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ENERGY + WATER + EFFICIENCY

M e m o r a n d u m

FROM: Michael Baker, SBW

TO: RTF Staff

DATE: February 11, 2013

RE: Phase I Review and Update Recommendations: Walk-in/Reach-in Door Retrofit

This memo documents the results of Cadmus's detailed review of the UES (Unit Energy Savings) measure *Walk-in/Reach-in Door Retrofit*. This measure has been classified by the RTF as *Proven*. This measure includes savings resulting from retrofitting glass doors to existing medium temperature walk-in cases with open reach-in merchandizing access. The reach-in cases, which include evaporator coils and fans, are removed and replaced with doors (with no evaporators).

Summary Recommendation. The status of this measure should be changed to *Out-of-Compliance*.

The following recommendation leads to a change in status to *Out-of-Compliance*.

1. The Refrigeration Case Load should be based on measured data using typical store conditions.
2. The Refrigeration Case Load values used in the calculation should be based on the average of models actually replaced and installed, rather than a single model for baseline and a single model for the efficient case.
3. The Average EER parameter needs to be derived transparently from publically available regional data.
4. The EFLH parameter needs to be derived transparently from publically available regional data.

The following recommendations lead to a change in status to *Under Review*.

1. The HVAC savings methodology should incorporate region-wide heating system and climate parameters.

Limitation of Review. PECI's *Engineering Specification for GrocerSmart™ 3.0* was not available or included as part of this review. HVAC interactive factors used in the 6th Plan were not reviewed.

Alterations to Workbook and Documentation.

- Since a standardized RTF measure workbook was not available, the standardized workbook ComGroceryWalkInCaseDoorRetrofit_v1_0.xlsm was developed using supporting information

from the RTF workbook DeemedMeasuresV26.xls. Obviously superfluous elements of that workbook were ignored. All subsequent review was of this new workbook.

- A sheet called "Summary" has been added to the workbook. This sheet describes how measures are identified, lists important constants and their sources, describes the savings estimation algorithm and the associated baseline and efficient case parameters and their sources for each measure and UES component.
- The review team added a sheet called "Add Doors to WIRI_v2" to the workbook. The sheet copies the original calculation sheet "Add Doors to WIRI." The new sheet features numerous modifications to correct input values for calculations or correct details from the equipment specification sheet. The following revisions from the original worksheet are in red text.
  - Correct input parameters based on updated equipment specifications for Hussmann D5XRRIS.
    - Original calculation lists case load per foot as 1,035 Btu/hr/ft. The updated equipment specification sheet lists case load as 965 Btu/hr/ft.
  - Remove the Degradation Factor of 0.98. This value is not needed for the calculation because the Average System EER already factors it in.
  - If the measure were to remain based on Portland climate, the following values have been updated to match latest ASHRAE values.
    - Cooling degree days are listed as 350 based on balance point of 67°F. There is no documentation to support a balance point of 67°F. A base point of 65°F was applied based on the 2009 ASHRAE Fundamentals Handbook that cites 423 CDD for Portland.
    - Heating degree days are listed as 4,900 based on balance point of 67°F. There is no documentation to support a balance point of 67°F. A base point of 65°F based on the 2009 ASHRAE Fundamentals Handbook that cites 4,222 HDD for Portland.
    - Design heating temperature is listed as 22°F using 1997 ASHRAE. The 2009 ASHRAE Fundamentals Handbook lists the design heating temperature at 23.9°F.
    - Design cooling temperature is listed as 90°F using 1997 ASHRAE. The 2009 ASHRAE Fundamentals Handbook lists the design cooling temperature at 91.2°F.
    - HVAC cooling EER is listed as 10 based on ASHRAE 90.1-2004. This would be appropriate for package units with cooling capacity below 65 kBtu/h. Cadmus believes a more appropriate range would be 65 kBtu/h to 135 kBtu/h based on our review of grocery packaged units during various energy efficiency evaluations. The appropriate minimum efficiency for packaged units in this size range is 10.3 EER.
- The review team updated measure-specific details on the following new worksheets:
    - MeasureTable
    - Measure_InputOutput
    - Lookup Table

Recommendations for Updates. The RTF should implement the following recommendations.

1) Measure Definition

a) No changes recommended.

2) UES Savings Estimation Method
   a) The method of estimating HVAC savings assumes only gas heating. This should be replaced with the region-wide average heating system. This deficiency causes the measure status to change to *Under Review*.
   b) The measure assumes Portland climate conditions. This should be replaced with region-wide average values. This deficiency causes the measure status to change to *Under Review*.
3) Input Parameters
   a) The Refrigeration Case Load parameter is based on manufacturer's cut sheets. These are design values rather than actual average values. The cooling load should be based on measured data using typical store conditions. This deficiency causes the measure status to change to *Out-of-compliance*.
   b) PECI informed us that this measure is not restricted to just the models shown in the cut sheets used in the calculations. The Refrigeration Case Load values used in the calculation should be based on the average for models actually replaced and installed, rather than a single cut sheet for baseline and a single cut sheet for efficient case. PECI informed us that this information is not necessarily available. This deficiency causes the measure to change status to *Out-of-Compliance.*
   c) The Average EER parameter is based on proprietary DOE 2.2-R simulations of Northwest grocery environments. This parameter needs to be derived transparently from publically available data. This deficiency causes a change of status to *Out-of-Compliance.*
   d) The Average System FLH needs to be derived transparently from publically available data. This deficiency causes the measure to change status to *Out-of-Compliance.*

Additional Considerations.

1) Sunset criteria: This measure should be reviewed every five years.
2) The method used in the workbook to estimate HVAC savings can be replaced with RTF HVAC interactive factors.
3) This measure may be a *Small Saver.*

Measure Approval Document for Manufacturer-Installed Rooftop Unit Controls

Valid Dates

3/1/2017 – 12/31/2020

Description

This measure is economizers, demand controlled ventilation (DCV), and supply fan variable frequency drives (VFDs) to units which are not required by code to include these features. These controls must be installed by the HVAC unit manufacturer as factory options in new units.

Scope

Measures are approved as cost-effective for use in the following market segments:

- Replacement
- New

Program Applicability

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

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

Only the DCV measure is applicable to projects in Washington, as this is the only measure that results in gas savings.

Purpose of Re-Evaluating Measure

This measure will replace the New Buildings Program's prescriptive economizer measure (MAD ID 185) and prescriptive DCV measure (MAD ID 96). Those prescriptive economizer and DCV measures were developed using the New Buildings program's 2010 OEESC HVAC calculator, which used bin calculations and equivalent full load hours to estimate savings. This update uses building energy modeling to determine savings.

Cost Effectiveness

Table 1 Cost Effectiveness Calculator Oregon

Measure	Measure Life (years)	Savings		Incremental Costs ($/ton)	Maximum Incentive ($/ton)	Utility BCR at Max Incentive	TRC BCR
		kWh /ton	therms /ton				
Economizer (gas)	15	174	-	$45	$45	4.15	4.15
DCV (gas)	15	16	21	$38	$38	3.44	3.44
VFD (gas)	15	587	(11)	$419	$419	1.08	1.08
Economizer (heat pump)	15	174	-	$45	$45	4.15	4.15
DCV (heat pump)	15	196	-	$38	$38	7.07	7.07
VFD (heat pump)	15	489	-	$419	$419	1.01	1.01

Table 2 Cost Effectiveness Calculator Washington

Measure	Measure Life (years)	Savings		Incremental Costs ($/ton)	Maximum Incentive ($/ton)	Utility BCR at Max Incentive	TRC BCR
		kWh /ton	therms /ton				
DCV (gas)	15	16	21	$38	$38	3.32	3.69

Requirements

- These measures are only applicable to installations of new rooftop units with DX cooling and either gas furnace or heat pump heating.
- Retrofits or add-on equipment to existing rooftop units are not applicable.

Economizers:

- Economizer savings may only be claimed when installed on rooftop units with cooling capacities less than 54,000 Btu/h.
- This measure is not applicable to projects in Washington.

DCV:

- DCV savings may only be claimed when installed in units which also have economizers.
- DCV savings may only be claimed for units which serve spaces that are not required by code to have DCV.
    - A list of spaces by building type which are not required to have DCV accompanies this document – all spaces not listed are required by code to have DCV, or are expected to have negligible DCV savings and so are excluded from this measure. The most common expected spaces in which DCV is not code-required are office spaces (excluding conference rooms and reception areas) and retail sales floors (excluding mall common areas).

Supply Fan VFD:

- Supply fan VFD savings may only be claimed when installed in units which also have both DCV and economizers.
- Supply fan VFD savings may only be claimed when installed on units with both cooling capacities less than 110,000 Btu/h and supply fan motors less than 10 horsepower.
- This measure is not applicable to projects in Washington.

Measure Analysis and Modeling

Savings for the advanced rooftop unit controls measure were modeled by CLEAResult's new construction engineering team using the New Buildings program's prototype models for the Small Office, Strip Mall Retail, and Primary School building types in eQuest 3.65. These models are meant to represent typical code-minimum new construction. Based on market research, controls are likely to be installed in one of three potential combinations and were modeled accordingly. These combinations are:

- Economizer
- Economizer + DCV
- Economizer + DCV + VFD

Economizers were modeled by allowing HVAC units to vary the amount of outside air in response to outside air temperature. Economizers were modeled with integrated operation (e.g. compressors are not locked out and economization is used in conjunction with mechanical cooling when needed) and with a high-limit cutoff of 70 degrees F.

