December 16, 2015

Ms. Kirsten Walli
Board Secretary
Ontario Energy Board
2300 Yonge Street, 27th Floor
Toronto, ON M4P 1E4

Dear Ms. Walli:

RE: EB-2015-0344 New and Updated DSM Measures - Joint Submission from Union Gas Ltd. and Enbridge Gas Distribution

Union Gas Limited ("Union") and Enbridge Gas Distribution Inc. ("Enbridge") request the approval of the Ontario Energy Board (the "Board") for the new and updated DSM measures.

In the DSM Guidelines for Natural Gas Utilities (EB-2008-0346), the Board directed the utilities to make an annual application to update input assumptions and encouraged the utilities to file a joint application.

This application updates the March 27, 2015 DSM input assumption filing (EB-2014-0354). Per the Joint Terms of Reference on Stakeholder Engagement for DSM Activities by Union and Enbridge dated November 4, 2011, one of the Technical Evaluation Committee's ("TEC") primary tasks is to develop a Technical Reference Manual ("TRM") for natural gas DSM activities. The TRM, currently in the finalization stage, will be filed by the utilities in early 2016.

Until such time as the TRM is approved by the Board, the common Table of Measure Assumptions and Substantiation Documents will continue to document the Board approved measure assumptions.

This joint application is made in consultation with the TEC, to update the common Table of Measure Assumptions and Substantiation Documents. With respect to this update, the TEC endorsement applies only to the following measure assumptions:

- New Measures:
  - Residential Adaptive Thermostat

- Updated Measures:
  - Commercial Condensing Tankless Water Heater

- Commercial Kitchen Demand Control Ventilation (Retrofit)
- Commercial Kitchen Demand Control Ventilation (New Construction)
- Commercial Condensing Make Up Air Unit
- Commercial Condensing Storage Water Heater
- Commercial Condensing Unit Heater
- Commercial Infrared Heater (New Construction)
- Commercial Infrared Heater (Retrofit)
- Commercial Pre-rinse Spray Nozzle (New Construction/Time of Natural Replacement)
- Commercial Pre-rinse Spray Nozzle (Retrofit/Early Replacement)
- Residential Programmable Thermostat (Retrofit)
- Residential Condensing Furnace
- Residential Low-Flow Showerheads
- Residential Tankless Water Heater
- Commercial Air Curtains
- Commercial Destratification Fans
- Commercial Condensing Furnace
- Commercial Heat Recovery Ventilator
- Commercial Energy Recovery Ventilator
- Commercial Heat Recovery Ventilator (50% effectiveness baseline)
- Commercial Energy Recovery Ventilator (50% effectiveness baseline)
- Residential Heat Reflector Panels
- Commercial Multi-Residential Showerhead

The TEC has endorsed the existing savings assumptions for prescriptive boilers for application to savings claimed by the utilities for their respective 2014 DSM Audits and Clearance of DSM Deferral and Variance Accounts. Upcoming boiler related study results (anticipated in 2016) should apply to future savings.

This update also includes free ridership values for Demand Control Ventilation (New Construction and Retrofit) and Adaptive Thermostat (New Construction and Retrofit) that have not gone through the full TEC review and endorsement process, and are therefore not TEC endorsed.

This application includes:

- Current approved measures assumptions
- Union's Custom EUL Table as per the Union Gas 2015-2020 DSM Plan (EB-2015-0029)
- Enbridge Measure Life Guide for Custom Offers with noted updates

The application contains the following exhibits:
Exhibit A, Tab 1, Schedule 1 Table of Contents
Exhibit B, Tab 1, Schedule 1 Background and Introduction
Exhibit B, Tab 1, Schedule 2 Updated Table of Measure Assumptions
Exhibit B, Tab 1, Schedule 3 New and Updated Substantiation Documents

This application was prepared jointly by Union and Enbridge. Please direct correspondence on this file to both Union and Enbridge representatives:

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Enbridge and Union request the Board’s approval of the new and updated DSM measures.

Sincerely,

[Original signed by]

Vanessa Innis
Manager, Regulatory Initiatives

c.c: Alex Smith (Torys)
EB-2011-0327 Intervenors

Dennis M. O'Leary
Stephanie Allman – Enbridge Gas Distribution Inc.
EB-2011-0295 Intervenors

TEC Members:
Ted Kesik – Independent Member
Bob Wirtshafter – Independent Member
Jay Shepherd – School Energy Coalition
Julie Girvan – Consumers Council of Canada
Chris Neme – Green Energy Coalition
Tina Nicholson – Union Gas Limited
Ravi Sigurdson – Enbridge Gas Distribution Inc.

EXHIBIT LIST

A - ADMINISTRATIVE

B – EVIDENCE

BACKGROUND AND INTRODUCTION

1. The 2008 Demand Side Management Guidelines for Natural Gas Utilities (“DSM Guidelines”; EB-2008-0346), encouraged Enbridge Gas Distribution (“Enbridge”) and Union Gas Ltd. (“Union”) to file a joint application of approved input assumption on an annual basis:

> “The application should be made annually, whether or not the natural gas utilities are requesting any changes to their set of input assumptions. The natural gas utilities’ annual application will provide a Board forum for stakeholders that will allow them to, among other things, request updates and/or additions to the set of input assumptions that may not have been identified by the natural gas utilities.”[1]

The 2015-2020 DSM Filing Guidelines for Natural Gas Distributors (EB-2014-0134) clarify the role of the Technical Evaluation Committee (“TEC”) in relation to the joint annual application of approved input assumptions:

> “The TEC’s role also includes administering any updates to the TRM on an annual basis to ensure that the standard set of energy efficient measures and assumptions reflect the best information available.”[2]

In the 2015-2020 DSM Framework for Natural Gas Distributors (EB-2014-0134) the Board directed Union and Enbridge to continue delivering their 2014 DSM offers in 2015 to help facilitate a smooth evolution into the new DSM framework[3].

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[1] Demand Side Management Guidelines for Natural Gas Utilities, EB-2008-0346, Ontario Energy Board, June 30, 2011, page 19.
[2] Filing Guidelines to the Demand Side Management Framework for Natural Gas Distributors (2015-2020), EB-2014-0134, Ontario Energy Board, December 22, 2014, page 24.
[3] Demand Side Management Framework for Natural Gas Distributors (2015-2020), EB-2014-0134, Ontario Energy Board, December 22, 2014, page 37.

2. A joint Table of Measures Assumptions filed in 2012 and last updated on March 27, 2015 brought together a common set of Substantiation Documents providing detailed information and savings calculations for each measure listed.

3. The 2008 DSM Guidelines requested that a Terms of Reference for Stakeholder Engagement ("Terms of Reference"; EB-2011-0295 Exhibit B, Tab 2, Schedule 9, Appendix A) be developed by the natural gas utilities in cooperation with stakeholders for the multi-year plan period. Under the Terms of Reference, Enbridge and Union engaged extensively with stakeholders through each utility's DSM Consultative, the utilities' respective Audit Committees and a joint TEC.

4. The Terms of Reference for Stakeholder Engagement mandated the TEC to develop a Technical Reference Manual ("TRM") for natural gas DSM activities. In 2013, the utilities, through the TEC, engaged a third party consultant to begin development of the TRM.

5. All of the substantiation documents that comprise the TEC TRM Project have been reviewed and endorsed by the TEC. The TRM is expected to be finalized early in 2016, at which time an update to this application will be filed.

This Update includes the following TEC endorsed elements:

Update Element	Update Description	Utility
New Measures	• Residential Adaptive Thermostat	Both
Update to	• Commercial Condensing Tankless Water Heater	Both

Measures	• Commercial Kitchen Demand Control Ventilation Retrofit • Commercial Kitchen Demand Control Ventilation New Construction • Commercial Condensing Make-up Air Unit • Commercial Condensing Storage Water Heater • Commercial Condensing Unit Heater • Commercial Infrared Heater New Construction • Commercial Infrared Heater Retrofit • Commercial Pre-rinse Spray Nozzle New Construction/Time of Natural Replacement • Commercial Pre-rinse Spray Nozzle Retrofit/Early Replacement • Residential Programmable Thermostat Retrofit • Residential Condensing Furnace • Residential Low-Flow Showerheads • Residential Tankless Water Heater • Commercial Air Curtains • Commercial Destratification Fans • Commercial Condensing Furnace • Commercial Heat Recovery Ventilator • Commercial Energy Recovery Ventilator • Commercial Heat Recovery Ventilator (50% effectiveness baseline) • Commercial Energy Recovery Ventilator (50% effectiveness baseline) • Residential Heat Reflector Panels • Commercial Multi-Residential Showerhead	
Prescriptive Boilers	• The TEC endorsed the current savings assumptions for prescriptive boilers for application to savings claimed by utilities for their respective 2014 DSM Audits and Clearance of DSM Accounts.	Both

This Update also includes the following update elements. Due to the timing, these elements have not gone through the full TEC review and endorsement process, and are therefore not TEC endorsed:

Update Element	Update Description	Utility
Free Ridership Value	• Demand Control Ventilation: The current free ridership rates of 5% for Retrofit and 20% for New Construction are based on best available information. There continues to be a lack of supporting jurisdictional free ridership results for this technology. There is currently no available jurisdiction to use as a proxy in the meantime. • Adaptive Thermostats: A Free Ridership rate of 4% is submitted for Residential, based on best available information.[4] A Free Ridership rate of 0% is submitted for Low Income (Enbridge) and 1% (Union) as per EB-2012-0394 (Enbridge) and EB 2012-0441 (Union).	Both
Custom Measure Life Table(s)	• Union Custom EUL Table (see detail in #6 below) • Enbridge Custom Measure Life Guide for Custom Offers (see detail in #7 below)	Both

6. Union's Custom EUL Table included in this evidence is the updated version reflecting best available substantiating references as per the Union Gas 2015-2020 DSM Plan (EB-2015-0029).

7. Enbridge's Measure Life Guide for Custom Offers included in this evidence provides updates reflecting best available substantiating references (See Exhibit B, Tab 1, Schedule 2).

[4] Commonwealth Edison (2015). Smart Thermostat: A CLEAResult White Paper. Available at: http://ilsagfiles.org/SAG_files/Meeting_Materials/2015/6-23-15_Meeting/CLEAResult_Smart_Thermostat_WhitePaper_20150505.pdf

For clarity, Enbridge has added a category for “Industrial Process/Industrial Equipment” separate from the existing Boiler – Industrial Process category. No change has been made to the measure life assumption.

The measure life assumptions for the following measures have been revised to reflect the values outlined in updated substantiation documents endorsed by the TEC:

- Infrared Heaters
- Heat Reflector Panels

The measure life assumptions for the following measures have been revised to reflect substantiated values based on best available information:

- Steam Pipe/Tank Insulation (the measure life has been applied to Multi Residential and Commercial in addition to Industrial)
- Steam Trap

In addition, the supporting reference/source has been updated in a few cases to reflect updated/best available information, but with no resulting change to the previous measure life assumption.

8. This application is comprised of the following exhibits:

- Exhibit A, Tab 1, Schedule 1 Table of Contents
- Exhibit B, Tab 1, Schedule 1 Background and Introduction
- Exhibit B, Tab 1, Schedule 2 Updated Table of Measure Assumptions
- Exhibit B, Tab 1, Schedule 3 New and Updated Substantiation Documents

Indicates a new update to Board-approved list of input assumptions

Residential Space Heating

Target Market		Equipment Details				Annual Resource Savings			Other				
Sector	New/Existing	Efficient Equipment	Details of Efficient Equipment	Base Equipment	Details of Base Equipment	Natural Gas (m3)	Electricity (kWh)	Water (L)	EUL	Incremental Cost ($)	Free Rider (%)	Utility Measure Applies to	Decision Type
Residential	Existing	Attic Insulation	upgrade to R-40	R-10		105	105	0	20	$ 580.00	33%	UG	Retrofit
Residential	Existing	Basement Wall Insulation	upgrade to R-12	R-1		261	145	0	25	$ 1,654.00	33%	UG	Retrofit
Residential	Existing	Draft Proofing Kit	(1) Spray Foam, can (1) Caulk, tube (30 ft) Foam Tape (4) Energy Saver Gasket with 2 child safety inserts	No Draft Proofing Kit		236	27	0	1	$ 20.00	55%	UG	Retrofit
Residential	New	Energy Star Home	version 3	Home built to OBC 2006		1,018	1,450	0	25	$ 3,200.00	48%	EGD	New
Residential	Existing	Fireplace intermittent ignition control retrofit		Natural gas fireplace with a pilot		104	-31	0	8	$ 150.00	1%	UG	Retrofit
Residential	New/ Existing	95% or Higher Efficiency Furnace	AFUE 95% or greater	High-Efficiency Furnace	AFUE 90%	1.05 /kBtu/hr input capacity	0	0	18	$ 528.00	0%	Both	New Construction/ Natural Replacement
Residential	New	High Efficiency Fireplace with Pilotless Ignition	Freestanding, Minimum 70% EnerGuide Rating	Freestanding fireplace	65% median efficiency	110	-31	0	20	$ 135.00	17%	EGD	New
Residential	New	High Efficiency Fireplace with Pilotless Ignition	Insert, Minimum 60% EnerGuide Rating	Insert	55% median efficiency	109	-31	0	20	$ 135.00	17%	EGD	New
Residential	New	High Efficiency Fireplace with Pilotless Ignition	Zero Clearance, >= 40 kBtu.h =Minimum 60% EnerGuide Rating	Zero Clearance	`	122	-31	0	20	$ 135.00	17%	EGD	New
Residential	New	High Efficiency Fireplace with Pilotless Ignition	Zero Clearance, < 40 kBtu.h =Minimum 70% EnerGuide Rating	Zero Clearance		108	-31	0	20	$ 135.00	17%	EGD	New
Residential	Existing	High Efficiency Fireplace with Pilotless Ignition	Freestanding, Minimum 70% EnerGuide Rating	Freestanding fireplace	65% median efficiency	110	-31	0	20	$ 135.00	17%	EGD	Replacement
Residential	Existing	High Efficiency Fireplace with Pilotless Ignition	Insert, Minimum 60% EnerGuide Rating	Insert	55% median efficiency	109	-31	0	20	$ 135.00	17%	EGD	Replacement
Residential	Existing	High Efficiency Fireplace with Pilotless Ignition	Zero Clearance, >= 40 kBtu.h =Minimum 60% EnerGuide Rating	Zero Clearance		122	-31	0	20	$ 135.00	17%	EGD	Replacement
Residential	Existing	High Efficiency Fireplace with Pilotless Ignition	Zero Clearance, < 40 kBtu.h =Minimum 70% EnerGuide Rating	Zero Clearance		108	-31	0	20	$ 135.00	17%	EGD	Replacement
Residential	Existing	Adaptive Thermostats - Retail Purchase	Adaptive Thermostat	Blended value. Non Programmable and programmable Thermostat		185.0	176	0	15	$ 300.00	4%	Both	Retrofit
Residential	Existing	Adaptive Thermostats - Direct Install	Adaptive Thermostat	Non-Programmable Thermostat		217.0	235	0	15	$ 300.00	4%	Both	Retrofit
Residential	Existing	Adaptive Thermostats - Direct Install	Adaptive Thermostat	Programmable Thermostat		173.0	235	0	15	$ 300.00	4%	Both	Retrofit
Residential	New	Adaptive Thermostats	Adaptive Thermostat	Programmable Thermostat		105.0	206	0	15	$ 200.00	4%	Both	New Construction
Residential	Existing	Programmable Thermostat	Programmable thermostat with at least two programming modes (weekday and weekend)	Non Programmable Thermostat		46.0	0	0	15	$ 68.00	43%	Both	Retrofit
Residential	Existing	Heat Reflector Panels	Heat reflector panel installed behind radiator	No heat reflector panel installed behind radiator		143.2	0	0	25	Actual Utility Cost	0%	Both	Retrofit

Residential Water Heating

Sector	New/Existing	Efficient Equipment	Details of Efficient Equipment	Base Equipment	Details of Base Equipment	Natural Gas (m3)	Electricity (kWh)	Water (L)	EUL	Incremental Cost ($)	Free Rider (%)	Utility Measure Applies to	Decision Type
Residential	New/Existing	Faucet Aerator	Bathroom, 1.5 GPM	Standard flow bathroom aerator (code compliant)	2.2 GPM	3.73	0	1459	10	$ 0.60	31%	EGD	New/Retrofit
Residential	New/Existing	Faucet Aerator	Bathroom, 1.0 GPM	Standard flow bathroom aerator (code compliant)	2.2 GPM	6.4	0	2,501	10	$ 0.60	33%	UG	New/Retrofit
Residential	New/Existing	Faucet Aerator	Bathroom, 1.0 GPM	Standard flow bathroom aerator (code compliant)	2.2 GPM	6.4	0	2,501	10	$ 0.60	31%	EGD	New/Retrofit
Residential	New/Existing	Faucet Aerator	Bathroom, 1.5 GPM	Standard flow bathroom aerator (code compliant)	2.2 GPM	3.73	0	1459	10	$ 0.60	33%	UG	New/Retrofit

Indicates a new update to Board-approved list of input assumptions

Target Market		Equipment Details				Annual Resource Savings			Other				
Sector	New/Existing	Efficient Equipment	Details of Efficient Equipment	Base Equipment	Details of Base Equipment	Natural Gas (m3)	Electricity (kWh)	Water (L)	EUL	Incremental Cost ($)	Free Rider (%)	Utility Measure Applies to	Decision Type
Residential	New/Existing	Faucet Aerator	Kitchen, 1.0 GPM	Standard flow kitchen aerator (code compliant)	2.2 GPM	19.82	0	7,742	10	$ 1.14	33%	UG	New/Retrofit
Residential	New/Existing	Faucet Aerator	Kitchen, 1.5 GPM	Standard flow kitchen aerator (code compliant)	2.2 GPM	11.56	0	4,516	10	$ 1.14	33%	UG	New/Retrofit
Residential	New/Existing	Faucet Aerator	Kitchen, 1.0 GPM	Standard flow kitchen aerator (code compliant)	2.2 GPM	19.82	0	7,742	10	$ 1.14	31%	EGD	New/Retrofit
Residential	New/Existing	Faucet Aerator	Kitchen, 1.5 GPM	Standard flow kitchen aerator (code compliant)	2.2 GPM	11.56	0	4,516	10	$ 1.14	31%	EGD	New/Retrofit
Residential	New/Existing	Low-flow showerhead	1.25 GPM (Per household)	Average Existing Stock	2.5 GPM	55.0	0	14,363	10	Actual Utility Cost	10%	Both	New Construction /Retrofit
Residential	New/Existing	Low-flow showerhead	1.5 GPM (Per Household)	Average Existing Stock	2.5 GPM	44.0	0	9,875	10	Actual Utility Cost	10%	Both	New Construction /Retrofit
Residential	Existing	Pipe Wrap	R 3.375	No pipe wrap	R-0.43	4.72 /ft	0	0	15	$0.25/ft	4%	Both	Retrofit
Residential	Existing	Solar Pool Heaters		Natural gas pool heater		1,116	-57	0	20	$ 1,450.00	10%	Both	Retrofit
Residential	New/Existing	Tankless Water Heater	High Efficiency Non-Condensing Tankless Water Heater, EF = 0.82	Storage Tank Water Heater,	EF=0.67	88.7	0	0	20	$ 1,611.00	2%	Both	New Construction/ Natural Replacement
Residential	New/Existing	Tankless Water Heater	Condensing Tankless Water Heater, EF = 0.91	Storage Tank Water Heater,	EF=0.67	127.9	0	0	20	$ 2,039.00	2%	Both	New Construction/ Natural Replacement
Residential	New	High Efficiency Gas Storage Water Heaters	High efficiency storage tank water heater (Energy Factor of 0.80)	ENERGY STAR power vented storage tank water heater	Energy factor of 0.67	68.3	0	0	16	$ 540.00		Both	New

