 43.00
4"	\$ 46.25	\$ 46.50
6"	-	\$ 53.50
8"	-	\$ 60.50

Table 8: Commercial Cost Differences

Bin Difference	Cost per 1" dia.
1"-2"	\$ 6.44
2"-3"	\$ 2.92
3"-4"	\$ 1.17
Average	\$ 3.50

² https://www.energytrust.org/wp-content/uploads/2021/05/EnergyTrust_CIGasBoilerMarketResearch-Memo_FINAL.pdf
³ <https://kw-engineering.com/how-to-optimize-condensing-boiler-system-maximum-energy-savings/>
⁴ [EnergyStar Water Heater 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 linear foot.

Follow-Up

- Any additional studies or evaluation results on commercial or industrial pipe insulation should be evaluated for inclusion in the analysis.
- Cost methodology should be reviewed during the next measure update and aged projects removed from the data set. Industrial costs in particular should be evaluated and possibly aligned with MAD 249.
- Any feedback from the Program Operations or Energy Advisor team must be considered.

Supporting Documents

The cost effectiveness screening for these measures is number 91.6.5. It is attached and can be found along with supporting documentation at: \\Etoo.org\home\Groups\Planning\Measure Development\Commercial and Industrial\Process Equipment\pipe insulation\Commercial Industrial pipe insulation



91.6.5_OR-WA-CE
Calculator_2025_v_2

Version History and Related Measures

Energy Trust has been offering pipe insulation 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
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
10/16/24	91.5	Costs, addition of pipe diameters, added electric resistance for commercial measures, insulation thicknesses, and steam measure consolidations were all reviewed and updated.
10/18/24	91.6	Correct Error in Prescriptive column of CEC

Table 10 Related Measures

Measures	MAD ID
Multifamily Pipe Insulation	111
Industrial DI Pipe Insulation	249

Approved & Reviewed by

Akanksha Rawal
Engineer- Planning & Evaluation

Disclaimer

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

Valid Dates
10/24/24 – 12/31/2027

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 to open, they release not only condensate but also release steam from the steam system into the 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

Within these programs, applicability to the following building types is expected but not limited to:

- 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 classes:

- Retrofit

Purpose of Re-Evaluating Measure

42.5 Add measure applications for steam traps operating above 50 psig for commercial space heating and non-space heating end uses.

42.6 Change start date to allow late use in late 2024.

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 2025-v2.1. The Oregon gas avoided cost year is 2025. The Washington gas avoided cost year is 2025. The values in these tables are per unit.

Table 1 Cost-Effectiveness Calculator Oregon, per unit

#	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	495.47	\$495.47	2.6	2.6	0%	100%
2	Steam Trap Replacement (all trap sizes) - Commercial Space Heating - Operating Pressure < 30 psig	6	331.79	553.99	\$553.99	6.5	6.5	0%	100%
3	Steam Trap Replacement (all trap sizes) - Commercial Space Heating - Operating Pressure ≥ 30 psig and ≤ 50 psig	6	697.80	581.97	\$581.97	12.9	12.9	0%	100%
4	Steam Trap Replacement (all trap sizes) - Dry Cleaners - Operating Pressure ≥ 75 psig and ≤ 125 psig	6	211.14	380.23	\$380.23	4.0	4.0	0%	100%
5	Steam Trap Replacement (all trap sizes) - Commercial Space Heating (High Use) - Operating Pressure < 30 psig	6	654.86	553.99	\$553.99	12.8	12.8	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	581.97	\$581.97	25.6	25.6	0%	100%
7	Steam Trap Repair (for trap size ≤ 1/2") - Multifamily Space Heating- Operating Pressure <5 psig	6	116.68	495.47	\$495.47	2.6	2.6	0%	100%
8	Steam Trap Repair (for trap size ≤ 1/2") - Commercial Space Heating - Operating Pressure < 30 psig	6	331.79	553.99	\$553.99	6.5	6.5	0%	100%
9	Steam Trap Repair (for trap size ≤ 1/2") - Commercial Space Heating - Operating Pressure ≥ 30 psig and ≤ 50 psig	6	697.80	581.97	\$581.97	12.9	12.9	0%	100%
11	Steam Trap Repair (for trap size ≤ 1/2") - Commercial Space Heating (High Use) - Operating Pressure < 30 psig	6	654.86	553.99	\$553.99	12.8	12.8	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	581.97	\$581.97	25.6	25.6	0%	100%
13	Steam Trap Repair (for trap size ≥ 3/4") - Multifamily Space Heating- Operating Pressure <5 psig	6	116.68	370.47	370.47	3.4	3.4	0%	100%
14	Steam Trap Repair (for trap size ≥ 3/4") - Commercial Space Heating - Operating Pressure < 30 psig	6	331.79	428.99	428.99	8.4	8.4	0%	100%
15	Steam Trap Repair (for trap size ≥ 3/4") - Commercial Space Heating - Operating Pressure ≥ 30 psig and ≤ 50 psig	6	697.80	456.97	456.97	16.5	16.5	0%	100%
17	Steam Trap Repair (for trap size ≥ 3/4") - Commercial Space Heating (High Use) - Operating Pressure < 30 psig	6	654.86	428.99	428.99	16.5	16.5	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	456.97	456.97	32.5	32.5	0%	100%
19	Steam Trap Replacement (all trap sizes) - Commercial Space Heating - Operating Pressure > 50 psi and < 200 psi	6	1,455.87	651.08	\$651.08	24.1	24.1	0%	100%
20	Steam Trap Replacement (all trap sizes) - Commercial Space Heating (High Use) - Operating Pressure > 50 psi and < 200 psi	6	2,873.43	651.08	\$651.08	47.7	47.7	0%	100%
21	Steam Trap Replacement (all trap sizes) - Commercial Continuous Use (non-space heating) - Operating Pressure > 50 psi and ≤ 150 psi	6	5,517.25	664.79	\$664.79	89.6	89.6	0%	100%
22	Steam Trap Replacement (all trap sizes) - Commercial Continuous Use (non-space heating) - Operating Pressure > 150 psig	6	9,077.87	664.79	\$664.79	147.5	147.5	0%	100%
23	Steam Trap Repair (for trap size ≤ 1/2")- Commercial Space Heating - Operating Pressure > 50 psi and < 200 psi	6	1,455.87	651.08	\$651.08	24.1	24.1	0%	100%
24	Steam Trap Repair (for trap size ≤ 1/2") - Commercial Space Heating (High Use) - Operating Pressure > 50 psi and < 200 psi	6	2,873.43	651.08	\$651.08	47.7	47.7	0%	100%
25	Steam Trap Repair (for trap size ≤ 1/2")- Commercial Continuous Use (non-space heating) - Operating Pressure > 50 psi and ≤ 150 psi	6	5,517.25	664.79	\$664.79	89.6	89.6	0%	100%
26	Steam Trap Repair (for trap size ≤ 1/2") - Commercial Continuous Use (non-space heating) - Operating Pressure > 150 psig	6	9,077.87	664.79	\$664.79	147.5	147.5	0%	100%
27	Steam Trap Repair (for trap size ≥ 3/4") - Commercial Space Heating - Operating Pressure > 50 psi and < 200 psi	6	1,455.87	526.08	526.08	29.9	29.9	0%	100%
28	Steam Trap Repair (for trap size ≥ 3/4") - Commercial Space Heating (High Use) - Operating Pressure > 50 psi and < 200 psi	6	2,873.43	526.08	526.08	59.0	59.0	0%	100%
29	Steam Trap Repair (for trap size ≥ 3/4") - Commercial Continuous Use (non-space heating) - Operating Pressure > 50 psi and ≤ 150 psi	6	5,517.25	539.79	539.79	110.4	110.4	0%	100%
30	Steam Trap Repair (for trap size ≥ 3/4") - Commercial Continuous Use (non-space heating) - Operating Pressure > 150 psig	6	9,077.87	539.79	539.79	181.6	181.6	0%	100%

Table 2 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	Steam Trap Replacement (all trap sizes) - Multifamily Space Heating- Operating Pressure <5 psig	6	116.68	495.47	\$495.47	2.9	2.9	0%	100%
2	Steam Trap Replacement (all trap sizes) - Commercial Space Heating - Operating Pressure < 30 psig	6	331.79	553.99	\$553.99	8.0	8.0	0%	100%
3	Steam Trap Replacement (all trap sizes) - Commercial Space Heating - Operating Pressure ≥ 30 psig and ≤ 50 psig	6	697.80	581.97	\$581.97	16.0	16.0	0%	100%
4	Steam Trap Replacement (all trap sizes) - Dry Cleaners - Operating Pressure ≥ 75 psig and ≤ 125 psig	6	211.14	380.23	\$380.23	3.9	3.9	0%	100%
5	Steam Trap Replacement (all trap sizes) - Commercial Space Heating (High Use) - Operating Pressure < 30 psig	6	654.86	553.99	\$553.99	15.7	15.7	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	581.97	\$581.97	31.5	31.5	0%	100%
7	Steam Trap Repair (for trap size ≤ 1/2") - Multifamily Space Heating- Operating Pressure <5 psig	6	116.68	495.47	\$495.47	2.9	2.9	0%	100%
8	Steam Trap Repair (for trap size ≤ 1/2") - Commercial Space Heating - Operating Pressure < 30 psig	6	331.79	553.99	\$553.99	8.0	8.0	0%	100%
9	Steam Trap Repair (for trap size ≤ 1/2") - Commercial Space Heating - Operating Pressure ≥ 30 psig and ≤ 50 psig	6	697.80	581.97	\$581.97	16.0	16.0	0%	100%
11	Steam Trap Repair (for trap size ≤ 1/2") - Commercial Space Heating (High Use) - Operating Pressure < 30 psig	6	654.86	553.99	\$553.99	15.7	15.7	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	581.97	\$581.97	31.5	31.5	0%	100%
13	Steam Trap Repair (for trap size ≥ 3/4") - Multifamily Space Heating- Operating Pressure <5 psig	6	116.68	370.47	370.47	3.9	3.9	0%	100%
14	Steam Trap Repair (for trap size ≥ 3/4") - Commercial Space Heating - Operating Pressure < 30 psig	6	331.79	428.99	428.99	10.3	10.3	0%	100%
15	Steam Trap Repair (for trap size ≥ 3/4") - Commercial Space Heating - Operating Pressure ≥ 30 psig and ≤ 50 psig	6	697.80	456.97	456.97	20.3	20.3	0%	100%
17	Steam Trap Repair (for trap size ≥ 3/4") - Commercial Space Heating (High Use) - Operating Pressure < 30 psig	6	654.86	428.99	428.99	20.3	20.3	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	456.97	456.97	40.1	40.1	0%	100%
19	Steam Trap Replacement (all trap sizes) - Commercial Space Heating - Operating Pressure > 50 psi and < 200 psi	6	1,455.87	651.08	\$651.08	29.8	29.8	0%	100%
20	Steam Trap Replacement (all trap sizes) - Commercial Space Heating (High Use) - Operating Pressure > 50 psi and < 200 psi	6	2,873.43	651.08	\$651.08	58.7	58.7	0%	100%
21	Steam Trap Replacement (all trap sizes) - Commercial Continuous Use (non-space heating) - Operating Pressure > 50 psi and ≤ 150 psi	6	5,517.25	664.79	\$664.79	110.4	110.4	0%	100%
22	Steam Trap Replacement (all trap sizes) - Commercial Continuous Use (non-space heating) - Operating Pressure > 150 psig	6	9,077.87	664.79	\$664.79	181.7	181.7	0%	100%
23	Steam Trap Repair (for trap size ≤ 1/2")- Commercial Space Heating - Operating Pressure > 50 psi and < 200 psi	6	1,455.87	651.08	\$651.08	29.8	29.8	0%	100%
24	Steam Trap Repair (for trap size ≤ 1/2") - Commercial Space Heating (High Use) - Operating Pressure > 50 psi and < 200 psi	6	2,873.43	651.08	\$651.08	58.7	58.7	0%	100%
25	Steam Trap Repair (for trap size ≤ 1/2")- Commercial Continuous Use (non-space heating) - Operating Pressure > 50 psi and ≤ 150 psi	6	5,517.25	664.79	\$664.79	110.4	110.4	0%	100%
26	Steam Trap Repair (for trap size ≤ 1/2") - Commercial Continuous Use (non-space heating) - Operating Pressure > 150 psig	6	9,077.87	664.79	\$664.79	181.7	181.7	0%	100%
27	Steam Trap Repair (for trap size ≥ 3/4") - Commercial Space Heating - Operating Pressure > 50 psi and < 200 psi	6	1,455.87	526.08	526.08	36.8	36.8	0%	100%
28	Steam Trap Repair (for trap size ≥ 3/4") - Commercial Space Heating (High Use) - Operating Pressure > 50 psi and < 200 psi	6	2,873.43	526.08	526.08	72.7	72.7	0%	100%
29	Steam Trap Repair (for trap size ≥ 3/4") - Commercial Continuous Use (non-space heating) - Operating Pressure > 50 psi and ≤ 150 psi	6	5,517.25	539.79	539.79	136.0	136.0	0%	100%
30	Steam Trap Repair (for trap size ≥ 3/4") - Commercial Continuous Use (non-space heating) - Operating Pressure > 150 psig	6	9,077.87	539.79	539.79	223.8	223.8	0%	100%

Requirements

- Must replace or repair existing steam trap.
- Steam traps 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 the 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 steam trap-pipe connection size and project costs in the Project Tracker for use in future measure updates.

Implementation Details

- Steam traps for use in space heating multifamily settings use measure #1,7, & 13
- Steam traps for use in space heating in commercial settings use measures #2, 3, 8, 9, 14, 15, 19, 23, & 27
- Steam traps for use in space heating in commercial high use settings use measures #5, 6, 11, 12, 17, 18, 20, 24, & 28
- This is applicable where steam is used in terminal HVAC equipment such as radiators, unit heaters, air handing units etc. to provide space heating in facilities which are occupied continuously, for example, hospitals, hotels.
- Steam traps for use in continuous use in commercial settings use measures #21, 22, 25, 26, 29, & 30
- Such continuous use systems include steam systems that run 24x7 and provide steam for end uses such as sterilization, domestic hot water, heating hot water, clean steam generators.

- Steam traps for use in dry cleaners use measure #4

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 method⁴ 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 research⁵.
- 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 must 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%⁶.

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.

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

Where,

- Boiler efficiency is assumed to be 80% based on the ‘Oregon Commercial and Industrial Boilers Market Characterization’ Study by Cadeo in December 2020⁷ (see Fig 10 of the report).
- Number of hours steam trap is under pressure and different steam end uses are defined below:
 - Steam system for space heating end use in commercial facilities (≤ 50psig, and > 50psig to < 200psig): 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) 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.

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>

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](https://www.icc.illinois.gov/downloads/public/2022%20IL-TRM%20Version%2010.0%20Volume%202%20Commercial%20and%20Industrial%20Measures%20(Final).pdf)

- Space heating end use in 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.
- Steam systems for space heating end use in commercial facilities (high use) (≤ 50 psig, and > 50 psig to < 200 psig): 4,380 hours/year. 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.
- Steam systems in continuous use and/or for non-space heating applications in commercial facilities (> 50 psig to ≤ 150 psig, and > 150 psig): 8,410 hours/year- This estimate is based on inputs from facility/plant operations staff at healthcare facilities. The steam for such systems is usually limited between the steam generator and a heat exchanger (on the other side of the exchanger can be hot water for domestic hot water or heating hot water). They are shut down for maintenance when needed and are run for 1-2 years continuously without a shut down. For calculation purposes in the MAD, a conservative estimate of annual shut down of around 2 weeks was assumed.
- 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./Latent Heat (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
150	857
200	837

- CR is Condensate Recovery Factor: When a steam trap fails in an 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:

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

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)

Facility Type	Operating Pressure (psig)	Orifice Size (inch)	Estimated Energy Savings (therms)
Commercial -space heating	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
	75	1/8	167.00
		7/32	511.43
		5/16	1,043.74
		1/2	2,671.97
	100	1/8	208.66
		7/32	639.01
		5/16	1,304.10
		1/2	3,338.51
	150	1/8	288.31
		7/32	882.94
		5/16	1,801.91
		1/2	4,612.90
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

Facility Type	Operating Pressure (psig)	Orifice Size (inch)	Estimated Energy Savings (therms)
Commercial (High Use) -space heating	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
	75	1/8	329.60
		7/32	1,009.40
		5/16	2,060.01
		1/2	5,273.63
	100	1/8	411.82
		7/32	1,261.21
		5/16	2,573.89
		1/2	6,589.16
	150	1/8	569.02
		7/32	1,742.64
		5/16	3,556.40
		1/2	9,104.40
Commercial Continuous Use (non-space heating)	75	1/8	632.87
		7/32	1,938.15
		5/16	3,955.41
		1/2	10,125.84
	100	1/8	790.74
		7/32	2,421.63
		5/16	4,942.10
		1/2	12,651.79
	150	1/8	1,092.58
		7/32	3,346.02
		5/16	6,828.62
		1/2	17,481.27
	200	1/8	1,380.01
		7/32	4,226.28
		5/16	8,625.06
		1/2	22,080.15

Table 5 Energy savings averaged by facility type and operating pressure

Facility Type	Operating Pressure Range (Psig)	Average Energy Savings (Therms)
Multifamily	≤ 5 psig	116.68
Commercial	< 30 psig	331.79
	≥ 30 psig and ≤ 50 psig	697.80
	> 50 psi and < 200 psi	1,455.87
Dry Cleaning	> 75 psig and ≤ 125 psig	211.14
Commercial (High Use)	< 30 psig	654.86
	≥ 30 psig and ≤ 50 psig	1,377.23
	> 50 psi and < 200 psi	2,873.43
	> 50 psi and ≤ 150 psi	5,517.25
Commercial Continuous Use (non-space heating)	> 150 psig	9,077.87

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
1" inv. Bucket	250	-	-	-	-	-	\$1,067.00

The energy savings calculations consider four orifice sizes - 1/8", 7/32", 5/16" and 1/2" and steam system pressure ranging between 0.5 psig and 200psig. 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.
 - c. For newly introduced steam traps with operating pressure ranges of 50-200psig where orifice size data was not available
- 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 the 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 2024 dollars using a 2021 to 2024 inflation factor obtained from the RTF's Standard Information Workbook v4.8¹⁰. The average resulting costs for trap replacement are shown in Table 7.

Feedback from Production Efficiency program staff indicated that the cost for steam traps with pressure ranges between 50-200psig are estimated to be 20% higher than those below 50psig. Accordingly, total costs for used for the higher-pressure commercial space heating (regular, high use, and continuous use) steam traps were increased by 20%.

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 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 could save more than \$100-\$150 over replacement on larger traps (≥ 1"). Since data on cost savings from repairs for larger

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

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

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	\$495.47	\$495.47	\$370.47
Commercial	< 30 psig	\$553.99	\$553.99	\$428.99
	≥ 30 psig and ≤ 50 psig	\$581.97	\$581.97	\$456.97
	> 50 psi and < 200 psi	\$651.08	\$651.08	\$526.08
Dry Cleaning	> 75 psig and ≤ 125 psig	\$380.23	\$380.23	\$255.23
Commercial (High Use)	< 30 psig	\$553.99	\$553.99	\$428.99
	≥ 30 psig and ≤ 50 psig	\$581.97	\$581.97	\$456.97
	> 50 psi and < 200 psi	\$651.08	\$651.08	\$526.08
Commercial Continuous Use	> 50 psi and ≤ 150 psi	\$664.79	\$664.79	\$539.79
	> 150 psig	\$664.79	\$664.79	\$539.79

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 unit (per 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 42.6.5. 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\commercial steam traps



42.6.5_OR-WA CE
Calculator v2.1 Com

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
10/18/24	42.5	Measure applications for 50-200psig steam pressure introduced, costs updated
10/24/24	42.6	Change start date

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 Commercial and Multifamily Condensing Boilers

Valid Dates
1/1/2026 through 12/31/2028

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 is 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
Update costs and savings.

Cost-Effectiveness
Cost-effectiveness is demonstrated for Oregon in Table 1 and Washington in Table 2. Cost-effectiveness was calculated using the tool: OR-WA-CE Calculator 2026-v1.0. The Oregon electric avoided cost year is 2026 and the Oregon gas avoided cost year is 2026. The Washington gas avoided cost year is 2026. 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	1.29	7.33	0.00	\$7.33	5.5	5.5	0%	100%
2	Condensing Boiler - Healthcare	25	0.00	4.09	7.33	0.00	\$7.33	17.2	17.2	0%	100%
3	Condensing Boiler - Office	25	0.00	0.66	7.33	0.00	\$7.33	2.8	2.8	0%	100%
4	Condensing Boiler - Restaurant	25	0.00	1.58	7.33	0.00	\$7.33	6.6	6.6	0%	100%
5	Condensing Boiler - Retail	25	0.00	0.98	7.33	0.00	\$7.33	4.1	4.1	0%	100%
6	Condensing Boiler - School	25	0.00	0.75	7.33	0.00	\$7.33	3.1	3.1	0%	100%
7	Condensing Boiler - Hotel	25	0.00	1.60	7.33	0.00	\$7.33	6.7	6.7	0%	100%
8	Condensing Boiler - Warehouse	25	0.00	0.73	7.33	0.00	\$7.33	3.1	3.1	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	1.28	7.33	0.00	\$7.33	8.2	8.2	0%	100%
2	Condensing Boiler - Healthcare	25	4.11	7.33	0.00	\$7.33	28.6	28.6	0%	100%
3	Condensing Boiler - Office	25	0.63	7.33	0.00	\$7.33	4.4	4.4	0%	100%
4	Condensing Boiler - Restaurant	25	1.60	7.33	0.00	\$7.33	11.1	11.1	0%	100%
5	Condensing Boiler - Retail	25	0.98	7.33	0.00	\$7.33	6.8	6.8	0%	100%
6	Condensing Boiler - School	25	0.75	7.33	0.00	\$7.33	5.2	5.2	0%	100%
7	Condensing Boiler - Hotel	25	1.60	7.33	0.00	\$7.33	11.1	11.1	0%	100%
8	Condensing Boiler - Warehouse	25	0.74	7.33	0.00	\$7.33	5.1	5.1	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 are assumed not to 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

Mixed use buildings shall be classified by the space type with the greatest square footage served by the system. The classification shall be used to determine the appropriate measure application. For example, for a mixed used building with office and retail space, if most of the conditioned space is retail, the project shall use measure application number 5: Condensing Boiler – Retail.

Baseline

This measure uses a Full Market Baseline.

ETO’s Commercial and Industrial Boiler Market Characterization Memo¹ highlights the high prevalence of above-code (condensing) efficient boilers. Therefore, the assumed baseline is a mix of non-condensing (minimally code complaint) and above-code (condensing) efficient boilers. Boiler efficiencies and their respective market shares are based on RTF’s current practice assumptions listed in their Commercial Gas Boiler Standard Protocol,² as shown 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% TE	Single stage	Balanced, non-condensing
	Scenario 2: Condensing boiler	40%	94% TE	Modulating, 5:1 turndown	Balanced, condensing

Baseline energy consumption is the weighted average of condensing and non-condensing boilers using the scenario weights listed in Table 3.

Measure Analysis

RTF’s Commercial Gas Boiler Calculator³ was used 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:

$$\text{Savings}_{\text{NewBoiler}} = (\text{CPS}_{\text{ShareNonCondensing}} * \text{Gas}_{\text{NonCondensingCP}} + \text{CPS}_{\text{ShareCondensing}} * \text{Gas}_{\text{CondensingCP}}) - \text{Gas}_{\text{new}}$$

Where:

- Savings_{NewBoiler} = annual energy savings, therms
- CPS_{ShareNonCondensing} = current practice share of non-condensing boilers
- Gas_{NonCondensingCP} = baseline annual gas consumption non-condensing boilers, therms
- CPS_{ShareCondensing} = current practice share of condensing boilers
- Gas_{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 (these factors are built into the calculator). The adjusted EUI is multiplied by a user defined square footage and an RTF assumed annual seasonal efficiency to determine the annual thermal load. The following are the user inputs and selections made in the calculator for each building type:

- Heating Zone
- Building Type
- Building Area
- Boiler Capacity
- Boiler Efficiency

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 TMYx weather files for Salem (Salem.Muni.AP-McNary.Field) for HZ1 and Redmond (Redmond.Muni.AP-Roberts.Field) for HZ2 as recommended in ETO’s Measure Development Technical Guidelines 2025. 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 for each building subsector (for both HZ1 and HZ2) were averaged and then weighted by their installed water boiler capacity weights (calculated using Commercial Building Stock Assessment 4-2019⁴), as summarized in Table 4.

¹ [EnergyTrust_CIGasBoilerMarketResearch-Memo_FINAL.pdf](#)
² <https://nwcouncil.box.com/v/ComGasBoilersSPv1-2>
³ <https://nwcouncil.box.com/v/ComGasBoilersCalc1-2>
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	0.64
	Outpatient Healthcare	0.36
Office	Office - Large	0.33
	Office - Medium	0.33
	Office - Small	0.33
Restaurant	Restaurant - full service	0.50
	Restaurant - quick service	0.50
Retail	Retail - stand alone	0.50
	Retail - strip mall	0.50
School	School - Primary	0.47
	School - Secondary	0.53
Lodging	Hotel - large	0.50
	Hotel - small	0.50
Warehouse	Warehouse	1.00

Subsector savings were then calculated using the subsector weights outlined above and normalized by boiler output capacity. Building areas were retrieved from ASHRAE Standard 90.1-2022 Prototype Building Models⁵. Total boiler capacity was determined by multiplying the RTF calculator’s design peak heating load output by ASHRAE’s Boiler Sizing Factor. Savings for each subsector for HZ1 and HZ2 are summarized in Table 5 and Table 6 below:

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	33,741	540	4,614	3,881	733	1.28
Hospital	241,501	3,350	150,570	135,068	15,502	2.79
Outpatient Healthcare	40,946	290	12,925	11,791	1,134	1.31
Office - Large	498,588	24,130	131,548	107,081	24,467	0.32
Office - Medium	53,628	6,400	13,490	11,533	1,957	0.10
Office - Small	5,502	340	1,714	1,481	233	0.22
Restaurant - full service	5,502	120	2,081	1,848	233	0.91
Restaurant - quick service	2,501	80	975	858	117	0.69
Retail - stand alone	24,692	400	4,538	3,992	546	0.64
Retail - strip mall	22,500	380	4,136	3,865	271	0.34
School - Primary	73,959	2,210	18,042	15,563	2,479	0.50
School - Secondary	210,887	5,820	46,770	43,854	2,916	0.25
Hotel - large	122,120	1,100	15,127	13,951	1,176	0.50
Hotel - small	43,202	340	5,654	4,861	793	1.10
Warehouse	52,045	660	7,355	6,837	518	0.74

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	33,741	490	5,450	4,676	774	1.48
Hospital	241,501	5,320	185,893	165,248	20,645	2.34
Outpatient Healthcare	40,946	360	16,297	14,688	1,609	1.50
Office - Large	498,588	25,010	156,177	129,280	26,897	0.34
Office - Medium	53,628	3,560	16,008	13,627	2,381	0.21
Office - Small	5,502	270	1,969	1,747	222	0.26
Restaurant - full service	5,502	130	2,379	2,223	156	0.56
Restaurant - quick service	2,501	80	1,153	1,024	129	0.76
Retail - stand alone	24,692	400	5,542	4,901	641	0.75
Retail - strip mall	22,500	410	4,983	4,724	259	0.30
School - Primary	73,959	2,100	21,484	18,930	2,554	0.54
School - Secondary	210,887	4,980	55,210	53,034	2,176	0.22
Hotel - large	122,120	1,120	17,795	16,688	1,107	0.46
Hotel - small	43,202	370	6,784	5,900	884	1.12
Warehouse	52,045	820	8,929	8,353	576	0.66

Final savings are weighted by heating zone - assuming 93% of projects in HZ1 and 7% in HZ2 and HZ3.⁶

Comparison to RTF or other programs

RTF’s Commercial Gas Boiler Protocol Calculator was used to determine savings for all building types. The calculator’s default weather files and hourly heating loads are for Seattle (HZ1) and Elko (HZ2). In this update, TMYx weather data for HZ1 Salem (Salem.Muni.AP-McNary.Field) and HZ2 Redmond (Redmond.Muni.AP-Roberts.Field) were used instead.

Measure Life

The measure life is assumed to be 25 years based on findings from the following sources:

⁵ <https://www.energycodes.gov/prototype-building-models#ASHRAE>

⁶ ETO’s Measure Development Technical Guidelines 2025

- ETO’s Commercial and Industrial Boiler Market Characterization 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. 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 reports on a 25-year life

Load Profile

Gas profile

- ‘Res Heating’ for Multifamily building type
- ‘Com Heating’ for all other building types

Electric profile

- “None’ for all building types

Cost

Costs for boilers <2,500 MBH were sourced from vendor/distributor online pricing. Pricing for boilers larger than 2,500 MBH was sourced from the DOE’s Energy Conservation Standards for Commercial Packaged Boilers; Final Rule⁷, with the reported values adjusted to 2026 dollars using RTF’s most up-to-date Standard Information Workbook⁸ inflation factor. 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.⁹ The incremental cost for each boiler category was weighted by its project uptake share (based on most current PT data), as shown in Table 7. The average incremental cost across all equipment categories is \$7.33.

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	23.42	36.26	30.23	39.12	8.89	15%	1.31
≥300 & ≤2,500	19.06	28.16	22.70	28.16	5.46	67%	3.66
>2,500 & ≤10,000	7.37	18.01	11.63	18.01	6.38	18%	2.36

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

- Update future building type subsector weights using Commercial Building Stock Assessment 2025¹⁰
- Check RTF for updates to its boiler standard protocol and calculator

Supporting Documents

The cost effectiveness screening for these measures is number 88.4.3. It is attached and can be found along with supporting documentation at: \\etoo.org\home\Groups\Planning\Measure Development\Commercial and Industrial\Commercial HVAC\boilers\Condensing hot water boiler



88.4.3_OR WA CEC
2026_v1.0 boilers.xls

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.

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.
8/26/2025	88.4	Update costs and savings

⁷ <https://www.energy.gov/eere/buildings/downloads/issuance-2016-12-28-energy-conservation-program-energy-conservation-1>

⁸ <https://nwcouncil.app.box.com/v/RTFSIWorkbook-5-0>

⁹ <https://www.regulations.gov/document?D=EERE-2013-BT-STD-0030-0083>

¹⁰ [Commercial Building Stock Assessment - Northwest Energy Efficiency Alliance \(NEEA\)](#)

Table 9 Related Measures

Measures	MAD ID
Modulating boiler burners and controls (inactive starting 2026)	142
Process hot water boiler calculator tool (inactive)	226
Commercial condensing tankless water heaters	72
Pool Heaters	238

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Disclaimer

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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-J₂) which is an efficiency metric with units of ft³/kWh/cycle. An MEF-J₂ 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-J₂ 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 2021⁵.

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 4.3⁶

Dryer use is calculated as follows:

$$D_E = [(F_{max} \cdot Max\ load\ weight) + (F_{avg} \cdot Avg\ load\ weight) + (F_{min} \cdot Min\ load\ weight)] \times (RMC_{corr} - 4\%) \cdot DEF \cdot DUF$$

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 Calculation 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 (ft³) is specific to each qualifying unit as determined in the CEC database
- MEF (modified energy factor, (ft³/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

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Planning Engineer

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Measure Approval Document for Commercial Condensing Gas Furnace

Valid Dates

January 1, 2025 through December 31, 2027

End Use or Description

Condensing natural gas AFUE rated furnaces with less than 225 kBtu/h input capacity installed in small to medium commercial buildings.

Applicability

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

- Existing Buildings
- New Buildings

Within these programs, applicability to the following building types is expected:

- All small and medium commercial buildings except for multifamily

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

- New
- Replacement

Purpose of Re-Evaluating Measure

- Updates to savings and cost estimates.

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_2025_v_2_1. The Oregon electric avoided cost year is 2025 and the Oregon gas avoided cost year is 2025. The Washington gas avoided cost year is 2025. The values in these tables are per kBtu/hr, sometimes referred to as kBtuh.

Table 1 Cost-Effectiveness Calculator Oregon, per kBtuh

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs (\$)	Total NEB (Annual \$)	Maximum Incentive (\$)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Furnace >=95% AFUE in existing commercial buildings	20	1.58	1.81	\$32.42	\$0.00	\$32.42	1.7	1.7	4%	96%
2	Furnace >=95% AFUE in new commercial buildings	20	2.18	1.58	\$32.42	\$0.00	\$32.42	1.5	1.5	7%	93%
3	Furnace >=95% AFUE in existing commercial buildings - Gas Only	20	0.00	1.81	\$32.42	\$0.23	\$32.42	1.6	1.7	0%	100%
4	Furnace >=95% AFUE in new commercial buildings - Gas Only	20	0.00	1.58	\$32.42	\$0.32	\$32.42	1.4	1.5	0%	100%

Table 2 Cost-Effectiveness Calculator Washington, per kBtuh

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs (\$)	Total NEB (Annual \$)	Maximum Incentive (\$)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Furnace >=95% AFUE in existing commercial buildings	20	1.81	\$32.42	\$0.12	\$32.42	2.1	2.1	0%	100%
2	Furnace >=95% AFUE in new commercial buildings	20	1.58	\$32.42	\$0.17	\$32.42	1.8	1.9	0%	100%

Requirements

- Natural gas condensing furnace must have input capacity less than 225 kBtu/h
- Furnace must be used as the primary heating source for the space
- Furnaces must meet minimum 95% AFUE efficiency requirement
- Furnaces must have either a multispeed or variable speed ECM supply fan.