DCV was modeled by changing the minimum air flow in spaces in which DCV is not code required to the code-prescribed per-square-foot value. Outside air flow in these spaces is then allowed to modulate in response to hourly occupancy, increasing the outside air flow based on the code-prescribed per-person value.

VFDs were modeled by assigning variable speed performance curves to HVAC supply fans, and allowing supply fans to ramp down to a minimum of 30% of design speed (in line with typical recommended VFD minimums).

The measures were modeled for the three main Oregon climate zones (Coast/Astoria, Valley/Portland, Central/Redmond). The savings for each climate zone were combined into a weighted average using the following program-assumed weightings:

- Coast: 3%
- Valley: 87%
- Central: 10%

The weighted average savings for each building type were combined into a weighted average using the following weightings, based on New Buildings Program enrollments from January 2015 to December 2016:

- Office: 44%
- Retail: 25%
- School: 30%

Weighting the savings results by building type and by climate zone as described above results in weighted average savings values that can be applied to all commercial building types throughout program territory.

A detailed description of the modeling and weighting methodologies can be found in the "Rooftop Unit Controls Modeling Methodology" supporting document.

Savings and Baseline

Each of these measures may be code required in particular locations and sizes of equipment and is considered baseline in those situations.

- 2014 Oregon Energy Efficiency Specialty Code (OEESC) Section 503.3.1 requires economizers on units with higher cooling capacities.
- In Oregon, code requirements for DCV are set forth in 2014 OEESC Section 503.2.5.1, which references Table 403.3 of the 2014 Oregon Mechanical Specialty Code (OMSC). In Washington, code requirements for DCV are set forth in 2015 Washington State Energy Code (WSEC) Section C403.2.6.2 which references Table 403.3.1.1 of the 2015 International Mechanical Code (IMC).
- 2014 OEESC Section 503.2.10.3.2 requires VFDs on supply fans for units with cooling capacities 110,000 Btu/h or greater, and 2014 OEESC Section 503.4.2 requires VFDs on supply fans 10 horsepower or greater.

Savings for these measures were determined using a rolling baseline approach, allowing a discrete savings value to be assigned to each control addition. Using this approach allows savings to be claimed for controls which are not required by code, even if they are combined with other controls that are required by code. The savings values and applicability for each control are detailed in Table 3.

Table 3 Savings Values and Applicability

	Measure	kWh/ton Savings	therms/ton Savings	Other Required Controls	Applicability
Gas Heat	Economizer	174	0	n/a	Savings not claimed for units with cooling capacities 54,000 Btu/h or larger
	DCV	16	21	Unit must have an economizer	Savings not claimed for units serving spaces required to have DCV
	Supply Fan VFD	587	-11	Unit must have an economizer and DCV	Savings not claimed for units with cooling capacities 110,000 Btu/h or larger, or units with supply fan motors 10 HP or larger
Heat Pump Heat	Economizer	174	0	n/a	Savings not claimed for units with cooling capacities 54,000 Btu/h or larger
	DCV	196	0	Unit must have an economizer	Savings not claimed for units serving spaces required to have DCV
	Supply Fan VFD	489	0	Unit must have an economizer and DCV	Savings not claimed for units with cooling capacities 110,000 Btu/h or larger, or units with supply fan motors 10 HP or larger

Using the rolling baseline approach, the savings for all applicable installed controls are added to determine the total savings per rooftop unit for these measures.

For example:

- A 3 ton heat pump serving a retail sales floor installing an economizer and DCV would have a savings of 174 kWh/ton + 196 kWh/ton = 370 kWh/ton.
- A 5 ton heat pump serving a retail sales floor installing an economizer and DCV would have a savings of 196 kWh/ton, as the economizer would be code-required.
- A 3 ton heat pump serving a classroom installing an economizer, DCV, and supply fan VFD on a 2 HP fan motor would have a savings of 174 kWh/ton + 489 kWh/ton = 663 kWh/ton, as the DCV would be code-required.

Comparison to RTF and Others

The Regional Technical Forum (RTF) does not have a standard measure equivalent to these measures. They do have a standard protocol for supply fan VFD, which is study method and does not indicated a deemed savings. Bonneville Power Administration (BPA) has preliminary deemed savings for advanced rooftop controllers (ARCs) which include many of the features of these measures, though it's assumed that most ARC savings are from the VFDs. BPA's savings are in the same range as the total savings for all the measures included in this MAD. Energy Trust believes the approach used in our analysis, which excludes savings from features that are required in some situations, will be more broadly applicable than the all-in-one deemed approach used by BPA and will represent savings more accurately.

The modeled savings values were compared to available estimates from PNNL's ARC retrofit field-test results [1], PNNL's Rooftop Unit Comparison Calculator [2], and PG&E's work papers for retrofit add-on of economizers, DCV, and supply fan VFDs [3, 4]. The comparison showed that the modeled savings were reasonably in the same range as these other sources, with expected differences arising from different assumptions regarding baselines, climates, applications, etc.

Economizer and DCV savings were compared to Energy Trust Existing Buildings Program's former RTU tune-up offer (MAD ID 193) which included both economizers and DCV in offices and retail. That comparison showed that the modeled savings were in the same range as those measured during tune-up pilot. The tune up offer was discontinued in 2013 due to poor evaluation results. Those results are attributed to contractor error while retrofitting existing units, many of which were in poor condition, and so that result is not expected to be an issue with these factory-installed features.

Savings were not compared to Energy Trust New Buildings DCV calculator (MAD ID 96) because the results of that tool, which calculated savings for each site based on characteristics such as climate, space type, floor area and 2010 building code baselines could not be normalized to savings per ton without extensive analysis.

Measure Life

The measure life is assumed to be 15 years, consistent with standard program assumptions regarding HVAC controls measures on new equipment.

Cost

Two leading HVAC manufacturers active in Oregon (referred to here as "MFGR1" and "MFGR2") were surveyed to determine the estimated cost of adding these control features to a 3 ton, 4-5 ton, and 7.5 ton rooftop unit. The manufacturers gave similar costs for the combination of all three measures, however the breakdown of the cost among the individual control features differed. Based on program staff experience, the breakdown from MFGR1 was deemed more representative of typical pricing, and so the total cost provided by MFGR2 was broken out based on the allocation of MFGR1's total cost. The manufacturer costs were averaged, then normalized by cooling capacity to determine a $/ton value for each measure. The cost information is summarized in Table 4 and Table 5.

Table 4 Manufacturer-Provided Cost Estimates

	Feature	Factory Installed Price			
		MFGR1	MFGR2	MFGR2 - Adjusted per MFGR 1 breakdown	Average
3 Ton	Advanced Digital Economizer	$200.00	$1,080.00	$129.58	$164.79
	CO2 sensor	$200.00	$475.00	$129.58	$164.79
	Variable speed supply fan motor (and additional sensors for variable flow)	$2,000.00	$0.00	$1,295.83	$1,647.92
	Digital Economizer, CO2, and SF VFD	$2,400.00	$1,555.00	$1,555.00	$1,977.50
4-5 Ton	Advanced Digital Economizer	$200.00	$1,080.00	$119.62	$159.81
	CO2 sensor	$200.00	$475.00	$119.62	$159.81
	Variable speed supply fan motor (and additional sensors for variable flow)	$2,200.00	$0.00	$1,315.77	$1,757.88
	Digital Economizer, CO2, and SF VFD	$2,600.00	$1,555.00	$1,555.00	$2,077.50
7.5 Ton	Advanced Digital Economizer	$200.00	$1,477.00	$165.80	$182.90
	CO2 sensor	$200.00	$1,010.00	$165.80	$182.90
	Variable speed supply fan motor (and additional sensors for variable flow)	$2,600.00	$0.00	$2,155.40	$2,377.70
	Digital Economizer, CO2, and SF VFD	$3,000.00	$2,487.00	$2,487.00	$2,743.50

Table 5 Average Costs Normalized by Cooling Capacity

Measure	Tons	Average Price	$/ton	Avg $/ton
Economizer	3	$164.79	$54.93	$45.22
	4.5	$159.81	$35.51	
DCV	3	$164.79	$54.93	$38.28
	4.5	$159.81	$35.51	
	7.5	$182.90	$24.39	
VFD	3	$1,647.92	$549.31	$418.99
	4.5	$1,757.88	$390.64	
	7.5	$2,377.70	$317.03	

Incentive Structure

Incentives will be structured per ton of cooling capacity. Like the savings values, incentive values will be calculated using an additive approach in which incentives are only added for the installed features which are not code-required.

The maximum incentives listed in Table 1, Table 2 and Table 6 are for reference only and are not suggested incentives. Bonuses or promotions, including Market Solutions, must not raise incentives above those in Table 1 and Table 2. Table 6 provides the maximum standard incentive for each measure that will allow up to 30% bonus available on these and other standard measures in Market Solutions offerings. Unless these measures are excluded from

those offerings, particularly restaurant and grocery offers which include the largest bonuses on standard measures, the New Buildings Program's standard incentive should not exceed those listed in Table 6.

Table 6 Maximum standard incentives to allow for bonuses

Measure	Max total incentive ($/ton)	Max standard incentive to allow 30% bonus ($/ton)
Economizer	$45	$34
DCV	$38	$29
VFD	$419	$322

Follow-Up

This measure has multiple applicability requirements based on sections of the OEESC and the OMSC. When the OEESC or OMSC is updated, this measure should be updated accordingly.