Low-Income Residential Space Heating

Sector	New/Existing	Efficient Equipment	Details of Efficient Equipment	Base Equipment	Details of Base Equipment	Natural Gas (m3)	Electricity (kWh)	Water (L)	EUL	Incremental Cost ($)	Free Rider (%)	Utility Measure Applies to	Decision Type
Low-Income	New/Existing	95% or Higher Efficiency Furnace	AFUE 95% or greater	High-Efficiency Furnace	AFUE 90%	1.05 /kBtu/hr input capacity	0	0	18	$ 528.00	0%	Both	New Construction/ Natural Replacement
Low-Income	Existing	Heat Reflector Panels	Heat reflector panel installed behind radiator	No heat reflector panel installed behind radiator		143.2	0	0	25	Actual Utility Cost	0%	Both	Retrofit
Low-Income	Existing	Adaptive Thermostats - Retail Purchase	Adaptive Thermostat	Blended value. Non Programmable and programmable Thermostat		185.0	176	0	15	$ 300.00	0% EGD, 1% UG	Both	Retrofit
Low-Income	Existing	Adaptive Thermostats - Direct Install	Adaptive Thermostat	Non-Programmable Thermostat		217.0	235	0	15	$ 300.00	0% EGD, 1% UG	Both	Retrofit
Low-Income	Existing	Adaptive Thermostats - Direct Install	Adaptive Thermostat	Programmable Thermostat		173.0	235	0	15	$ 300.00	0% EGD, 1% UG	Both	Retrofit
Low-Income	New	Adaptive Thermostats	Adaptive Thermostat	Programmable Thermostat		105.0	206	0	15	$ 200.00	0% EGD, 1% UG	Both	New Construction
Low-Income	Existing	Programmable Thermostat	Programmable thermostat with at least two programming modes (weekday and weekend)	Non Programmable Thermostat		46.0	0	0	15	$ 68.00	1% UG, 0% EGD	Both	Retrofit

Low-Income Residential Water Heating

Sector	New/Existing	Efficient Equipment	Details of Efficient Equipment	Base Equipment	Details of Base Equipment	Natural Gas (m3)	Electricity (kWh)	Water (L)	EUL	Incremental Cost ($)	Free Rider (%)	Utility Measure Applies to	Decision Type
Low-Income	New/Existing	Faucet Aerator	Bathroom, 1.0 GPM	Standard flow bathroom aerator (code compliant)	2.2 GPM	6.40	0	2,501	10	$ 0.60	1%	UG	New/Retrofit
Low-Income	New/Existing	Faucet Aerator	Bathroom, 1.5 GPM	Standard flow bathroom aerator (code compliant)	2.2 GPM	3.73	0	1459	10	$ 0.60	1%	UG	New/Retrofit
Low-Income	New/Existing	Faucet Aerator	Kitchen, 1.0 GPM	Standard flow kitchen aerator (code compliant)	2.2 GPM	19.82	0	7,742	10	$ 1.14	1%	UG	New/Retrofit
Low-Income	New/Existing	Faucet Aerator	Kitchen, 1.5 GPM	Standard flow kitchen aerator (code compliant)	2.2 GPM	11.56	0	4,516	10	$ 1.14	1%	UG	New/Retrofit
Low Income	New/Existing	Faucet Aerator	Bathroom, 1.0 GPM	Standard flow bathroom aerator (code compliant)	2.2 GPM	6.40	0	2,501	10	$ 0.60	0%	EGD	New/Retrofit
Low Income	New/Existing	Faucet Aerator	Kitchen, 1.5 GPM	Standard flow bathroom aerator (code compliant)	2.2 GPM	3.73	0	1459	10	$ 0.60	0%	EGD	New/Retrofit

	Indicates a new update to Board-approved list of input assumptions

Target Market		Equipment Details				Annual Resource Savings			Other				
Sector	New/Existing	Efficient Equipment	Details of Efficient Equipment	Base Equipment	Details of Base Equipment	Natural Gas (m3)	Electricity (kWh)	Water (L)	EUL	Incremental Cost ($)	Free Rider (%)	Utility Measure Applies to	Decision Type
Low Income	New/Existing	Faucet Aerator	Kitchen, 1.0 GPM	Standard flow kitchen aerator (code compliant)	2.2 GPM	19.82	0	7,742	10	$ 1.14	0%	EGD	New/Retrofit
Low Income	New/Existing	Faucet Aerator	Bathroom, 1.5 GPM	Standard flow bathroom aerator (code compliant)	2.2 GPM	3.73	0	1459	10	$ 0.60	0%	EGD	New/Retrofit
Low income	New/Existing	Low-flow showerhead	1.25 GPM (Per household)	Average Existing Stock	2.5 GPM	55.0	0	14,363	10	Actual Utility Cost	0% EGD, 1% UG	Both	New Construction /Retrofit
Low income	New/Existing	Low-flow showerhead	1.5 GPM (Per Household)	Average Existing Stock	2.5 GPM	44.0	0	9,875	10	Actual Utility Cost	0% EGD, 1% UG	Both	New Construction /Retrofit
Low-Income	Existing	Pipe Wrap	R 3.375	No pipe wrap	R-0.43	4.72 / ft	0	0	15	$0.25/ft	UG 1%, EGD 0%	Both	Retrofit

Low-Income Multi-Residential Water Heating

Low-Income	New/Existing	Faucet Aerator	Bathroom, 1.0 GPM	Standard flow bathroom aerator (code compliant)	2.2 GPM	6.40	0	2,501	10	$ 0.60	1%	UG	New/Retrofit
Low-Income	New/Existing	Faucet Aerator	Bathroom, 1.5 GPM	Standard flow bathroom aerator (code compliant)	2.2 GPM	3.73	0	1459	10	$ 0.60	1%	UG	New/Retrofit
Low-Income	New/Existing	Faucet Aerator	Kitchen, 1.0 GPM	Standard flow kitchen aerator (code compliant)	2.2 GPM	19.82	0	7,742	10	$ 1.14	1%	UG	New/Retrofit
Low-Income	New/Existing	Faucet Aerator	Kitchen, 1.5 GPM	Standard flow kitchen aerator (code compliant)	2.2 GPM	11.56	0	4,516	10	$ 1.14	1%	UG	New/Retrofit
Low Income	New/Existing	Faucet Aerator	Bathroom, 1.0 GPM	Standard flow bathroom aerator (code compliant)	2.2 GPM	6.40	0	2,501	10	$ 0.60	0%	EGD	New/Retrofit
Low Income	New/Existing	Faucet Aerator	Bathroom, 1.5 GPM	Standard flow bathroom aerator (code compliant)	2.2 GPM	3.73	0	1459	10	$ 0.60	0%	EGD	New/Retrofit
Low Income	New/Existing	Faucet Aerator	Kitchen, 1.0 GPM	Standard flow kitchen aerator (code compliant)	2.2 GPM	19.82	0	7,742	10	$ 1.14	0%	EGD	New/Retrofit
Low Income	New/Existing	Faucet Aerator	Kitchen, 1.5 GPM	Standard flow kitchen aerator (code compliant)	2.2 GPM	11.56	0	4,516	10	$ 1.14	0%	EGD	New/Retrofit
Low-Income	New/Existing	Low-flow showerhead	1.25 GPM	Average existing stock	2.5 GPM	38.3	0	12,105	10	Actual Utility Cost	1%UG, 0%EGD	Both	New Construction / Retrofit
Low-Income	New/Existing	Low-flow showerhead	1.50 GPM	Average existing stock	2.5 GPM	30.6	0	8,322	10	Actual Utility Cost	1%UG, 0%EGD	Both	New Construction / Retrofit

Low-Income Multi-Residential Space Heating

Low income	New	Condensing Boiler - Space Heating (<100 Mbtu/h)	90% AFUE	Non-condensing Boiler	82% AFUE	0.01019 /Btu/hr	0	0	25	$ 1,475.00	Union 5%, EGD 0%	Both	New
Low income	New	Condensing Boiler - Space Heating (100 to 199 Mbtu/h)	90% AFUE	Non-condensing Boiler	82% AFUE	0.01019 /Btu/hr	0	0	25	$ 2,414.00	Union 5%, EGD 0%	Both	New
Low income	New	Condensing Boiler - Space Heating (200 to 299 Mbtu/h)	90% AFUE	Non-condensing Boiler	82% AFUE	0.01019 /Btu/hr	0	0	25	$ 3,227.00	Union 5%, EGD 0%	Both	New
Low income	Existing	Condensing Boiler - Space Heating (<100 Mbtu/h)	90% AFUE	Non-condensing Boiler	82% AFUE	0.01019 /Btu/hr	0	0	25	$ 2,045.00	Union 5%, EGD 0%	Both	Replacement
Low income	Existing	Condensing Boiler - Space Heating (100 to 199 Mbtu/h)	90% AFUE	Non-condensing Boiler	82% AFUE	0.01019 /Btu/hr	0	0	25	$ 2,984.00	Union 5%, EGD 0%	Both	Replacement
Low income	Existing	Condensing Boiler - Space Heating (200 to 299 Mbtu/h)	90% AFUE	Non-condensing Boiler	82% AFUE	0.01019 /Btu/hr	0	0	25	$ 3,797.00	Union 5%, EGD 0%	Both	Replacement
Low income	New/Existing	Condensing Boilers - Space Heating, 300 and above MBTUH	88% seasonal efficiency	Non-condensing boiler	76% estimated seasonal efficiency	0.0104 m3/Btu/hr	0	0	25	$12/kBtu/hr	5%	UG	New/Replacement
Low income	New	High Efficiency Boiler - Space Heating (<100 Mbtu/h)	85% AFUE	Non-condensing Boiler	82% AFUE	0.00318 /Btu/hr	0	0	25	$ 1,238.00	Union 5%, EGD 0%	Both	New
Low income	New	High Efficiency Boiler - Space Heating (100 to 199 Mbtu/h)	85% AFUE	Non-condensing Boiler	82% AFUE	0.00318 /Btu/hr	0	0	25	$ 1,544.00	Union 5%, EGD 0%	Both	New
Low income	New	High Efficiency Boiler - Space Heating (200 to 299 Mbtu/h)	85% AFUE	Non-condensing Boiler	82% AFUE	0.00318 /Btu/hr	0	0	25	$ 1,388.00	Union 5%, EGD 0%	Both	New
Low income	Existing	High Efficiency Boiler - Space Heating (<100 Mbtu/h)	85% AFUE	Non-condensing Boiler	82% AFUE	0.00318 /Btu/hr	0	0	25	$ 1,808.00	Union 5%, EGD 0%	Both	Replacement
Low income	Existing	High Efficiency Boiler - Space Heating (100 to 199 Mbtu/h)	85% AFUE	Non-condensing Boiler	82% AFUE	0.00318 /Btu/hr	0	0	25	$ 2,114.00	Union 5%, EGD 0%	Both	Replacement

	Indicates a new update to Board-approved list of input assumptions

Target Market		Equipment Details				Annual Resource Savings			Other				
Sector	New/Existing	Efficient Equipment	Details of Efficient Equipment	Base Equipment	Details of Base Equipment	Natural Gas (m3)	Electricity (kWh)	Water (L)	EUL	Incremental Cost ($)	Free Rider (%)	Utility Measure Applies to	Decision Type
Low income	Existing	High Efficiency Boiler - Space Heating (200 to 299 Mbtu/h)	85% AFUE	Non-condensing Boiler	82% AFUE	0.00318 /Btu/hr	0	0	25	$ 1,958.00	Union 5%, EGD 0%	Both	Replacement
Low income	Existing	Prescriptive High Efficiency Boiler - Space Heating	83-84% Efficient, 300-2000 MBH	Space Heating Boiler	80.5% Thermal Efficiency	2,474-19,340	0	0	25	$3900-$4950	Union 5%, EGD 0%	Both	Replacement
Low income	Existing	Prescriptive High Efficiency Boiler - Space Heating	85-88% Efficient, 300-2000 MBH	Space Heating Boiler	80.5% Thermal Efficiency	3,496-27,325	0	0	25	$4,500-$7,050	Union 5%, EGD 0%	Both	Replacement
Low income	New	Prescriptive High Efficiency Boiler - Space Heating	83-84% Efficient, 300-2000 MBH	Space Heating Boiler	80.5% Thermal Efficiency	2,474-19,340	0	0	25	$3900-$4950	Union 5%, EGD 0%	Both	New
Low income	New	Prescriptive High Efficiency Boiler - Space Heating	85-88% Efficient, 300-2000 MBH	Space Heating Boiler	80.5% Thermal Efficiency	3,496-27,325	0	0	25	$4,500-$7,050	Union 5%, EGD 0%	Both	New

Commercial Cooking

Commercial	New/Existing	Energy Star Fryer	Energy Star Rated Fryer	Non-Energy Star rated Fryer		1408	0	0	12	$ 3,405.00	20%	Both	New/Replacement
Commercial	New/Existing	Energy Star Convection Ovens - Full Size	Energy Star Rated Convection Oven (Full Size)	Conventional Convection Oven (Full Size)		865	0	0	12	$ 875.00	20%	Both	New/Replacement
Commercial	New/Existing	Energy Star Steam Cookers	Energy Star Rated Steam Cooker	Boiler-based steam cooker		8889	0	340142	12	$ 1,035.00	20%	Both	New/Replacement
Commercial	New/Existing	High Efficiency Under-Fired Broilers - 3 foot	pre-heat =< 40,500 Btu and cooking energy rate =< 72,000 Btu/hr	Conventional Efficiency Under-Fired Broiler	pre-heat =< 48,000 Btu and cooking energy rate =< 96,000 Btu/hr	2,511	0	0	12	$ 1,900.00	20%	Both	New/Replacement
Commercial	New/Existing	High Efficiency Under-Fired Broilers - 4 foot	pre-heat 40,501 to 54,000 Btu and a cooking energy rate 72,001 to 96,000 Btu/hr	Conventional Efficiency Under-Fired Broiler	pre-heat 48,001 to 64,000 Btu and a cooking energy rate 96,000 to 128,000 Btu/hr	3,347	0	0	12	$ 1,900.00	20%	Both	New/Replacement
Commercial	New/Existing	High Efficiency Under-Fired Broilers - 5 foot	pre-heat 54,001 to 67,500 Btu and cooking energy rate 96,001 to 120,000 Btu/hr	Conventional Efficiency Under-Fired Broiler	pre-heat 64,001 to 80,000 Btu and cooking energy rate 128,001 to 160,000 Btu/hr	4,184	0	0	12	$ 1,900.00	20%	Both	New/Replacement
Commercial	New/Existing	High Efficiency Under-Fired Broilers - 6 foot	pre-heat 67,501 to 81,000 Btu and cooking energy rate 120,001 to 144,000 Btu/hr	Conventional Efficiency Under-Fired Broiler	pre-heat 80,001 to 96,000 Btu and cooking energy rate 160,001 to 192,000 Btu/hr	5,021	0	0	12	$ 1,900.00	20%	Both	New/Replacement

Commercial Space Heating

Commercial	New/Existing	Air Curtains	Single door 7' x 3'	Non - air curtain doors		671.0	-137	0	15	$ 1,000.00	5%	Both	New Construction /Retrofit
Commercial	New/Existing	Air Curtains	Single door 7' x 6'	Non - air curtain doors		1,343.0	-78	0	15	$ 1,400.00	5%	Both	New Construction /Retrofit