Conditional Requirements for New Construction Program Use

- Adoption of ASHRAE 90.1-2022 as the new Oregon Energy Efficiency Specialty Code is expected to occur sometime in 2024. If Oregon adopts the Energy Credits requirements of ASHRAE 90.1-2022 (Section 11.5) and if Energy Credit selections can be verified by programs, projects claiming the HVAC Heating Performance Improvement Energy Credit for code compliance are ineligible for these measures.

Baseline

This measure uses a Code Baseline.

Based on information from the Existing Building Program's local outreach team, small and medium building customers are assumed to purchase code efficient furnace products 1) to avoid the extra cost and 2) the potential for added difficulty with condensing system ventilation requirements.

Preliminary market research from the AHRI and California Energy Commissioning (CEC) databases show that most units have AFUEs of 81% or less. This generally aligns with the 80% or 81% AFUE required by codes. Furthermore, online web-scraping from four prominent online retailers shows a similar breakdown of efficiencies available for sale in the market. Although this is not sales data, this database and online retailer analysis shows that minimally code compliant efficiencies make up between 56% and 64% of available models in the market.

The Building Codes Division (BCD) is set to adopt ASHRAE 90.1–2022 for the upcoming 2024 OEESC update. ASHRAE 90.1- 2022¹ uses the same minimum required furnace efficiency as the outgoing code version OEESC / ASHRAE 90.1-2019². These also correspond to Code of Federal Regulations (CFR) 10 CFR 430 Appendix N³.

Baseline Furnace Efficiency

Baseline furnace AFUE is 80% based on ASHRAE 90.1 2022 Table F-4 minimum required efficiency for non-weatherized gas fired warm air furnaces with input capacity less than 225,000 Btu/h. Although Table F-4 does provide an 81% minimum AFUE for weatherized furnaces, according to the Appliance Standards Awareness Project, non-weatherized units are by far the most common units installed.

Figure 1 ASHRAE 90.1-2019, Appendix F, Table F-4
Table F-4 Residential Furnaces—Minimum Efficiency Requirements for U.S. Applications (see 10 CFR 430)

Product Class	Size Category (input)	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure ^a
Furnace, gas fired	<225,000 Btu/h	Nonweatherized excluding mobile home	80% AFUE	10 CFR 430 Appendix N
		Nonweatherized mobile home	80% AFUE	
		Weatherized	81% AFUE	
Furnace oil fired	<225,000 Btu/h	Nonweatherized excluding mobile home	83% AFUE $P_{W,SB} \leq 11\text{ W}$ $P_{W,OFF} \leq 11\text{ W}$	10 CFR 430 Appendix N
		Nonweatherized mobile home	75% AFUE $P_{W,SB} \leq 11\text{ W}$ $P_{W,OFF} \leq 11\text{ W}$	
		Weatherized	78% AFUE	
Electric furnace	<225,000 Btu/h	All	78% AFUE $P_{W,SB} \leq 10\text{ W}$ $P_{W,OFF} \leq 10\text{ W}$	10 CFR 430 Appendix N

a. Section 13 contains a complete specification of the referenced test procedure.

Baseline Fan Controls

ASHRAE 90.1 Section 6.5.3.2.1 Supply Fan Airflow Control states that systems should have modulating fan control with minimum speed not exceeding 50%, at which the fan shall draw no more than 30% power. Additional details on this requirement are found in ASHRAE 90.1-2022, Appendix F, Table G3.1.3.15 “Part-Load Performance for VAV Fan Systems.” ASHRAE does not require multi-speed or variable speed controls specifically.

Furnaces in the market include several different control capabilities such as single speed, multispeed, and continuously variable speed (also known as variable air volume or VAV). To inform modelling inputs for fan control, various sources were reviewed. The AHRI database has no information on the fan control capabilities of each furnace, and the CEC database has very limited information. Based on the online retailer data collected, all units available online have either multispeed or variable speed fans. A weighting of both the multispeed and variable speed units was used in the baseline and efficient case. The unit energy consumption for both fan control types were weighted based on the percentage of baseline efficiency units that use each control type.

Table 3 Fan Control Distribution from Online Retailer Analysis

Description	Percent Multispeed Units (%)	Percent Variable Speed Units (%)
Standard Efficiency, 80% AFUE Rated Furnace	77%	23%
Condensing Furnace, ≥95% AFUE Rated Furnace	52%	48%

Measure Analysis

Energy modeling was conducted using Modelkit with EnergyPlus to determine energy consumption in both baseline and measure cases. Commercial building simulation models published by the RTF⁴, listed in Table 4 below, were used as prototype building models for both existing and new buildings. The models are based on commercial building prototype models published by the Department of Energy and are calibrated to regional monthly billing data of the Pacific Northwest using Commercial Building Stock Assessment (CBSA) 2019 data by the RTF.

Table 4 RTF Building Prototypes

Modeled RTF Building Types
Healthcare - Outpatient
Small Office
Restaurant - Full Service
Restaurant - Quick Service
Retail - Stand Alone
Retail - Strip Mall
School - Primary
Warehouse

Furnace Efficiency

Energy Plus models do not include an input parameter that is exactly analogous to AFUE. Instead, furnace systems use a parameter called burner efficiency, which represents the amount of useful heat that the air absorbs from the burner/heating coil compared to burner input heat. AFUE represents the ratio of total useful heating energy to the total fuel consumption for the system, which includes parameters like parasitic loads and other losses. As a proxy value to burner efficiency, the estimated thermal efficiency (TE) for each unit in the AHRI database was calculated by taking the ratio of its output and input capacities. Subsequently, the average thermal efficiency values for all units within a range of AFUE values associated with the base and efficient cases were found. The values in Table 5 were used to model the base and efficient case burner efficiencies.

¹ American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE). 2022. ANSI/ASHRAE/IES Standard 90.1-2022, Energy Standard for Buildings Except Low-Rise Residential Buildings (I-P Edition).
² Oregon Department of Energy. 2019. 2019 OREGON ZERO ENERGY READY COMMERCIAL CODE, PART I, Commercial Energy Provisions
³ United States Department of Energy. 2020. Title 10: Energy, Part 430 - ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS Subpart C—Energy and Water Conservation Standards
⁴ Commercial Building Simulation Models - <https://rtf.nwccouncil.org/commercial-building-simulation-models/>

Table 5 Average Thermal Efficiencies from AHRI Database

Efficiency Tier	Average TE (%)
Base Case, 80% AFUE	81%
Efficient Case, ≥95% AFUE	97%

Fan Curves

Part load fan performance for fans in existing buildings was obtained from ASHRAE 90.1-2022 Appendix F, Table G3.2.3.15 “Part-Load Performance for VAV Fan Systems.”

Figure 2 ASHRAE 90.1-2022, Appendix F, Table G3.1.3.15

Table G3.2.3.15 Part-Load Performance for VAV Fan Systems

Method 1—Part-Load Fan Power Data	
Fan Part-Load Ratio	Fraction of Full-Load Power
0.00	0.00
0.10	0.03
0.20	0.07
0.30	0.13
0.40	0.21
0.50	0.30
0.60	0.41
0.70	0.54
0.80	0.68
0.90	0.83
1.00	1.00
Method 2—Part-Load Fan Power Equation	
$P_{fan} = 0.0013 + 0.1470 \times PLR_{fan} + 0.9506 \times (PLR_{fan})^2 - 0.0998 \times (PLR_{fan})^3$	
where	
P_{fan} = fraction of full-load fan power and	
PLR_{fan} = fan part-load ratio (current cfm/design cfm)	

Part load fan performance for fans in new buildings was obtained from ASHRAE 90.1-2022 Appendix L, Table L4.2.3-1 “Fan and Pump Power Curve Coefficients”. For new buildings, the fans have static pressure reset.

Figure 3 ASHRAE 90.1-2022, Appendix L, Table L4.2.3-1

Table L4.2.3-1 Fan and Pump Power Curve Coefficients

Equation Term	Fan Power Coefficients		Pump Power Coefficients	
	VSD (no Static Pressure Reset)	VSD + Static Pressure Reset	Ride Pump Curve	VSD + Differential Pressure/Valve Reset
b	0.0013	0.0408	0	0
x	0.147	0.088	3.2485	0.0205
x^2	0.9506	−0.0729	−4.7443	0.4101
x^3	−0.0998	0.9437	2.5295	0.5753

Fan Control Weighting

The market is represented mainly by multispeed and variable speed units. The percentages of multispeed and variable speed units were found based on the online pricing analysis and were used to weight the energy consumption for the base and efficient cases.

Table 6 Model Weighting Percentages for Different Fan Controls and Efficiency Tiers

Efficiency Tier	Multispeed Fan Weight (%)	Variable Fan Weight (%)
Base Case, 80% AFUE	77%	23%
Efficient Case, ≥95% AFUE	52%	48%

Fan Efficiency

ASHRAE 90.1 Section 6.5.3.1.3 Fan Efficiency provides fan efficiency requirements for HVAC systems. However, there is an exception for embedded fans of 5 HP or less. The AFUE rated furnaces applicable to this offer will not have motors greater than 3 or 4 HP, thus ASHRAE’s fan efficiency requirements do not apply.

AHRI database includes fan efficiency data in the form of the Fan Energy Rating (FER) and is expressed as watts used per 1000 CFM. After analyzing the data no relationships could be identified between FER and other furnace parameters such as furnace capacity, AFUE, and motor type. Thus, no fan efficiency improvement is assumed between the base and measure case fan efficiencies. The average FER for all units in the AHRI database is 266 W/1000 CFM, or 0.266 W/CFM.

Savings

The difference in modeled electric energy (kWh) and natural gas (therms) between the weighted baseline and efficient cases was found and then divided by the total modelled furnace capacity (kBtuh) to calculate the normalized unit energy savings for each building type and climate zone permutation, using the formula below.

$$Unit\ Energy\ Savings_{kWh\ or\ therms} = \frac{Baseline\ Energy_{kWh\ or\ therms} - Efficient\ Case\ Energy_{kWh\ or\ therms}}{Total\ Furnace\ Capacity_{kBtuh}}$$

The furnace capacities (kBtuh) are left for Modelkit to autosize for each model. Thus, each permutation of building type and climate zone has a different capacity used in the calculation.

Energy models were completed for all relevant RTF prototype models for both existing and new buildings. The savings for existing and new buildings are found in the Table 7 and Table 8 below:

Table 7 Existing Building Savings

Building Type	Heating Zone 1		Heating Zone 2	
	Savings (Therms/kBtuh)	Savings (kWh/kBtuh)	Savings (Therms/kBtuh)	Savings (kWh/kBtuh)
Healthcare - Outpatient	2.25	2.60	2.32	2.74
Small Office	1.70	2.53	1.44	2.05
Restaurant - Full Service	3.05	0.70	2.67	1.08
Restaurant - Quick Service	2.60	0.66	2.41	0.94
Retail - Stand Alone	1.25	2.37	1.05	1.97
Retail - Strip Mall	1.77	1.04	1.40	1.37
School - Primary	1.18	1.58	1.07	1.79
Warehouse	2.14	0.00	1.78	0.00

Table 8 New Building Savings

Building Type	Heating Zone 1		Heating Zone 2	
	Savings (Therms/kBtuh)	Savings (kWh/kBtuh)	Savings (Therms/kBtuh)	Savings (kWh/kBtuh)
Healthcare - Outpatient	2.21	4.19	2.27	4.44
Small Office	1.21	3.16	1.12	2.46
Restaurant - Full Service	2.97	1.91	2.60	2.40
Restaurant - Quick Service	2.56	1.86	2.38	2.17
Retail - Stand Alone	0.94	2.65	0.80	2.17
Retail - Strip Mall	1.72	1.93	1.38	2.33
School - Primary	0.95	2.50	0.87	2.84
Warehouse	1.86	0.59	1.53	0.67

Climate Zone and Building Type Weighting

The above savings were then weighed according to building type and climate zone.

To estimate the weights for building type, data from CBSA 2019 was used, which provided information about the total area of a particular building type in Oregon. The building type categories listed in CBSA data were different from the categories of the modeled RTF building types. Building type categories were aligned between the two sources, and those in the CBSA not relevant to this measure were removed from the dataset. The building type weight percentages can be found in Table 9 below:

Table 9 Building Type Weights

Modeled RTF Building Types	% Weights
Healthcare - Outpatient	14.49%
Small Office	19.57%
Restaurant - Full Service	1.75%
Restaurant - Quick Service	0.89%
Retail - Stand Alone	20.00%
Retail - Strip Mall	20.00%
School - Primary	0.91%
Warehouse	22.38%

The climate type weights are based guidance from on Energy Trust Measure Development Technical Guidelines 2024 for heating or heating-dominated measures. The guidelines state that simplified population weightings as shown in Table 14-6 in the document may be used. The weightings are shown in Table 10 below.

Table 10 Climate Zone Weights

Heating Zone	Weight
1	93.00%
2 and 3	7.00%

After applying the weights in the above tables, the final savings are listed in Table 11 below:

Table 11 Energy Savings per kBtuh

Measure	Savings (kWh/kBtuh)	Savings (Therms/kBtuh)
Furnace >=95% AFUE in existing commercial buildings	1.81	1.58
Furnace >=95% AFUE in new commercial buildings	1.58	2.18

Comparison to RTF or other programs

The Energy Trust New Commercial Construction program offers a measure for condensing furnaces in multifamily buildings. The measure currently uses an eQuest 3.5 energy model to estimate savings and the heating loads are assumed to be different.

Measure Life

20 years based on SB1149 guidelines and DEER database for High Efficiency Furnace (EUL ID: HVAC-Frnc).

Load Profile

The electric profile is Retail Ventilation, and the gas profile is Com Heating

Cost

Incremental costs were calculated by using the difference between baseline and measure case costs.

To estimate the baseline costs, an inflation factor was applied to baseline costs calculated in the previous version of this MAD (220.1). The baseline costs are inclusive of materials and labor.

The inflation factor was derived from the GDP Deflator tool in the RTF Standard Information Workbook v4.8⁵. The baseline cost estimate was \$37.77 per kBtu.

The measure case costs were estimated using Project Tracker data. A median of costs of all the projects implemented using this measure was used to estimate the measure case costs. The data included 26 projects and the costs are inclusive of materials and labor. The measure cost estimate was \$70.19 per kBtuh.

The incremental measure cost used for this measure is \$32.42 per kBtuh.

Non-Energy Benefits

In gas-only territories, customer electric bill savings were converted to non-energy benefits using blended commercial retail rates.

Incentive Structure

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

Follow-Up

Participation by building type will be tracked for existing and new buildings to reestablish weighting and to inform if additional building types must be modelled.

Supporting Documents

The cost effectiveness screening for these measures is number 270.2.2 It is attached and can be found along with supporting documentation at: \\Etoo.org\home\Groups\Planning\Measure Development\Commercial and Industrial\Commercial HVAC\Furnaces\commercial furnace



270.2.2_OR-WA-CE
Calculator_2025_v_2

References

If there are lots of references listed here, footnotes are an option too. Use what works for you.
If you mention any other MAD, list ID and version number.

Version History and Related Measures

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

Table 12 Version History

Date	Version	Reason for revision
2004	86	Various commercial gas measures (deactivated at an unknown date)
7/26/2021	270.1	Introduce commercial furnaces
10/18/2024	270.2	Savings update due to updated prototype models and updates to cost estimates

Table 13 Related Measures

Measures	MAD ID
Condensing Furnaces in Multifamily	203

Approved & Reviewed by

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(he/him)

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⁵ RTF Standard Information Workbook v4.8 - <https://nwcouncil.box.com/v/RTF-SIW-v4-8>

Measure Approval Document for High Efficiency Commercial Fryers

Valid Dates
1/1/2025 – 12/31/2027

End Use or Description
High efficiency commercial electric and gas fryers which exceed ENERGY STAR v3.0 specifications.

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, but not limited to:

- Full and quick service restaurants, including those in mixed use buildings such as hotels or casinos.
- Cafeterias or other commercial kitchens such as those found in grocery stores, hospitals, schools etc.

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

- New
- Replacement

Purpose of Re-Evaluating Measure
Reintroduced with new high efficiency requirements.

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 2025-v2.1. The Oregon electric avoided cost year is 2025 and the Oregon gas avoided cost year is 2025. The Washington gas avoided cost year is 2025. 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 (\$)	Maximum Incentive (\$)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Gas Fryers - Standard Vat (≥ 54% efficiency, ≤ 8000 BTU/hr)	12	0.00	259.74	3,073.50	\$3,073.50	1.1	1.1	0%	100%
2	Gas Fryers - Large Vat (≥ 56% efficiency, ≤ 10,000 BTU/hr)	12	0.00	317.69	4,336.17	\$4,148.95	1.0	1.0	0%	100%
3	Electric Fryers - Standard or Split Vat (≥ 85% efficiency, ≤ 700watts)	12	2,724.82	0.00	1,197.50	\$1,197.50	2.5	2.5	100%	0%
4	Electric Fryers - Large Vat (≥ 88% efficiency, ≤ 1,000 watts)	12	1,949.50	0.00	1,430.50	\$1,430.50	1.5	1.5	100%	0%

Table 2 Cost-Effectiveness Calculator Washington, per unit

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs (\$)	Maximum Incentive (\$)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Gas Fryers - Standard Vat (≥ 54% efficiency, ≤ 8000 BTU/hr)	12	259.74	3,073.50	\$3,073.50	1.1	1.1	0%	100%
2	Gas Fryers - Large Vat (≥ 56% efficiency, ≤ 10,000 BTU/hr)	12	317.69	4,336.17	\$4,200.52	1.0	1.0	0%	100%

Requirements
Participants must be customers of participating utility providing the fryer fuel.

Fryer must be labeled as ENERGY STAR v.3 (or be on the current ENERGY STAR QPL) and meet the following additional requirements in Table 3 according to fryer type:

Table 3 Requirements

	Gas Fryers	Electric Fryers
Standard Vat	≥ 54% efficiency Idle Energy Rate ≤ 8000 BTU/hr	≥ 85% efficiency Idle Energy Rate ≤ 700 watts
Large Vat	≥ 56% efficiency Idle Energy Rate ≤ 10,000 BTU/hr	≥ 88% efficiency Idle Energy Rate ≤ 1,000 watts

Baseline
This measure uses a market baseline equivalent to code. Baseline equipment is defined by meeting the minimum ENERGY STAR v.2¹ requirements which have been the Oregon Code standard as of Jan 2022 per HB2062.²

¹https://www.energystar.gov/ia/partners/prod_development/revisions/downloads/commercial_fryers/Final_Version_2.0_Commercial_Fryer_Specification.pdf?6f81-cd61
² <https://olis.oregonlegislature.gov/liz/2021R1/Downloads/MeasureDocument/HB2062/Enrolled>

Table 4 ENERGY STAR v.2 requirements
Cooking Energy Efficiency and Idle Energy Rate Requirements – Standard Fryers

Table 1: Energy Efficiency Requirements for Standard Open Deep-Fat Gas Fryers	
Heavy-Load Cooking Energy Efficiency	≥ 50%
Idle Energy Rate	≤ 9,000 Btu/hr

Table 2: Energy Efficiency Requirements for Standard Open Deep-Fat Electric Fryers	
Heavy-Load Cooking Energy Efficiency	≥ 80%
Idle Energy Rate	≤ 1000 watts

Cooking Energy Efficiency and Idle Energy Rate Requirements – Large Vat Fryers

Table 3: Energy Efficiency Requirements for Large Vat Open Deep-Fat Gas Fryers	
Heavy-Load Cooking Energy Efficiency	≥ 50%
Idle Energy Rate	≤ 12,000 Btu/hr

Table 4: Energy Efficiency Requirements for Large Vat Open Deep-Fat Electric Fryers	
Heavy-Load Cooking Energy Efficiency	≥ 80%
Idle Energy Rate	≤ 1,100 watts

Efficiency standards have not changed significantly between v2.0 and v3.0, and specifications for gas fryers and large vat electric fryers have not changed (see Table 4). Furthermore, feedback from vendors has confirmed that customers tend to purchase code-baseline models, and so v 2.0 will serve as the baseline for this measure.**Error! Reference source not found.** Table 5 is a summary comparison of requirements between v2.0³ and v3.0⁴:

Table 5 ENERGY STAR v.2 vs. v3 requirements

Fryer Type		Efficiency Parameter	Difference between ES v2.0 and v3.0
Gas Fryers	Standard	Heavy Load Cooking Efficiency	No change ≥ 50%
		Idle Energy Rate	No change ≤ 9,000 Btu/hr
	Large Vat	Heavy Load Cooking Efficiency	No change ≥ 50%
		Idle Energy Rate	No change ≤ 12,000 Btu/hr
Electric Fryers	Standard	Heavy Load Cooking Efficiency	Updated ≥ 80% (v2.0) vs. ≥ 83% (v3.0)
		Idle Energy Rate	Updated ≤ 1,000 watts (v2.0) vs. ≤ 800 watts (v3.0)
	Large Vat	Heavy Load Cooking Efficiency	No change ≥ 80%
		Idle Energy Rate	No change ≤ 1,100 watts

Measure Analysis and Savings

Savings were calculated using ENERGY STAR’s Commercial Food Service (CFS) Calculator⁵ for each model in the ENERGY STAR QPL⁶ meeting the proposed high-efficiency requirements. This was done by editing the following inputs in the Calculator’s ‘fryer savings’ tab:

- Baseline: minimum ENERGY STAR v.2 cooking energy efficiency and idle energy rate
- Proposed: cooking energy efficiency and idle energy rate of high-efficiency model
- Baseline and Proposed: Production/Shortening Capacity as listed on ENERGY STAR’s QPL (the same for both cases)

The default assumptions in ENERGY STAR’s calculator for all remaining inputs were not edited. As there is no known single fryer type dominating the market, individual model savings were then averaged by fryer type using a straight average by product count. Model requirements and savings are summarized in Table 6 below:

Table 6 Savings summary

Type	Baseline Requirement (ES v.2)		Measure Requirement (high efficiency)		Savings		
	Cooking Efficiency	Idle Energy Rate	Cooking Efficiency	Idle Energy Rate	Min	Max	Average
Gas Fryers - Standard Vat	≥ 50% efficiency	≤ 9000 BTU/hr	≥ 54% efficiency	≤ 8000 BTU/hr	128	383	260 therms
Gas Fryers - Large Vat	≥ 50% efficiency	≤ 12,000 BTU/hr	≥ 56% efficiency	≤ 10,000 BTU/hr	149	448	318 therms
Electric Fryers - Standard or Split Vat	≥ 80% efficiency	≤ 1,000 watts	≥ 85% efficiency	≤ 700watts	2196	3261	2725 kWh
Electric Fryers - Large Vat	≥ 80% efficiency	≤ 1,100 watts	≥ 88% efficiency	≤ 1,000 watts	1655	2316	1950 kWh

Comparison to RTF

The RTF recently introduced new tiers for fryers⁷ in response to state standards. Because of timing, their requirements for cooking efficiency and idle rate for fryers differ from Energy Trusts. RTF used a different savings analysis approach resulting in lower savings than this analysis.

³ Program Requirements Product Specification for Commercial Fryers (energystar.gov)
⁴ ENERGY STAR Commercial Fryers Final Draft V3.0 Specification
⁵ https://www.energystar.gov/sites/default/files/2024-03/CFS%20Equipment%20Calculator.xlsx
⁶ https://www.energystar.gov/productfinder/download/certified-commercial-fryers/
⁷ https://rtf.nwcouncil.org/measure/fryers/

Measure Life

An estimated useful equipment life of 12 years is based on the industry-standard assumption for equipment life span and matches the default assumptions in the ENERGY STAR CFS Calculator for all fryer types.

This measure life is intended to represent the life of the equipment including it’s potential future presence in the use equipment market.

Load Profile

Gas fryers:

- Electric Load Profile: “None – ele”
- Gas Load Profile: “Flat – gas”

Electric fryers:

- Electric Load Profile: “Restaurant Cooking”
- Gas Load Profile: “None – gas”

Cost

Costs for both baseline and proposed fryers were primarily collected from vendors; this was done by providing vendors with ENERGY STAR’s current QPL for the vendors to fill out cost information for the models they carry. In instances where more cost data points were needed for baseline and/or proposed fryers, costs were gathered from online retailers. All costs collected for both baseline and proposed cases were confirmed as ‘for equipment only’ by requesting that vendors quote costs for additional features separately. This eliminated most models from the cost analysis. For example, add-on oil filters can cost extra and were not included in the baseline and efficient case costs. Costs were then averaged by fryer type (i.e. Gas Fryers – Standard, Gas Fryers - Large Vat, Electric Fryers - Standard or Split Vat, Electric Fryers - Large Vat) for both baseline and proposed cases. A summary of costs collected is in Table 7 below:

Table 7 Cost Summary

Type	Baseline		Measure		Incremental Cost
	Cost Range	Average Cost	Cost Range	Average Cost	
Gas Fryers - Standard Vat	\$1,100-\$5,681	\$2,977.00	\$1,602-\$8,300	\$6,050.50	\$3,073.50
Gas Fryers - Large Vat	\$4,200-\$4,875	\$4,537.50	\$8,010-\$9,500	\$8,873.67	\$4,336.17
Electric Fryers - Standard or Split Vat	\$7,343	\$7,343.00	\$6,600-\$9,800	\$8,540.50	\$1,197.50
Electric Fryers - Large Vat	\$13,070	\$13,070.00	\$9,900-\$23,318	\$14,500.50	\$1,430.50

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. The max incentive for standard gas is higher than some of the qualifying product costs, incentives should not exceed actual product cost.

Follow-Up

- Costs and savings should be re-evaluated in future iterations of this measure, especially if ENERGY STAR develops new standards beyond v.3 and/or updates its commercial savings calculator.
- Realistic costs should be assumed in the future, especially if project data indicates customers are selecting models with additional features excluded from current cost analyses.
- Sales volume data by model should be gathered in future interactions with vendors so that costs and savings can be weighed by quantity of models sold/installed by type.
- Program should consider aligning requirements with RTF.
- If they remain on the same update schedule, this measure should be included in the food service equipment MAD (101).

Supporting Documents

The cost effectiveness screening for these measures is number 272.2.2. It is attached and can be found along with supporting documentation at: \\Etoo.org\home\Groups\Planning\Measure Development\Commercial and Industrial\Food Service\Cooking Equipment\fryers



272.2.2 OR_WA CE
Calculator 2025 v2.1

Version History and Related Measures

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

Table 8 Version History

Date	Version	Reason for revision
4/7/05	x.x	Revise gas fryer measures.
3/22/07	x.x	Revise gas fryer savings, add gas convection oven.
10/14/09	101.x	Merge several cooking approvals into single document, revise all savings and costs, remove electric griddles and electric fryers.
7/16/13	101.x	Update fryer costs.
9/23/13	101.x	Change format to include maximum incentives.
8/7/14	101.1	Update costs. Add electric griddles, electric fryers, electric combination ovens and gas combination ovens. Add multifamily and production efficiency as applicable programs.
7/9/2018	101.2	Update hours of use and latest Energy Star specifications. Cost updates.
7/25/18	101.3	Add rack ovens to food service MAD.
8/2/21	272.1	Temporary approval for fryers, expiring on a different schedule than 101 due to state standard.
10/23/24	272.2	Reintroducing commercial fryer measure for high-efficiency models.

Table 9 Related Measures

Measures	MAD ID
Commercial Energy Star Cooking Equipment	101
Commercial Dishwashers	35
Commercial Ice Machines	90
Venthood Controls Prescriptive	122
Venthood Controls Calculator	184

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Measure Approval Document for Commercial Insulation

Valid Dates
1/1/2026 – 12/31/2028

End Use or Description

Installation of insulation above the roof deck, in walls, below the roof deck / under flat ceilings, under pitched attics, and on the floor of attics in commercial buildings/facilities where there was none previously or only a negligible amount is present. Increased insulation reduces heat transfer through the building envelope. This leads to reduced heating and cooling loads and that results in 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 building types (but is not limited to):

- Healthcare (hospital, outpatient, & residence)
- Hotel
- Office
- Restaurant
- Retail
- School
- Warehouse

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

- Retrofit

Purpose of Re-Evaluating Measure

Building prototype models, savings, and costs have been updated. In addition, new measures were added for metal building wall and roof insulation.

Cost-Effectiveness

Cost-effectiveness is demonstrated for Oregon in Table 1 through Table 4 and Washington in Table 5. Cost-effectiveness was calculated using the tool: OR-WA-CE Calculator 2026-v1.0. The Oregon electric avoided cost year is 2026 and the Oregon gas avoided cost year is 2026. The Washington gas avoided cost year is 2026. The values in these tables are per sf of insulation.