Supporting Documents and References

The cost effectiveness screening is attached and can be found at:
I:\Groups\Planning\Measure Development\Commercial and Industrial\Commercial HVAC\Economizers and controls\bencost

RTU Controls_CE Calculator_02162017

Supporting documentation including analysis files can be found at:
I:\Groups\Planning\Measure Development\Commercial and Industrial\Commercial HVAC\Economizers and controls

DCV Eligible Space Types

DCV - Eligible Space Types.docx

References

[1] PNNL Advanced Rooftop Control (ARC) Retrofit: Field-Test Results
http://www.pnl.gov/main/publications/external/technical_reports/PNNL-22656.pdf

[2] PNNL Rooftop Unit Comparison Calculator
http://www.pnnl.gov/uac/costestimator/main.stm

[3] PG&E Work-Paper Savings Values
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwi96LnbgtnPAhUQ7mMKHZ2MDtcQFggcMAA&url=http%3A%2F%2Fwww.performancealliance.org%2FPortals%2F4%2FDocuments%2FCommittees%2FGoal2%2FCQM%2FPGECOHVC168_R0_execsumm.xlsx&usg=AFQjCNG7nJijkXwq5VRPOPIgaqxaZFiS7g&sig2=kazDgD5uG2eohmDHG0vIQg&bvm=bv.135475266,d.cGc

[4] PG&E Work-Paper Information
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0ahUKEwiIrKXghNnPAhUYS2MKHZS3Ai8QFggiMAE&url=https%3A%2F%2Fcal-tf.squarespace.com%2Fs%2FStatewide-Workpaper-List_Cal-TF_160119_PUBLIC.xlsx&usg=AFQjCNF2z4BeJKehYvwZAje4SMeroesPwA&sig2=WKmU56vQK3fjSqT_V8e3BA&bvm=bv.135475266,d.cGc

Version History and Related Measures

Energy Trust has been incentivizing economizers and DCV for many years and the offerings have evolved over time and have often been bundled with other measures. The approval of these measures predates our current approval systems and record retention timelines. Table 7 includes many revisions of these measures' approvals but may not be fully complete, particularly for approvals issued before 2012.

Table 7 Incomplete Version History

Date	Version	Reason for revision
12/22/05	185.x	Approves air, water and ground source heat pumps, chillers, heat exchangers and DCV for use in New Buildings
6/05/08	185.x	Add Existing buildings to above.
6/19/08	185.x	Add PE to above.
7/24/09	194.x	Rooftop tune-up pilot approval. Rooftop tune-up included contractor-installed economizers and DCV on existing RTUs.
4/05/10	194.x	Transition rooftop tune-up from pilot to standard offer. Updates to savings and structure based on pilot evaluation.
8/11/10	194.x	Add split-systems and other updates to tune-up offer.
10/6/10	96.x	New Buildings DCV prescriptive measure, aligned with 194.x. Superseded DCV in 185.x above.
2/11/11	185.x	Approval for New Buildings HVAC calculator for unitary equipment including air, ground and water-source heat pumps and air conditioners.
2/14/11	185.x	Adds Existing Buildings and PE as applicable programs to 185.
2/14/11	96.x	Approval for DCV calculator module of New Buildings HVAC calculator, replaces prescriptive DCV for New Buildings.
5/25/11	194.x	Add Production Efficiency as applicable program to tune-up offer.
7/14/11	x	Approval of Economizer module of New Buildings HVAC Calculator.
12/21/11	185.x	Replaces New Buildings HVAC calculator with prescriptive measures for unitary HVAC and economizers for use in New and Existing Buildings.
3/14/12	185.x	Add PE to above.
12/31/13	194.x	Tune up offering canceled, economizers and DCV no longer approved for Existing Buildings. MAD 194 moved to inactive.
3/1/17	195.1	New approval for Economizers, DCV and VFD on supply fans for New and Existing Buildings and PE. With this update, the New Buildings HVAC calculator is no longer in use for any measure. This economizer measure here supersedes the economizers in 185.x This DCV measure supersedes 96.x, which will be moved to inactive.

Table 8 Related Measures

Measures	MAD ID
Ground and water-source heat pumps	185.x
Duplicate of 185, inactive	121.x
Market Solutions Restaurant	158.x
Market Solutions Retail	160.x
Market Solutions Grocery	161.x
Market Solutions Office	164.x
Market Solutions Schools	165.x

Approved & Reviewed by

Jackie Goss, P.E.
Planning Engineer

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Disclaimer

2017 ESK Re-design

Here is a recap of the logic that we reviewed and discussed during our in-person meetings the led to the updated install rates in the 2017 ESK MAD.

The 2016 Processes evaluation done by Energy Trust with Illume Advising saw showerhead install rates drop to 48% in the 2016 study. Through an overall analysis of customer feedback Illume speculated that many customers were inadvertently requesting more water saving items than they truly wanted. Customers also cited the desire to see the images of the products that were in the kits before ordering them. When asked about showerheads some customers cited the desire to have a shower wand as an option.

Our Energy Saver Kit Redesign process took the recommendations provided in the Illume study and developed the following enhancements related to improving the showerhead installation rates:

- Updating kit configurations by including a shower wand option and improving the aesthetics and performance of the existing showerhead product
- Updating order form logic to require customers to choose if they would like to receive water saving devices, or not, before they proceed to place their order
- Adding images of the kit contents to the order form experience
- Redesigning the structure of the kit order form to make the experience more visually appealing and user-friendly

Based on these changes the program requested we update installation rates for the remainder of 2017 as these form changes will almost certainly have a positive impact on installation rates. It should be noted that the updated installation rates for the 2017 MAD will be used for 2017 savings after the Energy Saver Kit redesign is complete and that Energy Trust will complete a follow up evaluation on 2017 installation rates that will impact 2018 Energy Saver Kit installation rates.

The primary logic for determining the 2017 installation rates:

- The redesigned order form forces customers to actively choose the number of showerheads they would like to receive rather than prescribing a number based on answers to questions about their home.
- This is how the Energy Saver Kits worked in 2013-2015 when they were fully custom and allowed any combination of products to be ordered
- The only consumer-facing change made to Energy Saver Kits between 2013 and 2016 (when the Illume process evaluation was conducted) was the change in order form logic that pre-populated selections for customers which ultimately limited the number of configurations a customer would choose from
- Therefore, if we revert to 2013 order form logic, the best installation rates to approximate would be the 2013 installation rates.

Table 3 Existing Homes Process Evaluation Installation Rates

	Received (Confirmed by Respondent)	Net Installed (Installed - Removed)	Net Install Rate	Installed and Planned within 6 Months	Installed and Planned within 12 Months	Projected 2017 Install Rates
A-lamps	1421	1053	74.1%	-	91.3%	**91.3%**
Reflectors	419	247	58.9%	-	90.7%	**90.7%**
Showerheads (2013 install and planned install rates)	-	-	62.0%	86.0%	-	**74.0%**
Kitchen Aerators (received at least one)	153	61	39.9%	47.1%	-	**43.5%**
Bath Aerators	244	113	46.3%	60.2%	-	**53.3%**

Showerhead installation rates use 2013 average of installation and planned installation within six months. These rates for showerheads are also being applied to shower wands as they have not previously been included as an option in kits and mail order installation rates are unknown for Energy Trust territory.

Kitchen Aerators:

- The 2016 version of the kit order form locked kitchen aerators to the number of bathrooms you selected, up to 2 kitchen aerators
- When Illume surveyed people, they recorded both “I installed all k-aerators” as well as “I installed some of the k-aerators” (see chart below)
- ESK kit design will cap the kitchen aerator quantity at 1
- If you assume that some who installed 1 of the 2 aerators they received would still install that aerator if it was the only kitchen aerator they received, then if follows that the installation rate for kitchen aerators when the max quantity is one should be the sum of people who said they installed all their kitchen aerators + people who said they installed some of the aerators.

New installation rates were determined by counting the number of recipients who reported receiving and installing at least one kitchen aerator less those recipients reporting that they uninstalled a kitchen aerator. This resulted in 61 out 183 survey respondents fitting this criteria or 40%.

For the planned installation rate those recipients who reported receiving at least one aerator, reported installing none and indicated they planned to install at least one aerator within 6 months. This group included 11 survey respondents, or roughly 7% of the total sample for a total

net installation and planned rate of 47%. To account for some recipients not carrying through on a planned installation, this rate was halved for a final estimated installation rate of 43% for kitchen aerators.

2016 kitchen aerator install analysis	Responses constrained to recipient receiving/installing/planning to install at least one aerator	Survey Question Figure Derived from
Net kitchen aerator installs	**61**	K1, K2, K6
Count of recipients who received >=1 kitchen aerators	153	K1
Net install rate of at least one kitchen aerator	40%	
Plan to install at least one kitchen aerator within 6 months	**11**	K3
Net install of at least one kitchen aerator plus plan to install at least one kitchen aerator within 6 months	72	K1, K2, K3, K6
Received at least one kitchen aerator	153	K1
Install and plan to install within 6 months	47%	
Average of at least one kitchen aerator net install and plan to install within 6 months	***43%***	

Let me know if this is sufficient.
Thanks

Eric Koch
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Measure Approval Document for Multifamily HVAC Hot Water Condensing Gas Boilers

Valid Dates
4/1/17 – 12/31/19

End Use
Gas-fired hot water condensing boilers for HVAC use

Program Applicability
Based on the referenced analysis and associated cost-effectiveness screening, the measures described below are approved as cost-effective on a prospective basis for inclusion in the following programs

- Existing Multifamily
- Existing Buildings, multifamily buildings in Washington only
- New Multifamily

Purpose of Re-Evaluating Measure
This revision approves the measure of multifamily use in Washington and clarifies requirements for larger capacity boilers. No changes to savings or other assumptions have been made since version 147.1 was approved in late 2015.