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Target Market		Equipment Details				Annual Resource Savings			Other				
Sector	New/Existing	Efficient Equipment	Details of Efficient Equipment	Base Equipment	Details of Base Equipment	Natural Gas (m3)	Electricity (kWh)	Water (L)	EUL	Incremental Cost ($)	Free Rider (%)	Utility Measure Applies to	Decision Type
Commercial	New/Existing	Air Curtains	Single door 8' x 6'	Non - air curtain doors		1,622.0	-58	0	15	$ 1,500.00	5%	Both	New Construction /Retrofit
Commercial	New/Existing	Air Curtains	Double door 2 x 7' x 3'	Non - air curtain doors		1,343.0	-273	0	15	$ 2,000.00	5%	Both	New Construction /Retrofit
Commercial	New/Existing	Air Curtains	Double door 2 x 7' x 6'	Non - air curtain doors		2,686.0	-156	0	15	$ 2,800.00	5%	Both	New Construction /Retrofit
Commercial	New/Existing	Air Curtains	Double door 2 x 8' x 6'	Non - air curtain doors		3,243.0	-115	0	15	$ 3,000.00	5%	Both	New Construction /Retrofit
Commercial	New/Existing	Air Curtains	Shipping and Receiving door 8' x 8'	Non - air curtain doors		12,108.0	-613	0	15	$ 3,500.00	5%	Both	New Construction /Retrofit
Commercial	New/Existing	Air Curtains	Shipping and Receiving door 8' x 10'	Non - air curtain doors		15,135.0	-1,997	0	15	$ 3,500.00	5%	Both	New Construction /Retrofit
Commercial	New/Existing	Air Curtains	Shipping and Receiving door 10' x 10'	Non - air curtain doors		20,796.0	-1,597	0	15	$ 4,500.00	5%	Both	New Construction /Retrofit
Commercial	New	Condensing Boiler - Space Heating (<100 Mbtu/h)	90% AFUE	Non-condensing Boiler	82% AFUE	0.01019 /Btu/hr	0	0	25	$ 1,475.00	5%	Both	New
Commercial	New	Condensing Boiler - Space Heating (100 to 199 Mbtu/h)	90% AFUE	Non-condensing Boiler	82% AFUE	0.01019 /Btu/hr	0	0	25	$ 2,414.00	5%	Both	New
Commercial	New	Condensing Boiler - Space Heating (200 to 299 Mbtu/h)	90% AFUE	Non-condensing Boiler	82% AFUE	0.01019 /Btu/hr	0	0	25	$ 3,227.00	5%	Both	New
Commercial	Existing	Condensing Boiler - Space Heating (<100 Mbtu/h)	90% AFUE	Non-condensing Boiler	82% AFUE	0.01019 /Btu/hr	0	0	25	$ 2,045.00	5%	Both	Replacement
Commercial	Existing	Condensing Boiler - Space Heating (100 to 199 Mbtu/h)	90% AFUE	Non-condensing Boiler	82% AFUE	0.01019 /Btu/hr	0	0	25	$ 2,984.00	5%	Both	Replacement
Commercial	Existing	Condensing Boiler - Space Heating (200 to 299 Mbtu/h)	90% AFUE	Non-condensing Boiler	82% AFUE	0.01019 /Btu/hr	0	0	25	$ 3,797.00	5%	Both	Replacement
Commercial	New/Existing	Condensing Boilers - Space Heating, 300 and above MBTUH	88% seasonal efficiency	Non-condensing boiler	76% estimated seasonal efficiency	0.0104 m3/Btu/hr	0	0	25	$12/Kbtu/hr	5%	UG	New/Replacement
Commercial	New/Existing	Condensing Make Up Air Unit (MUA) - Commercial	Constant Speed	Conventional MUA	80% Thermal Efficiency	0.407/CFM	0	0	20	$870.00 + $0.66/CFM	5%	Both	New Construction/ Natural Replacement
Commercial	New/Existing	Condensing Make Up Air Unit (MUA) - Commercial	2 Speed	Conventional MUA	80% Thermal Efficiency	1.22/CFM	1.24/CFM	0	20	$870.00 + $1.01/CFM	5%	Both	New Construction/ Natural Replacement
Commercial	New/Existing	Condensing Make Up Air Unit (MUA) - Commercial	VFD	Conventional MUA	80% Thermal Efficiency	2.03/CFM	2.04/CFM	0	20	$870.00 + 1.02/CFM	5%	Both	New Construction/ Natural Replacement
Commercial	New/Existing	Condensing Make Up Air Unit (MUA) - MR and LTC	Constant Speed	Conventional MUA	80% Thermal Efficiency	0.919/CFM	0	0	20	$870.00 + $0.66/CFM	5%	Both	New Construction/ Natural Replacement
Commercial	New/Existing	Condensing Make Up Air Unit (MUA) - MR and LTC	2 Speed	Conventional MUA	80% Thermal Efficiency	2.45/CFM	1.61/CFM	0	20	$870.00 + $1.01/CFM	5%	Both	New Construction/ Natural Replacement
Commercial	New/Existing	Condensing Make Up Air Unit (MUA) - MR and LTC	VFD	Conventional MUA	80% Thermal Efficiency	3.00/CFM	2.30/CFM	0	20	$870.00 + $1.02/CFM	5%	Both	New Construction/ Natural Replacement
Commercial	Existing	Condensing Unit Heater	90% Thermal Efficiency, 89% Annual Efficiency	Non-Condensing Unit Heater	30-100 kBtu/hr 80% Thermal Efficiency, 78% Annual Efficiency	7.89 /kBtu/hr input capacity	296	0	18	$12.90/kBtu/hr input capacity	0%	Both	Natural Replacement
Commercial	Existing	Condensing Unit Heater	90% Thermal Efficiency, 89% Annual Efficiency	Non-Condensing Unit Heater	125-200 kBtu/hr 80% Thermal Efficiency, 78% Annual Efficiency	7.89 /kBtu/hr input capacity	530	0	18	$12.90/kBtu/hr input capacity	0%	Both	Natural Replacement
Commercial	Existing	Condensing Unit Heater	90% Thermal Efficiency, 89% Annual Efficiency	Non-Condensing Unit Heater	225-300 kBtu/hr 80% Thermal Efficiency, 78% Annual Efficiency	7.89 /kBtu/hr input capacity	546	0	18	$12.90/kBtu/hr input capacity	0%	Both	Natural Replacement
Commercial	New	Condensing Unit Heater	90% Thermal Efficiency, 89% Annual Efficiency	Non-Condensing Unit Heater	30-100 kBtu/hr 80% Thermal Efficiency, 78% Annual Efficiency	5.92 /kBtu/hr input capacity	222	0	18	$12.90/kBtu/hr input capacity	0%	Both	New Construction
Commercial	New	Condensing Unit Heater	90% Thermal Efficiency, 89% Annual Efficiency	Non-Condensing Unit Heater	125-200 kBtu/hr 80% Thermal Efficiency, 78% Annual Efficiency	5.92 /kBtu/hr input capacity	398	0	18	$12.90/kBtu/hr input capacity	0%	Both	New Construction

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Target Market		Equipment Details				Annual Resource Savings			Other				
Sector	New/Existing	Efficient Equipment	Details of Efficient Equipment	Base Equipment	Details of Base Equipment	Natural Gas (m3)	Electricity (kWh)	Water (L)	EUL	Incremental Cost ($)	Free Rider (%)	Utility Measure Applies to	Decision Type
Commercial	New	Condensing Unit Heater	90% Thermal Efficiency, 89% Annual Efficiency	Non-Condensing Unit Heater	225-300 kBtu/hr 80% Thermal Efficiency, 78% Annual Efficiency	5.92 /kBtu/hr input capacity	410	0	18	$12.90/kBtu/hr input capacity	0%	Both	New Construction
Commercial	Existing	Demand Control Kitchen Ventilation	0 - 5,000 CFM	Constant Volume Kitchen Ventilation		4,207.0	4,940	0	15	$ 3,300.00	5%	Both	Retrofit
Commercial	Existing	Demand Control Kitchen Ventilation	5,001 - 10,000 CFM	Constant Volume Kitchen Ventilation		10,517.0	16,294	0	15	$ 8,325.00	5%	Both	Retrofit
Commercial	Existing	Demand Control Kitchen Ventilation	10,001 - 15,000 CFM	Constant Volume Kitchen Ventilation		17,529.0	28,929	0	15	$ 13,875.00	5%	Both	Retrofit
Commercial	New	Demand Control Kitchen Ventilation	0 - 5,000 CFM	Constant Volume Kitchen Ventilation		4,207.0	4,940	0	15	$ 1,665.00	5%	Both	New Construction/ Natural Replacement
Commercial	New	Demand Control Kitchen Ventilation	5,001 - 10,000 CFM	Constant Volume Kitchen Ventilation		10,517.0	16,294	0	15	$ 4,162.00	5%	Both	New Construction/ Natural Replacement
Commercial	New	Demand Control Kitchen Ventilation	10,001 - 15,000 CFM	Constant Volume Kitchen Ventilation		17,529.0	28,929	0	15	$ 6,930.00	5%	Both	New Construction/ Natural Replacement
Commercial	New	Destratification Fans		No destratification fans		583/fan	-	0	15	$ 6,100.00	10%	Both	New Construction
Commercial	Existing	Destratification Fans		No destratification fans		1,734 /fan	-	0	15	$ 6,100.00	10%	Both	Retrofit
Commercial	New/Existing	High Efficient 65% Energy Recovery Ventilation High Use Group (Multi-Residential, Health Care, Nursing Homes)	Minimum 65% Sensible Heat Recovery Effectiveness and 63% Total Energy Recovery Effectiveness at 32°F	Minimum 50% Energy Recovery Effectiveness as per Ontario Building Code 2015		1.37 /CFM	0 /CFM	0	14	$1.00/CFM	5%	Both	New Construction/ Natural Replacement
Commercial	New/Existing	High Efficient 75% Energy Recovery Ventilation High Use Group (Multi-Residential, Health Care, Nursing Homes)	Minimum 75% Sensible Heat Recovery Effectiveness and 73% Total Energy Recovery Effectiveness at 32°F	Minimum 50% Energy Recovery Effectiveness as per Ontario Building Code 2015		2.42 /CFM	0 /CFM	0	14	$2.00/CFM	5%	Both	New Construction/ Natural Replacement
Commercial	New/Existing	High Efficient 85% Energy Recovery Ventilation High Use Group (Multi-Residential, Health Care, Nursing Homes)	Minimum 85% Sensible Heat Recovery Effectiveness and 83% Total Energy Recovery Effectiveness at 32°F	Minimum 50% Energy Recovery Effectiveness as per Ontario Building Code 2015		3.48 /CFM	0 /CFM	0	14	$3.00/CFM	5%	Both	New Construction/ Natural Replacement
Commercial	New/Existing	High Efficient 65% Energy Recovery Ventilation Medium Use Group (Hotel, Restaurant, Retail,)	Minimum 65% Sensible Heat Recovery Effectiveness and 63% Total Energy Recovery Effectiveness at 32°F	Minimum 50% Energy Recovery Effectiveness as per Ontario Building Code 2015		0.76 /CFM	0 /CFM	0	14	$1.00/CFM	5%	Both	New Construction/ Natural Replacement
Commercial	New/Existing	High Efficient 75% Energy Recovery Ventilation Medium Use Group (Hotel, Restaurant, and Retail,)	Minimum 75% Sensible Heat Recovery Effectiveness and 73% Total Energy Recovery Effectiveness at 32°F	Minimum 50% Energy Recovery Effectiveness as per Ontario Building Code 2015		1.34 /CFM	0 /CFM	0	14	$2.00/CFM	5%	Both	New Construction/ Natural Replacement
Commercial	New/Existing	High Efficient 85% Energy Recovery Ventilation Medium Use Group (Hotel, Restaurant, Retail,)	Minimum 85% Sensible Heat Recovery Effectiveness and 83% Total Energy Recovery Effectiveness at 32°F	Minimum 50% Energy Recovery Effectiveness as per Ontario Building Code 2015		1.93 /CFM	0 /CFM	0	14	$3.00/CFM	5%	Both	New Construction/ Natural Replacement
Commercial	New/Existing	High Efficient 65% Energy Recovery Ventilation Low Use Group (Office, Warehouse, School)	Minimum 65% Sensible Heat Recovery Effectiveness and 63% Total Energy Recovery Effectiveness at 32°F	Minimum 50% Energy Recovery Effectiveness as per Ontario Building Code 2015		0.49 /CFM	0 /CFM	0	14	$1.00/CFM	5%	Both	New Construction/ Natural Replacement
Commercial	New/Existing	High Efficient 75% Energy Recovery Ventilation Low Use Group (Office, Warehouse, School)	Minimum 75% Sensible Heat Recovery Effectiveness and 73% Total Energy Recovery Effectiveness at 32°F	Minimum 50% Energy Recovery Effectiveness as per Ontario Building Code 2015		0.86 /CFM	0 /CFM	0	14	$2.00/CFM	5%	Both	New Construction/ Natural Replacement
Commercial	New/Existing	High Efficient 85% Energy Recovery Ventilation Low Use Group (Office, Warehouse, School)	Minimum 85% Sensible Heat Recovery Effectiveness and 83% Total Energy Recovery Effectiveness at 32°F	Minimum 50% Energy Recovery Effectiveness as per Ontario Building Code 2015		1.23 /CFM	0 /CFM	0	14	$3.00/CFM	5%	Both	New Construction/ Natural Replacement
Commercial	New / Existing	High Use Group Energy Recovery Ventilation (Multi-Residential, Health Care, Nursing Homes)	Ventilation with ERV Integrated	Ventilation without ERV		6.64 /CFM	0 /CFM	0	14	$4.49/CFM	5%	Both	Retrofit/ New Construction
Commercial	Existing	High Use Group Energy Recovery Ventilation (Multi-Residential, Health Care, Nursing Homes)	Ventilation with ERV Standalone	Ventilation without ERV		6.64 /CFM	-4.62 /CFM	0	14	$7.20/CFM	5%	Both	Retrofit
Commercial	New / Existing	Medium Use Group Energy Recovery Ventilation (Hotels, Restaurant, Retails)	Ventilation with ERV Integrated	Ventilation without ERV		3.68/CFM	0 /CFM	0	14	$4.49/CFM	5%	Both	Retrofit/ New Construction
Commercial	Existing	Medium Use Group Energy Recovery Ventilation (Hotels, Restaurant, Retails)	Ventilation with ERV Standalone	Ventilation without ERV		3.68 /CFM	-2.57 /CFM	0	14	$7.20/CFM	5%	Both	Retrofit
Commercial	New / Existing	Low Use Group Energy Recovery Ventilation (Office, Warehouse, School)	Ventilation with ERV Integrated	Ventilation without ERV		2.36 /CFM	0 /CFM	0	14	$4.49/CFM	5%	Both	Retrofit/ New Construction
Commercial	Existing	Low Use Group Energy Recovery Ventilation (Office, Warehouse, School)	Ventilation with ERV Standalone	Ventilation without ERV		2.36 /CFM	-1.64 /CFM	0	14	$7.20/CFM	5%	Both	Retrofit
Commercial	New/Existing	High Efficient 65% Heat Recovery Ventilation High Use Group (Multi-Residential, Health Care, Nursing Homes)	HRV with Minimum 65% Sensible Heat Recovery Effectiveness at 32°F	HRV with Minimum 50% Sensible Heat Recovery Effectiveness as per Ontario Building Code 2015		1.16 /CFM	0 /CFM	0	14	$1.00/CFM	5%	Both	New Construction/ Natural Replacement

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Target Market		Equipment Details				Annual Resource Savings			Other				
Sector	**New/Existing**	**Efficient Equipment**	**Details of Efficient Equipment**	**Base Equipment**	**Details of Base Equipment**	**Natural Gas (m3)**	**Electricity (kWh)**	**Water (L)**	**EUL**	**Incremental Cost ($)**	**Free Rider (%)**	**Utility Measure Applies to**	**Decision Type**
Commercial	New/Existing	High Efficient 75% Heat Recovery Ventilation High Use Group (Multi-Residential, Health Care, Nursing Homes)	HRV with Minimum 75% Sensible Heat Recovery Effectiveness at 32°F	HRV with Minimum 50% Sensible Heat Recovery Effectiveness as per Ontario Building Code 2015		1.93 /CFM	0 /CFM	0	14	$2.00/CFM	5%	Both	New Construction/ Natural Replacement
Commercial	New/Existing	High Efficient 85% Heat Recovery Ventilation High Use Group (Multi-Residential, Health Care, Nursing Homes)	HRV with Minimum 85% Sensible Heat Recovery Effectiveness at 32°F	HRV with Minimum 50% Sensible Heat Recovery Effectiveness as per Ontario Building Code 2015		2.70 /CFM	0 /CFM	0	14	$3.00/CFM	5%	Both	New Construction/ Natural Replacement
Commercial	New/Existing	High Efficient 65% Heat Recovery Ventilation Medium Use Group (Hotel, Restaurant, Retail)	HRV with Minimum 65% Sensible Heat Recovery Effectiveness at 32°F	HRV with Minimum 50% Sensible Heat Recovery Effectiveness as per Ontario Building Code 2015		0.64 /CFM	0 /CFM	0	14	$1.00/CFM	5%	Both	New Construction/ Natural Replacement
Commercial	New/Existing	High Efficient 75% Heat Recovery Ventilation Medium Use Group (Hotel, Restaurant, Retail)	HRV with Minimum 75% Sensible Heat Recovery Effectiveness at 32°F	HRV with Minimum 50% Sensible Heat Recovery Effectiveness as per Ontario Building Code 2015		1.07 /CFM	0 /CFM	0	14	$2.00/CFM	5%	Both	New Construction/ Natural Replacement
Commercial	New/Existing	High Efficient 85% Heat Recovery Ventilation Medium Use Group (Hotel, Restaurant, Retail)	HRV with Minimum 85% Sensible Heat Recovery Effectiveness at 32°F	HRV with Minimum 50% Sensible Heat Recovery Effectiveness as per Ontario Building Code 2015		1.50 /CFM	0 /CFM	0	14	$3.00/CFM	5%	Both	New Construction/ Natural Replacement
Commercial	New/Existing	High Efficient 65% Heat Recovery Ventilation Low Use Group (Office, Warehouse, School)	HRV with Minimum 65% Sensible Heat Recovery Effectiveness at 32°F	HRV with Minimum 50% Sensible Heat Recovery Effectiveness as per Ontario Building Code 2015		0.41 /CFM	0 /CFM	0	14	$1.00/CFM	5%	Both	New Construction/ Natural Replacement
Commercial	New/Existing	High Efficient 75% Heat Recovery Ventilation Low Use Group (Office, Warehouse, School)	HRV with Minimum 75% Sensible Heat Recovery Effectiveness at 32°F	HRV with Minimum 50% Sensible Heat Recovery Effectiveness as per Ontario Building Code 2015		0.68 /CFM	0 /CFM	0	14	$2.00/CFM	5%	Both	New Construction/ Natural Replacement
Commercial	New/Existing	High Efficient 85% Heat Recovery Ventilation Low Use Group (Office, Warehouse, School)	HRV with Minimum 85% Sensible Heat Recovery Effectiveness at 32°F	HRV with Minimum 50% Sensible Heat Recovery Effectiveness as per Ontario Building Code 2015		0.96 /CFM	0 /CFM	0	14	$3.00/CFM	5%	Both	New Construction/ Natural Replacement
Commercial	New/Existing	High Use Group Heat Recovery Ventilation (Multi-Residential, Health Care, Nursing Homes)	Ventilation with HRV Integrated	Ventilation without HRV		5.00 /CFM	0 /CFM	0	14	$4.93/CFM	5%	Both	New Construction / Retrofit
Commercial	Existing	High Use Group Heat Recovery Ventilation (Multi-Residential, Health Care, Nursing Homes)	Ventilation with HRV Standalone	Ventilation without HRV		5.00 /CFM	-4.62 /CFM	0	14	$7.64/CFM	5%	Both	Retrofit
Commercial	New/Existing	Medium Use Group Heat Recovery Ventilation (Hotel, Restaurant, Retail)	Ventilation with HRV Integrated	Ventilation without HRV		2.78 /CFM	0 /CFM	0	14	$4.93/CFM	5%	Both	New Construction / Retrofit
Commercial	Existing	Medium Use Group Heat Recovery Ventilation (Hotel, Restaurant, Retail)	Ventilation with HRV Standalone	Ventilation without HRV		2.78 /CFM	-2.57 /CFM	0	14	$7.64/CFM	5%	Both	Retrofit
Commercial	New/Existing	Low Use Group Heat Recovery Ventilation (Office, Warehouse, School)	Ventilation with HRV Integrated	Ventilation without HRV		1.78 /CFM	0 /CFM	0	14	$4.93/CFM	5%	Both	New Construction / Retrofit
Commercial	Existing	Low Use Group Heat Recovery Ventilation (Office, Warehouse, and School)	Ventilation with HRV Standalone	Ventilation without HRV		1.78 /CFM	-1.64 /CFM	0	14	$7.64/CFM	5%	Both	Retrofit
Commercial	New	High Efficiency Boiler - Space Heating (<100 Mbtu/h)	85% AFUE	Non-condensing Boiler	82% AFUE	0.00318 /Btu/hr	0	0	25	$ 1,238.00	5%	Both	New
Commercial	New	High Efficiency Boiler - Space Heating (100 to 199 Mbtu/h)	85% AFUE	Non-condensing Boiler	82% AFUE	0.00318 /Btu/hr	0	0	25	$ 1,544.00	5%	Both	New
Commercial	New	High Efficiency Boiler - Space Heating (200 to 299 Mbtu/h)	85% AFUE	Non-condensing Boiler	82% AFUE	0.00318 /Btu/hr	0	0	25	$ 1,388.00	5%	Both	New
Commercial	Existing	High Efficiency Boiler - Space Heating (<100 Mbtu/h)	85% AFUE	Non-condensing Boiler	82% AFUE	0.00318 /Btu/hr	0	0	25	$ 1,808.00	5%	Both	Replacement
Commercial	Existing	High Efficiency Boiler - Space Heating (100 to 199 Mbtu/h)	85% AFUE	Non-condensing Boiler	82% AFUE	0.00318 /Btu/hr	0	0	25	$ 2,114.00	5%	Both	Replacement
Commercial	Existing	High Efficiency Boiler - Space Heating (200 to 299 Mbtu/h)	85% AFUE	Non-condensing Boiler	82% AFUE	0.00318 /Btu/hr	0	0	25	$ 1,958.00	5%	Both	Replacement
Commercial	New	High Efficiency Condensing Furnace	>=95% AFUE	Condensing Furnace	AFUE 90%	2.33 /KBtu/hr	0	0	18	$346.00	17.5%	Both	New Construction
Commercial	Existing	High Efficiency Condensing Furnace	>=95% AFUE	Condensing Furnace	AFUE 90%	3.11 /KBtu/hr	0	0	18	$346.00	17.5%	Both	Natural Replacement
Commercial	Existing	Single Stage & High Intensity Infrared Heaters	0 - 49,999 BTU/hr	Regular Unit Heater		11.5 /kBtu/hr input capacity	0	0	17	$25.50/kBtu/hr input capacity	33%	Both	Retrofit
Commercial	Existing	2-Stage Infrared Heaters	0 - 49,999 BTU/hr	Regular Unit Heater		13.1/kBtu/hr input capacity	0	0	17	$25.50/kBtu/hr input capacity	33%	Both	Retrofit
Commercial	Existing	Single Stage & High Intensity Infrared Heaters	50,000 - 164,999 BTU/hr	Regular Unit Heater		11.5/kBtu/hr input capacity	300	0	17	$25.50/kBtu/hr input capacity	33%	Both	Retrofit
Commercial	Existing	2-Stage Infrared Heaters	50,000 - 164,999 BTU/hr	Regular Unit Heater		13.1/kBtu/hr input capacity	300	0	17	$25.50/kBtu/hr input capacity	33%	Both	Retrofit
Commercial	Existing	Single Stage & High Intensity Infrared Heaters	165,000 - 300,000 BTU/hr	Regular Unit Heater		11.5/kBtu/hr input capacity	1,040	0	17	$25.50/kBtu/hr input capacity	33%	Both	Retrofit
Commercial	Existing	2-Stage Infrared Heaters	165,000 - 300,000 BTU/hr	Regular Unit Heater		13.1/kBtu/hr input capacity	1,040	0	17	$25.50/kBtu/hr input capacity	33%	Both	Retrofit
Commercial	New	Single Stage & High Intensity Infrared Heaters	0 - 49,999 BTU/hr	Regular Unit Heater		8.6/kBtu/hr input capacity	0	0	17	$9.47/kBtu/hr input capacity	33%	Both	New Construction
Commercial	New	2-Stage Infrared Heaters	0 - 49,999 BTU/hr	Regular Unit Heater		9.8/kBtu/hr input capacity	0	0	17	$9.47/kBtu/hr input capacity	33%	Both	New Construction
Commercial	New	Single Stage & High Intensity Infrared Heaters	50,000 - 164,999 BTU/hr	Regular Unit Heater		8.6/kBtu/hr input capacity	225	0	17	$9.47/kBtu/hr input capacity	33%	Both	New Construction
Commercial	New	2-Stage Infrared Heaters	50,000 - 164,999 BTU/hr	Regular Unit Heater		9.8/kBtu/hr input capacity	225	0	17	$9.47/kBtu/hr input capacity	33%	Both	New Construction
Commercial	New	Single Stage & High Intensity Infrared Heaters	165,000 - 300,000 BTU/hr	Regular Unit Heater		8.6/kBtu/hr input capacity	510	0	17	$9.47/kBtu/hr input capacity	33%	Both	New Construction