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
1	HZ1 - Above Roof Deck Insulation - R0 to R30 - ER	25	18.86	0.00	8.70	0.00	\$8.70	6.6	6.6	100%	0%
2	HZ2 - Above Roof Deck Insulation - R0 to R30 - ER	25	21.60	0.00	8.70	0.00	\$8.70	7.6	7.6	100%	0%
5	HZ1 - Above Roof Deck Insulation - R0 to R30 - HP	25	13.09	0.00	8.70	0.00	\$8.70	3.4	3.4	100%	0%
6	HZ2 - Above Roof Deck Insulation - R0 to R30 - HP	25	16.42	0.00	8.70	0.00	\$8.70	4.2	4.2	100%	0%
7	HZ1 - Above Roof Deck Insulation - R5 or less to R30 - ER	25	4.45	0.00	8.70	0.00	\$8.70	1.6	1.6	100%	0%
8	HZ2 - Above Roof Deck Insulation - R5 or less to R30 - ER	25	5.56	0.00	8.70	0.00	\$8.70	1.9	1.9	100%	0%
11	HZ1 - Above Roof Deck Insulation - R5 or less to R30 - HP	25	3.24	0.00	8.70	0.00	\$7.26	1.0	0.8	100%	0%
12	HZ2 - Above Roof Deck Insulation - R5 or less to R30 - HP	25	4.15	0.00	8.70	0.00	\$8.70	1.1	1.1	100%	0%
13	HZ1 - Attic & Below Deck Insulation - R0 to R38 - ER	30	7.29	0.00	2.77	0.00	\$2.77	9.2	9.2	100%	0%
14	HZ2 - Attic & Below Deck Insulation - R0 to R38 - ER	30	8.47	0.00	2.77	0.00	\$2.77	10.7	10.7	100%	0%
17	HZ1 - Attic & Below Deck Insulation - R0 to R38 - HP	30	6.15	0.00	2.77	0.00	\$2.77	5.6	5.6	100%	0%
18	HZ2 - Attic & Below Deck Insulation - R0 to R38 - HP	30	7.06	0.00	2.77	0.00	\$2.77	6.5	6.5	100%	0%
19	HZ1 - Attic & Below Deck Insulation - R5 or less to R38 - ER	30	2.62	0.00	2.77	0.00	\$2.77	3.3	3.3	100%	0%
20	HZ2 - Attic & Below Deck Insulation - R5 or less to R38 - ER	30	3.26	0.00	2.77	0.00	\$2.77	4.1	4.1	100%	0%
23	HZ1 - Attic & Below Deck Insulation - R5 or less to R38 - HP	30	1.93	0.00	2.77	0.00	\$2.77	1.8	1.8	100%	0%
24	HZ2 - Attic & Below Deck Insulation - R5 or less to R38 - HP	30	2.55	0.00	2.77	0.00	\$2.77	2.3	2.3	100%	0%
25	HZ1 - Wall Insulation - R0 to R20 - ER	30	7.74	0.00	1.98	0.00	\$1.98	13.6	13.6	100%	0%
26	HZ2 - Wall Insulation - R0 to R20 - ER	30	8.67	0.00	1.98	0.00	\$1.98	15.2	15.2	100%	0%
29	HZ1 - Wall Insulation - R0 to R20 - HP	30	5.87	0.00	1.98	0.00	\$1.98	7.5	7.5	100%	0%
30	HZ2 - Wall Insulation - R0 to R20 - HP	30	6.26	0.00	1.98	0.00	\$1.98	8.0	8.0	100%	0%
31	HZ1 - Wall Insulation - R5 or less to R20 - ER	30	2.28	0.00	1.98	0.00	\$1.98	4.0	4.0	100%	0%
32	HZ2 - Wall Insulation - R5 or less to R20 - ER	30	2.76	0.00	1.98	0.00	\$1.98	4.8	4.8	100%	0%
35	HZ1 - Wall Insulation - R5 or less to R20 - HP	30	1.65	0.00	1.98	0.00	\$1.98	2.1	2.1	100%	0%
36	HZ2 - Wall Insulation - R5 or less to R20 - HP	30	1.97	0.00	1.98	0.00	\$1.98	2.5	2.5	100%	0%

#	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	HZ1 - Metal Building Roof Insulation - R0 to R30 - ER	25	25	24.53	0.00	3.63	0.00	\$3.63	20.6	100%	0%
38	HZ2 - Metal Building Roof Insulation - R0 to R30 - ER	25	25	28.08	0.00	3.63	0.00	\$3.63	23.6	100%	0%
41	HZ1 - Metal Building Roof Insulation - R0 to R30 - HP	25	25	12.23	0.00	3.63	0.00	\$3.63	7.6	100%	0%
42	HZ2 - Metal Building Roof Insulation - R0 to R30 - HP	25	25	15.88	0.00	3.63	0.00	\$3.63	9.8	100%	0%
43	HZ1 - Metal Building Roof Insulation - R5 or less to R30 - ER	25	25	4.73	0.00	3.63	0.00	\$3.63	4.0	100%	0%
44	HZ2 - Metal Building Roof Insulation - R5 or less to R30 - ER	25	25	6.03	0.00	3.63	0.00	\$3.63	5.1	100%	0%
47	HZ1 - Metal Building Roof Insulation - R5 or less to R30 - HP	25	25	2.39	0.00	3.63	0.00	\$3.63	1.5	100%	0%
48	HZ2 - Metal Building Roof Insulation - R5 or less to R30 - HP	25	25	3.39	0.00	3.63	0.00	\$3.63	2.1	100%	0%
49	HZ1 - Metal Building Wall Insulation - R0 to R20 - ER	30	30	4.90	0.00	1.68	0.00	\$1.68	10.2	100%	0%
50	HZ2 - Metal Building Wall Insulation - R0 to R20 - ER	30	30	5.98	0.00	1.68	0.00	\$1.68	12.4	100%	0%
53	HZ1 - Metal Building Wall Insulation - R0 to R20 - HP	30	30	2.27	0.00	1.68	0.00	\$1.68	3.4	100%	0%
54	HZ2 - Metal Building Wall Insulation - R0 to R20 - HP	30	30	3.07	0.00	1.68	0.00	\$1.68	4.7	100%	0%
55	HZ1 - Metal Building Wall Insulation - R5 or less to R20 - ER	30	30	1.44	0.00	1.68	0.00	\$1.68	3.0	100%	0%
56	HZ2 - Metal Building Wall Insulation - R5 or less to R20 - ER	30	30	1.86	0.00	1.68	0.00	\$1.68	3.9	100%	0%
59	HZ1 - Metal Building Wall Insulation - R5 or less to R20 - HP	30	30	0.67	0.00	1.68	0.00	\$1.68	1.0	100%	0%
60	HZ2 - Metal Building Wall Insulation - R5 or less to R20 - HP	30	30	0.96	0.00	1.68	0.00	\$1.68	1.5	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
3	HZ1 - Above Roof Deck Insulation - R0 to R30 - Gas heat	25	1.26	0.87	8.70	0.00	\$8.70	3.4	3.4	10%	90%
4	HZ2 - Above Roof Deck Insulation - R0 to R30 - Gas heat	25	1.41	1.00	8.70	0.00	\$8.70	3.9	3.9	9%	91%
9	HZ1 - Above Roof Deck Insulation - R5 or less to R30 - Gas heat	25	0.24	0.21	8.70	0.00	\$7.02	1.0	0.8	8%	92%
10	HZ2 - Above Roof Deck Insulation - R5 or less to R30 - Gas heat	25	0.36	0.26	8.70	0.00	\$8.70	1.0	1.0	9%	91%
15	HZ1 - Attic & Below Deck Insulation - R0 to R38 - Gas heat	30	0.40	0.32	2.77	0.00	\$2.77	4.4	4.4	8%	92%
16	HZ2 - Attic & Below Deck Insulation - R0 to R38 - Gas heat	30	0.47	0.38	2.77	0.00	\$2.77	5.1	5.1	9%	91%
21	HZ1 - Attic & Below Deck Insulation - R5 or less to R38 - Gas heat	30	(0.03)	0.12	2.77	0.00	\$2.77	1.5	1.5	0%	100%
22	HZ2 - Attic & Below Deck Insulation - R5 or less to R38 - Gas heat	30	0.00	0.15	2.77	0.00	\$2.77	1.8	1.8	0%	100%
27	HZ1 - Wall Insulation - R0 to R20 - Gas heat	30	0.36	0.37	1.98	0.00	\$1.98	6.8	6.8	7%	93%
28	HZ2 - Wall Insulation - R0 to R20 - Gas heat	30	0.36	0.42	1.98	0.00	\$1.98	7.7	7.7	6%	94%
33	HZ1 - Wall Insulation - R5 or less to R20 - Gas heat	30	0.00	0.11	1.98	0.00	\$1.98	2.0	2.0	0%	100%
34	HZ2 - Wall Insulation - R5 or less to R20 - Gas heat	30	0.02	0.14	1.98	0.00	\$1.98	2.4	2.4	1%	99%
39	HZ1 - Metal Building Roof Insulation - R0 to R30 - Gas heat	25	0.73	1.02	3.63	0.00	\$3.63	9.1	9.1	5%	95%
40	HZ2 - Metal Building Roof Insulation - R0 to R30 - Gas heat	25	1.01	1.15	3.63	0.00	\$3.63	10.4	10.4	6%	94%
45	HZ1 - Metal Building Roof Insulation - R5 or less to R30 - Gas heat	25	0.14	0.20	3.63	0.00	\$3.63	1.7	1.7	5%	95%
46	HZ2 - Metal Building Roof Insulation - R5 or less to R30 - Gas heat	25	0.21	0.25	3.63	0.00	\$3.63	2.2	2.2	6%	94%
51	HZ1 - Metal Building Wall Insulation - R0 to R20 - Gas heat	30	0.15	0.20	1.68	0.00	\$1.68	4.4	4.4	5%	95%
52	HZ2 - Metal Building Wall Insulation - R0 to R20 - Gas heat	30	0.22	0.25	1.68	0.00	\$1.68	5.3	5.3	6%	94%
57	HZ1 - Metal Building Wall Insulation - R5 or less to R20 - Gas heat	30	0.05	0.06	1.68	0.00	\$1.68	1.3	1.3	5%	95%
58	HZ2 - Metal Building Wall Insulation - R5 or less to R20 - Gas heat	30	0.07	0.08	1.68	0.00	\$1.68	1.7	1.7	6%	94%

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
61	HZ1 - Above Roof Deck Insulation - R0 to R30 - Gas heat Gas only	25	0.00	0.87	8.70	\$0.21	\$8.70	3.1	3.5	0%	100%
62	HZ2 - Above Roof Deck Insulation - R0 to R30 - Gas heat Gas only	25	0.00	1.00	8.70	\$0.23	\$8.70	3.5	3.9	0%	100%

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs (\$)	Total NEB (Annual \$)	Maximum Incentive (\$)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
63	HZ1 - Above Roof Deck Insulation - R5 or less to R30 - Gas heat Gas only	25	0.00	0.21	8.70	\$0.04	\$6.47	1.0	0.8	0%	100%
64	HZ2 - Above Roof Deck Insulation - R5 or less to R30 - Gas heat Gas only	25	0.00	0.26	8.70	\$0.06	\$7.97	1.0	1.0	0%	100%
65	HZ1 - Attic & Below Deck Insulation - R0 to R38 - Gas heat Gas only	30	0.00	0.37	1.98	\$0.06	\$1.98	6.4	6.9	0%	100%
66	HZ2 - Attic & Below Deck Insulation - R0 to R38 - Gas heat Gas only	30	0.00	0.42	1.98	\$0.06	\$1.98	7.3	7.8	0%	100%
67	HZ1 - Attic & Below Deck Insulation - R5 or less to R38 - Gas heat Gas only	30	0.00	0.11	1.98	\$0.00	\$1.98	2.0	2.0	0%	100%
68	HZ2 - Attic & Below Deck Insulation - R5 or less to R38 - Gas heat Gas only	30	0.00	0.14	1.98	\$0.00	\$1.98	2.4	2.4	0%	100%
69	HZ1 - Wall Insulation - R0 to R20 - Gas heat Gas only	25	0.00	1.02	3.63	\$0.12	\$3.63	8.6	9.1	0%	100%
70	HZ2 - Wall Insulation - R0 to R20 - Gas heat Gas only	25	0.00	1.15	3.63	\$0.17	\$3.63	9.8	10.5	0%	100%
71	HZ1 - Wall Insulation - R5 or less to R20 - Gas heat Gas only	25	0.00	0.20	3.63	\$0.02	\$3.63	1.7	1.8	0%	100%
72	HZ2 - Wall Insulation - R5 or less to R20 - Gas heat Gas only	25	0.00	0.25	3.63	\$0.03	\$3.63	2.1	2.3	0%	100%
73	HZ1 - Metal Building Roof Insulation - R0 to R30 - Gas heat Gas Only	30	0.00	0.20	1.68	\$0.02	\$1.68	4.1	4.4	0%	100%
74	HZ2 - Metal Building Roof Insulation - R0 to R30 - Gas heat Gas Only	30	0.00	0.25	1.68	\$0.04	\$1.68	5.0	5.4	0%	100%
75	HZ1 - Metal Building Roof Insulation - R5 or less to R30 - Gas heat Gas Only	30	0.00	0.06	1.68	\$0.01	\$1.68	1.2	1.3	0%	100%
76	HZ2 - Metal Building Roof Insulation - R5 or less to R30 - Gas heat Gas Only	30	0.00	0.08	1.68	\$0.01	\$1.68	1.6	1.7	0%	100%
77	HZ1 - Metal Building Wall Insulation - R0 to R20 - Gas heat Gas Only	25	0.00	0.87	8.70	\$0.21	\$8.70	3.1	3.5	0%	100%
78	HZ2 - Metal Building Wall Insulation - R0 to R20 - Gas heat Gas Only	25	0.00	1.00	8.70	\$0.23	\$8.70	3.5	3.9	0%	100%
79	HZ1 - Metal Building Wall Insulation - R5 or less to R20 - Gas heat Gas Only	25	0.00	0.21	8.70	\$0.04	\$6.47	1.0	0.8	0%	100%
80	HZ2 - Metal Building Wall Insulation - R5 or less to R20 - Gas heat Gas Only	25	0.00	0.26	8.70	\$0.06	\$7.97	1.0	1.0	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
81	HZ1 - Above Roof Deck Insulation - R0 to R30 – Gas/other heat Elec only	25	1.26	0.00	8.70	\$1.02	\$2.84	1.0	2.1	100%	0%
82	HZ2 - Above Roof Deck Insulation - R0 to R30 – Gas/other heat Elec only	25	1.41	0.00	8.70	\$1.16	\$3.19	1.0	2.4	100%	0%
83	HZ1 - Above Roof Deck Insulation - R5 or less to R30 – Gas/other heat Elec only	25	0.24	0.00	8.70	\$0.25	\$0.55	1.0	0.5	100%	0%
84	HZ2 - Above Roof Deck Insulation - R5 or less to R30 – Gas/other heat Elec only	25	0.36	0.00	8.70	\$0.30	\$0.83	1.0	0.6	100%	0%
85	HZ1 - Attic & Below Deck Insulation - R0 to R38 – Gas/other heat Elec only	30	0.40	0.00	2.77	\$0.38	\$1.02	1.0	2.6	100%	0%
86	HZ2 - Attic & Below Deck Insulation - R0 to R38 – Gas/other heat Elec only	30	0.47	0.00	2.77	\$0.44	\$1.20	1.0	3.0	100%	0%
89	HZ1 - Wall Insulation Measures - R0 to R20 – Gas/other heat Elec only	30	0.36	0.00	1.98	0.43	\$0.91	1.0	4.0	100%	0%
90	HZ2 - Wall Insulation Measures - R0 to R20 – Gas/other heat Elec only	30	0.36	0.00	1.98	0.49	\$0.90	1.0	4.5	100%	0%
92	HZ2 - Wall Insulation Measures - R5 or less to R20 – Gas/other heat Elec only	30	0.02	0.00	1.98	0.16	\$0.06	1.0	1.4	100%	0%
93	HZ1 - Metal Building Roof Insulation - R0 to R30 – Gas/other heat Elec only	25	0.73	0.00	3.63	1.18	\$1.66	1.0	5.4	0%	100%
94	HZ2 - Metal Building Roof Insulation - R0 to R30 – Gas/other heat Elec only	25	1.01	0.00	3.63	1.35	\$2.30	1.0	6.2	0%	100%
95	HZ1 - Metal Building Roof Insulation - R5 or less to R30 – Gas/other heat Elec only	25	0.14	0.00	3.63	0.23	\$0.31	1.0	1.0	100%	0%
96	HZ2 - Metal Building Roof Insulation - R5 or less to R30 – Gas/other heat Elec only	25	0.21	0.00	3.63	0.29	\$0.47	1.0	1.3	100%	0%

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs (\$)	Total NEB (Annual \$)	Maximum Incentive (\$)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
97	HZ1 - Metal Building Wall Insulation - R0 to R20 – Gas/other heat Elec only	30	0.15	0.00	1.68	0.24	\$0.38	1.0	2.5	100%	0%
98	HZ2 - Metal Building Wall Insulation - R0 to R20 – Gas/other heat Elec only	30	0.22	0.00	1.68	0.29	\$0.55	1.0	3.1	100%	0%
99	HZ1 - Metal Building Wall Insulation - R5 or less to R20 – Gas/other heat Elec only	30	0.05	0.00	1.68	0.07	\$0.11	1.0	0.7	100%	0%
100	HZ2 - Metal Building Wall Insulation - R5 or less to R20 – Gas/other heat Elec only	30	0.07	0.00	1.68	0.09	\$0.17	1.0	1.0	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 - Above Roof Deck Insulation - R0 to R30 - Gas heat Gas only	25	0.87	8.70	\$0.10	\$8.70	5.1	5.3	0%	100%
2	HZ2 - Above Roof Deck Insulation - R0 to R30 - Gas heat Gas only	25	1.00	8.70	\$0.11	\$8.70	5.9	6.1	0%	100%
3	HZ1 - Above Roof Deck Insulation - R5 or less to R30 - Gas heat Gas only	25	0.21	8.70	\$0.02	\$8.70	1.2	1.3	0%	100%
4	HZ2 - Above Roof Deck Insulation - R5 or less to R30 - Gas heat Gas only	25	0.26	8.70	\$0.03	\$8.70	1.5	1.6	0%	100%
5	HZ1 - Attic & Below Deck Insulation - R0 to R38 - Gas heat Gas only	30	0.32	2.77	\$0.03	\$2.77	6.7	6.9	0%	100%
6	HZ2 - Attic & Below Deck Insulation - R0 to R38 - Gas heat Gas only	30	0.38	2.77	\$0.04	\$2.77	7.7	8.0	0%	100%
7	HZ1 - Attic & Below Deck Insulation - R5 or less to R38 - Gas heat Gas only	30	0.12	2.77	\$0.00	\$2.77	2.5	2.5	0%	100%
8	HZ2 - Attic & Below Deck Insulation - R5 or less to R38 - Gas heat Gas only	30	0.15	2.77	\$0.00	\$2.77	3.1	3.1	0%	100%
9	HZ1 - Wall Insulation - R0 to R20 - Gas heat Gas only	30	0.37	1.98	\$0.03	\$1.98	10.6	10.8	0%	100%
10	HZ2 - Wall Insulation - R0 to R20 - Gas heat Gas only	30	0.42	1.98	\$0.03	\$1.98	12.1	12.3	0%	100%
11	HZ1 - Wall Insulation - R5 or less to R20 - Gas heat Gas only	30	0.11	1.98	\$0.00	\$1.98	3.3	3.3	0%	100%
12	HZ2 - Wall Insulation - R5 or less to R20 - Gas heat Gas only	30	0.14	1.98	\$0.00	\$1.98	4.0	4.0	0%	100%
13	HZ1 - Metal Building Roof Insulation - R0 to R30 - Gas heat Gas Only	25	1.02	3.63	\$0.06	\$3.63	14.3	14.5	0%	100%
14	HZ2 - Metal Building Roof Insulation - R0 to R30 - Gas heat Gas Only	25	1.15	3.63	\$0.08	\$3.63	16.3	16.6	0%	100%
15	HZ1 - Metal Building Roof Insulation - R5 or less to R30 - Gas heat Gas Only	25	0.20	3.63	\$0.01	\$3.63	2.8	2.8	0%	100%
16	HZ2 - Metal Building Roof Insulation - R5 or less to R30 - Gas heat Gas Only	25	0.25	3.63	\$0.02	\$3.63	3.5	3.6	0%	100%
17	HZ1 - Metal Building Wall Insulation - R0 to R20 - Gas heat Gas Only	30	0.20	1.68	\$0.01	\$1.68	6.9	7.0	0%	100%
18	HZ2 - Metal Building Wall Insulation - R0 to R20 - Gas heat Gas Only	30	0.25	1.68	\$0.02	\$1.68	8.4	8.5	0%	100%
19	HZ1 - Metal Building Wall Insulation - R5 or less to R20 - Gas heat Gas Only	30	0.06	1.68	\$0.00	\$1.68	2.0	2.1	0%	100%
20	HZ2 - Metal Building Wall Insulation - R5 or less to R20 - Gas heat Gas Only	30	0.08	1.68	\$0.01	\$1.68	2.6	2.7	0%	100%

Exceptions

Order No. 22-482 from the OPUC covers exceptions for all measure applications in this MAD with TRC BCRs less than 1.0 for UCT BCR up to 0.8 until 3/2028.

Requirements

All insulation must be installed in areas of the building envelope that separate a conditioned space, as defined below and unconditioned space. Insulation installed between conditioned spaces does not qualify. A conditioned space as defined by ASHRAE 90.1 - 2022¹ is an enclosed space within a building that is heated or heated & cooled by HVAC equipment whose total output relative to the floor area is greater than or equal to the criteria in Table 6. This may be used to verify whether a space can be considered conditioned or not for the purposes of this measure.

Table 6 Heated and Cooled Space Criteria

Space Definition	Climate Zone	Heating or Cooling Output (BTU/h*ft²)
Heated Space	Heating Zone 1	≥8
Heated Space	Heating Zone 2	≥12
Cooled Space	NA	≥3.4

¹ <https://www.ashrae.org/technical-resources/bookstore/standard-90-1>

Projects with damaged or missing insulation using the no insulating value (R-0) measure applications must be prequalified and documented by the installation contractor.

Above roof deck insulation:

- Existing insulation must be R5 or less (including R0)
- Must retrofit to at least R30
- When R-30 requirements cannot be met due to existing site restrictions, a minimum insulation of R-15 must be achieved

Attic & Below Deck insulation:

- Existing insulation must be R5 or less (including R0)
- Must retrofit to at least R38 or fill cavity

Wall insulation:

- Existing insulation must be R5 or less (including R0)
- Must retrofit to at least R20 or fill cavity

Metal building roof insulation:

- Existing insulation must be R5 or less (including R0)
- Must retrofit to at least R30
- When R-30 requirements cannot be met due to existing site restrictions, a minimum insulation of R-20 must be achieved

Metal building wall insulation:

- Existing insulation must be R5 or less (including R0)
- Must retrofit to at least R20 or fill cavity

Implementation details

Measures are organized by space heating fuel, participating utility and state according to Table 7

Table 7 Summary of CEC Tables

CEC Table	Building Heating fuel	Use in			
		Dual Fuel Territory	Gas-Only Territory	Electric-Only Territory	State
Table 1	Electricity	✓		✓	Oregon
Table 2	Natural Gas	✓			Oregon
Table 3	Natural Gas		✓		Oregon
Table 4	Natural Gas or Other			✓	Oregon
Table 5	Natural Gas		✓		Washington

- 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
- Metal buildings are defined as a complete integrated set of mutually dependent components and assemblies that form a building, which consists of a steel framed superstructure and metal skin (definition from ASHRAE 90.1-2022).
- For metal building roof measures, installations either above or below the roof deck are eligible.

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 calculated using whole building simulations performed using Modelkit Flannel v0.7.4. This software uses EnergyPlus v9.2 as the simulation engine and utilizes building prototype models. These building models are maintained by the RTF and are based on DOE commercial building prototypes that have been tailored to existing buildings in the Pacific Northwest using CBSA-2019² data. 17 building types were used to simulate added insulation above the roof deck, in walls, below the roof deck / under flat ceilings, under pitched attics, and on the floor of attics. Models were simulated using TMYX weather files at Salem Municipal Airport (McNary Field) and Redmond Municipal Airport (Roberts Filed) for heating zones 1 and 2/3, respectively.

The RTF building prototype default values were used in all cases except the following:

- The type of heat pump heating system was manually chosen for all simulations using a heat pump as the primary heating source. While many heat pump heating systems have RTF default characteristics, there is no clear indication of which type of heat pump system to use. CBSA 2019 data was used to select the most prevalent type of heat pump heating solution per building type.
- The default warehouse building type frame material is changed to create the modified metal warehouse building type. This prototype is used for all metal building measure simulations.

Table 8 lists the reference building models. For each model, the areas used for unitization, the type of insulation upgrade simulated (X), and heat pump system type used for heat pump measures are also shown. This does not imply that only certain insulation types are applicable to a certain building. All buildings are eligible to participate for all types of insulation, save for metal buildings which must use the associated metal building measures.

² <https://neea.org/commercial-building-stock-assessment/>

Table 8 Energy Modeling Prototype Information

Building Type	Wall Area (sf)	Roof Area (sf)	Above Roof Deck	Wall	Under flat ceiling / under flat roof deck	Under pitched attic	Floor of attic	Metal Building Wall and Roof	Heat Pump Type
Healthcare – Hospital	55,805	40,250	X	X	X	X	X		HP RTU with electric reheat
Healthcare – Outpatient	17,592	13,678	X	X	X	X	X		HP RTU with electric reheat
Healthcare – Residence	23,220	8,435	X	X	X	X	X		PTHP
Hotel – Large	43,334	15,904	X	X	X	X	X		PTHP
Hotel – Small	18,242	10,800	X	X	X				PTHP
Office – Large	124,749	38,353	X	X	X				HP RTU with electric reheat
Office – Medium	21,290	17,875	X	X	X				HP RTU with electric reheat
Office – Small	3,031	6,114		X		X	X		HP RTU with electric reheat
Restaurant – Full Service	2,968	5,502		X		X	X		HP RTU with electric reheat
Restaurant – Quick Service	2,001	2,501		X		X	X		HP RTU with electric reheat
Retail – Stand Alone	12,670	24,692	X	X	X				HP RTU with electric reheat
Retail – Strip Mall	12,746	22,500	X	X	X				HP RTU with electric reheat
Retail – Supermarket	17,322	45,001	X	X	X				HP RTU with electric reheat
School – Primary	27,042	73,858	X	X	X				HP RTU with electric reheat
School – Secondary	68,724	128,112	X	X	X				HP RTU with electric reheat
Warehouse	32,690	49,495	X	X	X				HP RTU with electric reheat
Modified metal warehouse								X	NA

Savings per square foot of insulation for each simulated case are then weighed by the expected participation across each building type. Expected participation is determined by the relative square footage of available conditioned floor space per building type according to CBSA 2019 data for buildings at a vintage equal to or older than the relevant insulation measure life. This is deemed to be more representative of expected participation when compared to PT data, especially as measure requirements and definitions have changed since the last version. Table 9 shows these weights, which are rounded in the MAD, for each simulated insulation upgrade. Due to the lack of granularity available in the CBSA data, all three retail subtypes were assumed to have an equal share of the overall retail space representation. Metal buildings measures are excluded from this table as only a single building type was simulated for those measures.

Table 9 Building Type Weights

Building Type	Above Roof Deck Measures	Wall Measures	Under Flat Ceiling / Under flat roof deck Measures	Under Pitched Attic & Floor of Attic Measures
Healthcare – Hospital	17%	19%	20%	
Healthcare – Outpatient	4%	1%	1%	
Healthcare – Residence	9%	7%	7%	
Hotel – Large	4%	5%	5%	
Hotel – Small	6%	4%	4%	
Office – Large	13%	16%	16%	
Office – Medium	9%	4%	4%	
Office – Small		1%		41%
Restaurant – Full Service		1%		49%
Restaurant – Quick Service		0%		11%
Retail – Stand Alone	2%	2%	2%	
Retail – Strip - Mall	2%	2%	2%	
Retail - Supermarket	2%	2%	2%	
School – Primary	9%	11%	11%	
School – Secondary	14%	16%	17%	
Warehouse	8%	9%	9%	

Weighted savings for insulation added under pitched attics, under flat ceilings / under flat roof decks, under pitched attics, and on the floor of attics are averaged together to create a single Attic & Below Deck measure application.

Additionally, above roof deck and metal building roof measures have been further weighted to condense multiple efficient case R value measures into single measures for each case. This is due to the variety of available space on existing roofs to install insulation and small savings differences between R15, R20, and R30 efficient case upgrades. Table 10 shows these weights and the rationale behind them.

Table 10 Roof Measure Weights

	Efficient Case R-Value	Weight	Rationale
Above Roof Deck Measures	R30	83%	Based on past roof measures PT data
	R15	17%	
Metal Building Roof Measures	R30	50%	Assumed because there is no such past data available
	R20	50%	

The provision of ‘fill cavity’ is for acceptance of cavity insulation R values below required values in wall, attic & below deck measures and is intended to serve edge cases where construction of the building does not make required level insulation possible. This provision is not expected to impact savings calculations as majority of the savings are achieved with the first few inches of insulation.

Measure Life

Insulation measure life will follow SB1149 measure life guidelines³. Attic & below deck insulation is categorized as cavity insulation.

- Above roof deck insulation will use 25 years
- Attic & below deck insulation will use 30 years
- Wall insulation will use 30 years

Load Profile

Per the Measure Development 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. See Table 11 for all load profiles.

Table 11 Load Profiles

	Electric Load Profile	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 for wall insulation are estimated on a square foot basis using median values from PT from 2023 up to the end of 2024. Due to changes in measure application definitions for attic & below deck and above roof deck insulation, costs are estimated using the mean value obtained from local contractor interviews. Estimated costs for the new metal building wall and roof measures are also estimated from using the mean value obtained from local contractor interviews. Additionally, above roof deck and metal roof measure costs have been weighted in the same manner as detailed in the Savings and Analysis section. All costs include material and labor. Costs per square foot, their source, and calculation method for each type of insulation are shown in Table 12.

Table 12 Costs per square foot

Type	Insulation Level (R-Value)	Estimated Cost	Source	Calculation Method
Wall Insulation	R20	\$1.98/ SF	PT	Median
Above Roof Deck Insulation	R30	\$8.70/ SF	Contractor Interviews	Mean, weighed for R15 and R30
Attic & Below Deck Insulation	R38	\$2.77/ SF	Contractor Interviews	Mean of values collected for Under Ceiling and Attic Floor
Metal Building Roof Insulation	R30	\$3.63/ SF	Contractor Interviews	Mean, weighted for R20 and R30
Metal Building Wall Insulation	R20	\$1.68/ SF	Contractor Interviews	Mean

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, Table 2, Table 3, Table 4 and Table 5 are for reference only and are not suggested incentives. Incentives will be structured per SF of insulation.

Follow-Up

For the next MAD update:

- Update costs
- Review latest code updates and code minimum trigger requirements
- NEEA is in the process of collecting data for a new CBSA dataset (2025). Update the CBSA dataset if available
- RTF building prototype models should appropriately update using the new CBSA data
- Consider reducing the total number of measures
- Check how well participation matches with assumed project weighting used, update if necessary.

Supporting Documents

The cost effectiveness screening for these measures is number 68.5.4. It is attached and can be found along with supporting documentation at:



68_5_4_OR-WA-CEC_2026_v_1_0_Comme

³ https://www.oregon.gov/energy/energy-oregon/Documents/SB1149_Schools_Program_Guidelines.pdf

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

Table 13 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
10/22/2025	68.5	Savings, costs, and measure insulation levels changed. Metal building wall and roof measures added

Table 14 Related Measures

Measures	MAD ID
Multifamily Insulation	110

Approved & Reviewed by
Kenji Spielman
Planning Engineer

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Measure Approval Document for Commercial Reach-In Glass Door Refrigerators and Freezers

Valid Dates

January 1, 2024 to December 31, 2026

End Use or Description

This measure covers the installation of new or replacement commercial reach-in refrigerators or freezers with ENERGY STAR compliance. Energy savings come from more efficient operation of the ENERGY STAR units compared to minimally code-compliant units. Units are defined by configuration (vertical glass door configurations are the only ones approved) as well as internal volume (V), as specified in the ENERGY STAR Commercial Refrigerators and Freezers Program Requirements, Version 5.0¹.

As this measure covers only self-contained units, interactive effects with building HVAC resulting from more efficient refrigeration units leads to additional electrical cooling savings and electrical or gas heating penalties. Since measure configurations require knowing building heating fuel, midstream delivery may not be suitable.

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, but not limited to:

- Food retail facilities, such as:
 - Grocery Stores
 - Supermarkets
 - Convenience Stores
 - Liquor Stores
 - Delis
- Facilities with commercial kitchens or commercial refrigeration, such as:
 - Restaurants
 - Hospitals
 - Schools
 - Hotels
 - Pharmacies

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

- New
- Replacement

Purpose of Re-Evaluating Measure

Re-introduce Commercial Refrigerators and Freezers with all-new analysis. Only vertical glass door freezers and vertical glass door refrigerators less than 15 cf are approved.

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 electric avoided cost year is 2024 and the Oregon gas avoided cost year is 2024. The values in this table are per unit.

Additional configurations were analyzed, but not approved due to limited product availability and/or poor cost effectiveness.

¹ [ENERGY STAR® Program Requirements for Commercial Refrigerators and Freezers, Version 5](#), p. 4 of 10.

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	Vertical Glass-Door Reach-In Refrigerator, 0 < V < 15, Electric Heating	10	66.22	0.00	\$22.32	\$0.00	\$22.32	1.8	1.8	100%	0%
9	Vertical Glass-Door Reach-In Freezer, 0 < V < 15, Electric Heating	10	143.29	0.00	\$40.05	\$0.00	\$40.05	2.2	2.2	100%	0%
10	Vertical Glass-Door Reach-In Freezer, 15 ≤ V < 30, Electric Heating	10	263.95	0.00	\$84.03	\$0.00	\$84.03	1.9	1.9	100%	0%
11	Vertical Glass-Door Reach-In Freezer, 30 ≤ V < 50, Electric Heating	10	439.09	0.00	\$196.36	\$0.00	\$196.36	1.4	1.4	100%	0%
12	Vertical Glass-Door Reach-In Freezer, 50 ≤ V, Electric Heating	10	699.43	0.00	\$344.01	\$0.00	\$344.01	1.2	1.2	100%	0%
21	Vertical Glass-Door Reach-In Refrigerator, 0 < V < 15, HP Heating	10	77.47	0.00	\$22.32	\$0.00	\$22.32	2.1	2.1	100%	0%
29	Vertical Glass-Door Reach-In Freezer, 0 < V < 15, HP Heating	10	167.65	0.00	\$40.05	\$0.00	\$40.05	2.5	2.5	100%	0%
30	Vertical Glass-Door Reach-In Freezer, 15 ≤ V < 30, HP Heating	10	308.83	0.00	\$84.03	\$0.00	\$84.03	2.2	2.2	100%	0%
31	Vertical Glass-Door Reach-In Freezer, 30 ≤ V < 50, HP Heating	10	513.74	0.00	\$196.36	\$0.00	\$196.36	1.6	1.6	100%	0%
32	Vertical Glass-Door Reach-In Freezer, 50 ≤ V, HP Heating	10	818.34	0.00	\$344.01	\$0.00	\$344.01	1.4	1.4	100%	0%
41	Vertical Glass-Door Reach-In Refrigerator, 0 < V < 15, Gas Heating	10	87.71	(0.96)	\$22.32	\$0.00	\$22.32	1.9	1.9	100%	0%
49	Vertical Glass-Door Reach-In Freezer, 0 < V < 15, Gas Heating	10	189.79	(2.09)	\$40.05	\$0.00	\$40.05	2.3	2.3	100%	0%
50	Vertical Glass-Door Reach-In Freezer, 15 ≤ V < 30, Gas Heating	10	349.62	(3.85)	\$84.03	\$0.00	\$84.03	2.1	2.1	100%	0%
51	Vertical Glass-Door Reach-In Freezer, 30 ≤ V < 50, Gas Heating	10	581.60	(6.40)	\$196.36	\$0.00	\$196.36	1.5	1.5	100%	0%
52	Vertical Glass-Door Reach-In Freezer, 50 ≤ V, Gas Heating	10	926.44	(10.19)	\$344.01	\$0.00	\$344.01	1.3	1.3	100%	0%
61	Vertical Glass-Door Reach-In Refrigerator, 0 < V < 15, Gas Heating, Electric Only	10	87.71	0.00	\$22.32	-\$1.14	\$22.32	2.4	2.0	100%	0%
69	Vertical Glass-Door Reach-In Freezer, 0 < V < 15, Gas Heating, Electric Only	10	189.79	0.00	\$40.05	-\$2.46	\$40.05	2.9	2.4	100%	0%
70	Vertical Glass-Door Reach-In Freezer, 15 ≤ V < 30, Gas Heating, Electric Only	10	349.62	0.00	\$84.03	-\$4.54	\$84.03	2.5	2.1	100%	0%
71	Vertical Glass-Door Reach-In Freezer, 30 ≤ V < 50, Gas Heating, Electric Only	10	581.60	0.00	\$196.36	-\$7.55	\$196.36	1.8	1.5	100%	0%
72	Vertical Glass-Door Reach-In Freezer, 50 ≤ V, Gas Heating, Electric Only	10	926.44	0.00	\$344.01	-\$12.02	\$344.01	1.6	1.4	100%	0%

Requirements

- Eligible units must meet ENERGY STAR v5.0 requirements.
- Eligible units must be packaged and “self-contained”, where the compressor for cooling is built-in rather than being external. Units with remote refrigeration systems do not qualify.
- Eligible units must have glass doors.
- Customers may not combine this measure with MAD 201 for the same equipment.
- Used or rebuilt equipment is not eligible.
- Sizes much match measure descriptions. Not all sizes are approved.