Cost Effectiveness
Cost effectiveness is demonstrated in Table 1 and Table 2 using 2017 avoided costs. A copy of the cost effectiveness calculator is attached in the Supporting Documents section below.

Table 1 Cost Effectiveness of condensing boilers, per kBtu/h capacity, Oregon.

Measure	Measure Life (years)	Savings kWh	Savings therms	Incre-mental Cost ($)	Max Incentive ($)	Utility BCR at Max Incentive	TRC BCR
MF boiler <300 kBtu/h	35	(2.11)	4.10	$16	$16	2.13	2.13
MF boiler ≥300 kBtu/h, ≤2,500 kBtu/h	35	(2.11)	4.10	$13	$13	2.62	2.62
MF boiler >2,500 kBtu/h	35	(2.11)	4.10	$10	$10	3.41	3.41
MF boiler - no size differentiation	35	(2.11)	4.10	$16	$10	3.13	2.13

Table 2 Cost Effectiveness of condensing boilers, per kBtu/h capacity, Washington

Measure	Measure Life (years)	Savings kWh	Savings therms	Incre-mental Cost ($)	Max Incentive ($)	Utility BCR at Max Incentive	TRC BCR
MF boiler <300 kBtu/h	35	(2.11)	4.10	$16	$16	3.08	2.91
MF boiler ≥300 kBtu/h, ≤2,500 kBtu/h	35	(2.11)	4.10	$13	$13	3.79	3.58
MF boiler >2,500 kBtu/h	35	(2.11)	4.10	$10	$10	4.92	4.66
MF boiler - no size differentiation	35	(2.11)	4.10	$16	$16	3.08	2.91

Program Requirements

- Boilers must have an efficiency as shown in Table 3.
- Incentives and savings are based on the size of the primary HVAC boiler(s). Backup boilers shall not factor into the incentives or savings.
- Boiler system must have design return temperature appropriate to condensing functionality.

Table 3 Required Efficiency Ratings

Boiler Capacity (kBtu/h)	Efficiency Rating	Minimum Efficiency
<300	AFUE	94%
300 – 2,500	Thermal Efficiency	94%
>2,500	Combustion Efficiency	94%

Measure Analysis

To determine the savings for this measure, eQUEST energy simulation model runs were performed by CLEAResult using the New Buildings Program's large multifamily prototype models. These models are intended to reflect typical buildings constructed to meet the minimum requirements of the Oregon Energy Efficiency Specialty Code. The models included three different central boiler HVAC configurations: hot water coil, water source heat pumps, and 4 pipe fan coils which are expected to be the most common application for condensing boilers incentivized through this measure. Model runs were performed using weather data for Portland, Redmond, and Astoria in order to quantify savings across the different Oregon climates.

The baseline case was modeled using a boiler heating input ratio of 1.250 (1/80%), which corresponds to the minimum requirements set forth in OEESC Table 503.2.5(5) for boilers of the sizes included in the models. To model the condensing boiler, the heating input ratio was modified, and the boiler type was changed from "HW-BOILER" to "HW-CONDENSING". Savings are based on proposed model runs utilizing a boiler heating input ratio of 1.064 (1/94%). At the time of the writing of this document, the AHRI directory lists 303 natural gas hot water condensing boiler models across 26 manufacturers which have thermal efficiencies of 94% or greater, demonstrating that this level of efficiency is fairly available in the market. All these models have electronic ignitions, so no additional savings are expected through ignition and ignition system as requirement is not necessary.

To determine a single savings value to be used across HVAC types, a weighted average of the modeled savings was taken. Based RBSA data and program experience, the most common boiler-based system in existing buildings is the steam radiator, which we consider equivalent to the modeled hot water coil for savings, weighted at 79%, water source heat pumps were weighted at 16% and 4 pipe fan coils rated at 5%. Savings were also weighted based on project location, assuming that 86.6% of projects will be in the Portland climate zone, 10.3% of projects will be in the Redmond climate zone, and 3.1% of projects will be in the Astoria climate zone. Savings for each building type were tested at each size range for cost effectiveness.

Negative kWh savings are due to increased fan energy compared to baseline boilers. Negative savings are booked as interactive adjustments.

Incentives

Although the savings are the same across capacity ranges, the incremental costs are different. Programs may choose to structure their boiler offers with different incentives at various size ranges. If that is the case the maximum incentives below apply. If a single incentive is set for the full size range, it must be less than $10.

- <300 kBtu/h $16
- ≥300 kBtu/h, ≤2,500 kBtu/h $13
- >2,5000 kBtu/ $10

The maximum incentive is listed for reference only and is based on incremental cost. This is not a suggested incentive.

Measure Life

The measure life is assumed to be 35 years for high efficiency boilers.

Costs

A number of different sources of incremental costs were reviewed to determine an average incremental cost for condensing boilers. The costs reviewed appear to be based on proposed efficiencies in the range of 92%-94%. The most recent sources examined were Xcel energy's condensing boiler measure, case studies from the GSA, and quotes obtained from local boiler sales reps. Two of the recent sources of incremental cost information assume boiler efficiencies of 94% or greater, and these sources are at the low end of the newest cost estimates. Therefore, the average of the gathered costs should be applicable for a 94% efficiency requirement.

Supporting Documents

The cost effectiveness calculator is attached and can be found at:
I:\Groups\Planning\Measure Development\Commercial and Industrial\Commercial HVAC\boilers\Condensing hot water boiler\Multifamily boilers\multifamily bencost

MF boiler
OR-WA-CE Calculatc

Supporting documents can be found at:
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Version History and Related Measures

Energy Trust has been incentivizing efficient boilers for many years. The offerings have changed over time and predate our current record keeping and documentation processes. The table below may not be fully comprehensive for revisions prior to 2013.

Table 4 Measure History

Date	MAD Version	Reason for revision
12/23/03	x	Hot water boilers approved for commercial and multifamily applications.
10/30/08	x	Multifamily boilers split from commercial due to differing loads.
6/23/09	x	All new savings calculations, divide savings and incentive by boiler capacity. Recombine multifamily and commercial.
6/9/14	x	Add maximum incentives.
2/11/15	x	Add Production Efficiency.
10/6/15	147.1	Multifamily boilers separated from other commercial boilers in MADs (IDs 147.1 and 88), superseding older combined measure. New analysis based on building modeling and 94% efficiency requirement. Measure life increased to 35 years.
3/28/17	147.2	Add Washington. Clarifies requirements for larger sizes.

Table 5 Related Measures

Measures	MAD ID
Commercial condensing boilers	88

Reviewed and Approved by

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Planning Engineer

Mike Bailey PE
Engineering Manager - Planning

Disclaimer

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Measure Approval Document for Multifamily Condensing Tankless Water Heaters ≤199 kBtu/h

Valid Dates
April 1, 2017 – December 31, 2019

End Use
Central domestic hot water (DHW) systems

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

- Existing Multifamily, Oregon
- Existing Buildings in Multifamily situations in Washington only
- New Buildings, Multifamily

Cost Effectiveness
Table 1 Cost Effectiveness Calculator Oregon

Measure	Measure Life (years)	Savings (therms)	Incremental Cost ($)	Maximum Incentive ($)	Utility BCR at Max Incentive	TRC BCR
Multifamily 199 kBtu/h Condensing Tankless Water Heater	15	82	$320	$320	1.30	1.30

Table 2 Cost Effectiveness Calculator Washington

Measure	Measure Life (years)	Savings (therms)	Incremental Costs ($)	Maximum Incentive ($)	Utility BCR at Max Incentive	TRC BCR
Multifamily 199 kBtu/h Condensing Tankless Water Heater	15	82	$320	$320	1.18	1.18

Program Requirements
- Stacked structures with central water heating
- Installation of condensing tankless water heaters with energy factor (EF) greater than or equal to 0.94
- Additional storage tanks are not added
- Input of 199 kBtu/h or less
    - Commercially sized equipment (>199 kBtu/h) is approved through MAD ID 72 with different savings and requirements.

Details
The practice of installing multiple residentially sized (typically 199 kBtu/h) tankless water heaters in parallel as a central domestic water heating system in multifamily buildings is relatively new and is displacing the use of more expensive domestic water boilers. This measure is designed to encourage the use of condensing tankless water heaters in such situations and discourage the addition of storage tanks which increase losses.

Baseline

The baseline technology is a non-condensing tankless water heater (TWH) which typically has an energy factor of 0.82. The savings from a condensing tankless water heater (CTWH) are generated by capturing latent heat from the combustion exhaust through condensation. All tankless water heaters are rated according to their energy factor which takes into account recovery efficiency, standby losses, and cycling losses.

Savings

The total domestic hot water consumption of a multifamily complex is calculated by using the DOE's Commercial Reference Building Models of the National Stock[1] calculated value for daily DHW demand of 44.0 gal/day/dwelling unit. The efficiencies of the condensing and non-condensing technologies were taken into account to determine savings.