	Indicates a new update to Board-approved list of input assumptions

Target Market		Equipment Details				Annual Resource Savings			Other				
Sector	New/Existing	Efficient Equipment	Details of Efficient Equipment	Base Equipment	Details of Base Equipment	Natural Gas (m3)	Electricity (kWh)	Water (L)	EUL	Incremental Cost ($)	Free Rider (%)	Utility Measure Applies to	Decision Type
Commercial	New	2-Stage Infrared Heaters	165,000 - 300,000 BTU/hr	Regular Unit Heater		9.8/kBtu/hr input capacity	510	0	17	$9.47/kBtu/hr input capacity	33%	Both	New Construction
Commercial	Existing	Prescriptive Higher Efficiency Boiler - Space Heating	83-84% Efficient, 300-2000 MBH	Space Heating Boiler	80.5% Thermal Efficiency	2,474-19,340	0	0	25	$3900-$4950	10/12/20%	Both	Replacement
Commercial	Existing	Prescriptive Higher Efficiency Boiler - Space Heating	85-88% Efficient, 300-2000 MBH	Space Heating Boiler	80.5% Thermal Efficiency	3,496-27,325	0	0	25	$4,500-$7,050	10/12/20%	Both	Replacement
Commercial	New	Prescriptive Higher Efficiency Boiler - Space Heating	83-84% Efficient, 300-2000 MBH	Space Heating Boiler	80.5% Thermal Efficiency	2,474-19,340	0	0	25	$3900-$4950	10/12/20%	Both	New
Commercial	New	Prescriptive Higher Efficiency Boiler - Space Heating	85-88% Efficient, 300-2000 MBH	Space Heating Boiler	80.5% Thermal Efficiency	3,496-27,325	0	0	25	$4,500-$7,050	10/12/20%	Both	New
Commercial	Existing	Prescriptive Schools - Elementary	hydronic boiler with 83%+ thermal efficiency	hydronic boiler with 80.5% thermal efficiency		12,217	0	0	25	$ 8,646.00	27%	UG	Replacement
Commercial	Existing	Prescriptive Schools - Elementary	hydronic boiler with 83%+ thermal efficiency	hydronic boiler with 80.5% thermal efficiency		12,217	0	0	25	$ 8,646.00	12%	EGD	Replacement
Commercial	Existing	Prescriptive Schools - Secondary	hydronic boiler with 83%+ thermal efficiency	hydronic boiler with 80.5% thermal efficiency		49,476	0	0	25	$ 14,470.00	27%	UG	Replacement
Commercial	Existing	Prescriptive Schools - Secondary	hydronic boiler with 83%+ thermal efficiency	hydronic boiler with 80.5% thermal efficiency		49,476	0	0	25	$ 14,470.00	12%	EGD	Replacement
Commercial	Existing	Programmable Thermostat		Standard thermostat		13 - 108**	15 - 77**	0	15	$ 110.00	20%	UG	Retrofit
Commercial	Existing	Programmable Thermostat	Educational - School	Standard thermostat		65	8	0	15	$ 110.00	20%	EGD	Retrofit
Commercial	Existing	Programmable Thermostat	Educational - University/College	Standard thermostat		58	57	0	0	$ 110.00	20%	EGD	Retrofit
Commercial	Existing	Programmable Thermostat	Food Service - Restaurant/Tavern	Standard thermostat		69	77	0	15	$ 110.00	20%	EGD	Retrofit
Commercial	Existing	Programmable Thermostat	Hotel/Motel	Standard thermostat		10	11	0	0	$ 110.00	20%	EGD	Retrofit
Commercial	Existing	Programmable Thermostat	Large Hotel	Standard thermostat		10	14	0	0	$ 110.00	20%	EGD	Retrofit
Multi-Residential	Existing	Programmable Thermostat	Multi Family	Standard thermostat		15	13	0	15	$ 80.00	20%	Both	Retrofit
Commercial	Existing	Programmable Thermostat	Recreation - Small Fitness / Spa	Standard thermostat		35	87	0	15	$ 110.00	20%	EGD	Retrofit
Commercial	Existing	Programmable Thermostat	Retail - Food	Standard thermostat		22	16	0	15	$ 110.00	20%	EGD	Retrofit
Commercial	Existing	Programmable Thermostat	Retail - Mall	Standard thermostat		14	19	0	15	$ 110.00	20%	EGD	Retrofit
Commercial	Existing	Programmable Thermostat	Retail - Strip Mall	Standard thermostat		11	19	0	15	$ 110.00	20%	EGD	Retrofit
Commercial	Existing	Programmable Thermostat	Small Office	Standard thermostat		39	43	0	0	$ 110.00	20%	EGD	Retrofit
Commercial	Existing	Programmable Thermostat	Warehouse / Wholesale	Standard thermostat		132	9	0	15	$ 110.00	20%	EGD	Retrofit
Commercial	New/Existing	Rooftop Unit	Two-stage rooftop unit	Single stage rooftop unit		255	0	0	15	$ 375.00	5%	Both	New/Replacement

	Indicates a new update to Board-approved list of input assumptions

Target Market		Equipment Details				Annual Resource Savings			Other				
Sector	New/Existing	Efficient Equipment	Details of Efficient Equipment	Base Equipment	Details of Base Equipment	Natural Gas (m3)	Electricity (kWh)	Water (L)	EUL	Incremental Cost ($)	Free Rider (%)	Utility Measure Applies to	Decision Type
Commercial	New	Demand Control Ventilation	Office	New single-zone, constant volume ventilation system	Provides min outdoor air requirements as specificed in Table 6.2.2.1 of ASHRAE Standard 62.1-2013 [1]	0.112 m3/ft2	0	0	10	$1050 per zone	20%	Both	New/Replacement
Commercial	New	Demand Control Ventilation (with a documented maintenance plan)	Office	New single-zone, constant volume ventilation system	Provides min outdoor air requirements as specificed in Table 6.2.2.1 of ASHRAE Standard 62.1-2013 [1]	0.112 m3/ft2	0	0	15	$1350 per zone	20%	Both	New/Replacement
Commercial	New	Demand Control Ventilation	Retail	New single-zone, constant volume ventilation system	Provides min outdoor air requirements as specificed in Table 6.2.2.1 of ASHRAE Standard 62.1-2013 [1]	0.392 m3/ft2	0	0	10	$1050 per zone	20%	Both	New/Replacement
Commercial	New	Demand Control Ventilation (with a documented maintenance plan)	Retail	New single-zone, constant volume ventilation system	Provides min outdoor air requirements as specificed in Table 6.2.2.1 of ASHRAE Standard 62.1-2013 [1]	0.392 m3/ft2	0	0	15	$1350 per zone	20%	Both	New/Replacement
Commercial	Existing	Demand Control Ventilation	Office	New single-zone, constant volume ventilation system	Provides min outdoor air requirements as specificed in Table 6.2.2.1 of ASHRAE Standard 62.1-2013 [1]	0.112 m3/ft2	0	0	10	$1350 per zone	5%	Both	Retrofit
Commercial	Existing	Demand Control Ventilation (with a documented maintenance plan)	Office	New single-zone, constant volume ventilation system	Provides min outdoor air requirements as specificed in Table 6.2.2.1 of ASHRAE Standard 62.1-2013 [1]	0.112 m3/ft2	0	0	15	$1650 per zone	5%	Both	Retrofit
Commercial	Existing	Demand Control Ventilation	Retail	New single-zone, constant volume ventilation system	Provides min outdoor air requirements as specificed in Table 6.2.2.1 of ASHRAE	0.392 m3/ft2	0	0	10	$1350 per zone	5%	Both	Retrofit
Commercial	Existing	Demand Control Ventilation (with a documented maintenance plan)	Retail	New single-zone, constant volume ventilation system	Provides min outdoor air requirements as specificed in Table 6.2.2.1 of ASHRAE Standard 62.1-2013 [1]	0.392 m3/ft2	0	0	15	$1650 per zone	5%	Both	Retrofit

Commercial Water Heating

Commercial	New/Existing	Commercial Ozone Laundry Treatment	Ozone Treatment Washer extractor =< 60 lbs	Commercial laundry with no ozone treatment system		0.0367 m3/lbs/yr	0.00213 kwh/lbs/yr	2.08L/lbs/yr	15	$ 11,000.00	8%	Both	New/Retrofit
Commercial	New/Existing	Commercial Ozone Laundry Treatment	Ozone Treatment Washer extractor 61 lbs to 499 lbs	Commercial laundry with no ozone treatment system		0.0367 m3/lbs/yr	0.00213 kwh/lbs/yr	2.08L/lbs/yr	15	$ 25,000.00	8%	Both	New/Retrofit
Commercial	New/Existing	Commercial Ozone Laundry Treatment	Ozone Treatment Washer extractor => 500 lbs	Commercial laundry with no ozone treatment system		0.0367 m3/lbs/yr	0.00213 kwh/lbs/yr	2.08L/lbs/yr	15	$ 31,000.00	8%	Both	New/Retrofit
Commercial	New/Existing	Commercial Ozone Laundry Treatment	Ozone Treatment Tunnel Washer <= 120 lbs	Commercial laundry with no ozone treatment system		0.0293 m3/lbs/yr	0.00150 kwh/lbs/yr	1.27 L/lbs/yr	15	$ 50,000.00	8%	Both	New/Retrofit
Commercial	New/Existing	Commercial Ozone Laundry Treatment	Ozone Treatment Tunnel Washer 121 lbs to 499 lbs	Commercial laundry with no ozone treatment system		0.0293 m3/lbs/yr	0.00150 kwh/lbs/yr	1.27 L/lbs/yr	15	$ 105,000.00	8%	Both	New/Retrofit
Commercial	New/Existing	Commercial Ozone Laundry Treatment	Ozone Treatment Tunnel Washer => 500 lbs	Commercial laundry with no ozone treatment system		0.0293 m3/lbs/yr	0.00150 kwh/lbs/yr	1.27 L/lbs/yr	15	$ 160,000.00	8%	Both	New/Retrofit
Commercial	Existing	Condensing Boiler - DHW (<100 Mbtu/h)	90% or greater AFUE	Non-condensing Boiler	82% AFUE	0.02170 /Btu/hr	0	0	25	$ 2,045.00	5%	Both	Replacement
Commercial	Existing	Condensing Boiler - DHW (100 to 199 Mbtu/h)	90% or greater AFUE	Non-condensing Boiler	82% AFUE	0.01332 /Btu/hr	0	0	25	$ 2,984.00	5%	Both	Replacement
Commercial	Existing	Condensing Boiler - DHW (200 to 299 Mbtu/h)	90% or greater AFUE	Non-condensing Boiler	82% AFUE	0.00996 /Btu/hr	0	0	25	$ 3,797.00	5%	Both	Replacement