Implementation Details

- Measure applications 1 and 9-12 are for use in buildings with electric resistance heating.
- Measure applications 21 and 29-32 are for use in buildings with electric heat pumps.
- Measure applications 41 and 49-52 are for use in buildings with gas heating for regions with dual fuel participating utilities.
- Measure applications 61 and 69-72 are for use in buildings with gas or other heating for regions with only electric participating utilities or customers on non-qualifying gas transport rates.

Baseline

This measure uses a Full Market Baseline.

The baseline is assumed to be a 50/50 average of minimally code-compliant² and ENERGY STAR v5.0-compliant refrigerators/freezers based on a 50% market penetration rate for ENERGY STAR v5.0 rated refrigerators and freezers sourced from 2021 ENERGY STAR data³. Minimally code-compliant refrigerators/freezers meet the latest Energy Conservation Standards of the Code of Federal Regulations, 10 CFR § 431.66, which took effect on March 28th, 2017.

Measure Analysis

This measure uses the same methodology used in the RTF’s UES measure for Commercial Refrigerator/Freezers⁴. However, the savings estimates from the RTF’s workbook are not used directly because it uses ENERGY STAR v4.0 specifications for measure case equipment. ENERGY STAR v5.0 specifications are used instead for this MAD. The ENERGY STAR certified product data set⁵ for commercial refrigerators and freezers used in the RTF measure was updated to analyze the most recent products meeting ENERGY STAR v5.0 specifications. In addition, interactive effects between the refrigeration units and the HVAC load were estimated, which are absent in the RTF’s measure methodology.

HVAC interactive effects are estimated using factors from RTF’s StandardInformationWorkbook_v4_8⁶ in the Com HVAC Interaction Factors tab. The Restaurant building type is referenced, as it corresponds best to self-contained refrigeration units. The

² [Code of Federal Regulations](#), Title 10 CFR 431.66.d., p. 3
³ [ENERGY STAR Unit Shipment and Market Penetration Report, Calendar Year 2021 Summary](#), Product Category of “Commercial Refrigerators & Freezers”, p. 5 of 6.
⁴ RTF measure for [Commercial Refrigerators/Freezers](#), Version 5.0.
⁵ [ENERGY STAR certified product data set for Commercial Refrigerators and Freezers](#), data pulled on 7/13/2023 meeting ENERGY STAR v5.0 specifications.
⁶ RTF [StandardInformationWorkbook_v4_8](#), Com HVAC Interaction Factors tab.

disaggregated interaction factors are used for three separate HVAC scenarios: electric heating and cooling, heat pump heating and cooling, and gas heating with electric cooling. Therefore, separate measure applications are needed for each of these HVAC scenarios. Additional measure applications are used for instances when buildings have electric and gas savings with electric-only participating utilities. In those cases of out-of-territory fuel savings, the gas savings are converted to NEB savings.

Energy savings for this measure are estimated as the difference of annual energy consumption of measure case equipment (ENERGY STAR v5.0 equipment) and market baseline equipment of the same type and volume category. The 50% market penetration rate is used to average the code-compliant and ENERGY STAR v5.0-compliant energy consumption for the market baseline.

The equations used for calculating code-compliant case equipment energy consumption is sourced from the Code of Federal Regulations, Title 10 CFR 431.66, which are also shown in Table 2:

Table 2 Code-Compliant Case Equipment Energy Consumption

EQUIPMENT DESCRIPTION (FT³) V = INTERNAL VOLUME IN CUBIC FEET	REFRIGERATION TYPE DESIGNATION	DESCRIPTION	DAILY ENERGY CONSUMPTION (KWH/DAY)
Vertical Solid-Door Reach-In Refrigerator	VCS.SC.M	Vertical Closed Solid, Self-Contained, Medium temp	≤ 0.05V + 1.36
Vertical Solid-Door Reach-In Freezer	VCS.SC.L	Vertical Closed Solid, Self-Contained, Low temp	≤ 0.22V + 1.38
Vertical Glass-Door Reach-In Refrigerator	VCT.SC.M	Vertical Closed Transparent, Self-Contained, Medium temp	≤ 0.1V + 0.86
Vertical Glass-Door Reach-In Freezer	VCT.SC.L	Vertical Closed Transparent, Self-Contained, Low temp	≤ 0.29V + 2.95
Horizontal Solid-Door Reach-In Refrigerator	HCS.SC.M	Horizontal Closed Solid, Self-Contained, Medium temp	≤ 0.05V + 0.91
Horizontal Solid-Door Reach-In Freezer	HCS.SC.L	Horizontal Closed Solid, Self-Contained, Low temp	≤0.06V + 1.12
Horizontal Glass-Door Reach-In Refrigerator	HCT.SC.M	Horizontal Closed Transparent, Self-Contained, Medium temp	≤0.06V + 0.37
Horizontal Glass-Door Reach-In Freezer	HCT.SC.L	Horizontal Closed Transparent, Self-Contained, Low temp	≤0.08V + 1.23

Equations for estimating energy consumption of measure case equipment are found in ENERGY STAR Product Specification for Commercial Refrigerators and Freezers v5.0. There were no horizontal glass door freezers listed on the ENERGY STAR v5.0 QPL.

Equipment is assumed to be operating 24 hours a day and 365 days a year.

Savings

Electrical savings from ENERGY STAR units, energy savings due to HVAC interactive effects, and NEB savings for all cost-effective measure applications are summarized in Table 3. All these values and their calculations are found in the CEC and the ComRefrigeratorFreezer_v5_0_adjust to ES v5.0⁷ workbook.

Table 3 Energy Savings Summary

		Refrigeration Savings	Refrigeration Interactive Effects for HVAC Savings/Penalties			Total Electrical Savings	Total NEB (Annual \$)
#	Measure	Savings (kWh)	Heating Savings (kWh)	Heating Savings (therms)	Cooling Savings (kWh)	Savings (kWh)	
1	Vertical Glass-Door Reach-In Refrigerator, 0 < V < 15, Electric Heating	82.89	-21.49	0.00	4.81	66.22	\$0.00
9	Vertical Glass-Door Reach-In Freezer, 0 < V < 15, Electric Heating	179.37	-46.51	0.00	10.42	143.29	\$0.00
10	Vertical Glass-Door Reach-In Freezer, 15 ≤ V < 30, Electric Heating	330.43	-85.67	0.00	19.19	263.95	\$0.00
11	Vertical Glass-Door Reach-In Freezer, 30 ≤ V < 50, Electric Heating	549.68	-142.51	0.00	31.92	439.09	\$0.00
12	Vertical Glass-Door Reach-In Freezer, 50 ≤ V, Electric Heating	875.59	-227.01	0.00	50.85	699.43	\$0.00
21	Vertical Glass-Door Reach-In Refrigerator, 0 < V < 15, HP Heating	82.89	-10.23	0.00	4.81	77.47	\$0.00
29	Vertical Glass-Door Reach-In Freezer, 0 < V < 15, HP Heating	179.37	-22.15	0.00	10.42	167.65	\$0.00
30	Vertical Glass-Door Reach-In Freezer, 15 ≤ V < 30, HP Heating	330.43	-40.79	0.00	19.19	308.83	\$0.00
31	Vertical Glass-Door Reach-In Freezer, 30 ≤ V < 50, HP Heating	549.68	-67.86	0.00	31.92	513.74	\$0.00
32	Vertical Glass-Door Reach-In Freezer, 50 ≤ V, HP Heating	875.59	-108.10	0.00	50.85	818.34	\$0.00
41	Vertical Glass-Door Reach-In Refrigerator, 0 < V < 15, Gas Heating	82.89	0.00	-0.96	4.81	87.71	\$0.00
49	Vertical Glass-Door Reach-In Freezer, 0 < V < 15, Gas Heating	179.37	0.00	-2.09	10.42	189.79	\$0.00
50	Vertical Glass-Door Reach-In Freezer, 15 ≤ V < 30, Gas Heating	330.43	0.00	-3.85	19.19	349.62	\$0.00
51	Vertical Glass-Door Reach-In Freezer, 30 ≤ V < 50, Gas Heating	549.68	0.00	-6.40	31.92	581.60	\$0.00
52	Vertical Glass-Door Reach-In Freezer, 50 ≤ V, Gas Heating	875.59	0.00	-10.19	50.85	926.44	\$0.00
61	Vertical Glass-Door Reach-In Refrigerator, 0 < V < 15, Gas Heating, Electric Only	82.89	0.00	0.00	4.81	87.71	-\$1.14
69	Vertical Glass-Door Reach-In Freezer, 0 < V < 15, Gas Heating, Electric Only	179.37	0.00	0.00	10.42	189.79	-\$2.46
70	Vertical Glass-Door Reach-In Freezer, 15 ≤ V < 30, Gas Heating, Electric Only	330.43	0.00	0.00	19.19	349.62	-\$4.54
71	Vertical Glass-Door Reach-In Freezer, 30 ≤ V < 50, Gas Heating, Electric Only	549.68	0.00	0.00	31.92	581.60	-\$7.55
72	Vertical Glass-Door Reach-In Freezer, 50 ≤ V, Gas Heating, Electric Only	875.59	0.00	0.00	50.85	926.44	-\$12.02

Comparison to RTF or other programs

RTF’s UES measure for Commercial Refrigerator/Freezers is the basis for this MAD’s savings analysis. While the RTF’s measure workbook was used for savings calculations, the following workbook adjustments were made for this MAD:

- ENERGY STAR v5.0 specifications are used, as the savings estimates from the RTF’s workbook use ENERGY STAR v4.0 specifications for measure case equipment.
- The ENERGY STAR certified product data set for commercial refrigerators and freezers used in the RTF measure was updated to analyze the most recent products meeting ENERGY STAR v5.0 specifications.
- The 50% market baseline was used rather than the code-minimum specifications in the RTF measure.
- Interactive effects between the refrigeration units and the HVAC load are absent in the RTF’s measure methodology, so they were added separately using RTF’s StandardInformationWorkbook_v4_8.

⁷ [ComRefrigeratorFreezer_v5_0_adjust to ES v5.0](#), a modified version of the RTF measure workbook referenced in footnote #4.

The RTF workbook was not used as a source for cost data for vertical configurations because its cost estimates are for the older ENERGY STAR v4.0 specifications.

Measure Life

The measure life is 10 years, which aligns with RTF’s UES measure for Commercial Refrigerator/Freezers.

Load Profile

Electric Load Profile:

- “Refrigeration” for all measure applications

Gas Load Profile:

- “None – gas” for space heating using electricity or for space heating using gas for cases of electric-only participating utilities
- “Flat – gas” for space heating using gas for cases of dual fuel participating utilities

Cost

For vertical configurations, the baseline and measure case material costs are based on 2021 costs from the California eTRM measure – Commercial Reach-In Refrigerator or Freezer⁸, which derives cost data from <https://www.webstaurantstore.com/> using inflation factors and San Francisco price indices. Costs from the California eTRM measure were adjusted for this measure using a San Francisco/Portland cost ratio calculated from 2023 RSMeans datasheets for refrigeration equipment for San Francisco, CA and Portland, OR⁹. Further cost adjustment was done to inflate the 2021 costs to 2023 costs using a 2023/2021 SIW ratio from RTFStandardInformationWorkbook_v4_8.

The baseline cost for each measure application was adjusted using the 50% ENERGY STAR market penetration rate, where 50% of the baseline cost was added to 50% of the measure cost to estimate the market baseline cost.

Incremental cost is the market baseline cost subtracted from the measure case cost. Baseline and measure case installation labor costs are expected to be equal and not included in the incremental costs.

Non Energy Benefits

Out-of-territory gas savings were converted to NEB savings for measure applications having electric-only participating utilities. For all such measure applications, the gas savings from HVAC interactive effects are penalties, resulting in negative NEB values.

Incentive Structure

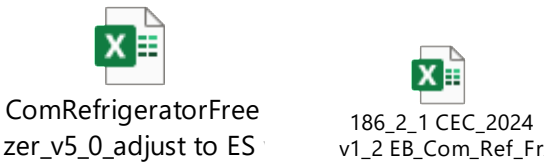
The maximum incentives listed in Table 1 are for reference only and are not suggested incentives. Incentives will be structured per unit.

Follow-Up

At the next update, the measure should be checked for updates to commercial refrigerator and freezer ENERGY STAR specification requirements, ENERGY STAR certified product data, market penetration rates, and costs.

Supporting Documents

The cost effectiveness screening for these measures is number 186.2.1. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Commercial and Industrial\Commercial Appliances\refrigerator and freezer_Commercial\bencost



Version History and Related Measures

Energy Trust has offered measures for commercial refrigerators in the past. These measure predate our measure approval documentation process and our record retention limitations. Table 4 maybe incomplete, especially for measures approved before 2013.

Table 4 Version History

Date	Version	Reason for revision
4/6/2010	186.n/a	Measure introduced for ENERGY STAR Commercial Refrigerators and Freezers.
12/13/2014	186.n/a	Measure sunset un-approval, due to not being cost-effective.
10/26/23	186.2	Measure introduced for Commercial Refrigerators and Freezers, using ENERGY STAR v5.0 requirements.

Table 5 Related Measures

Measures	MAD ID
Refrigerated Case Door Retrofit	47
LED Refrigeration Case Lighting	78
Grocery Refrigeration on Rack Systems	105
Multifamily Refrigerators	112
Antisweat Heater Controls	114
Grocery Evaporator Fan Motors	149
New Refrigerated Cases with Doors	201
Refrigeration Control Calculator Tool	214

⁸ [Commercial Reach-In Refrigerator or Freezer](#), Measure ID SWCR018, Version 03-4, CPUC Approved Sep 1, 2022.

⁹ Data pulled on 5/18/2023.

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Measure Approval Document for Commercial Smart Thermostats

Valid Dates
January 1, 2026 – December 31, 2028

End Use or Description
Smart thermostats that serve single-zone HVAC systems in commercial buildings. The thermostats save energy by optimizing fan mode scheduling and temperature setback/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 methods, building types, and program tracks are expected:

- 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
Savings have been updated to align with the latest RTF workbook. Costs have been updated. Certain requirements have been updated for clarity.

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_2026_v_1_0. The Oregon electric avoided cost year is 2026 and the Oregon gas avoided cost year is 2026. The Washington gas avoided cost year is 2026. 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	%Ele	%Gas
1	Smart Thermostat Grocery - Resistance Heat w/cooling - HZ1	10	2,505.75	0.00	400.00	\$0.00	\$400.00	7.1	7.1	100%	0%
2	Smart Thermostat Grocery - Resistance Heat w/cooling - HZ2	10	2,877.71	0.00	400.00	\$0.00	\$400.00	8.2	8.2	100%	0%
3	Smart Thermostat Grocery - Heat Pump w/ cooling - HZ1	10	1,475.50	0.00	400.00	\$0.00	\$400.00	4.2	4.2	100%	0%
4	Smart Thermostat Grocery - Heat Pump w/ cooling - HZ2	10	1,730.58	0.00	400.00	\$0.00	\$400.00	4.9	4.9	100%	0%
5	Smart Thermostat Grocery - Gas Heat w/ Cooling - HZ1	10	538.91	88.59	400.00	\$0.00	\$400.00	4.7	4.7	26%	74%
6	Smart Thermostat Grocery - Gas Heat w/ Cooling - HZ2	10	687.72	98.58	400.00	\$0.00	\$400.00	5.4	5.4	29%	71%
7	Smart Thermostat Grocery - Resistance Heat NO Cooling - HZ1	10	2,496.30	0.00	400.00	\$0.00	\$400.00	7.1	7.1	100%	0%
8	Smart Thermostat Grocery - Resistance Heat NO Cooling - HZ2	10	2,857.57	0.00	400.00	\$0.00	\$400.00	8.1	8.1	100%	0%
9	Smart Thermostat Grocery - Gas Heat NO Cooling - HZ1	10	529.47	88.59	400.00	\$0.00	\$400.00	4.7	4.7	26%	74%
10	Smart Thermostat Grocery - Gas Heat NO Cooling - HZ2	10	667.58	98.58	400.00	\$0.00	\$400.00	5.4	5.4	28%	72%
11	Smart Thermostat Non-Grocery - Resistance Heat w/cooling - HZ1	10	938.29	0.00	400.00	\$0.00	\$400.00	2.9	2.9	100%	0%
12	Smart Thermostat Non-Grocery - Resistance Heat w/cooling - HZ2	10	1,324.64	0.00	400.00	\$0.00	\$400.00	4.1	4.1	100%	0%
13	Smart Thermostat Non-Grocery - Heat Pump w/ cooling - HZ1	10	581.12	0.00	400.00	\$0.00	\$400.00	1.8	1.8	100%	0%
14	Smart Thermostat Non-Grocery - Heat Pump w/ cooling - HZ2	10	811.22	0.00	400.00	\$0.00	\$400.00	2.5	2.5	100%	0%
15	Smart Thermostat Non-Grocery - Gas Heat w/ Cooling - HZ1	10	256.42	30.98	400.00	\$0.00	\$400.00	1.8	1.8	33%	67%
16	Smart Thermostat Non-Grocery - Gas Heat w/ Cooling - HZ2	10	344.47	44.52	400.00	\$0.00	\$400.00	2.5	2.5	31%	69%
17	Smart Thermostat Non-Grocery - Resistance Heat NO Cooling - HZ1	10	917.24	0.00	400.00	\$0.00	\$400.00	2.8	2.8	100%	0%
18	Smart Thermostat Non-Grocery - Resistance Heat NO Cooling - HZ2	10	1,284.88	0.00	400.00	\$0.00	\$400.00	4.0	4.0	100%	0%
19	Smart Thermostat Non-Grocery - Gas Heat NO Cooling - HZ1	10	235.38	30.98	400.00	\$0.00	\$400.00	1.8	1.8	31%	69%
20	Smart Thermostat Non-Grocery - Gas Heat NO Cooling - HZ2	10	304.71	44.52	400.00	\$0.00	\$400.00	2.5	2.5	29%	71%
Gas only Territory Measures											
22	Smart Thermostat Grocery - Gas Heat w/ Cooling - HZ1 G.O.T	10	0.00	88.59	400.00	\$89.36	\$400.00	3.5	5.3	0%	100%

#	Measure	Measure Life (years)	Savings (kWh)	Savings (therms)	Incremental Costs (\$)	Total NEB (Annual \$)	Maximum Incentive (\$)	UCT BCR at Max Incentive	TRC BCR	%Ele	%Gas
23	Smart Thermostat Grocery - Gas Heat w/ Cooling - HZ2 G.O.T	10	0.00	98.58	400.00	\$114.04	\$400.00	3.9	6.1	0%	100%
24	Smart Thermostat Grocery - Gas Heat NO Cooling - HZ1 G.O.T	10	0.00	88.59	400.00	\$87.79	\$400.00	3.5	5.2	0%	100%
25	Smart Thermostat Grocery - Gas Heat NO Cooling - HZ2 G.O.T	10	0.00	98.58	400.00	\$110.70	\$400.00	3.9	6.1	0%	100%
26	Smart Thermostat Non-Grocery - Gas Heat w/ Cooling - HZ1 G.O.T	10	0.00	30.98	400.00	\$42.52	\$400.00	1.2	2.1	0%	100%
27	Smart Thermostat Non-Grocery - Gas Heat w/ Cooling - HZ2 G.O.T	10	0.00	44.52	400.00	\$57.12	\$400.00	1.7	2.9	0%	100%
28	Smart Thermostat Non-Grocery - Gas Heat NO Cooling - HZ1 G.O.T	10	0.00	30.98	400.00	\$39.03	\$400.00	1.2	2.0	0%	100%
29	Smart Thermostat Non-Grocery - Gas Heat NO Cooling - HZ2 G.O.T	10	0.00	44.52	400.00	\$50.53	\$400.00	1.7	2.8	0%	100%
Electric only Territory Measures											
31	Smart Thermostat Grocery - Gas/Other Heat w/ Cooling - HZ1 E.O.T	10	538.91	0.00	400.00	\$242.49	\$400.00	1.2	6.0	100%	0%
32	Smart Thermostat Grocery - Gas/Other Heat w/ Cooling - HZ2 E.O.T	10	687.72	0.00	400.00	\$269.86	\$400.00	1.6	6.9	100%	0%
35	Smart Thermostat Non-Grocery - Gas/Other Heat w/ Cooling - HZ1 E.O. T	10	529.47	0.00	400.00	\$242.49	\$400.00	1.2	6.0	100%	0%
36	Smart Thermostat Non-Grocery - Gas/Other Heat w/ Cooling - HZ2 E.O. T	10	667.58	0.00	400.00	\$269.86	\$400.00	1.5	6.9	100%	0%
31	Smart Thermostat Grocery - Gas/Other Heat w/ Cooling - HZ1 E.O. T	10	581.12	0.00	400.00	\$0.00	\$400.00	1.8	1.8	100%	0%
34	Smart Thermostat Grocery - Gas/Other Heat NO Cooling - HZ2 E.O. T	10	344.47	0.00	400.00	\$121.88	\$320.09	1.0	3.2	100%	0%
37	Smart Thermostat Non-Grocery - Gas/Other Heat NO Cooling - HZ1 E.O. T	10	235.38	0.00	400.00	\$84.81	\$218.72	1.0	2.2	100%	0%
38	Smart Thermostat Non-Grocery - Gas/Other Heat NO Cooling - HZ2 E.O. T	10	304.71	0.00	400.00	\$121.88	\$283.15	1.0	3.1	100%	0%

Table 2 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	400.00	\$41.55	\$400.00	5.7	6.6	0%	100%
2	Smart Thermostat Grocery - Gas Heat w/ Cooling - HZ2	10	98.58	400.00	\$53.02	\$400.00	6.4	7.5	0%	100%
3	Smart Thermostat Grocery - Gas Heat NO Cooling - HZ1	10	88.59	400.00	\$40.82	\$400.00	5.7	6.6	0%	100%
4	Smart Thermostat Grocery - Gas Heat NO Cooling - HZ2	10	98.58	400.00	\$51.47	\$400.00	6.4	7.4	0%	100%
5	Smart Thermostat Non-Grocery - Gas Heat w/ Cooling - HZ1	10	30.98	400.00	\$19.77	\$400.00	2.0	2.4	0%	100%
6	Smart Thermostat Non-Grocery - Gas Heat w/ Cooling - HZ2	10	44.52	400.00	\$26.56	\$400.00	2.9	3.4	0%	100%
7	Smart Thermostat Non-Grocery - Gas Heat NO Cooling - HZ1	10	30.98	400.00	\$18.15	\$400.00	2.0	2.4	0%	100%
8	Smart Thermostat Non-Grocery - Gas Heat NO Cooling - HZ2	10	44.52	400.00	\$23.49	\$400.00	2.9	3.4	0%	100%

Requirements

- Measures are applicable to most commercial spaces
 - Lodging, spaces with 24/7 operation, and semi-conditioned spaces are excluded from participation.
- The 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.
- Thermostats controlling Ductless Heat Pump systems, single-zone or multi-zone are not eligible.
- The thermostats listed in BPA’s Qualified Products List are eligible for this measure¹.
 - Thermostats meeting the following specifications are also eligible for the measure:
 - Thermostat must be capable of web-connectivity (LAN or WAN).
 - Support multiple temperature setback schedules
 - Support fan-mode scheduling (continuous on. vs auto-mode)
 - Support limited duration overrides (i.e. reverts to programming after 24 hours)
 - Automatically restore programmed settings after power outage
 - Supports multiple cooling stages unless installed with equipment that has been manufactured with only one stage of cooling.
- Support for utility approved demand response protocols or web connection is not required by Energy Trust but may be required by utility co-funding partners.
- Direct/Contractor Install incentives cannot exceed actual project costs.
- Sites with fuels other than gas – such as propane – may use the gas heat electric only territory measures (rows 31-38), if they are within a participating electric utility.

¹ BPA Connected Thermostats Qualified Products List - <https://www.bpa.gov/-/media/Aep/energy-efficiency/document-library/connected-thermostat-qualified-products-list.pdf>

Installation and setpoint requirements:

- The 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.
 - Where two or more HVAC systems serve “invisible zones” within a space, temperature setpoints, schedules, and deadbands must match to avoid simultaneous heating and cooling.
- Thermostats controlling Ductless Heat Pump systems, single-zone or multi-zone are not eligible.
- The temperature setback must be scheduled.
- 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 three hours or less.
- Heat pump with auxiliary resistance heat shall enable lock-out with appropriate temperature set-points.

Baseline

This measure uses an Existing Condition Baseline.

The baseline is assumed to be a mix of thermostats with and without scheduled temperature setback/set-up or ability to place the fan in “auto” during unoccupied hours.

Measure Analysis

The savings are based on RTF’s Commercial Connected Thermostat v2.1 workbook², which summarizes savings by cooling, heating, and fan energy end-uses.

The baseline energy consumption in kWh/ft² 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 3 summarize the end-use EUIs for each of the following building models: Small Office, Retail Stand-alone, Retail Strip, and Grocery (Supermarket).

Table 3 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 ft²/ton rather than rely on the simulated capacity of the energy models. Table 4 summarizes the design load by building type.

Table 4 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 5, which were determined by the RTF’s from 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 5 Savings Rate by End Use

HVAC End Use	Savings Rate
Fan Energy	6.7%
Cooling Energy	1.3%
Heating Energy	6.7%

Savings by end use are summarized in Table 6 by building type (grocery/nongrocery), heating type (electric resistance/heat pump/gas), presence of cooling (yes/no), and heating zone (HZ1/HZ2).

² Commercial Connected Thermostat Workbook v2.1 - <https://nwcouncil.app.box.com/v/comconnectthermostat2-1>

Table 6 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 7 summarizes savings for Heating Zone 1 and Heating Zone 2 for measure applications by building type, heating type, and cooling presence. Heat pump measures with no cooling were not included as this combination is not expected in practice.

Table 7 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	2878	0
	Heat Pump	Yes	1476	0	1731	0
	Gas	Yes	539	89	688	99
	Resistance Heat	No	2496	0	2858	0
	Gas	No	529	89	668	99
Not Grocery	Resistance Heat	Yes	938	0	1325	0
	Heat Pump	Yes	581	0	811	0
	Gas	Yes	256	31	344	45
	Resistance Heat	No	917	0	1285	0
	Gas	No	235	31	344	45

Comparison to RTF or other programs

Savings are directly leveraged from RTF’s Commercial Connected Thermostats v2.1 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 Data³: 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.

Load Profile

Load profiles vary by measure application according to heating type and building type are shown in Table 8.

Table 8 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

³ ASHRAE Owning and Operating Cost Database - http://weblegacy.ashrae.org/publicdatabase/system_service_life.asp?selected_system_type=7

Costs

Costs were determined using Project Tracker (PT) data. The median value of costs of all projects implemented using this measure from 2023 to present was used to estimate the measure costs. The data included 504 projects, and the costs are inclusive of materials and labor. The cost estimate is \$400 per thermostat.

Costs were also sourced from Portland Gas and Electric’s Direct Install program. They provided material costs for two thermostat models. Since they could not provide labor costs, it was decided to use PT data to determine costs, as cost information in the PT data is inclusive of both materials and labor.

Non-Energy Benefits

In gas-only territories, customer electric bill savings were converted to non-energy benefits using blended commercial retail rates. In electric-only territories, customer gas/other bill savings were converted to non-energy benefits using retail rates for propane.

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 by per thermostat.

Follow-Up

At the next update, check if there are any updates to the RTF workbook. Energy Trust is considering further evaluation activities on this measure. If available, those results must be considered.

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 235.4.4. It is attached and can be found along with supporting documentation at: \\Etoo.org\home\Groups\Planning\Measure Development\Commercial and Industrial\Commercial HVAC\EMS and thermostats\connected SZ thermostats



235.4.4_OR-WA-CE
Calculator_2026_v_1

Version History and Related Measures

Energy Trust has been offering xyz measure for many years. These predate our approval measure 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
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
7/29/2025	255.4	Updates to costs, alignment with the latest RTF workbook.

Table 10 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

Akanksha Rawal
Engineer- Planning & Evaluation

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Measure Approval Document for Energy Recovery Ventilation Calculator

Valid Dates
8/1/2025 – 12/31/2028

End Use or Description
This measure is an internal-facing spreadsheet tool that calculates gas and electricity savings achieved by installing an air-to-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. The tool can account for any energy recovery device that has rated effectiveness values. Including but not limited to the common device types: flat plate/membrane, rotary heat wheel, or run-around coils.

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 2025 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

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

- New
- Replacement

Purpose of Re-Evaluating Measure
Update the weather data used in the tool from TMY3 to TMYx 2009-2023, include baseline scenario for ASHRAE 90.1-2022 Energy Credit H06, and a minor bug fix. There are no changes to the savings methodology of the tool or to the measure requirements.

Cost-Effectiveness
Cost effectiveness must be determined individually for each project.

Requirements

- Incremental costs and cost-effectiveness must be determined for each project. Only cost-effective projects will qualify.
 - Any negative savings must be included in cost effectiveness calculation and claimed.
 - Cost effectiveness should be tested using the programs’ current custom cost effectiveness tool or savings summary workbook.
- Multifamily dwelling units should not be analyzed using this tool as 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). That measure also includes savings from heat recovery from an associated dedicated outside air system (DOAS).
- Tool is intended for use in buildings permitted under the OZERCC 2019, OEESC 2021, and OEESC 2025 energy codes.
 - Existing buildings projects and Washington projects must determine if proposed ERVs are required by applicable codes.
- 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.

Baseline
This measure uses a Code baseline, which is assumed to be equivalent to a market 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. If ASHRAE 90.1-2022 Energy Credit H06 (Dedicated Outdoor Air System with Zone Fan Control) is claimed by the project for code compliance, the code minimum effectiveness is 65% in cooling and heating mode per 90.1-2022 Table 11.5.2.2.6. 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: f. Gas g. Electric h. Gas and Electric	Mechanical plans
Heating Efficiency Rating	Dropdown with the following selections for electric heat systems: i. Heating COP @ 47°F j. HSPF k. HSPF2 And the following default for gas heat systems: l. 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: m. SEER n. EER o. Cooling COP p. SEER2 q. EER2	Mechanical plans
Cooling Efficiency Value	User-input efficiency value	Mechanical plans
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: r. Split-System Ducted s. Split-System Ductless t. 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 TMYx location for the project (a hyperlink to an interactive map of Oregon is provided to aid in determination of the closest TMYx 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
Code Required ERV	Checkbox to indicate energy recovery is required, thus setting the baseline effectiveness to 50% in cooling and heating mode	Operating Schedule(s) for annual operating hours and review of applicable code section (90.1 section 6.5.6.1)
2025 OEESC Energy Credit H06 Claimed	Checkbox to indicate 2025 OEESC Energy Credit H06 is being claimed for the project, thus setting the baseline effectiveness to 65% in cooling and heating mode	2025 COMcheck output

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, utilizing TMYx data (2009-2023 era) weather data contained in the tool. 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:

$$BTU_{bin} = 1.08 \times CFM \times \Delta T \times \text{hours}_{bin}$$

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/ft³ specific heat of 0.24 Btu/lb·°F:

$$1.08 = 60 \text{ min/hr} \times 0.074887 \text{ lb/ft}^3 \times 0.24 \text{ Btu/lb} \cdot ^\circ\text{F}$$

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:

$$\text{Savings}_{\text{heating}} = \sum \frac{BTU_{bin < \text{heating setpoint}}}{COP_{\text{heating}}} \times \text{eff}_{\text{ERV heating}}$$
$$\text{Savings}_{\text{cooling}} = \sum \frac{BTU_{bin > \text{cooling setpoint}}}{COP_{\text{cooling}}} \times \text{eff}_{\text{ERV cooling}}$$

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 equations², depending on the user input:

$$EER = -0.0228 \times SEER^2 + 1.1522 \times SEER$$

$$COP_{\text{cooling}} = \frac{EER}{3.412}$$

$$COP_{\text{heating}} = -0.0235 \times HSPF^2 + 0.6293 \times HSPF$$

SEER2/EER2/HSPF2 inputs are converted to SEER/EER/HSPF for calculations using the Energy Trust crosswalk table³.

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):

$$BHP_{fan} = \frac{CFM \times SP}{\text{eff}_{fan} \times 6356}$$
$$kW_{fan} = \frac{BHP_{fan} \times 746}{1000}$$

$$\text{Electric Penalty} = (kW_{\text{supply fan}} + kW_{\text{exhaust fan}} + kW_{\text{recovery wheel}}) \times \text{hours}_{\text{total operation}}$$

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; inactive as of 1/1/2025) 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 motors⁴.

Load Profile

The appropriate load profile will be determined per project based on the building type and predominant end-use savings for each fuel (heating, ventilation or cooling). The user is expected to make the appropriate Sector and Sub-Sector selections relevant to the project.

¹ https://www.johnsoncontrols.my/-/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 Technical Guidelines and Resources for Energy Efficiency Measures, Energy Trust of Oregon, February 13, 2025, available at [Measure Development Technical Guidelines 2025 .pdf](#) (see Table 10-1 Conversion factors for 2024 HVAC equipment ratings)

⁴ <https://www.caetrm.com/cpuc/table/effusefullife/>

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 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. If there are negative savings for one fuel, the standard incentive may need to be modified to ensure compliance with the UCT.