Sizing assumptions

For multi-unit tankless systems sizing refers to quantity tankless water heaters in parallel rather than the capacity of the water heaters themselves or the volume of available storage. Since these systems have no storage to handle intermittent spikes in DHW demand, tankless systems are sized based on the expected peak demand per minute whereas storage systems are sized with respect to the peak hourly demand. The number of dwelling units served by the system has a significant effect on system sizing. When the number of dwelling units is large, there is greater diversity in the time of water use which means that *actual* peak demand is much lower than total *possible* peak demand. In other words, as there are more water fixtures, the probability that they will be in use concurrently decreases due to the broader range of occupancy and usage patterns of the tenants. This allows for a higher ratio of dwelling units served per water heater as building size increases.

This analysis used the modified Hunter's method[2] to determine appropriate sizing based on the number of water supply fixture units (WSFU) in typical multifamily installations. The modified Hunter's method provides WSFU values for typical equipment such as a shower, kitchen faucet, bathroom sink, etc. To determine the number of bathrooms in a typical apartment, it is assumed there will be a one-to-one ratio between bathrooms and bedrooms. The Multifamily RBSA lists the average number of bedrooms in multifamily buildings in Oregon to be 1.6. These values were used to determine a peak demand which was used to determine the number of necessary water heaters in various sizes of multifamily buildings, as shown in Table 3.

The average number of dwelling units per building is assumed to be 40 based on the DOE's Commercial Reference Buildings for midrise apartments. The savings for a 40-dwelling unit system are used for this measure. To prevent the use of this measure in small multifamily buildings where savings (and cost effectiveness) are much lower, this offer is limited to stacked structures.

[1] http://www.nrel.gov/docs/fy11osti/46861.pdf
[2] American Society of Heating, Refrigeration, and Air-conditioning Engineers, (2015) HVAC Applications.

Table 3 Dwelling units and condensing tankless water heaters in central water heat configurations

Dwelling units	Min number of CTWH	Dwelling units / CTWH	Savings / System	Savings / CTWH
2	1.87	1.07	17	16
5	2.81	1.78	46	26
10	3.93	2.55	95	37
20	5.42	3.69	198	54
30	6.36	4.72	325	69
40	7.11	5.63	462	82
50	7.86	6.37	591	93
150	14.03	10.69	1668	156
300	22.44	13.37	2607	195

Measure Life

The measure life is 15 years which is in agreement with commercial tankless water heater measures in other Energy Trust programs. For residential applications, the measure life is 20 years but the expected use in Multifamily is expected to bear more resemblance to commercial applications. The expected full load hours are much higher in commercial applications.

Cost

The difference in material cost was determined by performing an online survey of prices from major manufacturers. Most manufacturer's offer both a TWH and CTWH option which allowed for a more representative cost across all manufacturers.

TWH's typically use stainless steel venting because of the higher exhaust gas temperatures. CTWH's have lower exhaust gas temperatures and use PVC venting which is less expensive. CTWH's require the installation of a condensate line. These costs were taken from a study[3] by the California Statewide Utility Codes and Standards Program. This study is for residential applications but the cost are expected to be independent of market sector.

With all costs taken into account, the incremental cost is $320.

Incentive Structure

The maximum incentive is $320 / water heater not to exceed project cost. *The maximum is specified for reference only and is not a suggested incentive.*

Follow-Up

In the future, the prevalence of storage tanks implemented with tankless water heaters should be analyzed in greater detail. If tank implementation is common enough, savings should be calculated specifically for that system, which are expected to depart significantly from a fully tankless system. Program will collect information regarding the prevalence of existing storage tanks.

This analysis assumes the average size installation will serve 40 dwelling units. The number of dwelling units will be collected by the program to verify this assumption. Capacity of condensing tankless water heaters will also be collected to verify assumptions and to monitor for trends.

[3]California Utilities Statewide Codes and Standards Team (2011). High-Efficiency Water Heater Ready. 2013 California Building Energy Efficiency Standards.

The US DOE is developing a new efficiency rating called uniform energy factor (UEF). It is unknown how this rating will relate to EF for condensing tankless water heaters as well as when EF will be phased out. As this information is determined, this measure or its requirements will be updated accordingly.

Supporting Documents

The cost effective screening for these measures is attached and can be found at:
I:\Groups\Planning\Measure Development\Commercial and Industrial\Commercial Water Heating\gas tankless water heat\Multifamily Tankless\bencost

MF 199 kBtu CTWH CEC.xlsm

Supporting documentation can be found at:
I:\Groups\Planning\Measure Development\Commercial and Industrial\Commercial Water Heating\gas tankless water heat\Multifamily Tankless

Version History and Related Measures

Table 4 Version History

Date	Version	Reason for revision
3/30/17	196.1	New measure
4/10/17	196.2	Include New Multifamily

Table 5 Related Measures

Measures	MAD ID
Commercial and Multifamily Condensing Tankless >199 kBtu/h	72
Commercial and Multifamily Condensing Tank Water Heaters	21
Multifamily DHW Recirculation Demand Control	66
New Homes Tankless	178

Approved & Reviewed by

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Measure Approval Document for Residential Gas Storage Water Heaters

Valid Dates
January 1, 2017 – December 31, 2017

End Use
ENERGY STAR gas storage water heaters sold to retailers, water heater contractors, builders and homeowners.

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

- Efficient Home Products
- Existing Homes
- Existing Manufactured Homes
- Existing Multifamily, buildings with 2-4 units and side by side structures
- Efficient New Homes
- New Small Multifamily

Purpose of Re-Evaluating Measure
In 2016, Energy Trust offered these measures under a one-year Oregon Public Utility Commission exception that expires December 31, 2016. This analysis updates the measure with more current costs and incorporates additional non-energy benefits and tax credits. Retail and contractor-installed costs and Oregon Department of Energy tax credits have been updated for 2017.

Cost Effectiveness
Cost effectiveness for gas tank water heaters are shown in Tables 1 and 2.

Table 1 Cost Effectiveness Calculator Oregon

Measure	Measure Life (Years)	Savings Therms	Incremental Costs ($)	Non-Energy Benefits (Annual $)	Maximum Incentive ($)	Utility BCR at Max Incentive	TRC BCR
0.67-0.69 EF Gas Storage Water Heater - Existing Construction	13	25.3	$214	$18.30	$114	1.00	1.37
0.70+ EF Gas Storage Water Heater - Existing Construction	13	31.5	$193	$23.24	$142	1.00	1.90
0.67-0.69 EF Gas Storage Water Heater - New Construction	13	25.3	$214	$5.95	$114	1.00	0.81
0.70+ EF Gas Storage Water Heater - New Construction	13	31.5	$193	$5.95	$142	1.00	1.03

Table 2 Cost Effectiveness Calculator Washington

Measure	Measure Life (Years)	Savings Therms	Incremental Costs ($)	Non-Energy Benefits (Annual $)	Maximum Incentive ($)	Utility BCR at Max Incentive	TRC BCR
0.67-0.69 EF Gas Storage Water Heater - Existing/New	13	25.3	$214	$5.56	$102	1.00	0.71
0.70+ EF Gas Storage Water Heater - Existing/New	13	31.5	$193	$5.56	$127	1.00	0.92

Exceptions and RETC
In prior years, Energy Trust residential gas water heating operated under various OPUC exceptions. First, the UM 1622 decision which was then extended in August 2015 on criteria that inclusion of the measure will increase market acceptance and lead to reduced costs. Energy Trust indicated to the OPUC their expectation request "…that with implementation of a range of upstream tactics to improve sales, some of which are being developed in concert with other programs across the country, there will be greater market acceptance of high efficiency gas water heaters and costs will go down." The upstream incentives and tactics discussed with the OPUC have been in active development throughout 2016, however the launch of the full suite of upstream strategies has been delayed until 2017.

Energy Trust had requested a two year additional extension to the existing TRC cost-effectiveness exception to allow these new strategies to launch and begin to show influence on water heater costs and availability. On 12/29/2016 the OPUC granted a one year exception and requested an update on the measure in advance of 2018 action plans. The exception covers 0.67 EF gas water heaters sold through any market channel and regardless of construction state. As of 12/29/2016, ODOE has not formally announced changes to the residential energy tax credits (RETC) for 2017, which would negate the need for an exception in 2017 for existing homes. Energy Trust assumes the 0.67 EF RETC will be adopted for 2017 (in addition to the 0.70 EF RETC which has been in place for several years) and has included the proposed tax credits in our analysis. Assuming these do go forward, 0.67 EF water heaters in existing construction have a TRC of 1.37. In the event that our assumptions about the tax credit are wrong, this MAD will be updated but the exceptions will allow for un-disrupted use of the measures in 2017.

Measure level cost effectiveness is not required in Washington.

Program Requirements
- Gas storage water heaters with an Energy Factor (EF) greater than or equal to 0.67 and ENERGY STAR approved qualify for this measure.
- Power vent models qualify for this measure, but power vent is not a requirement.
- Condensing units, whether storage or tankless, are *excluded* from these measures. Currently, the only residential tank condensing models available are very expensive.
- Manufacturers have created a category of "hybrid" gas water heaters between tankless and storage, that have a greater than 2 gallon tank and a greater than 75 kBtu/hr burner. Further testing of the hybrids is needed to determine their energy savings potential. These are *excluded* from this measure.