Indicates a new update to Board-approved list of input assumptions

Target Market		Equipment Details				Annual Resource Savings			Other				
Sector	New/Existing	Efficient Equipment	Details of Efficient Equipment	Base Equipment	Details of Base Equipment	Natural Gas (m3)	Electricity (kWh)	Water (L)	EUL	Incremental Cost ($)	Free Rider (%)	Utility Measure Applies to	Decision Type
Commercial	New	Condensing Boiler - DHW (<100 Mbtu/h)	90% or greater AFUE	Non-condensing Boiler	82% AFUE	0.02170 /Btu/hr	0	0	25	$ 1,475.00	5%	Both	New
Commercial	New	Condensing Boiler - DHW (100 to 199 Mbtu/h)	90% or greater AFUE	Non-condensing Boiler	82% AFUE	0.01332 /Btu/hr	0	0	25	$ 2,414.00	5%	Both	New
Commercial	New	Condensing Boiler - DHW (200 to 299 Mbtu/h)	90% or greater AFUE	Non-condensing Boiler	82% AFUE	0.00996 /Btu/hr	0	0	25	$ 3,227.00	5%	Both	New
Commercial	New/Existing	Condensing Storage Water Heater - Low Utilization	> 75 kBtu/hr and <=250 kBtu/hr. input Estimated overall efficiency of units shipped = 94.5%	Non-condensing storage water heater	Non-condensing storage water heater Greater than 75 kBtu/hr. input Estimated overall efficiency of units shipped = 80.1%	1.36/kBtu/hr input capacity	0	0	15	$2,215.00	5%	Both	New Construction/ Natural Replacement
Commercial	New/Existing	Condensing Storage Water Heater - Medium Utilization	> 75 kBtu/hr and <=250 kBtu/hr. input Estimated overall efficiency of units shipped = 94.5%	Non-condensing storage water heater	Greater than 75 kBtu/hr. input Estimated overall efficiency of units shipped = 80.1%	2.22/kBtu/hr input capacity	0	0	15	$2,215.00	5%	Both	New Construction/ Natural Replacement
Commercial	New/Existing	Condensing Storage Water Heater - High Utilization	> 75 kBtu/hr and <=250 kBtu/hr. input Estimated overall efficiency of units shipped = 94.5%	Non-condensing storage water heater	Greater than 75 kBtu/hr. input Estimated overall efficiency of units shipped = 80.1%	3.09/kBtu/hr input capacity	0	0	15	$2,215.00	5%	Both	New Construction/ Natural Replacement
Commercial	New/Existing	Condensing Storage Water Heater - Low Utilization	>250 kBtu/hr. input Estimated overall efficiency of units shipped = 94.5%	Non-condensing storage water heater	Greater than 75 kBtu/hr. input Estimated overall efficiency of units shipped = 80.1%	1.36/kBtu/hr input capacity	0	0	15	$3,816.00	5%	Both	New Construction/ Natural Replacement
Commercial	New/Existing	Condensing Storage Water Heater - Medium Utilization	>250 kBtu/hr. input Estimated overall efficiency of units shipped = 94.5%	Non-condensing storage water heater	Greater than 75 kBtu/hr. input Estimated overall efficiency of units shipped = 80.1%	2.22/kBtu/hr input capacity	0	0	15	$3,816.00	5%	Both	New Construction/ Natural Replacement
Commercial	New/Existing	Condensing Storage Water Heater - High Utilization	>250 kBtu/hr. input Estimated overall efficiency of units shipped = 94.5%	Non-condensing storage water heater	Greater than 75 kBtu/hr. input Estimated overall efficiency of units shipped = 80.1%	3.09/kBtu/hr input capacity	0	0	15	$3,816.00	5%	Both	New Construction/ Natural Replacement
Commercial	New	Drain Water Heat Recovery (DWHR)	Laundromat	No DWHR		49,735	0	0	25	$ 37,211.00	5%	Both	New
Commercial	New	Drain Water Heat Recovery (DWHR)	Entertainment, Arena	No DWHR		394 per Showerhead	0	0	25	$776 per Showerhead	5%	Both	New
Commercial	New	Drain Water Heat Recovery (DWHR)	University/College Cafeterias - Dishwashing	No DWHR		4.6 per Meal Served/Day	0	0	25	$3.41 per Meal Served/Day	5%	Both	New
Commercial	New	Drain Water Heat Recovery (DWHR)	Hospital - Dishwashing	No DWHR		12 per Bed	0	0	25	$11.88 per Bed	5%	Both	New
Commercial	New	Drain Water Heat Recovery (DWHR)	Hospital - Laundry	No DWHR		295 Per Bed	0	0	25	$250 per Bed	5%	Both	New
Commercial	New	Drain Water Heat Recovery (DWHR)	Nursing Home - Dishwashing	No DWHR		12 per Bed	0	0	25	$16.54 per Bed	5%	Both	New
Commercial	Existing	Drain Water Heat Recovery (DWHR)	Laundromat	No DWHR		49,735	0	0	25	$ 40,811.00	5%	Both	Retrofit
Commercial	Existing	Drain Water Heat Recovery (DWHR)	Entertainment, Arena	No DWHR		394 per Showerhead	0	0	25	$1209.00 per Showerhead	5%	Both	Retrofit
Commercial	Existing	Drain Water Heat Recovery (DWHR)	University/College Cafeterias - Dishwashing	No DWHR		11.6 Meal Served per Day	0	0	25	$6.26 per Meal Served per day	5%	Both	Retrofit
Commercial	Existing	Drain Water Heat Recovery (DWHR)	Hospital - Dishwashing	No DWHR		31 per Bed	0	0	25	$18.19 per Bed	5%	Both	Retrofit
Commercial	Existing	Drain Water Heat Recovery (DWHR)	Hospital - Laundry	No DWHR		295 per Bed	0	0	25	$274 per Bed	5%	Both	Retrofit
Commercial	Existing	Drain Water Heat Recovery (DWHR)	Nursing Home - Dishwashing	No DWHR		31 per Bed	0	0	25	$25.33 per Bed	5%	Both	Retrofit
Commercial	New/Existing	Energy Star Dishwasher	Undercounter – High Temperature	Non-Energy Star Dishwasher		142	1,790	20,371	10	$ 120.00	40%	Both	New/Replacement
Commercial	New/Existing	Energy Star Dishwasher	Undercounter – Low Temperature	Non-Energy Star Dishwasher		333	0	47,827	10	$ 50.00	40%	Both	New/Replacement
Commercial	New/Existing	Energy Star Dishwasher	Stationary Single Tank Door – High Temperature	Non-Energy Star Dishwasher		922	4,167	132,263	15	$ 770.00	20%	Both	New/Replacement
Commercial	New/Existing	Energy Star Dishwasher	Stationary Single Tank Door – Low Temperature	Non-Energy Star Dishwasher		2,120	0	304,205	15	$ -	20%	Both	New/Replacement
Commercial	New/Existing	Energy Star Dishwasher	Single Tank Conveyor – High Temperature	Non-Energy Star Dishwasher		560	4,247	80,303	20	$ 2,050.00	27%	Both	New/Replacement

(green)	Indicates a new update to Board-approved list of input assumptions

Target Market		Equipment Details				Annual Resource Savings			Other				
Sector	New/Existing	Efficient Equipment	Details of Efficient Equipment	Base Equipment	Details of Base Equipment	Natural Gas (m3)	Electricity (kWh)	Water (L)	EUL	Incremental Cost ($)	Free Rider (%)	Utility Measure Applies to	Decision Type
Commercial	New/Existing	Energy Star Dishwasher	Single Tank Conveyor - Low Temperature	Non-Energy Star Dishwasher		1,712	0	245,631	20	$ -	27%	Both	New/Replacement
Commercial	New/Existing	Energy Star Dishwasher	Multi Tank Conveyor - High Temperature	Non-Energy Star Dishwasher		2,124	9,668	304,677	20	$ 970.00	27%	Both	New/Replacement
Commercial	New/Existing	Energy Star Dishwasher	Multi Tank Conveyor - Low Temperature	Non-Energy Star Dishwasher		2,469	0	354,276	20	$ 970.00	27%	Both	New/Replacement
Commercial	Existing	High Efficiency Boiler - DHW (<100 Mbtu/h)	85% or greater AFUE	Non-Condensing Boiler	82% AFUE	0.00468 /Btu/hr	0	0	25	$ 1,808.00	5%	Both	Replacement
Commercial	Existing	High Efficiency Boiler - DHW (100 to 199 Mbtu/h)	85% or greater AFUE	Non-Condensing Boiler	82% AFUE	0.00287 /Btu/hr	0	0	25	$ 2,114.00	5%	Both	Replacement
Commercial	Existing	High Efficiency Boiler - DHW (200 to 299 Mbtu/h)	85% or greater AFUE	Non-Condensing Boiler	82% AFUE	0.00215 /Btu/hr	0	0	25	$ 1,958.00	5%	Both	Replacement
Commercial	New	High Efficiency Boiler - DHW (<100 Mbtu/h)	85% or greater AFUE	Non-Condensing Boiler	82% AFUE	0.00468 /Btu/hr	0	0	25	$ 1,238.00	5%	Both	New
Commercial	New	High Efficiency Boiler - DHW (100 to 199 Mbtu/h)	85% or greater AFUE	Non-Condensing Boiler	82% AFUE	0.00287 /Btu/hr	0	0	25	$ 1,544.00	5%	Both	New
Commercial	New	High Efficiency Boiler - DHW (200 to 299 Mbtu/h)	85% or greater AFUE	Non-Condensing Boiler	82% AFUE	0.00215 /Btu/hr	0	0	25	$ 1,388.00	5%	Both	New
Commercial	Existing/New	Pre-Rinse Spray Nozzle (Full Service)	0.64 GPM	Pre-rinse spray nozzle	1.6 GPM	472.0	0	97,529	5	Actual Utility Cost	0%	Both	Retrofit/ Early Replacement /New Construction /Natural Replacement
Commercial	Existing/New	Pre-Rinse Spray Nozzle (Limited)	0.64 GPM	Pre-rinse spray nozzle	1.6 GPM	92.0	0	19,100	5	Actual Utility Cost	0%	Both	Retrofit/ Early Replacement /New Construction /Natural Replacement
Commercial	Existing/New	Pre-Rinse Spray Nozzle (Other)	0.64 GPM	Pre-rinse spray nozzle	1.6 GPM	111.0	0	23,025	5	Actual Utility Cost	0%	Both	Retrofit/ Early Replacement /New Construction /Natural Replacement
Commercial	New	Prescriptive Higher Efficiency Boiler - DWH	83-84% Efficient, 300-1500 MBH	DWH Boiler	80.5% Thermal Efficiency	1,168-4,693	0	0	25	$3900 -$5900	10/12/20%	Both	New
Commercial	New	Prescriptive Higher Efficiency Boiler - DWH	85-88% Efficient, 300-1500 MBH	DWH Boiler	80.5% Thermal Efficiency	1,861-7,475	0	0	25	$4500-$7400	10/12/20%	Both	New
Commercial	Existing	Prescriptive Higher Efficiency Boiler - DWH	83-84% Efficient, 300-1500 MBH	DWH Boiler	80.5% Thermal Efficiency	1,168-4,693	0	0	25	$3900 -$5900	10/12/20%	Both	Replacement
Commercial	Existing	Prescriptive Higher Efficiency Boiler - DWH	85-88% Efficient, 300-1500 MBH	DWH Boiler	80.5% Thermal Efficiency	1,861-7,475	0	0	25	$4500-$7400	10/12/20%	Both	Replacement
Commercial	New/Existing	Condensing Tankless Water Heater - Low Utilization	>75 and <200 kBtu/hr Thermal efficiency = 92.9%	Non-Condensing Storage Water Heater	48.75 kBtu/hr. and greater Thermal efficiency of units shipped = 80.1% Stand-by Loss Q/0.8 +110√V0	212 + 0.79/kBtu/hr input capacity	0	0	20	$ 2,183.00	2%	Both	New Construction/ Natural Replacement
Commercial	New/Existing	Condensing Tankless Water Heater - Medium Utilization	>75 and <200 kBtu/hr Thermal efficiency = 92.9%	Non-Condensing Storage Water Heater	48.75 kBtu/hr. and greater Thermal efficiency of units shipped = 80.1% Stand-by Loss Q/0.8 +110√V2	212 + 1.29/kBtu/hr input capacity	0	0	20	$ 2,183.00	2%	Both	New Construction/ Natural Replacement
Commercial	New/Existing	Condensing Tankless Water Heater - High Utilization	>75 and <200 kBtu/hr Thermal efficiency = 92.9%	Non-Condensing Storage Water Heater	48.75 kBtu/hr. and greater Thermal efficiency of units shipped = 80.1% Stand-by Loss Q/0.8 +110√V4	212 + 1.79/kBtu/hr input capacity	0	0	20	$ 2,183.00	2%	Both	New Construction/ Natural Replacement
Commercial	New/Existing	Condensing Tankless Water Heater - Low Utilization	>=200 kBtu/hr Thermal efficiency = 92.9%	Non-Condensing Storage Water Heater	48.75 kBtu/hr. and greater Thermal efficiency of units shipped = 80.1% Stand-by Loss Q/0.8 +110√V1	326 + 0.79/kBtu/hr input capacity	0	0	20	$ 2,183.00	2%	Both	New Construction/ Natural Replacement

(green)	Indicates a new update to Board-approved list of input assumptions

Target Market		Equipment Details				Annual Resource Savings			Other				
Sector	**New/Existing**	**Efficient Equipment**	**Details of Efficient Equipment**	**Base Equipment**	**Details of Base Equipment**	**Natural Gas (m3)**	**Electricity (kWh)**	**Water (L)**	**EUL**	**Incremental Cost ($)**	**Free Rider (%)**	**Utility Measure Applies to**	**Decision Type**
Commercial	New/Existing	Condensing Tankless Water Heater - Medium Utilization	>=200 kBtu/hr Thermal efficiency = 92.9%	Non-Condensing Storage Water Heater	48.75 kBtu/hr. and greater Thermal efficiency of units shipped = 80.1% Stand-by Loss Q/0.8 +110√V3	326 + 1.29/kBtu/hr input capacity	0	0	20	$ 2,183.00	2%	Both	New Construction/ Natural Replacement
Commercial	New/Existing	Condensing Tankless Water Heater - High Utilization	>=200 kBtu/hr Thermal efficiency = 92.9%	Non-Condensing Storage Water Heaterr	48.75 kBtu/hr. and greater Thermal efficiency of units shipped = 80.1% Stand-by Loss Q/0.8 +110√V4	326 + 1.79/kBtu/hr input capacity	0	0	20	$ 2,183.00	2%	Both	New Construction/ Natural Replacement
Multi-Residential Water Heating													
Multi-Residential	New/Existing	CEE Tier 2 Front-Loading Clothes Washer	MEF=2.20, WF=5.1	Conventional top-loading, vertical axis clothes washer	MEF=1.26, WF=9.5	117	396	58,121	11	$ 600.00	10%	Both	New/Replacement
Multi-Residential	New/Existing	Energy Star Front-Loading Clothes Washer	MEF=1.72 ,WF=8.0	Conventional top loading vertical axis washers	MEF = 1.26, WF=9.5	76	201	19,814	11	$ 150.00	48%	UG	New/Replacement
Multi-Residential	New/Existing	Faucet Aerator	Bathroom, 1.0 GPM	Standard flow bathroom aerator (code compliant)	2.2 GPM	6.40	0	2,501	10	$ 0.60	10%	Both	New/Retrofit
Multi-Residential	New/Existing	Faucet Aerator	Bathroom, 1.5 GPM	Standard flow bathroom aerator (code compliant)	2.2 GPM	3.73	0	1459	10	$ 0.60	10%	Both	New/Retrofit
Multi-Residential	New/Existing	Faucet Aerator	Kitchen, 1.0 GPM	Standard flow kitchen aerator (code compliant)	2.2 GPM	19.82	0	7,742	10	$ 1.14	10%	Both	New/Retrofit
Multi-Residential	New/Existing	Faucet Aerator	Kitchen, 1.5 GPM	Standard flow kitchen aerator (code compliant)	2.2 GPM	11.56	0	4,516	10	$ 1.14	10%	Both	New/Retrofit
Multi-Residential	New/Existing	Low-flow showerhead	1.25 GPM	Average existing stock	2.5 GPM	38.3	0	12,105	10	Actual Utility Cost	10%	Both	New Construction / Retrofit
Multi-Residential	New/Existing	Low-flow showerhead	1.50 GPM	Average existing stock	2.5 GPM	30.6	0	8,322	10	Actual Utility Cost	10%	Both	New Construction / Retrofit

* Efficiency ratings and natural gas savings will vary by fireplace type. Please see substantiation sheet for type specific efficiency ratings and savings.
** Savings will vary for different segments. Please see substantiation sheet for segment specific savings.

Union Gas Custom Projects	
Sector	**Free Rider (%)**
Agriculture	54%
Industrial	54%
Commercial	54%
Multi-Residential	54%
New Construction	54%
Low-Income - Weatherization	0%
Low-Income - Custom	5%
Residential - Home Reno Rebate	15%

Enbridge Custom Projects	
Sector	**Free Rider (%)**
Agriculture	40%
Industrial	50%
Commercial	12%
Multi-Residential	20%
New construction	26%
Low-Income - Custom	0%
Residential - Home Energy Conservation (formerly Community Energy Retrofit)	15%

	Indicates a new update to Board-approved list of input assumptions

Target Market		Equipment Details				Annual Resource Savings			Other				
Sector	New/Existing	Efficient Equipment	Details of Efficient Equipment	Base Equipment	Details of Base Equipment	Natural Gas (m3)	Electricity (kWh)	Water (L)	EUL	Incremental Cost ($)	Free Rider (%)	Utility Measure Applies to	Decision Type

Union Gas Effective Useful Life (EUL)[1] Guide
Commercial/Industrial Custom Offering

Equipment Type	Sector	EUL	
		Years	Source

Boilers

Industrial Process - greater than 2500 MBHp	Industrial	20	2
Space heating - Under 300 MBHp	Commercial & Multi-Residential	20*	4
Space heating - 300 to 2500 MBHp	Commercial & Multi-Residential	20*	4
Domestic Hot Water	Commercial & Multi-Residential	20*	4
Controls	All	20*	4
Combustion Tune-Up	Industrial & Commercial	1	
Air Makeup (line)	Industrial	20	
Oxy-Fuel	Industrial	20	
Low NOx Boiler	Industrial	20	

Building Optimization

Building Optimization Program/RunSmart - Behavioral Savings Project	Commercial	5	3

Economizers

Conventional and condensing	Industrial & Commercial	20	9

Electronic Burner Control

Linkage-Less Controls, Modulating Motors, Mod Motors	Industrial & Commercial	20	9, 10

Agriculture

IR Poly	Greenhouse	5	2
Energy Curtains	Greenhouse	10	10, 11
Grain Dryer	Commercial	20	5

[1] Where site specific information or a relevant prescriptive EUL is available to support an alternate EUL value for a specific custom project, Union Gas will use the alternate value for that custom project."

HVAC

Air Curtains (single and double door)	Commercial	15	2
Building Automation System - New	Industrial & Commercial	20	4, 9
Cooling tower for HVAC systems	Commercial	15	1, 2
Combustion Tune-Up	Industrial & Commercial	1	5
Dessicant Cooling	Commercial	15	6
Exhaust Fan Controls	Commercial	15	5
Heat Recovery	Industrial & Commercial	Comm 15 Indust 20	9, 10
Infiltration Controls - Dock Seals, Air Doors	Commercial	15	2
Make-Up Air	All	20	12
Heat Reflector Panels	Commercial & Multi-Residential	15	
VFD retrofit on MUA	Commercial & Multi-Residential	10	
Turndown controls on Modulating Boiler	Commercial	20	5

Heat Exchangers

Plate - Plate or Tube-Tube	Industrial & Commercial	Comm 14 Indust 20	2, 11
Air -Air	Commercial	Comm 14 Indust 20	2

Insulation

Roof/Ceiling insulation	Industrial & Commercial	20	2
Outside Pipe - exposed to the environment, properly protected	Industrial & Commercial	20	10, 11
Building Weatherization - Air sealing	Commercial	15	1
Tank Exterior Insulation	Industrial & Commercial	20	5, 11

Ovens and Thermal oxidizers

Low Temperature (less than 300°C)	Industrial	20	
Medium Temperature (300°C - 1000°C)	Industrial	20	
High Temperature (>1000°C)	Industrial	20	

Process Controls

Electronic Loop Controllers	Industrial	20	
PLC's	Industrial	20	
Flame Supervision (relays)	Industrial	20	

Steam Distribution

Steam Traps	Industrial & Commercial	7	5, 9, 11
Steam Piping Leaks	Industrial & Commercial	20	5, 9, 10, 11
Steam Valve	Industrial Food Services	10	10, 11

Water Conditioners

Reverse Osmosis (RO)	Industrial	20	
Ion Exchange	Industrial	20	

Industrial Equipment

All other industrial equipment	Industrial	Up to 20 yrs	Best available info

References

*	Useful Life estimates are most dependent on the application and quality of maintenance. Any equipment life that was reported higher than 20 years was reduced to 20 years to conform to Union Gas's 20 year limit.
1	2011 Commercial Opportunity Screening Report May 02 2011, Navigant for Union Gas
2	DEER EUL Summary 2014
3	Measure Life for Retro-Commissioning and Continuous Commissioning Projects, Finn Projects for Enbridge
4	ASHRAE Service Life & Maintenance Cost Database (Jan 14, 2015)
5	Union Gas 2010 DSM Audited Results
6	Enbridge Approved IA
7	2011 Commercial Hydronic Boiler System Baseline Study, ICF Marbek for Enbridge
8	Confirmation of high quality feed water required for 10 year life
9	Union Gas 2011 DSM Audited Results
10	Union Gas 2012 DSM Audited Results
11	Union Gas 2013 DSM Audited Results
12	Prescriptive TRM Sub Doc (Source ASHRAE Handbook – HVAC Applications I-P Edition, Atlanta: ASHRAE, 2008, p. 32.8)