Follow-Up

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

A placeholder cost effectiveness tool for these measures is number 280.3.3. It is attached and can be found along with supporting documentation at: \\Etoo.org\home\Groups\Planning\Measure Development\Commercial and Industrial\Commercial HVAC\Energy Recovery



280.3.3_OR-WA-CE
C2026_v_1_0 ERV cal

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 to tool version 2023 v1.0
6/9/2025	280.3	Update to tool version 2025 v1.0

Table 3 Related Measures

Measures	MAD ID
Air Cooled VRF with DOAS (inactive)	216

Approved & Reviewed by

Jackie Goss, PE
Lead Engineer – Planning & Evaluation

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Measure Approval Document for Commercial Food Service Cooking Measures

Valid Dates

January 1, 2025 to December 31, 2027

End Use or Description

This measure is for efficient ENERGY STAR certified electric and gas commercial 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 is 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
- Food trucks in permanent locations such as food cart pods, using participating fuels

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

- New
- Replacement

Purpose of Re-Evaluating Measure

Savings were updated for all measure applications except for broilers. Costs were updated for all measure applications. NEBs were added for combination ovens to account for water savings.

This update removes rack ovens, convection ovens, and combination ovens for Washington (WA). Commercial ovens are now required to meet ENERGY STAR (ES) v2.2 in WA, and there are limited oven models available in the market that exceed ES v2.2 specifications to justify keeping those measure applications.

Griddles were reintroduced for OR, as they are now cost effective.

Measure application binning was updated for hot food holding cabinets (new size categories), combination ovens (new pan capacities), and steamers (new categories for steamer types, pan capacities, and building types) to align with the RTF’s updated workbooks.

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 2025-v2.1. The Oregon electric avoided cost year is 2025, and the Oregon gas avoided cost year is 2025. The Washington gas avoided cost year is 2025. The values in these tables are per cooking appliance 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	% Ele	% Gas
1	Hot Food Holding Cabinet, Non-Schools - <13 ft3	12	317.30	0.00	\$150.42	\$0.00	\$150.42	2.3	2.3	100%	0%
8	Rack Oven - Gas - Double	13	522.12	108.30	\$927.84	\$0.00	\$927.84	2.3	2.3	29%	71%
10	Rack Oven – Gas/propane - Double - Electric Only Territory	13	522.12	0.00	\$927.84	\$117.72	\$606.41	1.0	1.9	100%	0%
12	Rack Oven - Gas - Double - Gas Only Territory	13	0.00	108.30	\$927.84	\$76.12	\$927.84	1.6	2.4	0%	100%
14	Convection Oven - Electric - Full-size	12	1,450.58	0.00	\$1,458.38	\$0.00	\$1,458.38	1.1	1.1	100%	0%
15	Convection Oven - Gas - Full-size	12	0.00	157.80	\$1,397.13	\$0.00	\$1,397.13	1.5	1.5	0%	100%
16	Combination Oven - Electric 5-14 Pan Capacity	12	1,080.67	0.00	\$1.00	\$33.94	\$1,190.00	1.0	1511.3	100%	0%
17	Combination Oven - Electric 15-28 Pan Capacity	12	615.74	0.00	\$1.00	\$72.80	\$680.00	1.0	1360.0	100%	0%
18	Combination Oven - Electric 29-40 Pan Capacity	12	4,048.10	0.00	\$1.00	\$202.53	\$4,460.00	1.0	6364.8	100%	0%
19	Combination Oven - Gas 5-14 Pan Capacity	12	0.00	58.81	\$1.00	\$65.23	\$760.00	1.0	1376.8	0%	100%
20	Combination Oven - Gas 15-28 Pan Capacity	12	0.00	54.28	\$1.00	\$124.44	\$700.00	1.0	1870.1	0%	100%
21	Combination Oven - Gas 29-40 Pan Capacity	12	0.00	65.29	\$1.00	\$159.00	\$850.00	1.0	2336.3	0%	100%
22	Griddles - Single Sided - Electric	8	1,781.15	0.00	\$1,508.37	\$0.00	\$1,508.37	1.0	1.0	100%	0%
23	Griddles - Single Sided - Gas	8	0.00	207.07	\$1,230.04	\$0.00	\$1,230.04	1.6	1.6	0%	100%
24	Steam Cookers - Electric Boilerless 3-4 Pans - Non-School	12	1,308.91	0.00	\$347.00	\$16.45	\$1,440.00	1.0	4.6	100%	0%
25	Steam Cookers - Electric Boilerless 5+ Pans - Non-School	12	1,758.38	0.00	\$1.00	\$25.60	\$1,940.00	1.0	2182.6	100%	0%
26	Steam Cookers - Electric Steam Generator 3+ Pans - Non-School	12	2,499.32	0.00	\$1.00	\$131.31	\$2,762.89	1.0	3988.1	100%	0%
27	Steam Cookers - Gas Boilerless 3+ Pans - Non-School	12	0.00	337.74	\$1.00	\$117.39	\$4,400.00	1.0	5506.2	0%	100%
28	Steam Cookers - Gas Steam Generator 3+ Pans - Non-School	12	0.00	285.05	\$5,128.00	\$322.14	\$3,722.63	1.0	1.3	0%	100%
29	Steam Cookers - Electric Boilerless 3-4 Pans - School	12	427.77	0.00	\$347.00	\$7.98	\$470.00	1.0	1.6	100%	0%
30	Steam Cookers - Electric Boilerless 5+ Pans - School	12	587.47	0.00	\$1.00	\$13.03	\$640.00	1.0	785.5	100%	0%
31	Steam Cookers - Electric Steam Generator 3+ Pans - School	12	787.83	0.00	\$1.00	\$41.73	\$870.00	1.0	1279.8	100%	0%
32	Steam Cookers - Gas Boilerless 3+ Pans - School	12	0.00	111.75	\$1.00	\$57.20	\$1,450.00	1.0	1993.1	0%	100%
34	Conveyor Broilers with belt width < 20"	12	7,143.84	1,145.29	\$3,108.74	\$0.00	\$3,108.74	7.4	7.4	35%	65%
35	Conveyor Broilers with belt width 20" - 26"	12	6,403.32	1,932.84	\$3,876.17	\$0.00	\$3,876.17	8.3	8.3	22%	78%
36	Conveyor Broilers with belt width > 26"	12	23,849.10	3,161.26	\$4,507.99	\$0.00	\$4,507.99	15.0	15.0	39%	61%
37	Conveyor Broilers with belt width < 20" - Electric Only Territory	12	7,143.84	0.00	\$3,108.74	\$1,244.94	\$3,108.74	2.5	6.3	100%	0%
38	Conveyor Broilers with belt width 20" - 26" - Electric Only Territory	12	6,403.32	0.00	\$3,876.17	\$2,101.01	\$3,876.17	1.8	6.9	100%	0%
39	Conveyor Broilers with belt width > 26" - Electric Only Territory	12	23,849.10	0.00	\$4,507.99	\$3,436.33	\$4,507.99	5.8	13.0	100%	0%
40	Conveyor Broilers with belt width < 20" - Gas Only Territory	12	0.00	1,145.29	\$3,108.74	\$1,041.48	\$3,108.74	4.8	7.9	0%	100%
41	Conveyor Broilers with belt width 20" - 26" - Gas Only Territory	12	0.00	1,932.84	\$3,876.17	\$933.52	\$3,876.17	6.5	8.8	0%	100%
42	Conveyor Broilers with belt width > 26" - Gas Only Territory	12	0.00	3,161.26	\$4,507.99	\$3,476.90	\$4,507.99	9.2	16.4	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	Griddles - Single Sided - Gas	8	207.07	\$1,230.04	\$0.00	\$1,230.04	2.1	2.1	0%	100%
2	Steam Cookers - Gas Boilerless 3+ Pans - Non-School	12	337.74	\$1.00	\$117.39	\$6,120.00	1.0	7260.6	0%	100%
3	Steam Cookers - Gas Steam Generator 3+ Pans - Non-School	12	285.05	\$5,128.00	\$322.14	\$5,128.00	1.0	1.6	0%	100%
4	Steam Cookers - Gas Boilerless 3+ Pans – School	12	111.75	\$1.00	\$57.20	\$2,025.00	1.0	2580.8	0%	100%
5	Steam Cookers - Gas Steam Generator 3+ Pans - School	12	97.77	\$5,128.00	\$102.26	\$1,771.54	1.0	0.5	0%	100%
6	Conveyor Broilers with belt width < 20"	12	1,145.29	\$3,108.74	\$550.08	\$3,108.74	6.7	8.4	0%	100%
7	Conveyor Broilers with belt width 20" - 26"	12	1,932.84	\$3,876.17	\$493.06	\$3,876.17	9.0	10.3	0%	100%
8	Conveyor Broilers with belt width > 26"	12	3,161.26	\$4,507.99	\$1863.38	\$4,507.99	12.7	16.7	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.

TRC cost effectiveness is not required in Washington programs.

Requirements

- ENERGY STAR products must appear on the most current ENERGY STAR certified list under the Commercial Food Service Equipment program¹.

¹ <https://www.energystar.gov/productfinder/>

- Food trucks/carts must have a permanent location and use energy from an ETO participating utility to qualify. Mobile food trucks are not eligible.

Equipment-specific requirements

- All products must meet or exceed 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.
- In Oregon, broilers and rack ovens fueled by an alternate fuel such as propane may use the electric only territory measures (#10, 37-39) if electricity is provided by a participating utility.

Table 3 Required Efficiency Levels

Equipment	Required Efficiency levels
Hot Food Holding Cabinets	Must meet or exceed ENERGY STAR version 2.0 ² for OR. ES v2.0 is code-required for WA ³ and is not offered.
Convection, Combination, Rack Ovens	Must meet or exceed ENERGY STAR version 3.0 ⁴ for OR. ES v2.2 is code-required for WA ⁵ and is not offered.
Griddles	Must meet or exceed ENERGY STAR version 1.2 ⁶ for OR and WA.
Steam Cookers	Must exceed the 40 th percentile of ENERGY STAR version 1.2 ⁷ Electric steamers must have: 3-pan: a cooking energy efficiency of ≥ 55% and an idle energy rate of ≤ 235 W. 4-pan: a cooking energy efficiency of ≥ 55% and an idle energy rate of ≤ 325 W. 5-pan: a cooking energy efficiency of ≥ 69% and an idle energy rate of ≤ 280 W. 6-pan: a cooking energy efficiency of ≥ 61% and an idle energy rate of ≤ 300 W. > 6-pan: a cooking energy efficiency of ≥ 67% and an idle energy rate of ≤ 330 W. Gas steamers must have: 3-pan: a cooking energy efficiency of ≥ 39% and an idle energy rate of ≤ 2,440 Btu/h. 4-pan: a cooking energy efficiency of ≥ 49% and an idle energy rate of ≤ 5,850 Btu/h. 5-pan: a cooking energy efficiency of ≥ 49% and an idle energy rate of ≤ 7,027 Btu/h. 6-pan: a cooking energy efficiency of ≥ 43% and an idle energy rate of ≤ 2,770 Btu/h. > 6-pan: a cooking energy efficiency of ≥ 48% and an idle energy rate of ≤ 11,287 Btu/h.
Automated Conveyor Broilers	There is no ENERGY STAR certification for conveyor broilers. Rather, as referenced in the CA eTRM SWFS017-03 ⁸ , 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.

Most baseline rates rely on the 2022 ENERGY STAR Unit Shipment and Market Penetration Report⁹ and areTable 4 summarized in Table 4.

Table 4 ENERGY STAR Market Penetration Rates for Oregon and Washington

Equipment	2024 ENERGY STAR Market Penetration Rates	
	Oregon	Washington
Hot Food Holding Cabinets	12%	100% - code-required
Convection Ovens	37%	
Combination Ovens	73% for electric, 74% for gas	
Rack Ovens	70%	
Griddles	21%	
Steamers	100% - code-required	
Conveyor Broilers	N/A – not ES-rated	

Ovens Baseline

For WA, commercial ovens (convection, combination, and rack ovens) and hot food holding cabinets (HFHCs) are required to meet specifications for ENERGY STAR v2.2 and v2.0, respectively¹⁰. The current ENERGY STAR version for ovens is v3.0. There is no difference between v2.2 and v3.0 for rack ovens. While there are differences between the two ENERGY STAR versions for convection and combination ovens, there are currently limited oven models in the market that exceed v2.2 and that cost more. The Energy Star Penetration report does not disaggregate by oven type. The market penetration by oven type is assumed by the RTF.

Hot Food Holding Cabinets Baseline

HFHCs are code-required in WA, as the current ENERGY STAR version for HFHCs is v2.0. For Oregon, there is no current requirement to meet ENERGY STAR specifications for ovens or HFHCs. Therefore, the latest RTF workbooks for convection, combination, and rack ovens as well as HFHCs were referenced to obtain the penetration rates (%) of ENERGY STAR products in the market, and these rates were used to allocate market share of ENERGY STAR vs non-ENERGY STAR equipment. The HFHC This measure is intended to displace electrically heated HFHC, not unheated portable cabinets, typically used by catering companies.

² https://www.energystar.gov/ia/partners/product_specs/program_reqs/Commercial_HFHC_Program_Requirements_2.0.pdf
³ <https://www.commerce.wa.gov/growing-the-economy/energy/appliances/>
⁴ https://www.energystar.gov/products/spec/commercial_ovens_specification_version_3_0_pd
⁵ <https://www.commerce.wa.gov/growing-the-economy/energy/appliances/>
⁶ https://www.energystar.gov/products/commercial_griddles/partners
⁷ https://www.energystar.gov/products/commercial_steam_cookers/partners
⁸ [Automatic Conveyor Broiler, Commercial | ETRM \(caetrm.com\)](https://www.energystar.gov/sites/default/files/2022%20Unit%20Shipment%20Data%20Summary%20Report.pdf)
⁹ <https://www.energystar.gov/sites/default/files/2022%20Unit%20Shipment%20Data%20Summary%20Report.pdf>
¹⁰ <https://www.commerce.wa.gov/growing-the-economy/energy/appliances/>

Griddles Baseline

There is no current requirement to meet ENERGY STAR specifications for griddles in Oregon or Washington.

Steam Cookers Baseline

For Washington¹¹ and Oregon¹², steam cookers are required to meet specifications for ENERGY STAR v1.2. This code requirement makes the penetration rate of ENERGY STAR steamer equipment in the market to be effectively 100% of new equipment, changing the market baseline to be equivalent to code. Therefore, the RTF recommends removing steamers for OR and WA. However, the current ENERGY STAR QPL for steamers includes several models that exceed ES v1.2. Therefore, steamer measure applications were retained for this measure while manually adjusting the RTF baseline to match the idle energy rate and cooking energy efficiency of the ES v1.2 specifications. The baseline, thus, became more efficient with this code requirement, and savings decreased.

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).¹³ Given the small number of broiler projects (16) participating in Energy Trust programs from 2019 to 2021, it is assumed that the efficient equipment has little to no market share. The baseline broiler is assumed to be an automatic conveyor broiler capable of maintaining a temperature above 600°F with a tested idle rate greater than:

- 40kBtu/h for a belt narrower than 20"
- 60kBtu/h for a belt between 20" and 26"
- 70kBtu/h for a belt wider than 26"

Baseline equipment performance specifications in the SWFS017-03 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 Nickel¹⁴ 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 taken from the RTF’s workbooks for each respective food service equipment. The RTF workbooks provide 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 per day, days of operation per year, and quantity of food cooked per day with each approved equipment type are shown in Table 5. All these assumptions, except for broilers, 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 – Non-Schools	8.1	364	N/A
Hot Food Holding Cabinets – Schools	6.0	180	
Rack Ovens	11.3	335	600 for Single Rack 1,200 for Double Rack
Convection Ovens	13.1	321	133 for Full-Size 66.5 for Half-Size
Combination Ovens	13.1	321	200 for 5-15 Pans 250 for 16-28 Pans 400 for 29-40 Pans
Griddles	12.1	333	128 Average for 3-15 ft² Griddles
Steam Cookers – Non-Schools	10.8	311	33 for Boilerless 3-4 Pans 66 for Boilerless 5+ Pans 100 for Steam Generator 3+ Pans
Steam Cookers – Schools	6.0	180	
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 equipment type are shown in Table 6 through Table 13. 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 RTF workbooks. 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 ENERGY STAR specification only for electrically heated hot food holding cabinets. This equipment comes in three sizes. Hot food holding cabinets, unlike other food service cooking equipment, are for food storage and not food cooking. So, cooking efficiency, production capacity, and preheat energy are not applicable to this equipment. Average idle energy rate is shown in Table 6.

¹¹ <https://www.commerce.wa.gov/growing-the-economy/energy/appliances/>
¹² <https://www.oregon.gov/energy/energy-oregon/Pages/Appliance-Standards.aspx>
¹³ “Automatic Conveyor Broiler, Commercial.” [Automatic Conveyor Broiler, Commercial | ETRM \(caetrm.com\)](#)
¹⁴ Fisher-Nickel, Inc. 2017. “Energy Efficient Underfired Broilers, ET ProjectNumber: ET16PGE1941.” Prepared on behalf of Pacific Gas & Electric. March 24, 2017.

Table 6 Hot Food Holding Cabinets ENERGY STAR v2.0 – Electric – Efficiency Values

Hot Food Holding Cabinets ENERGY STAR v2.0 - Electric	Non-ES			Exceeding ES v2.0			Market Baseline		
	<13 ft³	≥13 and <28 ft³	≥28 ft³	<13 ft³	≥13 and <28 ft³	≥28 ft³	<13 ft³	≥13 and <28 ft³	≥28 ft³
Average Idle Energy Rate (W)	248	540	593	143	204	294	235	500	557

Rack Ovens

There is ENERGY STAR specification only for gas heated rack ovens. This equipment comes in single and double sizes. 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	Non-ES		Exceeding ES v3.0		Market Baseline	
	Single	Double	Single	Double	Single	Double
Average Energy Efficiency (%)	44.5	53.3	50.3	58.3	48.6	56.8
Average Production Capacity (lb/hr)	145	284	139	286	141	286
Average Preheat Energy (Btu)	54,817	79,544	39,522	61,677	44,304	67,037
Average Idle Energy Rate (Btu/hr)	25,745	29,855	19,698	23,128	21,512	25,146

Convection Ovens

There are ENERGY STAR specifications for electric and gas heated convection ovens. Electric convection ovens are rated in half and full sizes. Electric convection oven efficiency metrics are shown in Table 8.

Table 8 Convection Ovens ENERGY STAR v3.0 - Electric - Efficiency Values

Convection Ovens ENERGY STAR v3.0 - Electric	Non-ES		Exceeding ES v3.0		Market Baseline	
	Half Size	Full Size	Half Size	Full Size	Half Size	Full Size
Average Energy Efficiency (%)	67	73	76	80	70	76
Average Production Capacity (lb/hr)	43	96	44	105	43	100
Average Preheat Energy (Wh)	790	1,493	549	1,140	700	1,361
Average Idle Energy Rate (W)	1,156	1,698	830	1,187	1,034	1,507

Gas convection ovens are rated only in full size. Gas convection oven efficiency metrics are shown in Table 9.

Table 9 Full Size Convection Ovens ENERGY STAR v3.0 – Gas – Efficiency Values

Convection Ovens ENERGY STAR v3.0 - Gas	Non-ES	Exceeding ES v3.0	Market Baseline
Average Energy Efficiency (%)	44	53	47
Average Production Capacity (lb/hr)	88	98	91
Average Preheat Energy (Btu)	12,571	8,513	11,054
Average Idle Energy Rate (Btu/hr)	13,913	8,315	11,820

Combination Ovens

There are ENERGY STAR specifications for electric and gas heated combination ovens. Electric and gas combination ovens are rated by pan quantity. 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. In addition to energy savings, highly efficient combination ovens use less water in steam mode. There is no water use in convection mode. **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, including water use.

Table 10 Combination Ovens ENERGY STAR v3.0 – Electric – Efficiency Values

Combination Ovens ENERGY STAR v3.0 – Electric	Non-ES						Exceeding ES v3.0						Market Baseline					
	5-14 Pans		15-28 Pans		29-40 Pans		5-14 Pans		15-28 Pans		29-40 Pans		5-14 Pans		15-28 Pans		29-40 Pans	
Mode	Conv.	Steam	Conv.	Steam	Conv.	Steam	Conv.	Steam	Conv.	Steam	Conv.	Steam	Conv.	Steam	Conv.	Steam	Conv.	Steam
Average Energy Efficiency (%)	74	55	77	58	76	61	80	63	82	66	82	67	78	61	81	64	80	66
Average Production Capacity (lb/hr)	76.3	9	181.6	298.8	314	478	90.9	148	188.9	309.5	364.1	571.5	87	137	187	307	350	546
Average Preheat Energy (Wh)	860		1,430		3,930		1,081		1,694		2,750		1,020		1,622		3,075	
Average Idle Energy Rate (W)	1,272	3,162	1,696	3,048	3,730	8,800	1,008	1,211	1,569	2,129	2,413	2,803	1,081	1,747	1,604	2,382	2,775	4,452
Water Use (gal/day)	N/A	27.6	N/A	51.8	N/A	118	N/A	9.2	N/A	12.4	N/A	8.4	N/A	14.3	N/A	23.2	N/A	38.5

Table 11 Combination Ovens ENERGY STAR v3.0 – Gas – Efficiency Values

Combination Ovens ENERGY STAR v3.0 - Gas	Non-ES						Exceeding ES v3.0						Market Baseline					
	5-14 Pans		15-28 Pans		29-40 Pans		5-14 Pans		15-28 Pans		29-40 Pans		5-14 Pans		15-28 Pans		29-40 Pans	
Mode	Conv.	Steam	Conv.	Steam	Conv.	Steam	Conv.	Steam	Conv.	Steam	Conv.	Steam	Conv.	Steam	Conv.	Steam	Conv.	Steam
Average Energy Efficiency (%)	54	44	61	45	60	53	61	50	61	50	64	49	59	48	61	49	63	50
Average Production Capacity (lb/hr)	112.1	165.5	191	227	386	490	105.2	191.8	183.7	293.7	375.8	611.6	107	185	186	277	378	580
Average Preheat Energy (Btu)	6,919		7,980		42,541		5,090		7,521		15,829		5,560		7,639		22,697	
Average Idle Energy Rate (Btu/hr)	6,697	14,015	7,626	17,482	12,866	17,014	3,848	5,653	5,850	8,166	6,804	9,798	4,581	7,803	6,307	10,562	8,363	11,653
Water Use (gal/day)	N/A	45.1	N/A	84.5	N/A	111.4	N/A	7.4	N/A	12.5	N/A	19.4	N/A	17.1	N/A	31.1	N/A	43.1

Griddles

To simplify the ETO measure offering for griddles, linear regression of kWh and therms savings from the RTF workbook’s numerous size categories provided savings for the average size electric and gas griddle. Therefore, the energy efficiency, production capacity, pre-heat energy, and idle energy rate for these average size griddles were not calculated or needed.

Steam Cookers

State appliance standards in OR and WA require all new steam cookers to meet ENERGY STAR v1.2. So, the market baseline is equivalent to the code baseline of ENERGY STAR v1.2. For the efficient equipment, measure case properties were taken from only models exceeding the 40th percentile of ES v1.2 qualified models in the ES QPL.

In addition to energy savings, highly efficient steam cookers use less water. Table 122 shows efficiency metrics for both gas and electric steam cookers, including water use, for 6-pan steamers. A 3-4 pan to 5+ pan ratio was used to convert energy and water values to fulfill all measure applications, as referenced in the RTF measure¹⁵.

Table 12 Steam Cookers– Electric and Gas –Efficiency Values

Steam Cookers - Electric and Gas	Code Baseline - ES v1.2		Efficient – 40 th Percentile	
	Ele	Gas	Ele	Gas
Average Energy Efficiency (%)	50%	38%	61%	43%
Production Capacity (lb/hr)	118	119	122	114
Preheat Energy (Wh or Btu)	1,670	18,696	1,780	9,778
Idle Energy Rate (W or Btu/hr)	800	12,500	300	2,770
Water Use (gal/hr)	6.7	22.95	1.5	1.2

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 133. 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, converted to Btu)
- $q_{gas,i}$ = idle gas energy rate (Btu/hr)
- $q_{elec,i}$ = idle electric energy rate (kW, converted to Btu)
- 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)

Table 13 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 summarized 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 the RTF and Energy Trust analysis, including:

- For steam cookers: the RTF analysis removed steam cookers from OR and WA since ENERGY STAR v1.2 is required in OR and WA. However, for the Energy Trust analysis, the baseline was adjusted to represent ES v1.2 specifications, while the measure case was adjusted to represent the equipment properties taken from only models exceeding the 40th percentile of ES v1.2 qualified models in the ES QPL. This adjustment decreased the savings for steam cookers.
- For griddles: the RTF analysis was based on griddle surface area (3ft² to 15 ft²), while the Energy Trust analysis averaged the RTF's multiple measure applications to represent one ETO measure application each for electric and gas griddles. In addition, QPL data and the market penetration of ENERGY STAR griddles were manually updated in the RTF workbook for this measure.

This update was done in parallel with the RTF measure updates in 2024. However, not all RTF workbooks were updated or finalized in time for this Energy Trust analysis. Some workbooks were updated but had not completed the Quality Control (QC) review stage. Below are notes about the RTF workbooks referenced for this Energy Trust analysis:

Post-QC RTF workbook versions for:

- Convection Ovens v6.1¹⁶
- Rack Ovens v3.1¹⁷

¹⁵ [Steamers](#)

¹⁶ <https://nwcouncil.box.com/v/cookingconvectovens6-1>

¹⁷ <https://nwcouncil.box.com/v/comcookingrackovens3-1>

- Combination Ovens v6.2¹⁸
- QC RTF workbook version for:
- HFHCs v6.1¹⁹
- Pre-QC RTF workbook version for:
- Steamers v6.0²⁰
- RTF's 2023 workbook version for:
- Griddles v2.1²¹ (the 2024 update had not yet been presented at time of analysis)
- As RTF does not have a measure for broilers, the CA eTRM SWFS017-03²² was referenced which used all the same calculations as the previous version SWFS017-02.

Measure Life

A useful equipment life of 12 years is used for most equipment. However, rack ovens and griddles have a useful equipment life of 13 years and 8 years, respectively. These values were based on the RTF workbooks and CA eTRM referenced for each measure.

Load Profile

For Oregon, the electric load profile used is Restaurant Cooking for most measures, and School Cooking for measures specified for schools, while the gas load profile used is Flat-gas.

For Washington, the gas load profile is Commercial Cooking.

Cost

For all equipment, the incremental equipment cost was calculated as the difference between the efficient measure case cost and the full-market or code baseline equipment cost.

Steam cookers vary widely in size and cost. In addition, the baseline was adjusted for this Energy Trust analysis to represent the ES v1.2 specifications. Online retail costs were searched for all steamer models in the ES QPL dataset. Data for all models with available costs were used to plot two graphs: one for cooking energy efficiency and cost and the other for idle energy rate and cost. From these two scatter plots, linear regression was done to calculate the costs for steamer models representing the ES v1.2 specifications. These two calculated costs from the two graphs were then averaged to represent the average baseline cost. For the measure case costs, only steamer models exceeding the 40th percentile of ES v1.2 qualified models in the ES QPL were used to average costs. While the RTF measure for steamers similarly sourced online retail costs for ES models, it did not include the full QPL dataset for cost calculations. Therefore, the full QPL dataset was inventoried for costs for this ETO measure.

Aside from the aforementioned steamer costs, other equipment costs were sourced from the RTF workbooks and the CA eTRM for broilers. Most measure applications used 2024 costs, while costs for griddles used an inflation factor to adjust 2016 dollars to 2024 dollars, and costs for broilers used an inflation factor to adjust 2017 dollars to 2024 dollars, using RTF's SIW (Standard Information Workbook) v4.8²³.

Table 14 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.

¹⁸ <https://rtf.nwcouncil.org/measure/combination-ovens/>
¹⁹ <https://nwcouncil.box.com/s/tav6gczmo802pa7r361yu0o2wf6ei3tc>
²⁰ <https://nwcouncil.box.com/v/comcookingsteamers6-0>
²¹ <https://nwcouncil.box.com/v/comcookgriddle2-1>
²² <https://www.caetrm.com/measure/SWFS017/03/permutation-reports/>
²³ RTFStandardInformationWorkbook_v4_8: <https://rtf.nwcouncil.org/standard-information-workbook/>

Table 14 - Cost Summary for all Equipment Types

Equipment Type	Inefficient Equipment Cost	Full Market Baseline Cost	Efficient Equipment Cost	Incremental Cost
Hot Food Holding Cabinet, Non-Schools - <13 ft3	\$4,187	\$4,207	\$4,357	\$150.42
Rack Oven - Gas - Double	\$41,271	\$42,199	\$44,364	\$927.84
Rack Oven - Gas - Double - Electric Only Territory	\$41,271	\$42,199	\$44,364	\$927.84
Rack Oven - Gas - Double - Gas Only Territory	\$41,271	\$42,199	\$44,364	\$927.84
Convection Oven - Electric - Full-size	\$5,387.00	\$6,243.51	\$7,701.88	\$1,458.38
Convection Oven - Gas - Full-size	\$7,318.20	\$8,138.73	\$9,535.86	\$1,397.13
Combination Oven - Electric 5-14 Pan Capacity	\$15,446	\$15,027	\$14,868	-\$159
Combination Oven - Electric 15-28 Pan Capacity	\$26,678	\$24,105	\$23,129	-\$976
Combination Oven - Electric 29-40 Pan Capacity	\$48,651	\$42,127	\$39,652	-\$2,475
Combination Oven - Gas 5-14 Pan Capacity	\$21,945	\$19,841	\$19,112	-\$728
Combination Oven - Gas 15-28 Pan Capacity	\$32,634	\$29,200	\$28,012	-\$1,189
Combination Oven - Gas 29-40 Pan Capacity	\$54,712	\$48,020	\$45,704	-\$2,316
Griddles - Single Sided - Electric	Incremental costs were calculated by linear regression.			\$1,508.37
Griddles - Single Sided - Gas				\$1,230.04
Steam Cookers - Electric Boilerless 3-4 Pans - Non-School	\$10,127	The baseline costs were calculated by linear regression for steamer models representing the ES v1.2 specifications. For the measure case costs, only steamer models exceeding the 40th percentile of ES v1.2 qualified models in the ES QPL were used to average costs.	\$10,474	\$347
Steam Cookers - Electric Boilerless 5+ Pans - Non-School	\$15,743		\$12,858	-\$2,885
Steam Cookers - Electric Steam Generator 3+ Pans - Non-School	\$16,479		\$14,446	-\$2,034
Steam Cookers - Gas Boilerless 3+ Pans - Non-School	\$20,286		\$13,335	-\$6,951
Steam Cookers - Gas Steam Generator 3+ Pans - Non-School	\$26,093		\$31,222	\$5,128
Steam Cookers - Electric Boilerless 3-4 Pans - School	\$10,127		\$10,474	\$347
Steam Cookers - Electric Boilerless 5+ Pans - School	\$15,743		\$12,858	-\$2,885
Steam Cookers - Electric Steam Generator 3+ Pans - School	\$16,479		\$14,446	-\$2,034
Steam Cookers - Gas Boilerless 3+ Pans - School	\$20,286		\$13,335	-\$6,951
Conveyor Broilers with belt width < 20"	\$10,943		\$14,052	\$3,108.74
Conveyor Broilers with belt width 20" - 26"	\$13,248	\$13,248	\$17,124	\$3,876.17
Conveyor Broilers with belt width > 26"	\$15,466	\$15,466	\$19,974	\$4,507.99
Conveyor Broilers with belt width < 20" - Electric Only Territory	\$10,943	\$10,943	\$14,052	\$3,108.74
Conveyor Broilers with belt width 20" - 26" - Electric Only Territory	\$13,248	\$13,248	\$17,124	\$3,876.17
Conveyor Broilers with belt width > 26" - Electric Only Territory	\$15,466	\$15,466	\$19,974	\$4,507.99
Conveyor Broilers with belt width < 20" - Gas Only Territory	\$10,943	\$10,943	\$14,052	\$3,108.74
Conveyor Broilers with belt width 20" - 26" - Gas Only Territory	\$13,248	\$13,248	\$17,124	\$3,876.17
Conveyor Broilers with belt width > 26" - Gas Only Territory	\$15,466	\$15,466	\$19,974	\$4,507.99

Non Energy Benefits

ENERGY STAR rated electric and gas steam cookers and electric and gas combination ovens in steam mode have water savings. These are included as non-energy benefits.

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.

Follow-Up

- Any RTF workbook updates and CA eTRM updates for broilers should be incorporated.
- Any future code and standards changes must be tracked for future revisions.
- Additional cost research including actual participating project costs, market share and local distributor pricing is recommended.
- 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.
- RTF analysis indicated high portion of participating hot food holding cabinets were portable types without equivalent non-energy start counterparts²⁴. This is not the intended use case of the measure. Program should monitor model numbers and add requirements if this becomes the dominating product type.
- Fryer measures could be included here instead of in a separate document.
- Consider changes to load profile selections if some equipment is more common in other businesses than restaurants, such as healthcare or grocery.