Details

In 2015, new federal energy efficiency standards for water heaters went into effect. These standards, based on capacity of storage tank, effectively increase the minimum EF rating to 0.60 for a 50 gallon water heater. ENERGY STAR efficiency specifications for gas storage water heaters remained unchanged with a minimum qualifying EF of 0.67.

Gas storage water heater designs which may be used to improve the efficiency to 0.67 EF include increased insulation, improved flue baffles, electronic ignition, and/or an electromechanical flue damper. These options may be combined with power venting at additional cost. Power vented models are included in this measure but very little uptake is expected for them, due to their cost. This measure does not include condensing water heaters or tankless water heaters.

Savings and Baseline

Savings for gas storage water heaters are based on an estimated water heating energy consumption of 218 therms for a baseline, 0.60 EF gas water heater. This figure is a result of the 2009 draft study by Stellar Processes, on contract for Energy Trust of Oregon. The savings for equipment with higher Energy Factors are calculated using the following equation:

$$\text{Savings} = 218 \text{ therms} * (1-(\text{baseline EF}/\text{efficient EF}))$$

The average energy factor participating in the program for each efficiency tier was used to calculate savings for that tier.

Table 3 Efficiency Tiers and Savings

Efficiency Tier	Average Energy Factor	Therm Savings
0.67-0.69 EF Gas Storage	0.679	25.3
0.70+ EF Gas Storage	0.701	31.5

Costs

Existing Homes Program median installed cost data from 2011-2015 was used to determine installed cost for high efficiency gas water heaters at a variety of efficiency levels. These values were normalized to 2015 dollars using the GDP deflator to ensure comparability. Sales tax was removed from Washington project costs. Installed cost information was not available for 0.60 EF units from program historical data. To estimate incremental costs program data from a retired 0.62-0.66 EF unit measure was used as a proxy for a 0.60 EF baseline installation. Incremental costs listed in Table 4 below are used in cost effectiveness testing as most activity is expected to continue be through the contractor channel until the distributor-level measure is introduced.

Table 4 Installed Costs from Baseline by Efficiency Tier

Efficiency Tier	Count	Median Cost	Average Energy Factor	Incremental Cost From Baseline
0.63 EF Baseline Proxy	277	$1,147	0.63	-
0.67-0.69 EF Gas Storage	1,870	$1,361	0.68	**$214**
0.70+ EF Gas Storage	139	$1,341	0.70	**$193**

Additional cost research through the retail channel was also conducted and used in warranty analysis. Given all water heaters in this tier have standing pilot lights their installation requirements would be similar. Given the narrow range of costs observed, the 0.62-0.66 EF program data was deemed suitable as a baseline proxy for incremental cost estimates.

Non-Energy Benefits

Warranty Benefit

Retail research revealed that qualifying atmospherically drafted ENERGY STAR units, which make up the majority of the products Energy Trusts expects to incent, had significantly longer warranty lives than then non-qualified units. Extended coverage offers a financial benefit to consumers who purchase qualifying equipment. Given that warranties are typically provided by manufacturers, retail water heater data was used to estimate the typical warranties for program qualifying equipment that is installed by contractors as well.

To estimate the benefit associated with the longer warranty lengths research conducted by Lawrence Berkeley National Laboratory on water heater stock over time was used.[i] The analysis used a Weibull distribution to model the turnover for water heaters over time. Modeled parameters determine the shape of the distribution as well as the speed at which equipment is estimated to fail. In addition, the LBNL analysis used a three year delay in their function to model units being replaced under warranty. This analysis removes this delay and instead uses the average length of warranties for qualifying and non-qualifying equipment.

The warranty benefit is estimated as the percent of units surviving relative to the baseline equipment's warranty. In the case of power vented units the warranty is actually a penalty, due to its shorter duration. Each qualifying equipment type's retail cost unit is multiplied by the relative fraction surviving relative to the baseline to calculate the lifetime warranty benefit. At the end of the average qualifying atmospheric unit's warranty 59% are estimated to be surviving relative to 44% at the end of the baseline warranty length. Multiplying the difference in survival rate by the qualifying units' retail cost yields a $113 benefit. This approach yields a -$62.77 penalty when comparing qualifying power vented units to baseline equipment.

Table 5 Warranty Lengths and Unit Cost by Venting Configuration and Efficiency Tier at Retail for Gas Storage Water Heaters

Venting Configuration	Average Warranty Length (Years)	Failure Percent Relative to Baseline	Average Retail Unit Cost	Warranty Benefit
Non-ENERGY STAR	7.6	-	-	-
Atmospheric 0.67+ EF	10.7	16%	$724	$112.70
Power vented 0.67+ EF	6.5	-6%	$994	-$62.60

To calculate an annual non-energy benefit, the value of the warranty benefit or penalty is annualized over its warranty life. To create an annualized benefit or penalty, the present value of the units is taken based on a discount rate of 4.5% in Oregon and 5.53% in Washington and the average warranty length for that piece of equipment. These values are then weighted by the share of program-incented water heaters that are power or atmospherically vented. This weighting is based on venting configuration, not on efficiency tiers. The final weighted annual warranty non-energy benefit is $5.89 in Oregon and $5.56 in Washington as shown in Table 6.

Table 6 Weighted Warranty Non-Energy Benefit by Venting Configuration

Venting Configuration	Weight In Program	Warranty Benefit At Year Of Failure	Present Value Of Warranty Benefit (Oregon)	Annualized (Oregon)	Present Value Of Warranty Benefit (Washington)	Annualized (Washington)
Atmospheric 0.67+ EF	85%	$112.70	$70.40	$8.43	$63.35	$8.00
Power vented 0.67+ EF	15%	-$62.60	-$47.00	-$8.50	-$44.12	-$8.26
Weighted annual warranty NEB				$5.95		$5.56

Residential Energy Tax Credit

A tax credit is available from the state of Oregon for residential gas storage water heaters. The credit is $125 for equipment with an EF of 0.67-0.69 and $175 for EF of 0.70 or greater. The values of these credits $12.35 and $17.29 respectively when annualized over the life of the water heater. These values are added as non-energy benefits for existing homes in Oregon. It is assumed that while some may qualify, most installations in new homes would not result in tax credits.

Table 7 shows the sum of the warranty and tax credits as they apply to each efficiency tier, construction stage and state.

Table 7 Summary of Non-Energy Benefits

Efficiency Tier	State	Construction Stage	Warranty Benefit	Tax Credit	Total Benefits
0.67-0.69 EF	Oregon	Existing	$5.95	$12.35	$18.30
0.70+ EF	Oregon	Existing	$5.95	$17.29	$23.24
0.67-0.69 EF	Oregon	New	$5.95	$0	$5.95
0.70+ EF	Oregon	New	$5.95	$0	$5.95
0.67-0.69 EF	Washington	Existing or New	$5.56	$0	$5.56
0.70+ EF	Washington	Existing or New	$5.56	$0	$5.56

Measure Life

The lifetime of this measure is 13 years, from the DOE Technical Support Document for the federal standard.

Incentive Structure

The maximum incentives listed in Table 1 and Table 2 are for reference only and are not suggested incentives. Incentives are likely to vary by program and sales channel and may be paid to end customers, home builders, or passed through or kept by retail channels or distributers.

Follow-Up

This MAD is approved through 2017 due to the annual RETC cycle and the limitations of the OPUC exception. Measures with RETC will need to be re-evaluated at that time. The OPUC has requested on update on the measure in advance of the 2018 budget and action plans. Given new midstream program design plans and the anticipated drop in costs that these are hoped to trigger, costs should be re-evaluated in 2017 or 2018.

Supporting Documents

The cost effective screening for these measures is attached and can be found at:
I:\Groups\Planning\Measure Development\Residential\Res Water Heating\gas storage water heat\bencost


Gas storage water heaters CE Calculatc

Further supporting documents can be found at:
I:\Groups\Planning\Measure Development\Residential\Res Water Heating\gas storage water heat

Version History and Related Measures

Energy Trust has been incentivizing gas water heaters for many years and the offering has evolved over time. The table below shows the measure history since 2010 when 0.67 EF was introduced as an efficiency tier in our residential program.

Table 8 Version History

Date	Version	Reason For Revision
5/26/10	102.x	Introduce 0.67 EF water heaters for existing and manufactured homes
5/27/10	102.x	Include small multifamily homes in prior approval.
6/2/10	102.x	Include condensing tank units.
8/10/10	102.x	Included distributor incentive.
1/6/12	102.x	Update cost and incentives.
6/19/12	102.x	Update approval to include maximum incentive.
9/2/15	102.x	Update savings due to federal standard influence of baseline. Removes condensing units.
9/15/15	102.x	Includes small multifamily.
2/16/16	102.x	Includes the products program.
12/30/16	102.x	Update costs and non-energy benefits.