Union Gas Effective Useful Life (EUL) Guide
Residential and Low Income Offerings

Offering	2015	2016-2020
Union Gas Home Reno Rebate – without furnace upgrade	25[2]	25[3]
Union Gas Home Reno Rebate – with furnace upgrade	15[4]	25[5]
Union Gas Low Income Weatherization	25[6]	25[4]
Residential Behavioural Offering	N/A	1

[2] Union Gas Independent Audit of 2012 DSM Program Results. Applies to 2014 results and 2015 roll over.
[3] As per Union Gas 2015-2020 DSM Plan (EB-2015-0029)
[4] EB-2012-0441; Exhibit B, Tab 1, Schedule 3
[5] See Home Reno Rebate Evaluation Plan in EB-2015-0029 for details on this EUL (results from a change in the base case in 2016 and beyond).
[6] Endorsed by the Technical Evaluation Committee, February 13, 2014

Enbridge Measure Life Update Elements

Update Element	Measure	Nature of Update	Supporting Reference
Update to EGD Custom Measure Life Table	Infrared Heaters	Increase from 10 to 17 years	Technical Reference Manual substantiation document, endorsed by TEC May 28, 2015
	Heat Reflector Panels	Increase from 15 to 25 years	Technical Reference Manual substantiation document, endorsed by TEC November 24, 2015
	Steam Pipe / Tank Insulation	Increase from 15 to 20 years	2011 ASHRAE Handbook – HVAC Applications, Chapter 37, Table 4
	Steam Trap	Increase from 5 to 6 years	Massachusetts 2013 Prescriptive Gas Impact Evaluation, Steam Trap Evaluation, June 17, 2015

Enbridge Measure Life Guide for Custom Offers*

	Commercial (years)	Industrial (years)	Multi Residential (years)
Boiler Related			
Boilers – DHW	25[1]	n/a	25[1]
Boilers - Industrial Process	n/a	20	n/a
Boilers – Space Heating	25[1]	25[1]	25[1]
Combustion Tune-up	5	5	n/a
Controls	15	15	15
Steam pipe/tank insulation	20[2]	20[2]	20[2]
Steam trap	6[3]	6[3]	n/a
Building Related			
Building envelope	25	25	25
Windows	25	25	25
Greenhouse curtains	n/a	10	n/a
Double Poly greenhouse	n/a	5	n/a
HVAC Related			
Dessicant cooling	15	n/a	n/a
Heat Recovery	15	15	n/a
Infrared heaters	17[4]	17[4]	n/a
Make-up Air	15	15	15
Heat Reflector Panels	25[5]	n/a	25[5]
Furnaces (gas-fired)	18[6]	n/a	18[6]
Re-Commissioning	5[7]	n/a	5[7]
Process Related			
Industrial Process/Industrial Equipment	n/a	20	n/a
Measure Life for Residential and Low Income Offers			
Enbridge Community Energy Retrofit – without furnace upgrade	25[8]		
Enbridge Community Energy Retrofit – with furnace upgrade	15[8]		
Enbridge Low Income Weatherization	25[9]		

* Where site specific information or a relevant prescriptive measure life is available to support an alternate measure life value for a specific custom project, Enbridge will use the alternate value for that custom project.

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1 2011 ASHRAE handbook-HVAC Applications, Chapter 37, Table 4 (Comparison of Service Life Estimates).
2 2011 ASHRAE handbook-HVAC Applications, Chapter 37, Table 4 (Comparison of Service Life Estimates).
3 Massachusetts 2013 Prescriptive Gas Impact Evaluation Steam Trap Evaluation Phase 1: FINAL, DNV GL (Kema Inc.), June 17, 2015.
4 Enbridge TRM, Substantiation Document – Infrared Heaters, endorsed by TEC May 28, 2015
5 Enbridge TRM, Substantiation Document – Heat Reflector Panels, endorsed by TEC November 24, 2015
6 2011 ASHRAE handbook-HVAC Applications, Chapter 37, Table 4 (Comparison of Service Life Estimates).
7 "Measure Life for Retro-Commissioning and Continuous Commissioning Projects", Finn Projects. Dec. 31, 2008.
8 Endorsed by Enbridge Audit Committee, February, 2014. Applicable to 2014 results and 2015 rollover year.
9 Endorsed by Technical Evaluation Committee, February 13, 2014.

NEW AND UPDATED

SUBSTANTIATION DOCUMENTS

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RESIDENTIAL ADAPTIVE THERMOSTATS - NEW CONSTRUCTION AND RETROFIT

DATE: 7/10/2015

TO: Ontario TEC Committee

FROM: ERS

RE: Residential Adaptive Thermostats – New Construction and Retrofit

This document presented the adaptive thermostats measure provided by the Ontario TEC Sub-committee. It is based on a draft substantiation sheet prepared by the committee and sent to ERS on February 4, 2015. The primary references include:

- Residential Market Survey 2013 Enbridge Gas Distribution Final Report
- Wi-Fi Programmable Controllable Thermostat Pilot Program Evaluation completed by The Cadmus Group, Inc.
- 2014 buildABILITY Final Report: Gas Consumption Profile for New Low Rise Residential Construction

RESIDENTIAL ADAPTIVE THERMOSTATS (NC/R)

Version Date and Revision History	
Draft date	7/10/2015
Version history	v.1
Effective date	TBD
End date	N/A
Residential → Adaptive Thermostats → New Construction/Retrofit	

Table 1 provides a summary of the key measure parameters with a deemed savings estimation.

Table 1. Measure Key Data

Parameter	Definition	
Measure category	Retrofit (R) and New Construction (NC)	
Baseline technology	Non-Programmable (NPT) or Programmable Thermostat (PT)	
Efficient technology	Adaptive Thermostat	
Market type	Residential	
Annual natural gas savings	Retrofit - Retail Purchase	185 m^3
	Retrofit (Direct Install) - Replacing Non-Programmable Thermostat	217 m^3
	Retrofit (Direct Install) - Replacing Programmable Thermostat	173 m^3
	New Construction - Replacing Programmable Thermostat	105 m^3
Measure life	15 years	
Annual electrical cooling savings	Retrofit – Retail Purchase	176 kWh
	Retrofit (Direct Install)	235 kWh
	New Construction	206 kWh
Incremental cost	Retrofit	$300
	New Construction	$200

Overview

Adaptive thermostats employ advanced features beyond conventional programmable thermostats. These more sophisticated, yet easier to use devices, address key usability and programming issues of traditional units. Functions may include remote access for additional flexibility and control, an important feature when the user's plans for the day have changed.

Leading manufacturers have developed competitive solutions in this area with unit prices ranging from $200 to $300.

Application

Residential customers that use a forced air heating and air conditioning system or hydronic space heating system would qualify under this program. Customers that have either a programmable or non-programmable thermostat would qualify for this measure.

Baseline Technology

In the 2010 Lawrence Berkeley Labs study, "How People Actually Use Thermostats," [1] research comprised of qualitative interviews, online surveys, and interaction experiments identified key barriers/issues with older style programmable thermostats. These included:

- Poor usability
- Time consuming & difficult to set up
- Menus too technical
- Confusing abbreviations
- Small and hard to read fonts
- Unpredictable at home & away times make programming useless
- Lack of feedback on programming

Adaptive or self-learning thermostats are different than traditional programmable thermostats and they resolve many of the challenges of programmable thermostats.

Efficient Technology

Adaptive or self-learning thermostats typically have the following key features and benefits:

- Ease of creating schedules
- Intuitive set up, typically using narrative & lifestyle related questions
- Pro-active or forced automatic energy savings adjustment features
- Greater control with remote web or app based control over home's settings if schedule changes
- Maintenance alerts
- Ongoing "Learning" of lifestyle schedules and preferences taking into account motion, humidity levels, occupancy and temperature preferences

While not inherently necessary for adaptive learning, most such thermostats also have wi-fi capabilities.

For an efficient technology to be eligible as a measure, the following four key automated features are required:

1. Proper setback scheduling
2. Occupancy based setbacks
3. System performance optimization
4. Encouragement of conservation behavior.

The features are subsequently described in additional detail.

Proper Setback Scheduling

Adaptive thermostats use different levels of sophistication to reduce the difficulties inherent in older thermostats when it comes to setting up a schedule. They typically use simpler dialogue-based set up menus where the user is prompted with lifestyle occupancy related questions. [2]

Occupancy-Based Setbacks

For households that do not maintain a regular schedule, this feature has an automated way of determining when a household is unoccupied. Geofencing and temperature/occupancy sensors are features that sense occupant location at any given time and will adjust schedules accordingly.

System Performance Optimization

System performance optimization capabilities use analytics to more efficiently run a household's HVAC equipment. This is typically based on data collected from the system's performance, coupled with feedback on external conditions such as temperature and humidity. While there is no direct communication between adaptive thermostats and the HVAC equipment, the data on system performance (HVAC equipment and building envelope) is 'learned' based on how the building temperatures respond to the thermostats control signals. This is largely an optimization of start-up and stop sequences, but also factors in feedback such as weather forecasts and humidity measurements. [2]

Encouraging Conservation Behavior

Encouraging conservation behavior leverages the on-going relationship that an adaptive thermostat builds to offer the occupants different forms of suggestions to conserve energy and save money. This can range from suggestions to lower the temperature, accept a new optimized setback schedule, or to change the furnace filter. [2]

Energy Impacts

These devices typically have sensors that monitor light, humidity levels, motion and occupancy, temperature. Most adaptive thermostats build schedules by asking users simple questions during setup to understand the residents' typical schedules and comfort preferences. Algorithm-based software establishes heating and cooling schedules accordingly resulting in natural gas savings and electric cooling savings, in some cases even modifying the schedules for additional moderate savings.

Natural Gas Savings Algorithms

In 2012, an independent impact and process evaluation study was conducted by the Cadmus Group on behalf of National Grid. [3] The Wi-Fi thermostat used in the pilot was an adaptive thermostat. This study reflects the climatic conditions for the Ontario Gas utilities.

A total of 86 households participated in the program accounting for 123 thermostats. Sixty-nine households were located in Massachusetts and 17 households were located in Rhode Island. The analysis was based on pre- and post-installation home energy use.

The gas savings attributed to the adaptive thermostat over a non-programmable thermostat replacement was 10% for the household. Comparatively, the gas savings attributed to the adaptive thermostat over a programmable thermostat was 8%. [3]As expected, when the Adaptive Thermostats are replacing programmable thermostats, the percent savings are lower than for non-programmable Thermostats. A smaller but similar study in New Hampshire found similar savings of 8%. [3] Manufacturer estimates of savings tend to be higher. NEST estimates 20% [4], ecobee estimates 23% [5], and Honeywell estimates about 20% for their Lyric.[1] [6]

Retrofit Natural Gas Savings

Savings from the Cadmus report were applied to end-use consumption by furnace type. First space heating energy use is calculated.

Enbridge load research data provides estimates of annual natural gas use of existing non-multifamily family homes with natural gas furnaces by furnace type (high, mid and conventional efficiency), as shown in Table 2.[2] [7] The market share of each furnace type is known from Enbridge's 2013 Residential Market Survey. [8] Unknown furnace types were distributed using known furnace type weighting. Based on this data the weighted average (column A * column C) Enbridge space heating single family natural gas use is 2,077 m^3/yr.

[1] Using their web calculator's default settings and assuming 2,077 m^3 per year from below

[2] Natural gas forced air furnaces comprise approximately 90% of the residential space heating market in Enbridge Service territory. For the purposes of this substantiation document, it is assumed that furnace energy usage is representative of the 10% that use non-furnace gas heating systems.

Table 2. Enbridge Existing Single Family Home Space Heating Gas Use [3] [8] [7]

Furnace Type, by Efficiency	Average Consumption for Furnace Type (m^3) From 2012 Load Research Report (A)	% Furnace Type from 2008 Residential Survey (B)	% Furnace Type Adjusted to Exclude Unknown (C)
High	1,916	52%	61%
Mid	2,248	27%	32%
Conventional	2,698	6%	7%
Unknown		15%	
Weighted Average Consumption / Total %	2,077	100%	100%

Union Gas analysis of a sample of 50 homes found average natural gas use for space heating of 2,315 m^3/yr. [9]

Based on a 60/40 share of customers for Enbridge and Union, respectively [10], the weighted average single family residential home energy use for space heating in Ontario is 2,172 m^3/yr. This number is consistent with 2,158 m^3 reported by Natural Resources Canada [11]. Applying the savings of 10% and 8% associated with replacement of non-programmable and programmable thermostats, respectively, the savings is 217 m^3/yr for a non-programmable baseline and 174 m^3/yr for a programmable baseline.

In the retail market the replaced thermostat type is unknown. Assuming 71% of the displaced thermostats are conventional programmable and 29% are nonprogrammable,[4] the weighted average savings is 185 m^3/yr for this scenario.

Retrofit Electric Cooling Savings

Cooling load was derived from analysis provided by Toronto Hydro[5] which establishes average annual electric energy use (kWh) related to air conditioning. The average annual electrical cooling consumption of 0.81 kWh/ft^2 was applied against the average house size of 1,812 ft^2 [8] as established in the Enbridge 2013 Residential Market Survey resulting in an estimated average cooling load for a typical customer of approximately 1,468 kWh/year. Applying the 16% savings

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[3] The "high" and "mid" annual energy use data comes from the Enbridge Gas Distribution Load Research-Strategy, Research and Planning group load research data as presented in Figure 1 of *Enbridge Load Research Newsletter* June 2012. The furnace type population distribution data comes from Residential Market Survey Data 2013, produced for Enbridge Gas Distribution by TNS, slide 41, weighted. Subsequent columns of data are calculated.

[4] As of 2007, 39% of all Canadian dwellings had programmable thermostats, based on NRCan data. [16] This estimate can be improved by considering additional factors. Ontario residents are 25% more likely than the average Canadian resident to have programmable thermostats, based on Statistics Canada data. [17] From the same source, homeowners, a group far more likely to buy adaptive thermostats than renters, were 15% more likely than average to have them and higher income households were 25% to 50% more likely than average households to have them. There are two other factors worth considering for which data were not available: The marketwide penetration has increased since 2007, and, the cohort of buyers willing to consider adaptive technology is more likely to have already invested in a programmable thermostat than the average buyer. Using a combined estimate of 33% more likely and then adding all of the adjustment factors together (additive is a conservative approach; the more logical multiplicative combining would lead to more than 100% programmable saturation), the estimated overall baseline replacement is 71% programmable.

[5] Peaksaver summary data provided by Toronto Hydro including 63,000 participants and based on a range of equipment efficiency and house sizes. Energy Efficiency ratings in the range of 9 to 13 BTU/w used by Toronto Hydro in their analysis was from the ASHRAE Fundamentals Handbook.

as established in the Cadmus Report for electric cooling savings [3], results in an estimated electric cooling savings of 235 kWh/year.

$$Retrofit\ Cooling\ Savings = 0.81\frac{kWh}{ft^2} \times 1{,}812\ ft^2 \times 16\% = 235\frac{kWh}{yr}$$

For the retail purchase market it is not known if the adaptive thermostat also controls central air conditioning. In Ontario 58% of households had central air conditioning as of 2007 [12]. As with the programmable/nonprogrammable assessment, current adaptive thermostat buyers are more likely to have central air conditioning than the average household in 2007. Using an assumption of a 75% penetration, the retail purchase impact is 176 kWh/yr.

New Construction Natural Gas Savings

The estimated annual space heating natural gas use for new construction in Ontario is 1,315 m^3.[6] [13]. For new homes that otherwise would have a programmable thermostat,

$$New\ Construction\ Natural\ Gas\ \ Savings = 1{,}315\ m^3 \times 8\% = 105\ m^3$$

New Construction Electric Cooling Savings

Cooling load for the typical Ontario new construction archetype [7] house is also derived from the Toronto Hydro data[8] but is based on the electrical cooling consumption per square foot associated with the highest efficiency air conditioner rating. Applying this electrical cooling consumption of 0.59 kWh/ ft^2 to the square footage of the new construction archetype (2,185 ft^2), cooling load is estimated to be 1,282 kWh/year. Applying the 16% savings to this amount from the Cadmus Report [3] results in an estimated electric cooling savings of 205 kWh for new homes with central air conditioning.

$$Retrofit\ Cooling\ Savings = 0.59\frac{kWh}{ft^2} \times 2{,}185\ ft^2 \times 16\% = 206\frac{kWh}{yr}$$

LIST OF ASSUMPTIONS

Table 3 provides a list of assumptions utilized in the measure savings algorithms to derive the savings values listed in Table 1 above.

[6] buildABILITY Final Report Table 5 Page 11 [12], The authors created a single building archetype in the modeling tool Hot2000 based on data from a sample of 100 recent new construction homes the Ontario Ministry of Municipal Affairs and Housing and from the Canada Mortgage and Housing Corporation Residential Building Activity Report. The energy use used in this document is that modeled for this archetype when located in Building Zone 1, the region with the most new construction activity in Ontario.
[7] buildABILITY Final Report Table 10 Page 16, Heating Zone 1, Package [12]
[8] Peaksaver data provided by Toronto Hydro including 63,000 participants and based on a range of equipment efficiency and house sizes. Energy Efficiency ratings in the range of 9 to 13 BTU/w used by Toronto Hydro in their analysis was from the ASHRAE Fundamentals Handbook.

Table 3. General Assumptions

Definition	Inputs	Source/Comments
Average household size – existing homes	1,812 ft^2	[8]
Average household size – new construction	2,185 ft^2	[13]
Estimated annual gas consumption for new construction	1,315	[13]
Estimated average annual gas consumption for existing homes	2,172	From utilities surveys and billing analysis (blended value between utilities) as described in the Home Energy Use section above
Annual savings fraction for residential new construction	8%	Calculated in algorithms section
Annual savings fraction for residential retrofit – non-programmable	10%	Calculated in algorithms section
Annual savings fraction for residential retrofit – programmable	8%	Calculated in algorithms section
Cooling savings fraction	16%	[3]
Annual electrical cooling consumption – new construction	0.59 kWh/ ft^2	Peaksaver data provided by Toronto Hydro
Annual electrical cooling consumption – existing homes	0.81 kWh/ft^2	Peaksaver data provided by Toronto Hydro

SAVINGS CALCULATION EXAMPLE

For savings derivations and results values, see the algorithms section.

USES AND EXCLUSIONS

This measure requires that one adaptive thermostat would replace a conventional programmable or non-programmable thermostat serving one single zone heating appliance.

MEASURE LIFE

Navigant Consulting estimates 15 years as the effective useful life base on the average lifetime of programmable thermostat from the ENERGY STAR website. [14]

INCREMENTAL COST

High-end adaptive thermostats such as the Nest and Honeywell Adaptive Thermostats retail at approximately $250. [15] The cost of a programmable thermostat retails for $50. Installation costs are similar for both types of thermostats. Hence the incremental cost to upgrade from a baseline code compliant programmable to adaptive thermostat at time of new construction is $200, as shown in Table 4. For retrofits, the full adaptable thermostat material cost plus the labor associated with installation, nominally $50 for a one half hour installation both apply and the total cost is $300. This applies to both programmable and nonprogrammable baselines.