Supporting Documents

The cost effectiveness screening for these measures is number 101.6.4 It is attached and can be found along with supporting documentation at: \\Etoo.org\home\Groups\Planning\Measure Development\Commercial and Industrial\Food Service\Cooking Equipment



101.6.4 OR-WA-CE
Calculator_2025_v_2

²⁴ [20240618ComCooking_HotFoodCabinet.pptx | Powered by Box](#) slide 29

Modified versions of the RTF and eTRM workbooks are attached.


2024_ComCooking
CombinationOven_v


2024_ComCooking_
ConvectionOvens_vt


2024_ComCooking
Griddle_v2_1_MAD 1


2024_ComCooking
HotFoodCabinet_v6


2024_ComCooking
RackOven_v3_1.xlsm


2024_ComCookingS
teamer_v6_0_MAD 1


2024_SWFS017-02_
WPSCGNRCC171226

Version History and Related Measures

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

Table 15 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
11/4/2024	101.6	Updated all measure applications

Table 16 Related Measures

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

Approved & Reviewed by

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Measure Approval Document for High-Speed Doors for Commercial Walk-In Coolers and Freezers

Valid Dates
January 1, 2025 to December 31, 2027

End Use or Description

This measure covers high-speed doors for walk-in coolers and freezers in buildings with commercial refrigeration. Heat gain from infiltration air represents a significant portion of the total refrigeration load for commercial retail and other cold storage spaces. This measure calculates the energy savings that result from installation of a high-speed door which reduces the amount of infiltrated air in these spaces. Walk-in units targeted for this measure are less than 3,000 ft² and large enough to accommodate forklifts through the doorway.

An air curtain and a door heater are typically paired with a high-speed door for walk-in freezers. The air curtain turns on only when the high-speed door opens to reduce heat transfer through the opening. The heater prevents frost from forming on components near the door when humid, warm air mixes with cold air and condenses/freezes water vapor. This measure includes savings from an air curtain/heater for high-speed doors for walk-in freezers.

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 commercial building types is expected, but not limited to:

- Food retail facilities, such as:
 - Supermarkets
 - Big-Box Retail Warehouses
 - Meat and Produce Retail Facilities
- Facilities with commercial kitchens or commercial refrigeration, such as:
 - Hospitals
 - Schools, including Colleges and Universities

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

- Retrofit
- New
- Replacement

Cost-Effectiveness

Cost-effectiveness is demonstrated for Oregon in Table 1. Cost-effectiveness was calculated using the tool: OR-WA-CE Calculator 2025-v2.1. The Oregon electric avoided cost year is 2025 and the Oregon gas avoided cost year is 2025. The values in this table are per unit (per high-speed door).

Table 1 Cost-Effectiveness Calculator Oregon, per unit (high-speed door)

#	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	Retrofit High-Speed Door on Walk-In Cooler	15	28,580.95	0.00	14,500.00	\$761.00	\$14,500.00	2.3	2.8	100%	0%
2	Replacement and New Install High-Speed Door on Walk-In Cooler	15	27,219.95	0.00	11,606.00	\$761.00	\$11,606.00	2.7	3.4	100%	0%
3	Retrofit High-Speed Door on Walk-In Freezer, Electric Heating	15	173,359.74	0.00	17,500.00	\$761.00	\$17,500.00	11.4	11.9	100%	0%
4	Replacement and New Install High-Speed Door on Walk-In Freezer, Electric Heating	15	165,200.91	0.00	14,606.00	\$761.00	\$14,606.00	13.0	13.6	100%	0%
5	Retrofit High-Speed Door on Walk-In Freezer, HP Heating	15	173,200.76	0.00	17,500.00	\$761.00	\$17,500.00	11.4	11.9	100%	0%
6	Replacement and New Install High-Speed Door on Walk-In Freezer, HP Heating	15	165,041.93	0.00	14,606.00	\$761.00	\$14,606.00	13.0	13.6	100%	0%
7	Retrofit High-Speed Door on Walk-In Freezer, Gas Heating	15	173,058.23	13.60	17,500.00	\$761.00	\$17,500.00	11.4	11.9	100%	0%
8	Replacement and New Install High-Speed Door on Walk-In Freezer, Gas Heating	15	164,893.92	13.71	14,606.00	\$761.00	\$14,606.00	13.0	13.6	100%	0%
9	Retrofit High-Speed Door on Walk-In Freezer, Gas Heating, Electric Only	15	173,058.23	0.00	17,500.00	\$775.78	\$17,500.00	11.4	11.9	100%	0%
10	Replacement and New Install High-Speed Door on Walk-In Freezer, Gas Heating, Electric Only	15	164,893.92	0.00	14,606.00	\$775.90	\$14,606.00	13.0	13.6	100%	0%

Requirements

- New high-speed doors equipped with or without air curtains and/or door heaters are eligible.
- Walk-in doorway must be at least 5 ft wide to be eligible.
- Walk-in coolers or freezers 3,000 ft² or greater are not eligible.
- High temperature refrigerated spaces set above 50°F are not eligible.
- Refrigerated warehouses and distribution centers are not eligible. They served by the Production Efficiency program and may use a similar measure with somewhat different requirements and program design (MAD 213).
- Electric only measures may be used for buildings heated with propane or other bulk fuels.
- Retrofit measure applications apply to:
 - Walk-ins with existing, operational, non-high speed door infiltration barriers, including, but not limited to, strip curtains with at least 50% strip coverage remaining, spring-hinged doors, impact doors, or another method of minimizing infiltration when doors are open
 - Walk-ins without any existing infiltration barrier

- Replacement and New Install measure applications apply to:
 - Walk-ins with non-high speed door infiltration barriers that have failed, including, but not limited to, strip curtains with less than 50% strip coverage remaining, spring-hinged doors, impact doors, or another failed infiltration barrier type
 - Walk-ins with existing high-speed doors that have failed
 - New walk-ins that are replacing old walk-ins that are at end-of-life
 - New walk-ins in new buildings

Baseline

This measure uses an Existing Condition Baseline for retrofit measure applications and a Market Baseline for replacement and new install measure applications.

Existing Condition Baseline:

Information from an Oregon-based contractor who specializes in refrigeration equipment identified typical existing infiltration barrier types and conditions for walk-in coolers and freezers with forklift traffic¹. Existing condition infiltration barriers identified include the following types:

- Hard door, no strip curtains
- Hard door with strip curtains
- Impact door
- Gap exposed during business hours only

Existing conditions commonly include gaps, missing strips, or open access for portions of the day. The insulation efficacy of existing barriers is considered via contractor-provided typical door gap dimensions² and an average strip curtain % efficacy calculated from project data from 40 Production Efficiency custom high-speed door projects³.

In addition, this contractor identified the following building types that would typically have walk-in units targeted for this measure (less than 3,000 ft² and large enough to accommodate forklifts through the doorway):

- Supermarkets
- Big-Box Retail Warehouses
- Meat and Produce Retail Facilities
- Hospitals
- Schools, including Colleges and Universities

A weighted average of the baseline kWh consumption was calculated using contractor-provided barrier type market weighting estimates and the baseline consumption from separate calculator runs each using one of the above infiltration barrier types. Therefore, the 4 existing barrier types listed above, and their respective insulation efficacy, were combined into one preliminary measure application per building type. The preliminary measure applications’ savings for each building type were later averaged with equal weightings to develop the final measure applications.

The code baseline references the Federal Energy Independence and Security Act of 2007, which took effect in January 2009⁴, and states that doorways of walk-in coolers and freezers “shall have strip doors [curtains], spring-hinged doors, or other method of minimizing infiltration when doors are open”. This code requirement applies to walk-in coolers and freezers with a total chilled storage area of less than 3,000 ft². Since walk-in units older than 2009 exist and predate this code requirement, some walk-ins in the field may not have any infiltration barrier. However, any existing walk-in that lacks an infiltration barrier would qualify as a retrofit measure application and would use the Existing Condition Baseline.

Market Baseline:

The Market Baseline for replacements and new installs is a weighted average of the code baseline referenced above and more insulated infiltration barriers, including the above 4 contractor-provided existing infiltration barrier types and high-speed doors.

Table 2 summarizes the contractor-provided market weightings per infiltration barrier type for the Existing Condition Baseline and Market Baseline.

Table 2 Market Weightings of Infiltration Barrier Types

Infiltration Barrier Type	% Prevalence	
	Existing Condition Baseline	Market Baseline
High-speed door, no air curtains	0%	5%
High-speed door with air curtains	0%	5%
Hard door, no strip curtains	30%	27%
Hard door with strip curtains	50%	45%
Impact door	15%	14%
Gap exposed during business hours only	5%	5%
Total	100%	100%

Measure Analysis

This measure adopts the use of the High-Speed Door Tool version 5.2 maintained by the Production Efficiency team and referenced in MAD 213.4 – High Speed Door Tool. This tool calculates annual baseline and measure case kWh consumption. The annual electric energy savings are calculated by taking the difference between the baseline and measure case kWh consumption.

The following data was input in the High-Speed Door Tool v5.2 to estimate savings for this measure. Unless otherwise noted, the inputs below were sourced from a local contractor who specializes in refrigeration equipment in OR⁵.

Participant Information:

- Zip – 97302 (to auto-select “Nearest weather station” of OR – Salem Municipal AP and “Facility Elevation” of 204 ft)
- Zip – 97756 (to auto-select “Nearest weather station” of OR – Redmond Municipal AP and “Facility Elevation” of 3,070 ft)

¹ Contractor information from OR: 2024_EB Calc Summary.xlsx, “Contractor Info” tab.
² Contractor information from CA: 2024_EB Calc Summary.xlsx, “Contractor Info” tab.
³ Average inputs specified for high-speed door custom Production Efficiency projects: 2024_EB Calc Summary.xlsx, “PE Custom Summary” tab.
⁴ Section 312 (G): 2023_Federal Energy Independence and Security Act of 2007.pdf
⁵ Contractor information from OR: 2024_EB Calc Summary.xlsx, “Contractor Info” tab.

- Both weather stations were used separately for all calculation runs, and the results were averaged with a 93% and 7% weighting for Salem and Redmond, respectively⁶.

Information About the Doors and Spaces:

- Describe Baseline Door – *Hard door, no strip curtains; Hard door with strip curtains; Impact door; Gap exposed during business hours only*
 - The four barrier types listed above were entered into separate calculator tool runs, and the results were combined into one measure application per building type using contractor-provided market weightings of the barrier types.
- Describe the Space the Door Opens to – Conditioned: *Inside to a refrigerated or air conditioned space*; Unconditioned: *Inside to ambient temp and humidity (no wind or AC)*
 - Meat and Produce Facilities are assumed to have walk-in units adjacent to conditioned space. Other facility types are assumed to have walk-in units adjacent to unconditioned indoor space.
- Door Upgrade Type – *High Speed Door*
- # of Identical Doors – 1
- Room Temperature Setpoint – Coolers: 34; Freezers: -5
- Avg Temp of Adjoining Spaces – Unconditioned: Blank; Conditioned: 75
- RH of cold space – 77%
- RH of adjoining space: Unconditioned: Blank; Conditioned – 76%
- Door Width (ft) – 8
- Door Height (ft) – 10
- Strip Curtain % Covered – 87%⁷
- Impact Door % Covered – 100%⁸
- Hard Door Gap (vertical gap) – width (in): 1.5; height (ft): 10⁹
- Door Heater Upgrade? – Coolers: No; Freezers: Yes
- Fast Acting Door Cycle Time (s) – 8
- Infiltration Mode – *Convection*¹⁰
- Business Start Time (am) – Supermarkets: 6; Big-Box Retail Warehouses: 10; Meat and Produce Facilities: 6; Hospitals: 0; Schools, including Colleges and Universities: 8¹¹
- Business Hours Per Day – Supermarkets: 17; Big-Box Retail Warehouses: 10; Meat and Produce Facilities: 10; Hospitals: 24; Schools, including Colleges and Universities: 8¹²
- Percent of business hours hard door is open¹³ – Hard door with strip curtains: 58%; Hard door, no strip curtains: 46%; Gap exposed during business hours only: 52%
 - The value for “Gap exposed during business hours only” is assumed to be an average of the other two hard door values.
- Predicted Average Door Cycles Per Day – Supermarkets: 163; Big-Box Retail Warehouses: 120; Meat and Produce Facilities: 175; Hospitals: 153; Schools, including Colleges and Universities: 153
- Door Heater kW – 12¹⁴

Information About the Refrigeration Equipment (Cold Side):

- Compressor Type – Coolers and Freezers: Packaged Condensing Unit¹⁵
- Refrigerant – Coolers and Freezers: *R404a*¹⁶
- Compressor Suction (°F) – Coolers: 22; Freezers: -22¹⁷
- Describe evaporator fan control in refrigerated space – Coolers and Freezers: *Evaporator fans always run*
- Is the refrigeration system able to maintain room temperature setpoint year round? – Yes

Information About the Refrigeration Equipment (Warm Side) [only applicable to Meat and Produce Facilities]:

- Compressor Type – Packaged Condensing Unit¹⁸
- Refrigerant – *R22*¹⁹
- Compressor Suction (°F) – 50²⁰
- Compressor Discharge psig minimum – 120²¹
- Condensers have VFD fan control? – Yes²²
- Describe evaporator fan control in refrigerated space – *Evaporator fan VFDs*²³
- Evaporator feed type – *Recirculated*²⁴
- Is the refrigeration system able to maintain room temperature setpoint year round? – Yes

Cost Information:

- Baseline cost (Equipment) – Existing Condition Baseline: \$0; Market Baseline: \$1,894²⁵
- Baseline cost (Installation) – Existing Condition Baseline: \$0; Market Baseline: \$1,000²⁶
- Estimated upgrade cost (Equipment) – Coolers: \$12,500; Freezers: \$15,500
- Estimated upgrade cost (Installation) – \$2,000

⁶ Measure Development Technical Guidelines 2024.pdf, p. 70

⁷ Average inputs specified for high-speed door custom Production Efficiency projects: 2024_EB Calc Summary.xlsx, “PE Custom Summary” tab.

⁸ Assumption for conservative savings.

⁹ Contractor information from CA: 2024_EB Calc Summary.xlsx, “Contractor Info” tab.

¹⁰ Average inputs specified for high-speed door custom Production Efficiency projects: 2024_EB Calc Summary.xlsx, “PE Custom Summary” tab.

¹¹ Online searches: 2024_EB Calc Summary.xlsx, “Business Hours” tab.

¹² *ibid*

¹³ Average inputs specified for high-speed door custom Production Efficiency projects: 2024_EB Calc Summary.xlsx, “PE Custom Summary” tab.

¹⁴ Online searches: 2024_EB Calc Summary.xlsx, “Door Heater” tab.

¹⁵ Typical for commercial walk-ins: 2024_EB Calc Summary.xlsx, “PE Custom Summary” tab.

¹⁶ *ibid*

¹⁷ *ibid*

¹⁸ Assumption for typical commercial HVAC unit.

¹⁹ *ibid*

²⁰ Assumption based on typical suction temperature of 35-65°F for HVAC compressor.

²¹ Assumption based on typical discharge pressure for HVAC compressor with R22 at about 70°F ambient.

²² Assumption for typical commercial HVAC unit.

²³ *ibid*

²⁴ *ibid*

²⁵ *Ibid*. This cost from custom PE projects represents the cost for the targeted door size of 8 ft wide x 10 ft high.

²⁶ *ibid*

- Reduction in O&M cost, annual – \$761²⁷

Using the High-Speed Door Tool v5.2, 80 separate calculator runs were created. This includes separate calculator runs for:

- 2 walk-in types (coolers and freezers)
- 5 facility types (Supermarkets, Big-Box Retail Warehouses, Meat and Produce Facilities, Hospitals, and Schools)
- 2 weather files (Salem and Redmond)
- 4 infiltration barrier types (Hard door with strip curtains; Hard door, no strip curtains; Impact door; and Gap exposed during business hours only)

Each of the 2 walk-types has 5 facility types, each facility type has 2 weather files, and each weather file has 4 infiltration barriers. Therefore, 2 x 5 x 2 x 4 = 80 calculator runs.

In addition, there are 2 baseline types (Existing Condition Baseline and Market Baseline). However, the Market Baseline type, used by the replacement and new install measure applications, did not require additional calculator runs. Rather, they used the same calculator runs used by the retrofit measure applications and applied a different weighting to those results.

Table 3 summarizes the measure application weighting for Retrofit high-speed doors.

Table 3 Measure Application Weighting for Retrofits

Weather File Weighting		Infiltration Barrier Type Weighting		Total Weighting
Salem	93%	Hard door, no strip curtains	30%	27.9%
		Hard door with strip curtains	50%	46.5%
		Impact door	15%	14.0%
		Gap exposed during business hours only	5%	4.7%
Redmond	7%	Hard door, no strip curtains	30%	2.1%
		Hard door with strip curtains	50%	3.5%
		Impact door	15%	1.1%
		Gap exposed during business hours only	5%	0.4%
Total				100.0%

Table 4 summarizes the measure application weighting for Replacement and New Install high-speed doors.

Table 4 Measure Application Weighting for Replacements and New Installs

Weather File Weighting		Infiltration Barrier Type Weighting		Adjusted Weighting	
				Coolers	Freezers
Salem	93%	High-speed door, no air curtains	5%	4.4%	0.0%
		High-speed door with air curtains	5%	0.0%	4.4%
		Hard door, no strip curtains	27%	26.6%	26.6%
		Hard door with strip curtains	45%	44.3%	44.3%
		Impact door	14%	13.3%	13.3%
		Gap exposed during business hours only	5%	4.4%	4.4%
Redmond	7%	High-speed door, no air curtains	5%	0.3%	0.0%
		High-speed door with air curtains	5%	0.0%	0.3%
		Hard door, no strip curtains	27%	2.0%	2.0%
		Hard door with strip curtains	45%	3.3%	3.3%
		Impact door	14%	1.0%	1.0%
		Gap exposed during business hours only	5%	0.3%	0.3%
Total				100.0%	100.0%

The infiltration barrier type weighting was adjusted to account for the fact that “High-speed door, no air curtains” only applies to coolers, and “High-speed door with air curtains” only applies to freezers, as confirmed by contractor information.

The above weightings were applied to the 80 calculator runs to result in weighted average savings for 20 preliminary measure applications, 10 for walk-in coolers and 10 for walk-in freezers.

While the door heater energy penalty was accounted for in the High-Speed Door Tool v5.2, savings from air curtains is not incorporated in the current tool. Therefore, air curtain analysis was based on a modified version of the RTF’s Refrigerated Doorway Air Curtain workbook v1.1²⁸.

HVAC interactive effects were estimated using factors from RTF’s [StandardInformationWorkbook_v4_8](#) in the Com HVAC Interaction Factors tab. The Grocery building type was referenced, as it corresponds best to remote-condensing refrigeration units. HVAC interactive effects are assumed negligible for remote-condensing refrigeration units, as the heat is removed outside the building. Since the walk-ins targeted for this measure are assumed to be remote-condensing, there are no HVAC interactive effects assumed for the refrigeration savings from high-speed doors. However, there are HVAC interaction effects assumed for walk-in freezers in Meat and Produce Facilities that have air curtains and are assumed to have conditioned space adjacent to walk-ins. The disaggregated interaction factors were used for three separate HVAC scenarios: electric heating and cooling, heat pump heating and cooling, and gas heating with electric cooling. Therefore, separate measure applications were needed for each of these HVAC scenarios. Additional measure applications were used for instances when buildings have both electric and gas savings with electric-only participating utilities. In those cases of out-of-territory fuel savings, the gas savings were converted to NEBs.

Therefore, the 10 preliminary measure applications for walk-in freezers were increased to 40 measure applications to capture HVAC interactive effects with savings from air curtains on walk-in freezers. There were, thus, 50 preliminary measure applications including walk-in coolers. These 50 preliminary measure applications were reduced to a final total of 10 measure applications by averaging the results of the 5 different building types with equal weightings. A weighted average of the building types was attempted with 2019 CBSA data. However, missing data for Big-Box Retail Warehouses, Meat and Produce Retail Facilities, and Colleges/Universities prohibited the use of CBSA data to calculate reliable building type weightings.

²⁷ ibid

²⁸ [2024_RefrigeratedDoorwayAirCurtains_v1_1.xlsm](#)

Savings

Average annual electric savings from high-speed doors (including the door heater penalty), electric savings from air curtains (including the air curtain fan motor penalty), electric and gas savings from HVAC interactive effects, and NEBs for all measure applications are shown in Table 5. For measure applications with both electric and gas savings and with electric-only participating utilities, gas savings were converted to NEBs using a commercial blended utility rate referenced in the CEC.

Table 5 Measure Application Annual Energy Savings

#	Measure Application	High-Speed Door Savings	Air Curtain Savings	Refrigeration Interactive Effects for HVAC Savings/Penalties			Total Electric Savings (kWh)	Total NEBs (Annual \$)
		Electric Savings (kWh)	Electric Savings (kWh)	Heating Savings (kWh)	Heating Savings (therms)	Cooling Savings (kWh)		
1	Retrofit High-Speed Door on Walk-In Cooler	28,580.95	0.00	0.00	0.00	0.00	28,580.95	\$761.00
2	Replacement and New Install High-Speed Door on Walk-In Cooler	27,219.95	0.00	0.00	0.00	0.00	27,219.95	\$761.00
3	Retrofit High-Speed Door on Walk-In Freezer, Electric Heating	171,450.64	1,635.00	301.51	0.00	-27.41	173,359.74	\$761.00
4	Replacement and New Install High-Speed Door on Walk-In Freezer, Electric Heating	163,286.33	1,635.00	306.99	0.00	-27.41	165,200.91	\$761.00
5	Retrofit High-Speed Door on Walk-In Freezer, HP Heating	171,450.64	1,635.00	142.53	0.00	-27.41	173,200.76	\$761.00
6	Replacement and New Install High-Speed Door on Walk-In Freezer, HP Heating	163,286.33	1,635.00	148.01	0.00	-27.41	165,041.93	\$761.00
7	Retrofit High-Speed Door on Walk-In Freezer, Gas Heating	171,450.64	1,635.00	0.00	13.60	-27.41	173,058.23	\$761.00
8	Replacement and New Install High-Speed Door on Walk-In Freezer, Gas Heating	163,286.33	1,635.00	0.00	13.71	-27.41	164,893.92	\$761.00
9	Retrofit High-Speed Door on Walk-In Freezer, Gas Heating, Electric Only	171,450.64	1,635.00	0.00	0.00	-27.41	173,058.23	\$775.78
10	Replacement and New Install High-Speed Door on Walk-In Freezer, Gas Heating, Electric Only	163,286.33	1,635.00	0.00	0.00	-27.41	164,893.92	\$775.90

As a “reality check” of these very high savings, they were compared to the 202 Idaho TRM²⁹. While having different combinations of measure applications, it does show savings in the same order of magnitude.

Table 6 Idaho 2020 TRM savings for high speed doors

kWh savings per 8x10ft door:		
Idaho TRM	Retrofit	NC
refrigerated space to dock:	32,000	28,800
Freezer Space to Dock	224,960	202,480
Freezer Space to Refrigerated Space	162,560	146,320

Comparison to RTF or other programs

There are no current RTF measures for high-speed doors in refrigerated spaces. However, the RTF has approved conducting research into such a measure and convened a subcommittee in 2024 to begin discussing the research.

The Production Efficiency team of Energy Trust leads the semi-prescriptive MAD 213.4 – High Speed Door Tool, for which the High-Speed Door Tool version 5.2 was created. MAD 213 is intended for high-speed doors installed in larger walk-in units in industrial settings.

Savings from air curtains were based on a modified version of the RTF’s Refrigerated Doorway Air Curtain workbook v1.1. The following modifications were made to the RTF’s workbook for this measure:

- Air curtain spec assumptions were updated for the 10’ high x 8’ wide high-speed door dimension targeted for this measure.
- Temperature and relative humidity of walk-in space and adjacent space were updated to align with the assumptions used for the high-speed door savings.
- The walk-in door opening time and annual hours of operation for building types were updated to align with the assumptions used for the high-speed door savings.

Measure Life

The measure life of a high-speed door is assumed to the full life of a typical walk-in unit, which is expected to be 15 years, as determined by custom Production Efficiency high-speed door projects. Contractor information provided a range of 15-20 years³⁰. The lower end of 15 years supports a conservative estimate for this measure.

Load Profile

- Electric Load Profile:
 - “Refrigeration” for all measure applications
- Gas Load Profile:
 - “None – gas” for all electric-heating measure applications
 - “Com Heating” for all gas-heating measure applications

Cost

The Existing Condition Baseline for retrofits assumes no cost. The Market Baseline for replacements and new installs assumes \$1,894 for material cost and \$1,000 for labor cost, which are average costs for non-high-speed door infiltration barriers from custom Production Efficiency high-speed door projects³¹.

²⁹ <https://docs.idahopower.com/pdfs/EnergyEfficiency/Reports/2020TRM.pdf>

³⁰ Contractor information from OR: 2024_EB Calc Summary.xlsx, “Contractor Info” tab.

³¹ Average inputs specified for high-speed door custom Production Efficiency projects: 2024_EB Calc Summary.xlsx, “PE Custom Summary” tab.

For the typical 8’ wide x 10’ high size of high-speed doors, the material cost is assumed to be \$12,500 for coolers and \$15,500 for freezers, and the labor cost is assumed to be \$2,000 for both coolers and freezers. These costs were derived from contractor-provided estimates, with material cost ranges of \$10,000-\$15,000 for coolers and \$13,000-\$18,000 for freezers³². The additional cost for the freezer doors accounts for the air curtain and additional door heater, both of which are typically installed only with high-speed freezer doors.

Non Energy Benefits

Reduced annual O&M (Operations & Maintenance) cost of \$761/yr is accounted for as a NEB and is derived from an average cost from custom Production Efficiency high-speed door projects. Project NEB values of \$0 were assumed to be not studied or quantified and were treated like blank values. O&M savings may include reduced maintenance needed on the walk-in refrigeration equipment, less time to de-ice the refrigeration coils, reduced maintenance needed to replace broken door springs, and reduced maintenance on heating equipment of adjacent heated spaces.

In addition, out-of-territory gas savings from HVAC interactive effects were converted to NEBs for measure applications having both electric and gas savings with electric-only participating utilities.

The total NEBs are the sum of NEB values from O&M savings and HVAC interactive effects.

Incentive Structure

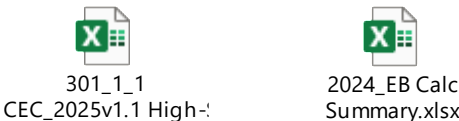
The maximum incentives listed in Table 1 are for reference only and are not suggested incentives. Incentives will be structured per door.

Follow-Up

- The latest market weightings of existing infiltration barrier types on commercial walk-in units should be checked and updated as needed.
- The latest building type weightings should be checked and used if available. Building types were weighted equally in this analysis because building type weightings were not available for all building types targeted in this MAD.
- HVAC heating type weightings should be checked and used. Measure applications were separated in this analysis by electric heating, heat pump heating, and gas heating because HVAC heating type weightings were not available for all building types targeted in this MAD. HVAC heating type weightings can be developed using project data in the next update because heating type will be recorded for each project.
- Cost estimates should be checked and updated as needed.
- Updates to code requirements for infiltration barrier types in commercial walk-in units should be checked.
- Input assumptions used in the High-Speed Door Tool should be checked and updated as needed.
- Updates to the RTF’s Refrigerated Doorway Air Curtain workbook should be checked.

Supporting Documents

The cost effectiveness screening for these measures is number 301.1.1. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Commercial and Industrial\Grocery\High Speed Doors



Version History and Related Measures

Table 7 Version History

Date	Version	Reason for revision
10/18/2024	301.1	Introduce High-Speed Doors for Commercial Walk-In Coolers and Freezers measure.

Table 8 Related Measures

Measures	MAD ID
Advanced Controls for walk ins	300
Refrigeration control calculator tool	214
Rack System Grocery Refrigeration Improvements	105
Grocery Evaporator Fan Motors	149
High Speed Door Tool	213

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³² Contractor information from OR: 2024_EB Calc Summary.xlsx, “Contractor Info” tab.

Measure Approval Document for Cooling Tower Fan VFD Tool

Valid Dates

January 1, 2024 - December 31, 2026

End Use or Description

This document approves use of the Cooling Tower Van VFD tool version 1.39. This tool calculates site-specific savings for adding variable speed control, such as a VFD or ECM to an industrial or agricultural cooling tower fan.

A cooling tower is used to cool water to a lower temperature by rejecting the heat to the atmosphere. A fan is used to blow ambient air across the water to cool it using evaporative condensing. The water is passed over a medium in order to increase the surface area and the time of contact between the air and water. Often the fan runs uncontrolled at full speed throughout the year. Energy can be saved by installing a VFD and controlling this fan to a cold water temperature setpoint, or wet bulb temperature setpoint, and slowing the fan down when it is not needed.

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

- Retrofit
- New
- Replacement

Purpose of Re-Evaluating Measure

This measure update will revise the avoided costs to the 2024 avoided costs and change the source data for weather to TMYx instead of TMY3.

Requirements

- One Cooling Tower
- Total Fan power of 100 hp or less

This Tool Is not approved for

- Cooling towers serving chillers. In this case, the change in chiller energy would also need to be calculated, which is beyond the scope of the tool.
- VFDs of pumps serving cooling towers
- Systems with multiple towers or total fan hp over 100 hp are more complex and should be custom evaluated by an engineer to optimize energy performance

Details

The tool uses the affinity laws to calculate the energy savings associated with adding variable speed control, such as a VFD or ECM to an industrial or agricultural cooling tower fan and was found to be technically sound. It incorporates a cost-effectiveness calculator within the tool itself, such that individual projects can be analyzed for cost-effectiveness on a case-by-case basis.

Baseline

This measure uses an

- Existing Condition Baseline for Retrofit projects or
- Full Market Baseline for New Construction or Replacement projects.

Baseline is generally a standard efficiency constant speed fan with no variable speed control. There are several possible baseline control schemes, outlined in the Baseline Fan Power section below. Site-specific baseline information details are provided by the vendor and confirmed by program staff.

Measure Analysis

Tool Inputs

- Nearest Weather Station
- Fan Make/Model
- Fan Motor hp
- Fan Quantity
- Water Flow Rate
- Fan Type (axial or centrifugal)
- Baseline Fan Control with associated setpoint
- Fan Variable Speed Control with associated setpoint
- Cooling Tower Performance Ratings (6 conditions including Range, Wet bulb and Condenser Water Temp)
- Average cooling load profile (16 bins including weekday day/evening/night shifts and /weekends, for each season)
- System operation during warm weather and high activity (how does the cooling tower handle the load?)
- Optional input: measured total fan power. If no measurement was taken, the tool will utilize the input nameplate motor hp to calculate baseline fan power as described below.

Load Factor

The aggregate load factor is calculated for 12 bins of data, day/evening/night shift for each season. The average load for each shift is calculated as a weighted average of the weekday (5/7) and weekend (2/7) loads.

The load factors are based on the following assumptions:

Table 1: Seasonal Load Factors

Load	Factor
High	1
Medium	0.67
Low	0.33
No Load	0.10
Off	0

An overall correction factor is applied to the load factor, based on how the system handles the load during warm weather and high activity based on the following assumptions:

Table 2: System Operation Load Factors

System Operation	Factor
Always meets the load with spare capacity	0.8
Meets the load effectively, but without extra capacity	1
Occasionally cannot meet the load	1.25
Often cannot meet the load	1.5

The load in tons of refrigeration (TR) is calculated using the seasonal load factor multiplied by the system operation factor multiplied by the average refrigeration load from the performance ratings.

Performance Ratings

The performance ratings include a range, wet bulb temperature, and cold water temperature. The range is the difference between the incoming hot water temperature and the leaving cold water temperature that is achievable at a given wet bulb temperature condition.

The refrigeration load, TR, can be calculated using the following equation:

$$Q = m \cdot C_p \cdot Range$$

Where:

- Q= refrigeration load (TR)
- m= mass flowrate of water (lbs/hr)
- C_p= specific heat of water (TR/lb/°F)
- Range= (T_{hot water}-T_{cold water}) (°F)

Using the performance ratings, coefficients are used to calculate the cold water temperature given the range and wet bulb temperatures, where cold water temperature is calculated as:

$$Cold\ Water\ Temp = a + b \cdot Range + c \cdot Wet\ Bulb\ Temp + d \cdot Range \cdot Wet\ Bulb\ Temp$$

The actual achievable range is calculated from the refrigeration load for each seasonal bin. The actual cold water temperature is calculated using the maximum of the baseline cold water temperature setpoint (if applicable) or the calculated cold water temperature from the actual range and wet bulb temperature for each temperature bin. For wet bulb approach control, the actual cold water temperature is calculated using the maximum of the minimum cold water temperature and the outdoor ambient wet bulb temperature plus the wet bulb approach.

The maximum range is calculated from the cold water temperature and the wet bulb temperature for each bin and the coefficients derived from the performance ratings.

Baseline Fan Power

The baseline full speed fan power is calculated using the measured fan power, if available. If not available, it utilizes the motor hp, an assumed 80% motor loading factor, and a motor efficiency value which is estimated from data from MotorMaster based on the motor hp.