Table 9 Related Measures

Water Heating Measures	MAD ID
Residential and existing small multifamily heat pump water heaters	52
New small multifamily heat pump water heaters	176
New homes and small multifamily tankless water heaters	178
Commercial condensing tank water heaters	21
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[i] James D. Lutz, Asa Hopkins, Virginie Letschert, Victor H. Franco, and Andy Sturges . Using National Survey Data to Estimate Lifetimes of Residential Appliances. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwjtmfa5-63PAhUK02MKHZI2B6UQFgghMAA&url=https%3A%2F%2Fpublications.lbl.gov%2Fislandora%2Fobject%2Fir%253A157288%2Fdatastream%2FPDF%2Fdownload%2Fcitation.pdf&usg=AFQjCNFmN6Mdlvs9kS10fGHANQnhY5baTw

August 17, 2015

REVISED measure approval document for gas fireplaces

Measure Description
A direct vent gas fireplaces measure is currently offered in the Existing Homes, Home Performance with ENERGY STAR programs, and the small multifamily subsector of the Multifamily Existing Buildings program. In the Multifamily Existing Buildings program, fireplaces are approved only for properties where the living units are side by side, not stacked. Fireplaces for new homes are not cost-effective and not approved as a standalone measure or a component of a package used to gauge the cost-effectiveness of the EPS. This memo adds an intermittent ignition measure that includes both direct vent fireplaces and log sets in Existing Homes and New Homes.

Energy savings based on thermal efficiency
The efficiency rating is the Fireplace Efficiency score from the Canadian P4 test. Savings are calculated according to the following formula:

$$\Delta therm = hr\ x\ \frac{kBtu}{hr}\ x\ (\frac{1}{baseline} - \frac{1}{FE})$$

Hours of use: Annual 600 hours of use were extrapolated from the Energy Trust hours of use metered study for Existing Homes. A survey of participants in our New Homes Program in 2015 asked for hours of use of fireplaces. The survey response indicated 8.2 hours per week from October to March (26 weeks). If the same over-reporting phenomenon that was applied in the Existing Homes program, calculated from the difference between self-reported and metered hours of use, then the average hours of use per week in the New Homes program would be 5.4.

Heat input and average efficiency: Data is for units recognized in the program tracking database from January 1, 2014 thru July 9, 2015. The figures in table 1 are used in the thermal efficiency savings estimate.

Table 1: Updated efficient unit FE and kBtu usage

Tier	Average FE	Average kBtu	Count
70 - 74.9 FE	72.3	32,900	1,792
75+ FE	78.2	31,700	246

The number of fireplaces in the new homes market and retrofits in existing homes: The average of new home builder reported and new home occupant survey findings for number of fireplaces is applied to the new gas heated home market estimate by separating the number of New Homes from fireplace sales to Existing Homes. The hearth market in Oregon for both new and existing homes is an estimated 10,500 units annually. The size of new home market was estimated in two ways: utility account activations and the 2014 Census reported residential permits less builder reported percent of new home market heated with electricity.

Method 1 for the number of new homes (utility data): Utility customer information for NWN and CNG was screened for new residential gas account activation in 2014. Single family detached, duplex and triplex structures were included in the estimate assuming that larger structures are less likely to be candidates for hearth installations during the building process.

Method 2 for the number of new homes (census data): Census data for permits issued in Oregon during 2014 were also sourced to provide another data point for the size of the housing market. Structures with less than four units were used as the total for this estimate. The data does not distinguish between heating fuel types so the 76% estimate of new construction for new homes reported by Evergreen Economics' 2015 builder interviews was used to de-rate the permit data.

Table2: Estimate of new gas heated home market size

Data source	Total permits	Percent of new gas heated homes	Total housing units
Census 2014 permits issued for < 5 unit structures[1]	8,919	76%	6,778
UCI 2014 <4 unit gas account activations	-	-	7,278
Average	**-**	**-**	**7,028**

Method 1 for the number of fireplaces in each new home (occupant survey): To estimate the number of hearths in a new gas heated home, the new home occupant survey data is weighted based on the number of observations in the dataset yielding an estimated 0.86 hearths per new gas heated home.

Method 2 for the number of fireplaces in each new home (builder interviews): Builder interviews reported 93% of new gas heated homes have at least one fireplace, with 95% of those having one unit installed, and the remaining 5% two or more. Given the unknown number of additional units, two units are assumed for the homes with more than one installation in-line with the new home owner survey. These figures are weighted and provide an estimate of 0.98 hearths per new gas heated home.

Evenly weighting the builder reported and new home survey data yields an estimated 0.92 hearths per new gas heated home, shown in Table 3 below:

Table 3: Estimated average number of hearths in new gas heated homes

New home occupant survey				**Builder reported**		**Overall Average hearths per new home**
Number of Hearths	Count	Percent	Weight	Percent	Weight	
1	110	75%	0.75	88%	0.88	
2	8	5%	0.11	5%	0.10	
0	28	19%	0	7%	-	
Total	146	**Hearths per home**	**0.86**		**0.98**	**0.92**

[1] Census permit data site: http://www.census.gov/construction/bps/stateannual.html

Divvying up fireplaces to new homes and existing homes: Using the new gas heated home market and hearths per home figure yields an estimated 6,453 hearths in new homes, leaving an existing home market of 4,047.

Table 4: Estimated new home and existing home hearth markets

Total estimated market	10,500
2014 New Homes unit estimate	7,028
Hearths per new home	0.92
Hearth units in new homes	6,453
Existing home market	4,047

Average efficiency of fireplaces in new homes: Table 5 below shows the distribution of efficiency levels for hearths found in new homes. Mid-points for the efficiency bin are sourced from incented units in the program tracking database for the 65+ FE units. Verifier data is used for the sub-65 efficiency levels rather than the mid-point of the bin. These figures are used to estimate the weighted FE score for the comparison region for the manufacturer and distributor reported 2014 unit sales and to remove the estimated new home thermal efficiency distribution from the total market estimate.

Table 5: Efficiency bin mid points

FE efficiency bin	Verifier sourced percent in bin	Estimated new home unit distribution	FE point estimate	FE point estimate source
75+	0%	-	78.2	2014-July 2015 average FE
70-74	2%	129	72.3	2014-July 2015 average FE
65-69	6%	387	67.5	2014 average FE
50-64	90%	5,808	55.8	New home verifier data
0-49	2%	129	45	New home verifier data
Total	**100%**	**6,453**	**56.6**	

Method 1 for the average efficiency of fireplaces in Existing Homes (manufacturer baseline): The efficiency distribution found by the verifiers (shown above in table 5) is applied to the new home hearth unit estimate and then subtracted from the manufacturer reported distribution of units for the entire market. The resulting average thermal efficiency for Existing Homes based on manufacturer data is 65.5 FE.

Table 6: Manufacturer weighted baseline

Manufacturer reported comparison region in 2014				Verifier sourced distribution removed	
Efficiency bin	Bin midpoint	Manufacturer reported 2014 distribution	Units in market	Less new homes	Weighted FE
75+	78.2	2%	210	210	4.1
70-74	72.3	9%	945	844	15.1

65-69	67.5	23%	2,415	2,012	33.6
50-64	55.8	62%	6,510	695	9.6
0-49	45.0	4%	420	286	3.2
Totals	**-**	**100%**	**10,500**	**4,047**	**65.5**

Method 2 for the average efficiency of fireplaces in Existing Homes (distributor baseline): The distributor baseline estimates follows the same procedure as the manufacturer data shown in table 6 with one deviation due to a lack of 2014 distributor reported units in the 70-74 FE bin. Subtraction of the new home efficiency distribution (shown in table 5) would result in a negative weighting for the 70-74 bin. To mitigate a negatively weighted efficiency bin the new home unit estimate is subtracted from the next less efficient bin until the entire new home unit estimate has been removed from the total market estimate. The resulting average thermal efficiency for Existing Homes based on distributor data is 54.3 FE.

Table 7: Distributor weighted baseline

Distributor reported comparison region in 2014				Verifier sourced distribution removed	
Efficiency bin	Bin midpoint	Distributor reported 2014 distribution	Units in market	Less new homes	Weighted FE
75+	78.2	3%	315	315	6.1
70-74	72.3	0%	-	-	-
65-69	67.5	4%	420	-	-
50-64	55.8	80%	8,400	2,501	34.5
0-49	45.0	13%	1,365	1,231	13.7
Totals	**-**	**100%**	**10,500**	**4,047**	**54.3**

Manufacturer and distributor reported data are weighted equally to provide a new thermal efficiency baseline for existing homes of 59.9 FE.

Energy savings based on intermittent ignition system

Intermittent ignition savings are calculated by multiplying the heat input by the number of hours the pilot would otherwise be on. The heat input of the pilot light is 1000 Btu/h, based on the DOE Technical Support Document for the federal standard. The hours are 8760 minus the hours the fireplace is in operation.

The baseline for the intermittent ignition system is the Eastern Washington market, where distributors surveyed in the market transformation study sold 46% of their product without intermittent ignition systems. An estimated 40% of the difference between the comparison region and our service territory, where 9% of products are sold without intermittent ignition systems, was attributed by the authors of the study to regional differences. The result is 32% of intermittent ignition systems can be influenced by our incentive, and that is the NTG ratio for the savings that we would claim for a retail or customer incentive (0.46-0.4*(0.46-0.11) = 0.32). The NTG will be applied to the working savings for reporting, but in accordance with Energy Trust practice is not used for the cost effectiveness calculation in this analysis.

NTG: Note that the Program is considering a midstream delivery model, with the baseline for each distributor calculated from the previous year's sales. In that case, the working savings would be multiplied by the number of additional units that each distributor sold above the previous year's baseline. It is not necessary to apply the NTG ratio to the midstream savings model, for that reason.

Even though these savings are based on the ignition system, it will be super important to record the thermal efficiency of all of the fireplaces, as potential market transformation savings will be based on direct vent fireplaces with thermal efficiency of 65 or better, while log sets with intermittent ignition systems will get program savings.