Table 4. Incremental Cost

Measure Category	Incremental Cost
Retrofit	$300
New Construction	$200

REFERENCES

[1] T. Peffer, M. Pritoni, A. Meier, C. Aragon and D. Perry, "Building and Environment: How people use thermostats in homes: A review," May 2011. [Online]. Available: http://eec.ucdavis.edu/files/How_people_use_thermostats_in_homes.pdf. [Accessed December 2014].

[2] CEATI International, "Inventory and Energy Savings Estimates for Residential Programmable Thermostats," CEATI, July 214.

[3] C. Johnson, A. Reynolds and M. Perussi, "Wi-fi Programmable Thermostat Pilot Program Evaluation," Cadmus, Salem, New Hampshire, 2013, (pg.18).

[4] Nest, "We didn't think thermostats mattered either," Nest, 2015. [Online]. Available: https://nest.com/thermostat/saving-energy/#we-didnt-think-thermostats-mattered-either. [Accessed 18 March 2015].

[5] ecobee, "Savings from your ecobee," ecobee, 2015. [Online]. Available: https://www.ecobee.com/Savings/. [Accessed 18 March 2015].

[6] Lyric Honeywell, "Savings and Rebates," Honeywell, 2014. [Online]. Available: http://lyric.honeywell.com/thermostat/savings-and-rebates/. [Accessed 18 March 2015].

[7] *Enbridge Load Research Newsletter June 2012,* Enbridge Gas Distribution, 2012.

[8] TNS, *Residential Market Survey 2013,* Toronto: Enbridge Gas Distribution, 2013.

[9] Torres, Jairo, *Natural Gas Consumption Residential Single Detached Home in Ontario,* Union Gas Ltd., 01/07/2015.

[10] J. Torres, "MEMO: Programmable and Adaptive thermostat common assumption," May 15, 2015.

[11] Natural Resources Canada: Comprehensive Energy Use Database Table, "Residential

Sector Canada Table 2: Secondary Energy Use and GHG Emissions by End-Use," 2011. [Online]. Available: http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=CP&sector=res&juris=ca&rn=2&page=4&CFID=34007269&CFTOKEN=de5d23c7717e5847-4641946D-B152-04FC-C9E13099C431B1DB. [Accessed December 2014].

[12] Natural Resources Canada, "Survey of Household Use 2007, Detailed Statistical Report, Table 4.1," 2010. [Online]. Available: https://oee.nrcan.gc.ca/publications/statistics/sheu07/pdf/sheu07.pdf.

[13] *Final Report: Gas Consumption Profile for New Low Rise Residential Construction,* buildABILITY, 2014, (pg. 10-11, 16).

[14] *EB-2011-0295 Demand Side Management ("DSM") Plan Table of Measured Assumptions, Exhibit B, Tab 2 Schedule 4, pg. 2,* Enbridge Gas Distribution Inc, 2012-2014.

[15] *Adaptive Thermostats Standalone, Networked, and Learning Adaptive Thermostats: Global Market Analysis and Forecasts,* Navigant Research Report, 2014, p. 6.

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Commercial Condensing Tankless Water Heater - New Construction/Time of Natural Replacement

DATE: May 19, 2015

TO: Ontario TEC Sub-Committee

FROM: ERS

RE: Commercial Tankless Water Heater TRM Section

The following TRM measure covers the installation of tankless water heaters in commercial buildings in the new construction and time of natural replacement measure categories. This is the sixth version of this document submitted to the TEC Sub-Committee.

This version recognizes that standby losses from the tankless units are minimal and defines the standby savings as the total standby losses of the storage units. The TEC Sub-Committee requested that the measure be made "more prescriptive" by defining a single weighted average value for standby losses. However, this was not completed because of the significant difference between these savings for installations greater and less than 200 kBtu of input capacity, and the absence of data that reflects the distribution of incentives awarded. We suggest that the standby losses be differentiated by input capacity of the installed tankless unit at this time, as reflected in Table 1. A weighted average value could be determined for a subsequent revision to this section, based on the distribution of incentives paid once the measure is implemented.

The TEC also requested that we revisit the EFLH derivation, reconsider the previous decision to not use water consumption and estimated unit sizing data provided by Caneta, and provide a more detailed explanation of how the EFLH values were derived. This review was completed and the decision not to use the Caneta data was confirmed. A detailed explanation of the derivation of the EFLH values, based on peak hourly and average daily consumption data taken from the ASHRAE HVAC Applications Handbook is provided in a separate document.

COMMERCIAL CONDENSING TANKLESS GAS WATER HEATERS – NEW CONSTRUCTION/TIME OF NATURAL REPLACEMENT

Version Date and Revision History	
Draft date	5/19/2015
Version history	v. 1
Effective date	TBD
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Commercial ->Tankless Water Heater -> New Construction Commercial ->Tankless Water Heater -> Time of Natural Replacement	

Table 1 provides a summary of the key measure parameters and deemed savings coefficients.

Table 1. Measure Key Data

Parameter	Definition			
Measure category	New Construction (NC)			
	Time of Natural Replacement (TNR)			
Baseline technology	Non-Condensing Storage Water Heater 48.75 kBtu/hr. and greater Thermal efficiency of units shipped = 80.1% Stand-by Loss $Q/0.8 + 110\sqrt{V_0}$			
Efficient technology	Condensing Tankless Water Heater 75 kBtu/hr. and greater Thermal efficiency of units shipped = 92.9% Stand-by Loss = negligible			
Market type	Commercial			
Annual Natural Gas Savings	**Utilization Category**	**Combustion Efficiency Savings**	**Input Rating**	**Storage Savings**
	Low	0.790 m^3/ kBtu/hr. input	<200 kBtu/hr.	212 m^3
			≥ 200 kBtu/hr.	326 m^3
	Medium	1.290 m^3/ kBtu/hr. input	<200 kBtu/hr.	212 m^3
			≥ 200 kBtu/hr.	326 m^3
	High	1.79 m^3/ kBtu/hr. input	<200 kBtu/hr.	212 m^3
			≥ 200 kBtu/hr.	326 m^3
Measure life	20 years			
Incremental cost	$2,183			
Restrictions	This measure applies to the installation of natural gas condensing tankless water heaters in commercial facilities.			

OVERVIEW

The measure consists of the installation of natural gas condensing tankless water heaters for hot water production in commercial facilities. Non-condensing tankless water heaters are not eligible under this measure.

Tankless, also called instantaneous or on-demand, water heaters provide hot water without using a storage tank. There is nominal "storage", in the form of water in the coil, but it is typically less than 2 gallons and standby losses can be considered negligible. This reduced storage capacity results in the need for higher capacity burners to generate the flow of hot water necessary to serve equivalent peak loads. This translates to higher equipment and installation costs for these units.

The savings from installing condensing tankless hot water units result from two factors: a higher average thermal efficiency and the elimination of the standby losses associated with the storage units.

Thermal Efficiency

Condensing water heaters reclaim a significant quantity of thermal energy from exhaust gases, improving the overall efficiency by up to 10% over non-condensing models. The shipment weighted average efficiency for non-condensing storage units provided in Table 1 were derived by Caneta Research Inc. as part of a 2009 study. [1] The efficiency, calculated using manufacturers published thermal efficiency data and market share information provided by the Consortium for Energy Efficiency is 80.1% and does not include the impact of standby losses.

The shipment weighted average efficiency for the condensing tankless units is taken from the same report by Caneta. The report indicates that market share data was not available for tankless units. The reported shipment weighted average efficiency of 92.9% assumes an even distribution of sales between manufactures offering a condensing tankless model.

The annual deemed savings values attributed to the increased thermal efficiency are reported in units of m^3 natural gas per kBtu/hr. rated input capacity of the tankless unit. These deemed savings values are differentiated by the anticipated utilization level of the water heater based on the type of facility where it is installed.

Standby Losses

There is continuous loss from storage water heaters to the surrounding space, with the magnitude of this loss largely dependent upon the size of the storage tank. The standby loss savings values reported in Table 1 were determined by applying the standby loss term from Ontario Building Code SB-10 document [2]

$$Storage\ loss = \frac{Q}{0.8} + 110\sqrt{V_0}$$

Where,

Q = the input rating of the water heater in kBtu/hr.

V_0 = the storage capacity in gallons

Annual deemed savings values attributed to the elimination of standby loss for tankless units are reported in units of m^3, and are differentiated by the input capacity of the tankless units being installed.

For most commercial installations, storage water heaters are located in mechanical spaces that are not intentionally maintained at the temperature of the occupied space, and savings resulting from reduced standby losses does not add to the space heating load for the facility. The deemed savings are not de-rated to reflect any increase in the overall facility space heating load.

The algorithms and the associated variables are presented in the “Natural Gas Savings Algorithm” section.

APPLICATION

This measure provides incentives for installing tankless natural gas water heaters in commercial facilities for either the new construction or time of natural replacement measure category. The units provide service hot water for entire commercial facilities, or in some cases for selected loads within the facility.

BASELINE TECHNOLOGY

The baseline technology for this measure is a non-condensing natural gas fueled storage water heater providing the service hot water needs for all or portions of commercial facilities.

Table 1 provides the shipment weighted average thermal efficiency for non-condensing storage water heaters meeting these criteria.

EFFICIENT TECHNOLOGY

The high efficiency technology is a natural gas fueled condensing tankless water heater. Tankless water heaters with input rating of 200 kBtu/hr. or greater are considered commercial units, but smaller units are frequently installed in commercial facilities to serve all of the service water needs or selected end uses. Units with input capacity of 75 kBtu/hr. or greater are eligible for this measure.

Table 1 provides the shipment weighted average thermal efficiency of tankless condensing water heaters from the Caneta report referenced earlier.

ENERGY IMPACTS

Natural gas savings are achieved as a result of the higher overall average thermal efficiency of the condensing tankless units and elimination of storage or standby losses.

There are no electric or water consumption impacts associated with this measure.

NATURAL GAS SAVINGS ALGORITHMS

Shipment-weighted overall average efficiency values for non-condensing storage and condensing tankless water heaters are as shown in Table 2. The values are based on manufacturers published efficiency ratings and market share data obtained in a 2009 study completed for Union Gas. [1]

Table 2. Shipment-Weighted Average Commercial Water Heater Efficiencies

Type	Average Efficiency
Storage	80.1%
Tankless	92.9%

The 2011 ASHRAE Application Handbook provides typical peak hourly demand and average daily hot water consumption data for several building types. [3] A 2012 Enbridge Gas funded study [4] indicates that water heaters are generally sized based on peak 15-minute demands with an oversizing factor applied. The same study includes data indicating the peak 15-minute demand can be estimated as 140% of the peak hourly demand. These values were used to derive Equivalent Full Load Hours (EFLH) values using the following algorithm.

$$EFLH = Demand_{avg.\ daily} \times \frac{1}{Demand_{peak\ 15\ minute} \times OS_{factor}} \times Days\ per\ year$$

Where,

$EFLH$	= The annual EFLH (hours/year)
$Demand_{avg.\ daily}$	= The reported average daily service hot water demand for a specific building type (US gallon/occupant-day) [3]
$Demand_{peak\ 15\ minute}$	= The peak 15-minute hot water demand for a specific building type (US gallon/occupant-hour) [3] [4]
OS_{factor}	= Typical tankless water heater oversizing factor relative to 15-minute peak demand (200%)[1] [4]
$Days\ per\ year$	= The number of days per year when the facility is operational

[1] This value is on the higher end of the range of typical oversizing for storage water heaters. Storage water heaters can be more closely sized to the peak load than tankless units. In the case of tankless water heaters there is no buffer, such as a hot water tank, to meet the demand.

Table 3 provides the EFLH values derived from this data and a description of typical building types and end uses for each utilization category.

Table 3. Utilization Categories and EFLH Values

Category	EFLH	Typical End Uses	Facility Types
Low Utilization	176	Lavatories (hand washing), kitchenette, custodial uses	Elementary schools, office, retail, churches
Medium Utilization	287	Low to moderate use showers, fast food kitchen	Secondary schools, fast food restaurant, dormitories, other
High Utilization	399	High use showers, full commercial kitchen, laundry	Fitness center, full service restaurant, hotels, in patient health care

These average efficiency and EFLH values are used to derive deemed savings values representing the annual natural gas savings (m^3 per kBtu/hr. input rating) associated with the increase in the thermal efficiency values for each utilization category based on the following algorithm.

$$Thermal\ Efficiency\ Savings = EFLH \times (\frac{\eta_{proposed}}{\eta_{baseline}} - 1)/NG_{ec}$$

Where,

Thermal Efficiency Savings =Annual natural gas saving in m^3 per kBtu/hr. input rating of condensing tankless water heater

EFLH =Annual Equivalent Full Load Hours for the utilization category (hours) (see Table 3)

$\eta_{proposed}$ =The weighted shipment average efficiency for tankless water heaters (see Table 2)

$\eta_{baseline}$ =The weighted shipment average efficiency for storage water heaters (see Table 2)

NG_{ec} = Natural Gas Energy content (35.738 kBtu/m^3)

The results are provided in Table 4 below.

Table 4. Natural Gas Savings Resulting from Thermal Efficiency Differential

Category	Savings
Low Utilization	0.79 m^3 per kBtu/hr. input
Medium Utilization	1.29 m^3 per kBtu/hr. input

High Utilization	1.79 m^3 per kBtu/hr. input

The stand-by loss equation from the Ontario Building Code was used to determine annual stand-by losses for the baseline storage water heaters.

$$SL_{baseline} = \frac{Q_{baseline}}{0.8} + 110\ X\ \sqrt{V_{0\ baseline}}$$

Where,

$SL_{baseline}$ = The calculated stand-by losses from the storage water heater (kBtu/yr.)

$Q_{baseline}$ = The input energy rating for the storage water heater (kBtu/hr.)[2]

$V_{0\ baseline}$ = The storage capacity of the storage water heater (gallons)[3]

The eliminated standby losses are summarized in Table 5 below:

Table 5. Natural Gas Savings Resulting from Eliminated Stand-by Losses

Tankless Unit Input Capacity	Savings
< 200 KBtu/hr	212 m^3
≥ 200 kBtu/hr.	326 m^3

The total savings are the sum of the savings associated with the thermal efficiency differential and the eliminated standby losses;

$$Total\ Savings = Thermal\ Efficiecny\ Savings + \ Eliminated\ Standby\ Losses$$

LIST OF ASSUMPTIONS

Table 6 provides a list of assumptions utilized in the measure savings algorithms to derive the deemed savings values listed in Table 1 above.

[2] Input energy ratings for the equivalent storage units are equal to 65% of the tankless input rating.

[3] For tankless units less than 200 kBtu/hr. input rating, the equivalent storage water heater tank capacity is assumed to be 50 gallons. For tankless units of 200 kBtu/hr. and greater input rating, the equivalent storage water heater tank capacity is assumed to be 100 gallons.

Table 6. General Assumptions

Variable	Definition	Inputs	Source/Comments
EFLH	Annual equivalent full load hours of operation	Typical peak and hourly average hot water consumption values	Based on data from the ASHRAE HVAC Application Handbook [3] as shown in EFLH formula in the Natural Gas Savings Algorithm section.
$\eta_{proposed}$ & $\eta_{baseline}$	Shipment weighted average efficiency of proposed and baseline units	Results of baseline study	Caneta Research Inc. [6]
$Q_{baseline}$	Input power rating for equivalent storage water heater	Assumed to be 65% of tankless input power rating	Water heater sizing guidelines from AMEC 2012 report [4]
$V_{0\ baseline}$	Volume of equivalent storage water heater storage	50 gallons for tankless units less than 200 kBtu/hr., 100 gallons for larger tankless units	Supported by manufacturers specifications data and sizing tools for typical storage units

SAVINGS CALCULATION EXAMPLE

The example below illustrates how savings would be calculated for a tankless water heater with rated input capacity of 400 kBtu/hr. in a full service restaurant.

Table 3 above indicates that installation in a full service restaurant is in the high utilization category, with a deemed savings value from Table 1 of 1.79 m^3 per kBtu/hr. rated input capacity, and standby loss value of 326 m^3.

Annual natural gas savings attributed to this installation are calculated as:

$$1.79\ {m^3}\Big/{\frac{kBtu}{hr}} \times 400\frac{kBtu}{hr} + 326\ m^3\ = 1{,}042 m^3$$

USES AND EXCLUSIONS

Natural gas-fueled condensing tankless water heaters installed in commercial facilities and serving all or part of the service water heating load qualify for this measure. The measure type must be new construction or time of natural replacement installation where the preexisting unit was a natural gas non-condensing, power vented, storage unit. Non-condensing tankless water heaters are not eligible.

MEASURE LIFE

The measure life is 20 years. [6]

INCREMENTAL COST

The incremental cost data is taken from an incremental cost study completed for six efficiency programs in the northeast US during 2011. [8]

Data reviewed form this and other studies did not show significant variation in incremental cost over the anticipated size range. The average values from the study are reported in Table 6.

Table 6.Tankless Water Heater incremental Cost

Material	Installation	Total
$1,678	$505	$2,183

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COMMERCIAL KITCHEN – DEMAND CONTROL VENTILATION RETROFIT

Version Date and Revision History	
Draft date	April 2, 2015
Version history	Version 1.
Effective date	TBD
End date	N/A
Commercial -> Kitchen – Demand Control Ventilation-> Retrofit /	

Table 1 provides a summary of the key measure parameters with a deemed savings coefficient.

Table 1. Measure Key Data

Parameter	**Definition**	
Measure category	Retrofit (R)	
Baseline technology	Constant volume commercial kitchen ventilation	
Efficient technology	Automated, variable/demand flow, commercial kitchen ventilation	
Market type	Commercial	
Annual natural gas savings	Hood Capacity	Deemed Savings
	Up to 5,000 CFM	4,207 m^3 per year
	5,001 – 10,000 CFM	10,517 m^3 per year
	10,001 – 15,000 CFM	17,529 m^3 per year
Annual electric savings	Hood Capacity	Deemed Savings
	Up to 5,000 CFM	4,940 kWh per year
	5,001 – 10,000 CFM	16,294 kWh per year
	10,001 – 15,000 CFM	28,929 kWh per year
Measure life	15 years	
Incremental cost	Hood Capacity	Incremental Cost
	Up to 5,000 CFM	$3,300
	5,001 – 10,000 CFM	$8,325
	10,001 – 15,000 CFM	$13,875
Restrictions	Limited to spaces with natural gas fueled space heating and commercial kitchen hoods with capacity of 15,000 CFM or less.	