There are five different potential baseline fan control strategies

Baseline, no controls

The baseline fan % duty is calculated, assuming that the fan runs at 100% duty for each bin as long as the system is not “off”. For systems that are used year-round, the fan would operate 8,760 hours/yr.

Baseline, Cold Water Temp Control (cycling)

The baseline fan % duty is calculated as the ratio of the required range/maximum range for each bin.

Baseline, Cold Water Temp Control (damper)

The baseline fan % duty is calculated, assuming that the fan runs at 100% duty for each bin as long as the system is not “off”. For systems that are used year-round, the fan would operate 8,760 hours/yr. The baseline fan % damper position is calculated as the ratio of the required range/maximum range for each bin. The % power is calculated from the % damper position based on the part load curve shown in Figure 1.

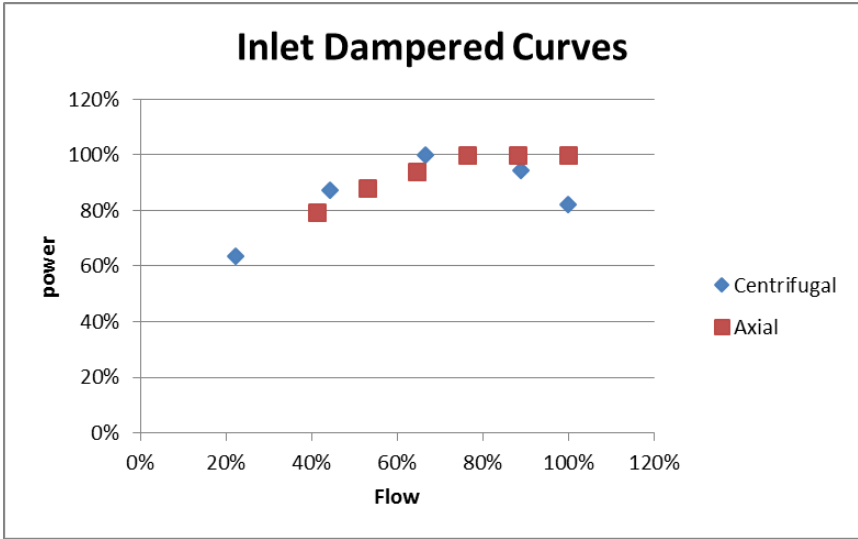


Figure 1: Inlet Damper Part Load Curves

Baseline, WB Approach Control (cycling)

The cold water temperature set point is calculated for each bin using the wet bulb temperature plus the approach temperature setpoint. The minimum cold water temperature setpoint for each bin is set at the minimum wet bulb temperature setpoint. The baseline fan % duty is calculated as the ratio of the required range/maximum range for each bin.

Baseline, WB Approach Control (damper)

The baseline fan % duty is calculated, assuming that the fan runs at 100% duty for each bin as long as the system is not “off”. For systems that are used year-round, the fan would operate 8,760 hours/yr. The baseline fan % damper position is calculated as the ratio of the required range/maximum range for each bin. The % power is calculated from the % damper position based on the part load curve shown in Figure 1.

Baseline Energy Summary

The baseline energy use is calculated to be the average of the calculated baseline fan power for each of the 12 seasonal weather bins multiplied by the total hours per year, 8,760. Note that the fan power during bins where the cooling tower is off shows 0 kW, so the average power reflects the off-time of the equipment.

Upgrade Fan Power

The upgrade full speed fan power is assumed to be the same as the baseline full speed fan power. Power at reduced speeds is calculated, using the following equation:

$$Power_{percent\ speed} = \frac{Power_{Full\ Speed} \cdot Percent\ Speed^{2.7}}{VFD\ Efficiency}$$

Where:

Power _{percent speed} =	Power at reduced speed (kW)
Power _{full speed} =	Baseline Power at full speed (kW)
Percent Speed=	% Speed (%)
2.7=	The affinity laws show a cubic relationship between speed and power. In practice, we have found this to be closer to 2.7 to be conservative.
VFD Efficiency=	VFD efficiency (%) is estimated at 97% due to line losses

Cold Water Temp Control (Variable Speed Control)

The cold water temperature set point is specified. The cold water temperature for each bin is determined as either the specified cold water temperature or 5 degrees higher than the wet bulb temperature, whichever is higher. The upgrade fan % speed is calculated as the ratio of the required range/maximum range for each bin. Note that the minimum speed is assumed to be 20%.

WB Approach Control (Variable Speed Control)

The cold water temperature set point is calculated for each bin using the wet bulb temperature plus the approach temperature setpoint. The minimum cold water temperature setpoint for each bin is set at the minimum wet bulb temperature setpoint. The upgrade fan % speed is calculated as the ratio of the required range/maximum range for each bin. Note that the minimum speed is assumed to be 20%.

Savings

The energy savings is calculated as the total baseline energy consumption minus the total upgrade energy consumption of the cooling tower fans. Note that the baseline and upgrade energy does not consider the pump energy consumption. It is assumed to operate constantly at a constant flow rate when the cooling tower is in operation in both the baseline and upgrade cases.

Measure Life

Measure life is based upon the industrial sector custom measure life of 15 years.

Load Profile

For any agricultural facilities, an Ag-Irrigation load profile will be used. For industrial facilities, operating hours will be input into the calculator, which will be the basis for use of a 1-Shift (if <4160 hours per year), 2-Shift (if <6240 hours per year), 3-Shift (if <8760 hours per year) or Flat (if 24/7 operations) Industrial load profile.

Cost

Costs are based upon vendor estimates for the particular site. The tool does not include any cost assumptions.

Non Energy Benefits

The tool allows user to input projected annual O&M or other cost savings associated with the measure. This is expected to be rare.

Incentive Structure

An integrated cost-effectiveness calculator ensures the specific installation is cost-effective before an incentive is offered. Not cost-effective projects will not qualify. Savings and incentives are calculated on case-by-case basis. Incentives will be offered in the format of a \$ per kWh savings rate capped at a specified percentage of project cost. The specific incentive rate and cap will be determined by the program not to exceed UCT limits.

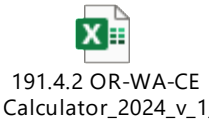
Follow-Up

This tool is approved with expectation that it will be updated with 2024 avoided costs. Tool must be updated for annually for electric avoided cost updates, even if these are released before the MAD expires.

Tool should be reapproved at any major update.

Supporting Documents

The cost effectiveness placeholder for these measures is number 191.4.2 It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Commercial and Industrial\Process Equipment\SI calculators\Cooling Tower Fan VFD



Version History and Related Measures

Energy Trust has been offering VFD calculator tools 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
8/2/16	191.1	New Measure, Tool version 1.1
12/26/17	191.2	Update to 2018 avoided costs, version 1.3
6/15/20	191.3	Update to 2021 avoided costs, version 1.32
11/16/23	191.4	Update to 2024 avoided costs, version 1.39

Table 4 Related Measures

Measures	MAD ID
Prescriptive Industrial Fan VFD	282
Prescriptive pump VFD (including cooling tower pumps)	284
Simple Fan tool	59

Approved & Reviewed by

Jackie Goss, PE
Sr. Engineer – Planning & Evaluation

Disclaimer

This Energy Trust document and its attachments may be used by you or shared, at no cost, with other parties who are interested in our work and analyses. Should you or anyone with whom this document is shared, have suggestions for improvement of our work, please let us know. You may modify this document and the attached economic and engineering analyses, but if so, please ensure that it is no longer identified as an Energy Trust document. Energy Trust makes no representations or warranties about the suitability of the documents for any particular use and disclaims all express and implied warranties with regard to the documents, including warranties of non-infringement, merchantability or fitness for a particular purpose.

Measure Approval Document for Industrial Steam Trap Replacement and Repair



Valid Dates
1/1/2025-12/31/2027

End Use or Description
Replacement or rebuild 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 classes:

- Replacement

Purpose of Re-Evaluating Measure
Version 200.5 Correct cell reference in workbook. Savings for row #14 updated.

Version 200.4: Updated costs and savings assumptions; revised measure definitions to represent line size rather than orifice size; added partial-year operation measure offerings.

Cost-Effectiveness
Cost-effectiveness is demonstrated for Oregon in Table 1 and for Washington in Table 2. Cost-effectiveness was calculated using the tool: OR-WA-CE Calculator 2025-v2.1. The Oregon gas avoided cost year is 2025. The Washington gas avoided cost year is 2025. 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	% Elec	% Gas
1	3/4 Inch Line, Low Pressure Steam Trap, Full Year Operation	6	0.00	519.52	755.17	\$0.00	\$755.17	4.9	4.9	0%	100%
2	1 Inch Line, Low Pressure Steam Trap, Full Year Operation	6	0.00	1,732.51	870.86	\$0.00	\$870.86	14.3	14.3	0%	100%
3	1 1/4 Inch Line, Low Pressure Steam Trap, Full Year Operation	6	0.00	2,112.82	1,344.48	\$0.00	\$1,344.48	11.3	11.3	0%	100%
4	1 1/2 Inch Line, Low Pressure Steam Trap, Full Year Operation	6	0.00	2,112.82	1,516.49	\$0.00	\$1,516.49	10.0	10.0	0%	100%
5	1/2 Inch Line, Medium Pressure Steam Trap, Full Year Operation	6	0.00	274.74	590.90	\$0.00	\$590.90	3.3	3.3	0%	100%
6	3/4 Inch Line, Medium Pressure Steam Trap, Full Year Operation	6	0.00	525.26	690.12	\$0.00	\$690.12	5.5	5.5	0%	100%
7	1 Inch Line, Medium Pressure Steam Trap, Full Year Operation	6	0.00	2,075.72	1,015.57	\$0.00	\$1,015.57	14.7	14.7	0%	100%
8	1 1/4 Inch Line, Medium Pressure Steam Trap, Full Year Operation	6	0.00	2,653.48	1,482.49	\$0.00	\$1,482.49	12.9	12.9	0%	100%
9	1 1/2 Inch Line, Medium Pressure Steam Trap, Full Year Operation	6	0.00	4,080.08	1,650.96	\$0.00	\$1,650.96	17.8	17.8	0%	100%
10	2 Inch Line, Medium Pressure Steam Trap, Full Year Operation	6	0.00	5,982.22	2,085.66	\$0.00	\$2,085.66	20.6	20.6	0%	100%
11	3/4 Inch Line, Low Pressure Steam Trap, Partial Year Operation	6	0.00	184.57	755.17	\$0.00	\$755.17	1.8	1.8	0%	100%
12	1 Inch Line, Low Pressure Steam Trap, Partial Year Operation	6	0.00	615.50	870.86	\$0.00	\$870.86	5.1	5.1	0%	100%
13	1 1/4 Inch Line, Low Pressure Steam Trap, Partial Year Operation	6	0.00	750.61	1,344.48	\$0.00	\$1,344.48	4.0	4.0	0%	100%
14	1 1/2 Inch Line, Low Pressure Steam Trap, Partial Year Operation	6	0.00	750.61	1,516.49	\$0.00	\$1,516.49	3.6	3.6	0%	100%
15	1/2 Inch Line, Medium Pressure Steam Trap, Partial Year Operation	6	0.00	105.55	590.90	\$0.00	\$590.90	1.3	1.3	0%	100%
16	3/4 Inch Line, Medium Pressure Steam Trap, Partial Year Operation	6	0.00	201.80	690.12	\$0.00	\$690.12	2.1	2.1	0%	100%
17	1 Inch Line, Medium Pressure Steam Trap, Partial Year Operation	6	0.00	797.49	1,015.57	\$0.00	\$1,015.57	5.7	5.7	0%	100%
18	1 1/4 Inch Line, Medium Pressure Steam Trap, Partial Year Operation	6	0.00	1,019.46	1,482.49	\$0.00	\$1,482.49	4.9	4.9	0%	100%
19	1 1/2 Inch Line, Medium Pressure Steam Trap, Partial Year Operation	6	0.00	1,567.56	1,650.96	\$0.00	\$1,650.96	6.8	6.8	0%	100%
20	2 Inch Line, Medium Pressure Steam Trap, Partial Year Operation	6	0.00	2,298.36	2,085.66	\$0.00	\$2,085.66	7.9	7.9	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	% Elec	% Gas
1	3/4 Inch Line, Low Pressure Steam Trap, Full Year Operation	6	519.52	755.17	\$0.00	\$755.17	4.9	4.9	0%	100%
2	1 Inch Line, Low Pressure Steam Trap, Full Year Operation	6	1,732.51	870.86	\$0.00	\$870.86	14.1	14.1	0%	100%
3	1 1/4 Inch Line, Low Pressure Steam Trap, Full Year Operation	6	2,112.82	1,344.48	\$0.00	\$1,344.48	11.1	11.1	0%	100%
4	1 1/2 Inch Line, Low Pressure Steam Trap, Full Year Operation	6	2,112.82	1,516.49	\$0.00	\$1,516.49	9.9	9.9	0%	100%
5	1/2 Inch Line, Medium Pressure Steam Trap, Full Year Operation	6	274.74	590.90	\$0.00	\$590.90	3.3	3.3	0%	100%
6	3/4 Inch Line, Medium Pressure Steam Trap, Full Year Operation	6	525.26	690.12	\$0.00	\$690.12	5.4	5.4	0%	100%
7	1 Inch Line, Medium Pressure Steam Trap, Full Year Operation	6	2,075.72	1,015.57	\$0.00	\$1,015.57	14.5	14.5	0%	100%
8	1 1/4 Inch Line, Medium Pressure Steam Trap, Full Year Operation	6	2,653.48	1,482.49	\$0.00	\$1,482.49	12.7	12.7	0%	100%
9	1 1/2 Inch Line, Medium Pressure Steam Trap, Full Year Operation	6	4,080.08	1,650.96	\$0.00	\$1,650.96	17.5	17.5	0%	100%
10	2 Inch Line, Medium Pressure Steam Trap, Full Year Operation	6	5,982.22	2,085.66	\$0.00	\$2,085.66	20.3	20.3	0%	100%
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20	2 Inch Line, Medium Pressure Steam Trap, Partial Year Operation	6	2,298.36	2,085.66	\$0.00	\$2,085.66	7.8	7.8	0%	100%

Requirements

- Steam traps must be installed on the steam system supply side. Steam traps on pressurized condensate return lines are not eligible.
- Must rebuild or replace existing steam trap.
- Steam systems must operate year-round, for a minimum of 7,600 hours per year (assuming annual system downtime) to be eligible for full-year incentives.
- The steam system must operate for a minimum of 2,700 hours per year to be eligible for partial-year incentives.
- Steam traps 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)
 - Line Size ≤1.5 inches
- Medium Pressure (15-200 psig)
 - Line Size ≤ 2 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 a 2007 ICF study (p.11)¹ which referenced an Enbridge study which showed that 16.3% of steam traps in industrial sites failed to open, and 7.7% of traps surveyed failed to close. 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 through (lb/hr) = FS x CV x √ΔP 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
- Pi = Inlet pressure (psia):
- Low pressure range: <15 psig
- Medium pressure range: 15-200 psig
- Po = Outlet pressure (psia) assumed at 14.7 psia
- ΔP: Pi – Po

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

¹ Steam Traps: An Opportunity to Save Natural Gas, by ICF (prepared for Energy Trust of Oregon), 2007

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

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
- Full-year Hours of Operation: 7,600 hours/yr (assumed to be 24/7 operation with occasional down time)
- Partial-year Hours of Operation: 2,000 hours/yr (assumed to be seasonal and/or part-time operation)
- 80% Boiler efficiency²

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.

$$\text{Leaking Trap Savings } \left(\frac{\text{therms}}{\text{yr}} \right) = FP_{\text{process}} \times \text{Process savings } \left(\frac{\text{therms}}{\text{yr}} \right) + FP_{\text{drip}} \times \text{Drip savings } \left(\frac{\text{therms}}{\text{yr}} \right)$$

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:

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

Energy savings (therms/yr) are calculated for a variety of scenarios using:

- Plant operating hours (partial or full year operation)
- Line sizes from vendor data
- Orifice sizes available for each line size (vendor data)
- Pressure rating for each combination of line size and orifice size (from vendor data).

Savings for twenty measure applications are then calculated by averaging savings across orifice sizes for each available line size, pressure range (low or medium), and plant operation (partial or full year). Savings for each scenario, along with average savings results, are presented in Table 3.

² https://www.energytrust.org/wp-content/uploads/2021/05/EnergyTrust_CIGasBoilerMarketResearch-Memo_FINAL.pdf

Table 3 Energy Savings Breakdown

			Estimated Energy Savings,	
Steam Pressure	Line Size	Orifice Size	Full Year Operation	Partial Year Operation
	(in)	(in)	(Therms/yr)	(Therms/yr)
Low Pressure (<=15 psig)	3/4	1/4	338	120
	3/4	9/25	701	249
	3/4 Inch Line, Low Pressure Steam Trap		520	185
	1	1/2	1,352	480
	1	5/8	2,113	751
	1 Inch Line, Low Pressure Steam Trap		1,733	615
	1 1/4	5/8	2,113	751
	1 1/4 Inch Line, Low Pressure Steam Trap		2,113	751
	1 1/2	5/8	2,113	751
	1 1/2 Inch Line, Low Pressure Steam Trap		2,113	751
Medium Pressure (> 15 psig)	1/2	3/16	214	82
	1/2	1/8	283	109
	1/2	7/64	322	124
	1/2	3/32	279	107
	1/2 Inch Line, Medium Pressure Steam Trap		275	106
	3/4	3/16	214	82
	3/4	1/8	283	109
	3/4	7/64	322	124
	3/4	3/32	279	107
	3/4	3/16	286	110
	3/4	5/32	417	160
	3/4	1/8	421	162
	3/4	3/32	332	128
	3/4	11/39	651	250
	3/4	1/4	1,072	412
	3/4	14/69	1,110	426
	3/4	5/32	916	352
	3/4 Inch Line, Medium Pressure Steam Trap		525	202
	1	3/8	1,150	442
	1	9/32	1,354	520
	1	1/4	1,683	647
	1	7/32	1,805	693
	1	1/2	2,045	786
	1	3/8	2,412	927
	1	11/32	3,186	1,224
	1	9/32	2,971	1,141
	1 Inch Line, Medium Pressure Steam Trap		2,076	797
	1 1/4	1/2	2,045	786
	1 1/4	3/8	2,412	927
	1 1/4	11/32	3,186	1,224
	1 1/4	9/32	2,971	1,141
	1 1/4 Inch Line, Medium Pressure Steam Trap		2,653	1,019
	1 1/2	1/2	2,045	786
	1 1/2	3/8	2,412	927
	1 1/2	11/32	3,186	1,224
	1 1/2	9/32	2,971	1,141
	1 1/2	7/8	5,472	2,102
	1 1/2	3/4	5,744	2,207
	1 1/2	1/2	6,731	2,586
	1 1/2 Inch Line, Medium Pressure Steam Trap		4,080	1,568
	2	7/8	5,472	2,102
	2	3/4	5,744	2,207
	2	1/2	6,731	2,586
	2 Inch Line, Medium Pressure Steam Trap		5,982	2,298

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 most of the time, rather than only during heating hours. Commercial steam traps continue to use orifice size as a measure determination criteria.

Measure Life

Measure life is 6 years, based on the ICF study (p.17) referenced above. This is consistent with Energy Trust’s steam trap offers. 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

Flat Gas

Cost

Conversations with program staff indicate that steam traps are being purchased by installers mainly via online vendors. Cost data by line size and pressure range was pulled from the most common online vendors. Labor rate was assumed at \$143/hr based on the Industrial Energy Trust Labor Rate tool v2024.2. Hours to change a trap were assumed to be 2 hrs/trap for all line sizes except 2”, which was assumed at 3 hrs/trap. Data used in the cost analysis is shown in Table 4.

Table 4 Cost Data

Measure Name	Pressure Class	Pipe Size (in)	Data Points	Average Cost per Trap from Vendor Data	Labor Hours	Labor Cost per Hour	Total Cost (Incremental Cost)
3/4 Inch Line, Low Pressure Steam Trap	Low	0.75	2	\$469	2	\$143	\$755
1 Inch Line, Low Pressure Steam Trap	Low	1	2	\$585	2	\$143	\$871
1 1/4 Inch Line, Low Pressure Steam Trap	Low	1.25	1	\$1,058	2	\$143	\$1,344
1 1/2 Inch Line, Low Pressure Steam Trap	Low	1.5	1	\$1,230	2	\$143	\$1,516
1/2 Inch Line, Medium Pressure Steam Trap	Medium	0.5	33	\$305	2	\$143	\$591
3/4 Inch Line, Medium Pressure Steam Trap	Medium	0.75	40	\$404	2	\$143	\$690
1 Inch Line, Medium Pressure Steam Trap	Medium	1	20	\$730	2	\$143	\$1,016
1 1/4 Inch Line, Medium Pressure Steam Trap	Medium	1.25	11	\$1,196	2	\$143	\$1,482
1 1/2 Inch Line, Medium Pressure Steam Trap	Medium	1.5	8	\$1,365	2	\$143	\$1,651
2 Inch Line, Medium Pressure Steam Trap	Medium	2	9	\$1,657	3	\$143	\$2,086

It is expected that we will start to see some projects where the customer is rebuilding a steam trap, rather than replacing it. We expect that the costs will be lower for rebuilding versus replacing. 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 effectiveness screening for these measures is CEC number 200.5.4. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Commercial and Industrial\Process Equipment\steam traps\Industrial steam traps\bencost



200.5.4 OR-WA-CE
Calculator_2025_v_2

Version History and Related Measures

Energy Trust has been offering this steam trap replacement measure for many years. These may predate our measure approval documentation process and record retention requirements. Table 5 may be incomplete, particularly for measures approved prior to 2013.

Table 5 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
9/4/24	200.4	Revised measure applications to represent line size rather than orifice size; added partial-year operation measure offerings
12/27/24	200.5	Correct error in row #14 in CEC tables

Table 6 Related Measures

Measures	MAD ID
Commercial and Multifamily Steam Traps	42

Approved & Reviewed by

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Jackie Goss, PE
Lead Engineer – Planning & Evaluation

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

Valid Dates
January 1, 2025 – December 31, 2027

End Use or Description

This measure applies to in-unit, front-loading clothes washers and laundry centers sold to the multifamily market. A laundry center is a consumer product that meets the definition of a residential clothes washer and a clothes dryer, which cleans and dries clothes in separate, stacked drums.

Applicability

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

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

Within these programs, applicability to the following program designs are expected:

- Buy-down
- Midstream including retail
- Other downstream offers

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

- New
- Replacement

Purpose of Re-Evaluating Measure

This MAD has been dormant, however, it continues to be approved to leave the opportunity open to build buy-down and midstream offerings parallel to the MAD 4 - Residential Clothes Washers.

Savings, costs, and NEBs have been updated per latest RTF data with exception of RBSA data. The RTF Residential Clothes Washer workbook was published prior to the release of the 2022 RBSA. In this analysis, the 2022 RBSA was used in lieu of the 2017 RBSA used in the RTF workbook.

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 2025-v2.1. The Oregon electric avoided cost year is 2025 and the Oregon gas avoided cost year is 2025. The Washington gas avoided cost year is 2025. The values in these tables are per clothes washer or laundry center unit.

Measures 5 and 10 use weighted DHW fuels to determine the maximum incentive allowable by the OPUC exception. They are shown for information only but they are not prescriptive offerings.

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 Clothes Washer - ELE DHW	14	168.47	0.11	\$131.40	\$30.22	\$131.40	1.8	4.2	99%	1%
2	MF Clothes Washer - GAS DHW	14	56.70	5.43	\$131.40	\$30.22	\$131.40	1.2	3.6	48%	52%
3	MF Clothes Washer - Electric only territory (EOT)	14	168.47	0.00	\$131.40	\$30.35	\$131.40	1.8	4.2	100%	0%
4	MF Clothes Washer - Gas only territory (GOT)	14	0.00	5.43	\$131.40	\$40.13	\$131.40	0.6	3.8	0%	100%
5	MF Clothes Washer - Weighted DHW	14	134.23	1.74	\$131.40	\$30.22	\$131.40	1.6	4.0	87%	13%
6	MF Laundry Center Washer/Dryer - Electric DHW	12	218.62	0.13	\$386.70	\$30.10	\$252.67	1.1	1.4	99%	1%
7	MF Laundry Center Washer/Dryer - Gas DHW	12	106.85	5.45	\$386.70	\$30.81	\$252.67	0.8	1.3	64%	36%
8	MF Laundry Center Washer/Dryer - Electric only territory (EOT)	12	218.62	0.00	\$386.70	\$30.19	\$252.67	1.1	1.4	100%	0%
9	MF Laundry Center Washer/Dryer - Gas only territory (GOT)	12	0.00	5.45	\$386.70	\$38.95	\$252.67	0.3	1.1	0%	100%
10	MF Laundry Center Washer/Dryer - Weighted DHW	12	184.37	1.76	\$386.70	\$30.10	\$252.67	1.0	1.4	91%	9%

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	% Ele	% Gas
1	MF WA Clothes Washer - GAS DHW	14	5.43	131.40	\$25.45	\$79.89	1.0	2.7	0%	100%
2	MF WA Laundry Center - GAS DHW	12	5.45	386.70	\$29.43	\$70.27	1.0	0.9	0%	100%

Measure-level TRC cost effectiveness is not required in Washington programs.

Exceptions

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

On November 5, 2012 the OPUC directed Energy Trust to consider incentives for clothes washer measures based on efficiency rating as a group, rather than split by fuel, resulting in a maximum incentive for all fuel combinations of \$148.39 for clothes washers and \$252.67 for laundry centers in Energy Trust’s Oregon service territory shown in rows 5 and 10 in Table 1.

The OPUC provided an exception on September 2, 2015 for higher incentives on clothes washers in gas service territory that are not cost-effective on the basis of the established exceptions listed in UM-551, Criteria C: “The measure is included for consistency with

other demand side management DSM programs in the region.” The OPUC directed Energy Trust to consider incentive cost-effectiveness for clothes washer measures based on efficiency rating as a group, rather than separating them into different measures based on territory. The weighting is based on program data showing that 69% of multifamily clothes washer participants have electric DHW while 31% multifamily clothes washer participants have gas DHW.

Requirements

- Residential front-loading clothes washers.
- At least 2.5 cubic feet tub capacity.
- Approved by EnergyStar using the 8.1 specification for front loading washers.¹
- Water heating fuel must be provided by an Energy Trust participating utility.
- Laundry Center combined washer/dryer units must meet EnergyStar 8.1 specifications for front loading washers and EnergyStar 1.1 specifications for dryers to be eligible.^{2,3}

Implementation Requirements

- Midstream offerings will include a mechanism to verify customer is purchasing for a multifamily use.
- Midstream offerings will include a mechanism to prevent double counting with downstream or buy-down offers, including New Buildings.
- Midstream offerings will develop a mechanism to identify customer water heat fuel or use a standardized and documented process to allocate measures appropriately.
- Overlap of incentives and savings with MAD 4 Residential Clothes Washers on individual clothes washers is not allowed, eligible programs will develop mechanisms to ensure savings and incentives are booked under one offering or the other.

Details

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

Baseline

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

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

Measure Analysis

Washing Machine Energy

Both clothes washer and the clothes washer portion of laundry centers’ analysis is taken from the RTF ResClothesWasher v8.1 workbook with the addition of Energy Trust specific adjustments.⁴

Per the RTF, energy use is determined from the energy used per cycle multiplied by 311 loads per year. Energy per cycle is a function of configuration (front vs top load) and IMEF and is calculated using DOE methods modified by the RTF. EnergyStar front load washers use slightly more electricity than the market baseline due to higher and longer spin cycles but use less energy overall through decreased dryer energy needed and hot water savings.

DHW Energy

DHW savings are the reduction in energy used to heat water resulting from reductions in water used by machines with lower IWF. For electric water heaters, a water heater efficiency of 100% is assumed. The energy savings for electric and gas DHW is 112 kWh and 5.3 therms, respectively. For the weighted DHW measure a value of 69% electric share was used based on PT data from 2016 thru April 2024. Additionally, the RTF conversion factor of 0.048 therms/kWh was used to determine hot water gas savings for the weighted and gas-only measures, respectively.

Dryer Energy

Dryer savings are determined by the difference in Rated Remaining Moisture Content (RMC) between the efficient washing machines and the full market baseline. This difference in moisture content is multiplied by the annual cloth weight and typical dryer energy usage per pound of moisture to determine the annual dryer energy savings. This is a savings of 63 kWh and 2.4 therms for electric and gas dryers, respectively. However, a weighted dryer fuel is used for all measures.

Dryer Fuel Weighting

The RTF uses a regional average of 94% electric dryers sourced from the 2017 RBSA which accounts for all housing types. This analysis used multifamily specific values from the 2022 RBSA data and found 96% of dryers to be electric.⁵ Since these measures are not differentiated by dryer type, this updated weighted value was used to determine the clothes dryer’s savings incorporated in total clothes washer savings for all measures.

Laundry Centers – Dryer Savings

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

As EnergyStar laundry center washers have the same requirements as stand-alone clothes washers, the motor and other efficiency requirements and savings are the same. Savings are drawn directly from the RTF’s analysis of annual clothes washer consumption and weighted to any dryer type as noted above.

The RTF ResClothesDryer v5.1 workbook was supplemented to determine the added dryer savings applicable to laundry centers.⁶ This annual consumption analysis uses NEEA market shares of EnergyStar and non-EnergyStar dryers to provide weighted current

¹ EnergyStar Clothes Washer [8.0 Specification](#).

² EnergyStar Clothes Washer [8.1 Specification](#).

³ EnergyStar Clothes Dryer [1.1 Specification](#).

⁴ Current RTF Residential Clothes Washer Workbook: [ResClothesWashers_v8_1.xlsm | Powered by Box](#)

⁵ Northwest Energy Efficiency Alliance Residential Building Stock Assessment II: <https://neea.org/resources/rbsa-ii-combined-database>

⁶ Residential Clothes Dryer Workbook v5.1: [ResClothesDryers_v5_1.xlsm | Powered by Box](#)

practice energy use for gas and electric dryers. Savings are then determined from the difference between current practice and EnergyStar energy consumption. The applicable RTF calculations used in the estimate of dryer annual consumption are:

- Annual consumption: [Annual Pounds Clothes] / [Utility Combined Energy Factor (UCEF)]
- HVAC Interactive effects: [Annual Infiltration] x {[Infiltration kWh heating per CF] + [Infiltration kWh cooling per CF]}

Estimated electric, gas, and non-utility fuel savings (or penalties) for gas and electric dryer fuel types are shown in Table 3.

Table 3 RTF Dryer Savings and Costs

Dryer Type	Energy Savings, relative to Current Practice Baseline			Incremental Cost (2024\$)
	Electricity (kWh/ year)	Gas (therms/ year)	Other fuels (kWh/ year)	
EnergyStar Electric Dryer	53	0	-1	\$23.50
EnergyStar Gas Dryer	-0.4	1.6	-0.5	\$21.61

Comparison to RTF or other programs

This analysis follows the RTFs ResClothesWasher v8.1 workbook analysis with the addition of Energy Trust specific adjustments:

- Dryer fuel splits are unique to Energy Trust. RTF uses 2017 RBSA data for all housing types while this analysis used 2022 RBSA data specific to multifamily to determine fuel weights.
- Due to concerns with incremental cost analysis from RTF and a lack of data on laundry centers, new methodology was used to determine incremental costs. All cost analysis was taken from MAD 4 for this iteration of MAD 152.
- MAD 4 requirements differ from MAD 152. MAD 4 does not allow electric dryers with their laundry centers or supply washers to Washington customers.

Measure Life

For clothes washers the measure life is 14 years, consistent with the RTF clothes washer analysis. For laundry centers the measure life is 12 years in alignment with the RTF dryer analysis and previous dryer MADs. When one of the units in a laundry center fails and cannot be repaired, it is assumed that the entire laundry center is replaced. Therefore, the measure life is set equal to the lower expected lifespan between the two equipment types.

Load Profile

These measures use residential sector load profiles. Load profiles of *Res Clotheswasher* and *Clotheswasher* for electric and gas savings respectively, were applied.

Cost

Based on the agreement between the Residential and EB Program teams and ETO Planning Leads, the cost analysis for this measure was aligned with MAD 4 - Residential Clothes Washers. Below is the description of the cost estimation methodology from MAD 4.

Cost for clothes washers and laundry centers were sourced from online price research.

For efficient clothes washers, individual model numbers were grouped into Model Families by manufacturer, capacity and efficiency level to remove noise associated with model variables such as color, display, and feature sets. Twenty-five individual Model Families were identified, with the top 10 model families accounting for 91 percent of program volume. For these top Model Families online costs were found for model numbers reported by the program retail partner. The MSRP for these model families were weighted by program volume to determine a weighted average efficient clothes washer cost of \$1,144, see Table 4. At the time of cost research many units were available at reduced prices, with an average discount of 24 percent. Consumer are expected to purchase items at the lower discounted price when available, per program discussion, MSRP was reduced by the average price reduction, yielding a final ENERGY STAR front load clothes washer price of \$871.