Energy savings based on on-demand ignition system.
The heat input of the pilot light is 1000 Btu/h, based on the DOE Technical Support Document for the federal standard. There are a total of 4368 hours in the heating season (from October 1 to March 31).

The on-demand pilot light allows the homeowner to shut down the fireplace, including the pilot light, when it is not in use, though it can be overridden by thermostat or remote control to extinguish the pilot light only after five consecutive days not in use. In the absence of other data, the default mode is assumed to be shutting off the fireplace after five consecutive days of it not being used.

Metered data used to determine hours of use included some on demand fireplaces. Superb statistical work by Energy Trust evaluators produced an average number of hours in excess of the five day lag time that an on demand fireplace would remain off during the heating season. This additional 372 hours off time is added to the savings for on demand ignition systems.

Weighting of different ignition systems: 13% of the models on the NRCAN product list are on demand. Intermittent ignition system savings are blended with the on demand savings based on that proportion of products in the market. In addition, the market transformation study also indicated that about 20% of products with intermittent ignition systems could be switched to standing pilot mode. The measure analysis deducts this percentage from the ignition system savings.

Measure Cost
Tax credits are available through ODOE. They are $350 for 70-74 FE fireplaces and $550 above 80 FE. **However, the tax credits are new this year, and Energy Trust has no information on their uptake. Although it may become necessary to subtract the tax credit from the incremental cost in future years, this measure analysis does not do so**.

The DOE Technical Support Document for the rulemaking process gives the incremental production cost of the electronic controls and starter as $28 for vented fireplaces and $70 for vented log sets. This analysis takes the higher number and applies a 50% contractor mark-up, which is also applied to the fireplace equipment cost below.

Incremental costs of $25 for thermal efficiency are taken from the median prices in the 2013 Cadmus market assessment between the 60 to 64FE baseline and the 70FE and above efficient case and given the same 50% mark-up from wholesale to retail costs that was applied to the ignition system. Costs for thermal efficiency for new homes are from the median price between the 55FE baseline and the 70FE efficient case. Thermal efficiency savings are not cost effective in new homes.

Cost Effectiveness Calculator: \\Etoo.org\home\Groups\Planning\Measure Development\Residential\fireplace\bencost\ETO CEC fireplace 2016.xlsm

Measure	Measure Life (yrs)	Savings		Incremental Costs ($)	Non-Energy Benefits (Annual $)	Maximum Incentive ($)	Utility BCR at Max Incentive	TRC BCR
		kWh	therms					
Fireplace ignition system	20		64	$105	$0	$105	3.81	3.81
Existing Homes fireplace thermal efficiency from 70 to 74 FE	20		57	$38	$0	$38	9.49	9.49
Existing Homes fireplace thermal efficiency at 75 FE and above	20		74	$38	$0	$38	12.48	12.48
New Homes fireplace thermal efficiency from 70 to 74 FE	20		18	$1,113	$0	$1,113	2.98	0.10
New Homes fireplace thermal efficiency at 75 FE and above	20		22	$1,113	$0	$1,113	3.65	0.12

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Reviewed by Mike Bailey & Fred Gordon

Measure Approval Document for Residential Gas Tankless Water Heaters in SW Washington

Valid Dates

June 1, 2017 – December 31, 2019

End Use

0.82+ EF gas tankless water heaters sold to homeowners.

Program Applicability

Based on the referenced analysis the measure described below is approved for use in the following programs offered in SW Washington:

- Existing Homes
- Existing Manufactured Homes
- Existing Multifamily: 2-4 units and side by side structures, administered by the residential programs

Purpose of Re-Evaluating Measure

In 2012, Energy Trust removed tankless water heater offerings for the Existing Homes program in both Oregon and Washington due to TRC ratio below 1. Beginning in 2015, the Washington Utilities and Transportation Commission (WUTC) no longer requires the TRC to be the primary metric for measure screening, relying instead on the Utility Cost Test. This update reintroduces tankless in Washington.

Cost Effectiveness

Cost effectiveness for gas tankless water heaters in Washington is shown in Table 1.

Table 1 Cost Effectiveness 2017 v1.3 Calculator - Washington

Measure	Measure Life (years)	Savings therms	Incremental Costs ($)	Maximum Incentive ($)	Utility BCR at Max Incentive	TRC BCR
0.82+ EF Tankless	20	74.2	$1,834	$444	1.00	0.24

Exceptions

Measure level total resource cost effectiveness is not required in NW Natural Washington's portfolio. The WUCT is anticipated to revisit this requirement in 2018 to determine if relying on the UCT as the primary cost effectiveness screening method for NW Natural Washington programs should continue.

Program Requirements

- Installed in SW Washington.
- Gas tankless water heaters with an energy factor (EF) greater than or equal to 0.82.
- Manufacturers have created a category of "hybrid" gas water heaters between tankless and storage that have a tank with a capacity over two gallons burner with a rating greater than 75 kBtu/hr. These are *excluded* from eligibility under this MAD.

Details

In 2015, new federal energy efficiency standards for water heaters went into effect. These standards, based on capacity of storage tank, effectively increase the minimum EF rating to 0.60 for a 50 gallon water heater. Tankless water heater designs can improve the efficiency factors to over 0.90 by eliminating standby losses incurred from storage tanks and electronic ignitions.

Savings and Baseline

Baseline equipment is a new gas storage water heater with and EF of 0.60. While the required minimum efficiency for tankless in the program is 0.82 EF, the expected average EF is 0.91 based on past installations.

Savings for gas storage water heaters are based on an estimated water heating energy consumption of 218 therms for a baseline, 0.60 EF gas water heater. This figure is a result of the 2009 draft study by Stellar Processes, on contract for Energy Trust of Oregon. Average tankless EF of 0.91 for savings calculations is sourced from past SW Washington program data on incented tankless units.

The savings for equipment with higher energy factors are calculated using the following equation:

$$\text{Savings} = 218 \text{ therms} * (1-(\text{baseline EF}/\text{efficient EF}))$$

Comparison to other offerings

Savings for this measure are higher than for the new homes tankless measure because we assume homeowners select tankless units with EF higher than builders.

Measure Life

Measure life of 20 years, based on federal water heater standard Technical Support Document.

Costs

Past project cost information from the Existing Homes program in Washington from 2009-2012 for tankless water heaters and 2011-2015 for gas storage units. These values were normalized to 2016 dollars using the RTF's GDP deflator to ensure comparability. Sales tax was removed from Washington project costs. Installed cost information was not available for 0.60 EF units from program historical data. The cost of installing tankless units in existing homes is higher than in new homes or the costs seen in retail or at distributers due to the frequent necessity of upgrading gas lines to accommodate the tankless units.

To estimate incremental costs, program data from a retired 0.62-0.66 EF measure was used as a proxy for a 0.60 EF baseline including installation given that these units all use a standing pilot light and are expected to have similar costs.

Table 2 Installed costs

Efficiency Tier	Cost
0.62-0.66 EF Storage Baseline Proxy	$1,167
0.82+ EF Tankless	$3,313
Increment	$2,146

The expected useful life of tankless water heaters is 20 years compared to 13 years for a gas storage unit. This longer measure life will result in a partially avoided replacement cost for a storage water heater after year 13, or 54% of a future storage water heater. The future value of the avoided replacement is $628, with a present value of $312, which is deducted from the initial incremental cost of $2,146 for a final value of $1,834. This process is described in Table 3.

Table 3 Avoided future cost calculations

	Calculation	Result
Useful life of tankless beyond baseline	20-13 = 7 7/13	54%
Estimated storage installation cost	From Table 2	$1,167
Avoided future replacement cost	$1,167 * 54%	$628
Present values of avoided future replacement at 5.53% discount rate	PV ($628, 5.53%,7)	$312
Incremental cost	From Table 2	$2,146
Final incremental cost	**$2,146 - $312**	**$1,834**

Incentive Structure

The maximum incentive listed in Table 1 is for reference only and is not a suggested incentive. Incentives are likely to vary by program and sales channel and may be paid to end customers, home builders, or passed through or kept by retail channels or distributers.

Follow-Up

If the WUTC reinstates TRC screening requirements this MAD will need to be revisited due to the TRC benefit cost ratios being less than 1.0.

Supporting Documents

The cost effective screening for these measures is attached and can be found at:
I:\Groups\Planning\Measure Development\Residential\Res Water Heating\tankless\Existing homes\Wa only\bencost

CEC 2017 Tankless WA.xlsm

Supporting documents can be found at:
I:\Groups\Planning\Measure Development\Residential\Res Water Heating\tankless\Existing homes

References

US DOE Technical Support Document for residential water heaters:
https://www.regulations.gov/contentStreamer?documentId=EERE-2006-STD-0129-0170&attachmentNumber=26&disposition=attachment&contentType=pdf.

Version History and Related Measures

Tankless measures predate our current approval and record keeping processes, Table 4 may be incomplete.

Table 4 Measure History

Date	Version	Reason for Revision
2007	x	Tankless in existing homes approved
12/31/2011	x	Measure canceled for existing homes
4/24/2017	197.1	Re-introduce tankless water heaters to existing homes in SW Washington

Table 5 Related Measures

Water Heating Measures	MAD ID
Residential gas storage water heaters	102
New homes and new small multifamily tankless water heaters	178
Multifamily central system tankless water heaters ≤199 kBtu/h	196
Commercial tankless water heaters	72

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