Table 4: Clothes washer efficient case pricing

Model Family	Program Volume	Percent of Program Volume	Average MSRP
Whirlpool - 4.3 - 2.76	2,783	22%	\$1,049
LG - 4.5 - 2.92	2,142	17%	\$1,053
Electrolux - 4.5 - 2.92	1,972	16%	\$1,345
GE - 4.8 - 2.76	1,554	12%	\$1,133
GE - 5 - 2.76	1,094	9%	\$1,221
Samsung - 4.5 - 2.95	577	5%	\$937
Maytag - 5 - 2.76	426	3%	\$1,399
Whirlpool - 4.5 - 2.76	381	3%	\$1,049
Maytag - 4.5 - 2.76	204	2%	\$999
LG - 5 - 3.1	192	2%	\$1,499
Weighted Average	11,325	91%	\$1,144

For non-qualified washers, online costs for fifty-three model numbers from the RTF Clothes Washer analysis were used. Washers were grouped according to loading configuration and efficiency level, a median price for each category was determined from the online cost data. As with the ENERGY STAR models, the MSRP was reduced by the price reduction observed online at time of data collection, 25 percent, for final top load washer price of \$598.26 and front load price of \$1,178.56. See Table 5 for MSRP, price reduction, and final prices for each washer category.

A market baseline cost of \$740 was determined by weighting the non-qualified median costs and program qualified weighted average cost, by NEEA market shares, as shown in **Error! Reference source not found..** The same weighted average \$894.75 price was used for both Front-Load CEE Tier 1 and CEE Tier 2 as qualified products could be either of these efficiency levels. Subtracting the program weighted average cost from the market baseline results in an incremental cost of \$131.40 for clothes washers.

Table 5: Clothes washer current practice market baseline and incremental cost

Clothes Washer Configuration & Efficiency		NEEA Market Share	MSRP	Price Reduction	Final Price	Price Source
Top Load	NQ	44%	\$799.00	25%	\$598.26	Median retail pricing RTF models
	ES	22%	\$1,099.00	24%	\$837.06	
	CEE Tier 1	6%	\$1,024.50	24%	\$780.32	
Front Load	NQ	0%	\$1,574.00	25%	\$1,178.56	Program partner weighted avg price
	CEE Tier 1	10%	\$1,143.84	24%	\$871.22	
	CEE Tier 2	18%	\$1,143.84	24%	\$871.22	
Current Practice Market Baseline					\$739.81	
ENERGY STAR Front Load Washer					\$871.22	
Incremental Cost					\$131.40	

For efficient laundry centers, the same model family analysis was performed, five model families were determined with one single model family representing 87 percent of laundry center volume. Of this single model family, there were only two distinct laundry center models reported. To expand the cost survey, online costs were found for the 8 distinct models reported through the program. These online costs were weighted by program volume for a weighted average of \$2,521. The average price reduction for laundry centers was found to be 28%, yielding a final cost of \$1,819. See Table 6Error! Reference source not found. for individual model numbers, program weight, price reductions, and weighted average cost.

Table 6: Laundry center cost details

Laundry Center Model Number	Quantity	Weight	Online MSRP	Final Laundry Center Cost
WKEX200H	578	61%	\$2,563.71	\$1,849.47
WKE100H	240	25%	\$2,354.03	\$1,698.21
ELTE7600	72	8%	\$2,499.00	\$1,802.79
WSEX200H	21	2%	\$2,599.00	\$1,874.93
ELTE7300	16	2%	\$2,499.00	\$1,802.79
WKEX300HBA	14	1%	\$2,899.00	\$2,091.35
WKHC202H	11	1%	\$3,400.00	\$2,452.77
WSEX200HNA	2	0%	\$2,797.00	\$2,017.77
Weighted Average	954	100.0%	\$2,521.82	\$1,818.53

The baseline cost for laundry centers is assumed to be the cost of a stand-alone washer and a stand-alone dryer. From the Clothes Dryer MAD 231.3, the market baseline dryer cost is \$692 and reflects non-ENERGY STAR, ENERGY STAR conventional dryers and heat pump dryers weighted by NEEA market share, as shown Table 7. Combing the market baseline clothes washer cost of \$740 and the market baseline dryer cost yields a washer and dryer set cost of \$1,432 and an incremental cost of \$387 for a qualified laundry center, see Table 8.

Table 7: Clothes dryer cost details

Electric Dryer Type	NEEA Market Share	Electric dryer cost
non-ESTAR Dryer	56.8%	\$648.22
ESTAR - Conventional electric dryer	42.8%	\$739.81
ESTAR - HP dryer	0.4%	\$1,130.84
Market Baseline Dryer Cost:		\$692.02

Table 8: Laundry set and laundry center incremental costs

Laundry Center Cost Comparison	Market Baseline Cost
Dryer Market Baseline Cost	\$692.02
Washer Market Baseline Cost	\$746.36
Washer & Dryer Set - Current Practice Market Cost	\$1,431.83
Front Load Laundry Center Elec Dryer	\$1,818.53
Laundry Center Incremental Cost	\$386.70

Non-Energy Benefits

- Water savings are estimated using the water rates provided in the 2025 CEC. In Oregon, a rate including a Combined Water Rate and the net of Embedded Energy was used while in Washington a Combined Water Rate alone was used.
- Therm savings for electric only territories and kWh gas only territories are converted to NEBs based on an Energy Trust blended residential rates updated 12/8/2023 with respect to the applicable state and fuel type.
- The RTF estimated that dryers save a small amount of non-utility fuels (converted to kWh/year) due to interactive effects. These values were converted to NEBs based on the Oregon or Washington residential electric rates.

Incentive Structure

The maximum incentives listed in Table 1 and Table 2 are for reference only and are not suggested incentives. Incentives will be structured per clothes washer or laundry center unit. If the buy-down pathway is chosen, we will offer incentives to retailers. And/or if the midstream pathway is chosen, we will provide incentives to distributors monthly or quarterly. Incentives will not exceed the max cost-effective incentive per CEC.

Follow-Up

Cost data should be updated as the market continues to change from new federal efficiency which are expected to become requirements in 2028.

There is expected to be an EnergyStar clothes dryer specification update at the next review of this MAD. All changes to RTF analysis should be considered for inclusion.

If future program designs allow for knowing both water heating and dryer fuels, unique measure identifiers should be created instead of blending dryer fuels.

Supporting Documents

The cost effectiveness screening for these measures is number 152.6.4. It is attached and can be found along with supporting documentation at: \\Etoo.org\home\Groups\Planning\Measure Development\Residential\Res Appliances\clothes washer\multifamily clothes washers



152.6.4_OR-WA-CE
Calculator_2025_v_2

Version History and Related Measures

Energy Trust has been offering multifamily clothes washer measures for many years. These predate our measure approval documentation process and record retention requirements. Table 9 may be incomplete, particularly for measures approved prior to 2013.

Table 9 Version History

Date	Version	Reason for revision
7/9/04	x	Residential Clothes washer measure for 1.26 and 1.42 MEF.
1/14/05	x	Residential Clothes washer measure for MEF 1.8.
2006	x	Residential Clothes washer measure for MEF 1.8, updated federal standard.
6/27/07	x	Residential Clothes washer measure for MEF 2.0.
12/3/07	x	Products program clothes washers for tiers at 2.0 and 2.2 MEF.
11/24/10	4.x	Differentiates baseline and savings between single family and multifamily applications. Weighted dryer fuel type. Tiers at 2.2 and 2.46 MEF.
11/21/12	4.x	Multifamily applications removed from MAD 4. Other changes to residential washer requirements.
10/29/15	152.x	Multifamily Clothes washer measures for IMEF 2.74. Cost update. Distributor buy-down only.
11/11/15	152.1	Align with ENERGY STAR specification, IMEF 2.38
8/25/2017	152.2	Update non-energy benefits. Clarifies delivery channel.
6/19/2018	152.3	Align with ENERGY STAR v8.0, IMEF ≥ 2.76 and IWF ≤ 3.2. update costs
9/13/2021	152.4	Updates to align with latest RTF ResClothesWashers_v7_1. Added laundry center measures.
11/4/2021	152.5	Correct allocation error
10/18/24	152.6	Savings, and NEBs have been updated per latest RTF data with exception of RBSA data; costs updated to align with MAD 4

Table 10 Related Measures

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

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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\(e\)\(1\)](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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Disclaimer

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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 (O₃), 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 Workpaper¹ 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 $\frac{\text{laundry washed}}{\text{year}}$ x hot water use factor

Annual Measure case usage = Annual baseline usage x (1 – hot water reduction factor)

Water Heating Energy = Density of water $\left(\frac{\text{lb}}{\text{gal}}\right) \times \text{Change in Enthalpy} \left(\frac{\text{Btu}}{\text{lb of water}}\right) \times \frac{1}{\text{Boiler Efficiency}}$

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: Source:	[lbs/Cycle] DATA	[Cycles/day] DATA	[Cycles/year] Calculation	[lbs/year] Calculation	[lbs/lbs-capacity] 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: Source:	[lbs/year] Table 3	[Gal/year] DATA	[Gal/lb] 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
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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: Source:	[Gal] DATA	[Gal] DATA	[Gal] 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: Source:	[lbs/year] Table 3	[Gal] DATA	[Gal] DATA	[Gal] Calculated	[%] Calculated	[Gal/lb] 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
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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 v11.0⁴ 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 program⁵ 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

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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

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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 effectiveness¹ 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 through² 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 mode³. Indoor pools heat transfer modes are the same.

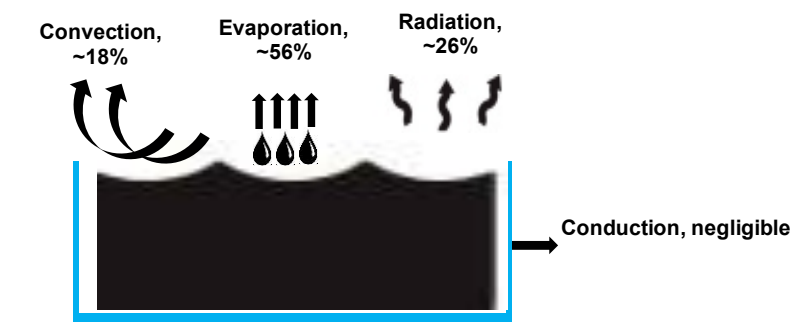


Figure 1: Heat loss ratios for outdoor swimming pools

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/ft².h)
- C = 290
- ρ_w = density of air at water surface (lb/ft³)
- ρ_r = density of air at room temperature and humidity (lb/ft³)
- 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](https://www.sciencedirect.com/science/article/pii/S0038092X9400003)

⁴ Shah, Mirza M. ASHRAE. “Methods for Calculation of Evaporation from Swimming Pools and Other Water Surfaces” (July 2014). <https://msshah.org/publications/ASHRAE%202014%20Evaporation%20paper.pdf>

Where:
 E_{occ} = rate of evaporation, occupied pools (lb/ft².h)
N = pool occupants per unit area

These equations provide evaporation rates with units of lb/ft².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 data⁵ 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	80°F	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 energy⁹ 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 ft² 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 charts¹⁴. 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/article/detail/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=408bdd1a8f4d308f0cdc14966fbd90a&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 Thermostatic Radiator Valves

Valid Dates
1/1/2025 – 12/31/2027

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 correction to a cell reference error in the calculations, resulting in a change in energy savings. The updated incremental costs also led to an increase in the maximum incentive.

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 2025-v2.1. In Oregon, the electric avoided cost year is 2025 and, in both Washington, and Oregon, the gas avoided cost year is 2025. The values in these tables are per TRV installed.

Table 1 Cost Effectiveness Calculator Oregon, per TRV

#	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	0.00	50.41	629.78	0	629.78	1.9	1.9	0%	100%

Table 2 Cost Effectiveness Calculator Washington, per TRV

#	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	55.99	629.78	0	629.78	2.4	2.4	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
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 City¹. 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.

The savings results from the study were in BTU/HDD-TRV. The results were converted to Therms/HDD-TRV and this resulted in 0.010800 Therms/HDD-TRV.

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

$$Energy\ savings\ (Therms\ per\ TRV) = \frac{0.010800\ Therms}{HDD.\ TRV} \times Avg.\ HDD\ for\ Oregon$$

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

Average HDD for Oregon was calculated with a weighted average HDD approach using data from Table 14-5 (Table 3 below) in Energy Trust’s 2024 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 4,668.

Table 3 Climate zones, Average HDDs and population weightings

Table 14-5 Climate zone population weightings

Climate Zone	Average HDD ₆₅	Average CDD ₆₅	Energy Trust Population Weighting
HZ1_CZ1	5,184	211	18.0%
HZ1_CZ2	4,348	426	64.0%
HZ1_CZ3	4,426	789	11.1%
HZ2_CZ1	6,597	242	4.0%
HZ2_CZ2	6,363	351	2.6%
HZ3_CZ1	7,896	80	0.4%

Using the above equation, average energy savings from installing TRVs in Oregon is 50.41 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 (5,184 HDD) because the majority Southwest Washington territory is HZ1_CZ1. The calculated energy savings using this approach is 55.99 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 data between 2020 and 2024. The cost is an average cost of 57 TRVs installed across three projects in 2020 and 2021. After calculating the average cost of the installation of a TRV, an inflation adjustment factor was applied to it as the inflation between 2020 and 2024 was high. The factor was derived from the GDP Deflator tool in RTF Standard Information Workbook, Version 4.8⁴. The cost per TRV adjusted to 2024 dollars is \$629.78 (includes installation).

Non Energy Benefits

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

Incentive Structure

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

Follow-Up

If the program participation for the TRV measure increases so that its savings contribute to 5% or more of overall natural gas savings, Energy Trust could consider performing a Measurement & Verification (M&V) study for TRVs. Such an M&V study could be valuable for future MAD updates as it could provide accurate energy savings for this measure.

The analysis for this measure is done based on one building in New York and an assumption that there are higher energy savings in colder climates. Additional data and sources should be researched in the future, which may lead to a better energy savings estimate.

Supporting Documents

The cost-effective screening for these measures is CEC number 45.4.3. It is attached and can be found along with supporting documentation at: \\Etoo.org\home\Groups\Planning\Measure Development\Commercial and Industrial\Commercial HVAC\thermostatic radiator valves



45.4.3 OR-WA-CE
Calculator_2025_v2.'

Version History and Related Measures

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
7/2/2024	45.4	Minor cell reference error in the calculations was corrected.

Table 5 Related Measures

Measures	MAD ID
Commercial & Multifamily Steam Traps	42

⁴ RTF Standard Information Workbook Version 4.8 - <https://rtf.nwcouncil.org/standard-information-workbook/>

Approved & Reviewed by

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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 eTRM¹.

The methodology used for estimating average dryer capacity uses the 2015 California on-premises Laundromat Dryers Market Study². 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 California³ 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 × 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% savings⁴ 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 NEEA⁵ 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 \(nicorgas.com\)](#)
⁵Modulating 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

Jackie Goss, PE
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Measure Approval Document for Virtual Grower Software

Valid Dates
7/15/2024 – 12/31/2027

End Use or Description

This document approves use of the USDA Virtual Grower Software tool v3.1 and the Greenhouse Wrapper Tool (v2.38). The Virtual Grower tool calculates site specific energy consumption for greenhouses. Outputs from that tool are used in the Greenhouse Wrapper tool to calculate savings and cost effectiveness for greenhouse improvements such as:

- Condensing Boiler Upgrades
- Greenhouse re-glazing with more efficient materials

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 (Washington only)
- Production Efficiency

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

- Greenhouses

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

- Retrofit
- Replacement
- New

Purpose of Re-Evaluating Measure

Virtual grower has been used in the SI program for several years, however a MAD was never created for it. As such, the program is documenting the use of the Virtual Grower software and associated Greenhouse Wrapper tool and how gas savings from greenhouse projects are being captured in the SI program. Additionally, the existing buildings program operating in Washington state serves greenhouse and this MAD clarifies applicability to that program.

Cost-Effectiveness

An integrated cost-effectiveness calculator in the Greenhouse Wrapper tool ensures the specific installation is cost-effective before an incentive is offered. Projects that are not cost-effective will not qualify. Cost-effectiveness on a sample of projects is demonstrated for Oregon in Table 1 and Washington in Table 2. Cost-effectiveness was calculated using the tool: OR-WA-CE Calculator 2025-v2.1. Both the Oregon and Washington gas avoided cost year is 2025.

Table 1 Cost-Effectiveness Calculator Oregon, per project

#	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	Nursery Project #1 Triple Wall Poly Upgrade	10	0.00	54,036.00	393,287.00	\$0.00	\$393,287.00	2.3	2.3	0%	100%
2	Nursery Project #2 Triple Wall Poly Upgrade	10	0.00	10,310.00	50,000.00	\$0.00	\$50,000.00	3.5	3.5	0%	100%
3	Nursery Project #3 Solexx 5mm Upgrade	10	0.00	46,684.00	173,097.00	\$0.00	\$173,097.00	4.5	4.5	0%	100%
4	Nursery Project #4 New Construction Upgrade	10	0.00	2,480.00	12,585.00	\$0.00	\$12,585.00	3.3	3.3	0%	100%
5	Nursery Project #5 Boiler Upgrade	25	0.00	2,771.00	33,806.00	\$0.00	\$33,806.00	2.7	2.7	0%	100%

Table 2 Cost-Effectiveness Calculator Washington, per project

#	Measure	Measure Life (years)	Savings (therms)	Incremental Costs (\$)	Total NEB (Annual \$)	Maximum Incentive (\$)	UCT BCR at Max Incentive	TRC BCR	% Elec	% Gas
1	Nursery Project #1 Triple Wall Poly Upgrade	10	54,036.00	393,287.00	\$0.00	\$393,287.00	2.9	2.9	0%	100%
2	Nursery Project #2 Triple Wall Poly Upgrade	10	10,310.00	50,000.00	\$0.00	\$50,000.00	4.3	4.3	0%	100%
3	Nursery Project #3 Solexx 5mm Upgrade	10	46,684.00	173,097.00	\$0.00	\$173,097.00	5.7	5.7	0%	100%
4	Nursery Project #4 New Construction Upgrade	10	2,480.00	12,585.00	\$0.00	\$12,585.00	4.1	4.1	0%	100%
5	Nursery Project #5 Boiler Upgrade	25	2,771.00	33,806.00	\$0.00	\$33,806.00	3.5	3.5	0%	100%

Requirements

- All projects must pass cost-effectiveness using the Greenhouse Wrapper tool (v2.38) to be eligible for incentives.
- The Virtual Grower software is approved for estimating energy consumption in greenhouse facilities only.
- Projects in Washington must use current Washington State Energy Code (2021 WSEC) for baseline U-factor inputs when evaluating envelope measures.

Implementation Requirements

As shown in Figure 1, on the Heating System Setup tab of Virtual Grower, the fuel cost should be set to \$1.00/therm (the default is \$2.00/therm.) This is due to how the outputs are used in the Greenhouse Wrapper tool to calculate energy consumption, which are given in terms of costs, not therms. By setting the default to \$1.00/therm the output costs can be directly used as therms.

Figure 1 Virtual Grower Default Fuel Cost Value

Heating Schedules

Heating System Setup

Heating System Name:

Fuel Type:

Natural Gas

Fuel Cost: \$ per therm

Click on image for larger image. Click on larger image to close it.

Details

Virtual Grower v3.1 is a tool developed by the USDA to assist greenhouse operators with obtaining a sense of the heating requirements and costs associated with their greenhouse. The Virtual Grower software generates an annual heating load for a specific greenhouse based on inputs from the program. Depending on inputs regarding climate zone, greenhouse envelope materials, heating system type, and annual operating hours, the software calculates a BTU load for each month of the year and produces an output showing the total estimated therm consumption. To derive savings, the program performs two runs – one baseline and one efficient case and copies the outputs from those runs into the Greenhouse Wrapper tool. This tool calculates savings as the difference in therm consumption between the two models and performs a cost-effectiveness calculation using site specific cost estimates to determine whether the project is eligible for an incentive.

Baseline

This measure uses:

- Existing Condition Baseline for Retrofit projects
- Market Baseline for New Construction and Replacement projects,

New construction and re-glazing projects (i.e., replacements) utilize a market baseline, defined as double-poly film for envelope upgrade measures. For new construction and replacement boiler measures, a federal standard boiler efficiency shall be used according to the type in below.

Table 3 Boiler Efficiency Table based on Federal Minimum Efficiencies, U.S. Department of Energy

Size Category (Input)	Gas-Fired Hot Water Efficiency	Gas-Fired Steam Efficiency
< 300,000 Btu/h	82% AFUE	80% AFUE
≥ 300,000 Btu/h and ≤ 2,500,000 btu/h	80% E _t	79% E _t
> 2,500,000 Btu/h	82% E _c	79% E _c

State Energy Code Requirements

Oregon law [ORS 455.315](#) prohibits agricultural buildings (including greenhouses) to be subjected to state codes, including energy codes. Therefore, there are no energy efficiency requirements for greenhouses in Oregon. Washington does have envelope efficiency requirements for greenhouses so long as they do not qualify as a low-energy building (i.e., have a peak heating or cooling rate less than 3.4 Btuh/sqft for space conditioning purposes). Due to the temperature maintenance requirements for greenhouses in Oregon, it is unlikely any would qualify as a low-energy building if a heating system were installed.

In Washington State, the 2021 energy code specifies minimum U-factor requirements for greenhouse walls and windows. The specific window U-factor requirements are shown below in for roof and wall areas with transparent envelope components. Exterior opaque envelope assemblies as well as any portion of the greenhouse that is connected to a conditioned space need to comply with Sections C402.2 and C402.4.4.

Table 4 Washington State Energy Code Greenhouse Envelope Requirements, 2021 WSEC

TABLE C402.1.1.3 FENESTRATION THERMAL ENVELOPE MAXIMUM REQUIREMENTS

Component	U-Factor BTU/h-ft²-°F
Skylights	0.5
Vertical Fenestration	0.6

These U-factor values (and the applicable code requirements for opaque wall assemblies and adjacent conditioned spaces) shall be used as the default U-factors in Virtual Grower for projects occurring in Washington State.

Measure Analysis

The measures analyzed in Virtual Grower are typically envelope and boiler system upgrades. The tool generates separate model runs to estimate energy consumption for baseline and efficient case conditions. Virtual Grower calculates the heat loss for a greenhouse for every hour in a year based on a user-defined heating schedule. After calculating heat flow for each hour, the total BTU is reported for each month in an output table. Consumption values are based on greenhouse location and the associated TMY3¹ weather file and standard thermodynamic heat loss equations. The software uses two basic heat loss components to calculate energy flow through a greenhouse: Conduction and Convection.

The Conduction component considers the heat transfer of the greenhouse structure (ex. Poly film, framing components, etc.). A user selects the appropriate material (or inputs specific material characteristics) and the associated area of that component, and the tool calculates the conductive losses to the outside across that component based on the temperature differential and heat loss rate.

The Convection component accounts for the heat exchange between indoor and outdoor air. The volume of the greenhouse is multiplied by the delta-T of the air temperature inside and outside the greenhouse for each hour. An estimate of air infiltration (qualitative input by the user) and wind speed (based on TMY3 data) are used to correct the convective heat loss rate. The total greenhouse heat loss is the sum of the conductive and convective heat loss components.

To account for heat gain through solar radiation, the software multiplies the amount of light energy intercepted per square foot of ground space by the total footprint of the greenhouse. This radiation component is provided by TMY3 data, and Virtual Grower assumes approximately 33% of the available radiation is beneficial to heating the greenhouse, with the rest being lost to reflection and plant

¹ Although Energy Trust has moved to using TMYx weather data, the Virtual Grower software does not allow weather station overrides and still relies on TMY3 at this time. It is expected that future open-source updates of the software will allow for user-defined weather files.

water evaporation. The final net heat change is the sum of the conductive and convective heat losses and the heat gains from solar radiation. A resulting deficit occurring during heating hours is expected to be made up by the heating system.

Virtual Grower Key Tool Inputs

Several inputs are needed by the user to describe the greenhouse and calculate the heating load. Those are:

- Project location zip code
- Greenhouse design geometry
- Roof and wall materials
- Separate room insulation levels (if connected to adjoining spaces)
- Air infiltration and gaps in greenhouse envelope
- Presence of a thermal curtain and quality of installation
- Heating schedule – daily and monthly
- Heating and ventilation system type(s), heat delivery method, heater age, and maintenance schedule

Several additional inputs are available in the tool; however, they do not impact heating energy consumption in the model. These are:

- Lighting type, quantity, wattage, and schedule
- Plant List

Inputs for geometry, material selection, and air infiltration are straightforward and intuitive to a user filling out the tool. Virtual Grower also provides several inputs to characterize the heating system. A user enters in the heater type (commonly a unit heater or boiler) and how that unit is ventilated (gravity ventilation, power ventilation, etc.) Once the heater type is selected, a heat delivery method is entered along with an approximation of equipment age and maintenance schedule. Combined, these selections determine an overall heating system efficiency which is used by the model when calculating annual heating consumption. Users can also enter a night time setback temperature on the heating schedule tab by selecting the “Day and Night Temperature” schedule type and entering in the corresponding day and night temperature setpoints.

Known Software Model Deficiencies

Virtual Grower states that all calculations are assuming dry air. While this shortens the calculation time, it ignores the latent heat of the crops (evaporation and condensation, and the contribution of solar radiation) and the impacts of humidity outside the greenhouse causing changes to heat inside the greenhouse. Furthermore, while the software allows a user to input lighting types, wattages, and schedules, it does not assume any heat gain from lighting fixtures when they overlap with the heating schedule. These two factors may contribute to overestimation of the Virtual Grower outputs and are expected to be corrected in future releases of the software by USDA.

Savings

Although the Virtual Grower tool is used to model energy consumption based on the inputs described above, it does not calculate energy savings. A baseline and efficient case model are run separately in Virtual Grower to determine annual consumption estimates for each case. These estimates are tabulated in an output file that is then copied into the Greenhouse Wrapper tool template. The wrapper tool automates the energy savings calculation by taking the difference in consumption between the two Virtual Grower runs.

Greenhouse Wrapper Key Tool Inputs

The only inputs the Greenhouse Wrapper tool needs to estimate savings are the raw Virtual Grower outputs from the baseline and efficient case runs and the number of greenhouses being considered in each run. Consumption estimates are copied onto the VG Model Output tab where yearly costs are shown in terms of \$/therm. Those costs are referenced on the Summary & Savings tab of the workbook and are used in the cost-effectiveness calculation. The user must also select whether the measure is a boiler measure or envelope measure from the dropdown list to assign the correct measure life for the cost-effectiveness test. An input for number of greenhouses is also provided for both the baseline and efficient case run to multiply the annual consumption by the number of greenhouses included in the measure.

Additional inputs are captured in the Greenhouse Wrapper tool for program reference but are not needed to estimate savings. These inputs are collected to assist with project documentation and in reconstructing the model if needed in the future. These inputs are:

- Number, length, and width of Spans
- Total Greenhouse Width
- Total Greenhouse Square Footage
- Roof Shape
- Kneewall and Side wall Height
- Height in Middle of Greenhouse
- Roof Material
- Endwall, Sidewall, and Kneewall Materials
- Infiltration through Gaps
- Total Heating Efficiency
- Energy Curtain Material (if present)
- Energy Curtain U Value (if present)
- Weather Site
- Heating Schedule

In addition to the above inputs, the “Proposed Upgrade” and “Extended Description of Case” fields on the Savings and Summary Tab should be populated to describe the reason for the efficiency project. These fields assist with documenting any known operational changes as a result of the measure that could assist in future evaluation efforts.

Energy Savings Adjustment Factor

Although the raw outputs from Virtual Grower are used as Greenhouse Wrapper tool inputs, the tool automatically imposes a default 20% reduction of calculated savings for all projects. This is due to a 2012 Energy Trust 3rd party evaluation which found through on-site verifications that savings estimates from Virtual Grower were likely too high (on the order of 50% in some cases). As Virtual Grower is not an open-source tool, troubleshooting the possible source of this discrepancy is difficult. As such, the program instituted a 20% reduction in Virtual Grower outputs on all affected projects to account for the likely overestimation occurring in the model. This was based on a recommendation from the 2020 Impact Evaluation to impose a uniform 20% reduction on savings for all measures that relied on Virtual Grower.

Comparison to RTF or other programs

The Production Efficiency program has several prescriptive Greenhouse measures related to heating system and envelope upgrades as detailed in MADs 103, 104, and 134. Those MADs are intended for discreet product choices however (under-bench heating,

condensing unit heaters, double-wall IR poly film, etc.). Greenhouses that utilize Virtual Grower to perform modeling are pursuing efficiency upgrades that do not fit those prescriptive measure descriptions, such as hot-water or steam boiler upgrades, or thicker polycarbonate panels with longer lifetime warranties.

Measure Life

Measure life is determined based on the component being upgraded. For envelope upgrade measures that commonly use polycarbonate panels, a 10-year measure life shall be used in the Greenhouse Wrapper tool which is in line with common product warranties for thicker polycarbonate panels with higher R-values.

For heating system upgrades, a 25-year measure shall be used in the Greenhouse Wrapper tool which is in line with the boiler measures in MAD #88, based on 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 boilers²
 - 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, based on the median lifetime estimated in DOE's technical support document for residential boilers.
- DOE Rulemaking Analyses
 - Commercial Consumer Boilers NOPR released July 28, 2023. The NOPR outlines measure life assumptions for hot water and steam boilers <300 kBtu/h and concludes that both fall within the range of 24-27 years.
<https://downloads.regulations.gov/EERE-2019-BT-STD-0036-0043/content.pdf>
 - Technical Support Document for Consumer Products and Commercial and Industrial Equipment: Commercial Packaged Boilers, released December 28, 2016. This TSD shows boilers ≥300 kBtu/h have a lifetime of around 25 years.
 - https://downloads.regulations.gov/EERE-2013-BT-STD-0030-0083/attachment_1.pdf

The corresponding measure lives shall be used into the Greenhouse Wrapper tool to determine cost-effectiveness for each component.

Load Profile

For greenhouse projects, the gas load profile should be set to Com-Heating in the Greenhouse Wrapper tool.

Cost

Costs are calculated on a project-by-project basis based on selected envelope or boiler equipment and vendor quotes. Costs are input into the Greenhouse Wrapper tool by program staff for baseline and efficient case conditions. For new or replacement measures, the incremental cost is used, while retrofit measures use the full cost. Incremental costs are determined by the vendor or contractor for each project for both the baseline and efficient cases. For new or replacement boiler projects, the baseline cost is considered the cost of a federally compliant boiler that matches the heating load used in the tool. For new or replacement envelope projects, the baseline cost is the cost of double poly-film covering the same square footage specified in the tool.

Non Energy Benefits

For envelope upgrades which result in longer measure life compared to the baseline, there are potential non-energy benefits from avoided replacement costs of cheaper poly-film components. However, at the Greenhouse Wrapper tool does not capture non-energy benefits at this time as there is uncertainty over baseline replacement options and most envelope measures are highly cost-effective, lessening the need to capture them for cost-effective purposes.

Incentive Structure

The incentives listed in Table 1 and Table 2 are for reference only and are not suggested incentives. Savings and incentives are calculated on a case-by-case basis. Incentives will be offered in the format of a \$ per therm savings rate capped at a specified percentage of project cost. The specific incentive rate and cap will be determined by the program, not to exceed UCT limits.

Follow-Up

The Greenhouse Wrapper tool is approved with 2025 avoided costs. This tool must be updated for any gas avoided cost updates, even if these are released before the MAD expires. Any relevant findings from Evaluation's Greenhouse research shall inform this measure's next update.

The current version of Virtual Grower (v3.1) has been available since 2011, with a new version from USDA expected in the coming year. This updated version is anticipated to be web-based, open-source, and will more accurately capture net heat loss on an annual basis as it aligns its heat loss methodology with ASHRAE guidelines. This MAD should be updated when the new version of Virtual Grower is released and has been analyzed to improve the calculation methodology and associated realization rates of installed projects.

Additionally, a small-sample analysis of billing data from past projects suggested increased load in several projects, likely due to increased production or operational changes after the efficiency measure was installed. Billing data along with documentation of the project reasoning in the Greenhouse Wrapper tool should be studied as part of the next update to help substantiate earlier findings.

Finally, at this time non-energy benefits are not included as part of the measure cost-effectiveness screening in the Greenhouse Wrapper tool. Should project volume increase or if changes to the software or program design result in projects becoming non cost-effective, the addition of NEBs for envelope upgrades should be explored further.

Supporting Documents

The cost effectiveness screening for these measures is number 299.1.1. It is attached and can be found along with supporting documentation at: I:\Groups\Planning\Measure Development\Commercial and Industrial\Agriculture\greenhouse\Virtual Grower

²http://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



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CEC_2025v2.1 Virtua

References

Impact Evaluation of Energy Trust of Oregon’s 2009-2011 Production Efficiency Program:
https://www.energytrust.org/wp-content/uploads/2016/12/PE_Impact_Eval_2009-11.pdf

Impact Evaluation of Energy Trust of Oregon’s 2020 Production Efficiency Program:
https://www.energytrust.org/wp-content/uploads/2022/04/2020-PE-Impact-Evaluation-Report_FINALwSR.pdf

Current Federal Commercial Packaged Boiler Regulations:
<https://www.federalregister.gov/documents/2023/09/19/2023-19908/energy-conservation-program-energy-conservation-standards-for-commercial-packaged-boilers>

Table 5 Version History

Date	Version	Reason for revision
7/15/24	299.1	Initial approval of Virtual Grower and Greenhouse Wrapper Tool

Table 6 Related Measures

Measures	MAD ID
Greenhouse Controller	103
Greenhouse Measures	104
Condensing Unit in Greenhouse	134

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