OVERVIEW

Commercial Kitchen Ventilation (CKV) systems exhaust smoke, flue gases, heat and cooking odors. Traditional systems use simple on/off fan motors controls that operate at full flow regardless of the quantity of contaminants to be exhausted. Make up air is supplied by a dedicated make-up air unit, or from a whole building ventilation system, either directly through ductwork, or indirectly from adjoining spaces. Commercial Demand Control Ventilation (DCV) systems are added to CKV systems to modulate the flow in response to the rate that contaminants are generated.

DCV systems are typically comprised of: variable frequency drives to control fan motor speed; a sensor or sensors to determine the level of contaminants; a controller or processor to interpret the sensor signal and send a corresponding signal to the drives; and some form of user interface. There are several manufacturers of kitchen DCV systems including Accuerex, Aerco Industries, CaptiveAire, Green Energy Hoods, Greenheck, Halton, Melink, Noveo, and Spring Air. [1]

There are several strategies for sensing the level of contaminants and modulating the exhaust flow-rate, with sensors that detect the exhaust stream opacity and/or temperature being the most common. Other types of control are based on a time schedule, or on feedback from appliances indicating their operating status. Controls are calibrated to modulate fan speed and exhaust flow between full rated capacity when high levels of contaminants are present and minimum flow when no contaminants are detected.

Energy savings are associated with reductions in fan power, space heating, and space cooling loads.

APPLICATION

This measure applies to existing constant volume commercial kitchen exhaust hoods with rated capacity of not more than 15,000 CFM that are retrofit with DCV systems as described above. Spaces must be heated with natural gas to qualify for this measure.

BASELINE TECHNOLOGY

A constant volume kitchen exhaust hood with rated capacity not greater than 15,000 CFM.

EFFICIENT TECHNOLOGY

The efficient technology is a commercial kitchen demand control ventilation system with rated capacity not greater than 15,000 CFM, consisting of sensor(s) that determine the level of contaminant in the exhaust air stream, a controller that processes inputs from the sensor(s), and variable frequency drives that receive a signal from the controller and modulate the exhaust and make up air fans to optimize flow rates.

ENERGY IMPACTS

The reduction in the requirement for make-up air results in natural gas savings during the heating season and electric energy savings during the cooling season. In addition, there is significant electric energy savings associated with reduced fan speeds.

There is no water usage associated with this measure.

NATURAL GAS SAVINGS ALGORITHMS

Natural gas savings result from reduced exhaust and corresponding make-up air flow rates. The deemed savings values reported in Table 1 are derived using accepted engineering principles and empirical data taken from published case studies representing nineteen commercial kitchen DCV installations. [2] [3] [4] [5]

Because the savings are directly dependent upon hood exhaust capacity expressed in CFM, deemed saving values are provided for three ranges of size, with the deemed savings value based on the midpoint of each flow range category.[1]

Data from the case studies includes measured average fan input power data for operation under constant volume (baseline case) conditions and with DCV systems installed (efficient case). This data was used in conjunction with the fan affinity laws to calculate the average % reduction in fan speed and air flow for each of the nineteen installations as follows.

$$\%\ Flow\ Reduction = ((Flow\ Baseline - Flow\ Efficient)/Flow\ Baseline)\ x\ 100\%$$

$$\%\ Flow\ Reduction = (1 - (Flow\ Efficient\ /Flow\ Baseline))\ x\ 100\%$$

Affinity law: $(Flow\ Efficient\ /\ Flow\ Baseline)^3 = (FP_{efficient}/FP_{baseline})$

Or, $(Flow\ Efficient\ /\ Flow\ Baseline) = (FP_{efficient}/FP_{baseline})^{0.333}$

Substituting leads to: $$\%\ Flow\ Reduction = \left[1 - \left(\frac{FP_{efficient}}{FP_{baseline}}\right)^{0.333}\right] \times 100\%$$

Where,

$\%\ Flow\ Reduction$	= The average % reduction in the exhaust flow rate resulting from the DCV installation (% of baseline flow)
$FP_{baseline}$	= The average total, (exhaust hood and make up air) fan power for the baseline condition. (kW)
$FP_{efficient}$	= The average total, (exhaust hood and make up air) fan power for the efficient case. (kW)

This resulted in a percent reduction in flow for each of the nineteen case studies ranging from 12% to 38% with an overall weighted average percent reduction of 25.1%.

[1] Because hood with capacity less than 1,000 cfm are rarely installed, the midpoint of the 0 - 5,000 CFM category was set at 3,000 cfm.

The overall average heating load associated with the introduction of outside air was determined using an Outdoor Air Load Calculator tool [6], developed by The Food Service Technology Center. Annual heating loads expressed in BTU per CFM of outside air were determined using climate data representing London, Ontario and North-Bay, Ontario, with heating season temperature set-points of 22.2⁰C (72⁰F), and a daily operating schedule of 6:00 AM through 10:00 PM.

A 2014 distribution of kitchen DCV projects provided by the utilities reflected approximately 70% of installations in areas represented by the London weather data, with 30% represented by North-Bay. These values were used with the London and North-Bay annual heating load to derive a weighted-average annual heating load value of 159,733 BTU per CFM.

This value was used in the following equation to derive deemed natural gas savings values for each of the three kitchen exhaust hood size categories.

$$NG\ Savings = \frac{(OAHL \times Capacity \times \%\ Flow\ Reduction)}{(Eff_{heating} \times EC_{NG})}$$

Where,

$NG\ Savings$	= Deemed annual natural gas savings (m³)
$OAHL$	= The weighted average annual outdoor air heating load (BTU/Year per CFM)
$Capacity$	= The midpoint of the kitchen hood size range (CFM)
$\%\ Flow\ Reduction$	= The average % reduction in the exhaust flow rate resulting from the DCV installation (% of baseline flow)
$Eff_{heating}$	= Efficiency of the space heating system (80%)
EC_{NG}	= Energy content of natural gas (35,738 BTU/m³)

This equation was used to calculate the natural gas savings for the midpoint of each kitchen hood capacity category as shown in Table 2 below.

Table 2. Natural Gas Savings

Hood Capacity (CFM)	Deemed Savings (m^3 per Year)
3,000	4,207
7,500	10,517
12,500	17,579

ELECTRIC SAVINGS ALGORITHMS

Electric energy savings associated with this measure primarily result from a reduction in fan energy associated with VFD controlled modulation of the exhaust hood and make-up air fans. Additional electric savings result from reduced cooling load associated with a decrease in outside air introduced to the space during the cooling season.

Data reflecting system capacities and average baseline fan energy for the case-studies referenced above revealed a relatively consistent increase in fan power relative to system capacity. The values were plotted against system capacity and revealed a roughly linear relationship described by the following equation.

$$Fan\ Input\ Power_{baseline} = 0.73010 \times System\ Capacity - 0.78175$$

Where,

$Fan\ Input\ Power_{baseline}$ = The baseline unitary input power (kW/1000 CFM)

$System\ Capacity$ = The rated capacity of the kitchen exhaust hood (1000 CFM)

This equation was used to calculate the baseline input fan power for the midpoint of each kitchen hood capacity category as shown in Table 3 below.

Table 3. Baseline Input Fan Power

Hood Capacity (CFM)	Baseline Input Fan Power (kW)
3,000	1.41
7,500	4.69
12,500	8.34

The values from table two, the average 25.1% flow reduction derived above, and the fan affinity laws were then used to predict the average input power with the DCV system installed, for the midpoint of each capacity category using the following equation.

$$FP_{efficient} = FP_{baseline} \times (1 - \%\ Flow\ Reduction)^3$$

Where,

$FP_{efficient}$ = The average total, (exhaust hood and make up air) fan power for the efficient case. (kW)

$FP_{baseline}$ = The average total, (exhaust hood and make up air) fan power for the baseline condition. (kW)

$\%\ Flow\ Reduction$ = The average % reduction in the exhaust flow rate resulting from the DCV installation (% of baseline flow)

The annual fan power savings for each exhaust hood capacity category was then calculated as follows:

$$FP\ Savings = \left(FP_{baseline} - FP_{efficient}\right) \times\ Annual\ Hours$$

Substituting the above equation for $FP_{efficient}$ leads to the following:

$$FP\ Savings = (FP_{baseline} - FP_{baseline}\ \times\ (1 - \%Flow\ Reduction)^3) \times\ Annual\ Hours$$

Where,

$FP\ Savings$	= The deemed annual fan power electric savings (kWh/Year)
$FP_{efficient}$	= The average total, (exhaust and make up air) fan power for the efficient case. (kW)
$FP_{baseline}$	= The average total, (exhaust and make up air) fan power for the baseline condition. (kW)
$Annual\ Hours$	= The annual operating hours of the system (5,840 Hours/Year)[2]

The resulting deemed fan power savings are shown in Table 4 below.

Table 4. Deemed Fan Power Savings

Hood Capacity (CFM)	Deemed Savings (kWh/year)
3,000	4,774
7,500	15,881
12,500	28,240

Cooling season energy savings are calculated in the same manner as the heating season savings with cooling equipment efficiency and electricity energy content substituted for the heating efficiency and natural gas energy content values. The algorithm is as follows.

$$Cooling\ Savings = \frac{(OACL\ \times\ Capacity\ \times\ \%\ Flow\ Reduction)}{\left(Eff_{cooling}\ \times\ EC_{Elec}\right)}$$

Where,

$Cooling\ Savings$	= Deemed annual cooling energy savings (kWh)
$OACL$	= The weighted average annual outdoor air cooling load (BTU/Year per CFM)
$Capacity$	= The midpoint of the kitchen hood size range (CFM)

[2] Sixteen hours per day, seven days per week is the assumed operating hours from the previous version of substantiation sheets. Data form the nineteen case studies referenced earlier supports this assumption.

$\% \, Flow \, Reduction$	= The average % reduction in the exhaust flow rate resulting from the DCV installation (% of baseline flow)
$Eff_{cooling}$	= Efficiency of the space cooling equipment (COP = 3.81)
EC_{elec}	= Energy content of electricity (3,413 BTU/kWh)

The resulting savings for each exhaust hood size category were added to the fan power savings to derive the overall electric deemed savings values reflected in Table 5 below. These values are added to the fan savings from Table 3 to derive the total deemed electric savings reported in Table 1.

Table 5. Deemed Fan Power Savings

Hood Capacity (CFM)	Deemed Savings (kWh/year)
3,000	166
7,500	413
12,500	689

List of Assumptions

Table 6 provides a list of assumptions utilized in the measure savings algorithms provided above and leading to the deemed savings values listed in Table 1.

Table 6. General Assumptions

Variable	Definition	Value	Inputs	Source
%Flow Reduction	The average reduction in exhaust hood flow rate as a % of rated capacity	25.1%	Derived from empirical fan input power data from nineteen case studies.	[2] [3] [4] [5]
Unitary Fan Input Power *baseline*	Baseline fan input power per CFM of exhaust hood capacity	0.73010 × 1000 CFM - 0.78715	Derived from empirical fan input power data from nineteen case studies.	[2] [3] [4] [5]
OAHL	The annual outdoor air heating load for the service territory. (BTU/CFM)	159,733 BTU/CFM	Weather data for London and North Bay, specified operating hours	[6]
OACL	The annual outdoor air cooling load for the service territory. (BTU/CFM)	2,856 BTU/CFM	Weather data for London and North Bay, specified operating hours	[6]
$Eff_{Heating}$	Heating equipment	80%		Common

Variable	Definition	Value	Inputs	Source
	efficiency			Assumptions
$Eff_{Cooling}$	Cooling System Efficiency	13 SEER 3.81 COP		[7]
EC_{NG}	Natural Gas Energy Content	35,738 BTU/m^3		Common Assumptions
EC_{Elec}	Electricity Energy Content	3,413 BTU/kWh		Common Assumptions
Annual Hours	Annual Operating Hours	5,840	16 hours per day, consistent with nineteen case studies	[2] [3] [4] [5]

Savings Calculation Example

The example below illustrates how deemed savings values are calculated for the 5,000 - 10,000 CFM exhaust hood size category.

Capacity = Midpoint of size category: 7,500 CFM

$$NG\ Savings = \frac{(OAHL\ \times\ Capacity\ \times\ \%\,Flow\ Reduction)}{(Eff_{heating}\ \times\ EC_{NG})}$$

= (159,733 BTU/CFM × 7,500 CFM × 25.1%) / (80.0% × 35,738 BTU/m^3)

= **10,517 m^3 per year**

$$FP\ Savings = (FP_{baseline} - FP_{baseline}\ \times\ (1 - \%Flow\ Reduction)^3)\ \times\ Annual\ Hours$$

= (4.69 kW – 4.69 kW × (1 – 25.1%)^3) × 5,840 hours per year

= **15,881 kWh per year**

$$Cooling\ Savings = \frac{(OACL\ X\ Capacity\ \times\ \%\ Flow\ Reduction)}{(Eff_{cooling}\ \times\ EC_{Elec})}$$

=(2,856 BTU/CFM × 7,500 CFM × 25.1%) / (3.81 × 3,413 BTU/kWh)

= **413 kWh per year**

Uses and Exclusions

This measure applies to existing constant volume commercial kitchen exhaust hoods with rated capacity of not more than 15,000 CFM that are retrofit with DCV systems as described above. Spaces must be heated with natural gas to qualify for this measure.

Projects for existing DCKV system of greater than 15,000 CFM rated capacity should be reviewed under custom project guidelines.

"Short-circuit" hoods that utilize the hood as a plenum for unconditioned make-up air are not eligible for this measure.

MEASURE LIFE

The measure life is 15 years. [8][3]

INCREMENTAL COST

Cost data provided for ten of the nineteen case studies reflected an average installed measure cost of $1.11 per CFM of hood capacity [2] [3] [4] [5]. Applying this value to the midpoint of the three size categories leads to the incremental cost values reported here.

Table 7: Incremental Cost Values

Category	Incremental Cost
Up to 5,000 CFM	$3,330
5,001 – 10,000 CFM	$8,325
10,001 – 15,000 CFM	$13,875

REFERENCES

[1] Consortium for Energy Efficiency, "Commercial Kitchen Ventilation - An Energy Efficiency Program Administrator's Guide to Demand Control Ventilation," Consortium for Energy Efficiency, Boston, MA, 2010.

[2] D. Fisher, "Future of DCV for Commercial Kitchens," *ASHRAE Journal,* no. February 2013, pp. 48 - 54, 2013.

[3] Food Service Technology Center, "Demand Control Ventilation in Commercial Kitchens - An Emerging Technology Case Study - FSTC Report 5001-06.13," Fisher Nickel, Inc., San Ramon, CA, 2006.

[4] San Diego Gas & Electric, "Work Paper WPSDGENRCC0019 - Commercial Kitchen Demand Controls - Electric," San Diego Gas & Electric, San Diego, CA, 2012.

[5] Southern California Edison - Design and Engineering Services, "Demand Control Ventilation for Commercial Kitchen Hoods," Southern California Edison, Rosemead, CA, 2009.

[6] Food Service Technology Center, "Food Service Technology Center - Outdoor Air Load Calculator," Fisher-Nickel, Inc. - for Pacific Gas and Electric, 2014. [Online]. Available: http://www.fishnick.com/ventilation/oalc/. [Accessed 3 November 2014].

[3] Measure life documentation for Kitchen DCV was not found. The CPUC DEER database provides measure life of 15 years for VFDs controlled with CO^2 sensors.

[7] Ministry of Municipal Affairs and Housing-Building and Development Branch, "Supplemental Standard SB-10 (Energy Efficiency Supplement)," Ministry of Municipal Affairs and Housing, Toronto, 2011.

[8] California Public Utilities Commission, "DEER2014 EUL Table Update," 4 February 2014. [Online]. Available: http://www.deeresources.com/. [Accessed 18 August 2014].

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COMMERCIAL KITCHEN DEMAND CONTROL VENTILATION- NEW CONSTRUCTION

DATE: April 2, 2015

TO: Ontario TEC Sub-Committee

FROM: ERS

RE: Commercial Kitchen DCV – New Construction

The following TRM measure covers commercial kitchen demand control ventilation.

This version corrects the equation used to calculate the % flow reduction in the natural gas savings algorithm section of this report. There are no other changes for the previously submitted and approved version.

COMMERCIAL KITCHEN – DEMAND CONTROL VENTILATION

Version Date and Revision History	
Draft date	April 2, 2015
Version history	Version 1.
Effective date	TBD
End date	N/A
Commercial -> Kitchen – Demand Control Ventilation-> New Construction / Time of Natural Replacement	

Table 1 provides a summary of the key measure parameters with a deemed savings coefficient.

Table 1. Measure Key Data

Parameter	Definition	
Measure category	New Construction (NC)	
	Time of Natural Replacement (TNR)	
Baseline technology	Constant volume commercial kitchen ventilation	
Efficient technology	Automated, variable/demand flow, commercial kitchen ventilation	
Market type	Commercial	
Annual natural gas savings	Hood Capacity	Deemed Savings
	Up to 5,000 CFM	4,207 m^3 per year
	5,001 – 10,000 CFM	10,517 m^3 per year
	10,001 – 15,000 CFM	17,529 m^3 per year
Annual electric savings	Hood Capacity	Deemed Savings
	Up to 5,000 CFM	4,940 kWh per year
	5,001 – 10,000 CFM	16,294 kWh per year
	10,001 – 15,000 CFM	28,929 kWh per year
Measure life	15 years	
Incremental cost	Hood Capacity	Incremental Cost
	Up to 5,000 CFM	$1,665
	5,001 – 10,000 CFM	$4,162
	10,001 – 15,000 CFM	$6,930
Restrictions	Limited to spaces with natural gas fueled space heating and commercial kitchen hoods with capacity of 15,000 CFM or less.	

OVERVIEW

Commercial Kitchen Ventilation (CKV) systems exhaust smoke, flue gases, heat and cooking odors. Traditional systems use simple on/off fan motor controls that operate at full flow regardless of the quantity of contaminants to be exhausted. Make up air is supplied by a dedicated make-up air unit, or from a whole building ventilation system, either directly through ductwork, or indirectly from adjoining spaces. Commercial Demand Control Ventilation (DCV) systems are added to CKV systems to modulate the flow in response to the rate that contaminants are generated.

DCV systems are typically comprised of: a variable frequency drive to control fan motor speed; a sensor or sensors to determine the level of contaminants; a controller or processor to interpret the sensor signal and send a corresponding signal to the drive; and some form of user interface. There are several manufacturers of kitchen DCV systems including Accuerex, Aerco Industries, CaptiveAire, Green Energy Hoods, Greenheck, Halton, Melink, Noveo, and Spring Air. [1]

There are several strategies for sensing the level of contaminants and modulating the exhaust flow-rate, with sensors that detect the exhaust stream opacity and/or temperature being the most common. Other types of control are based on a time schedule, or on feedback from appliances indicating their operating status. Controls are calibrated to modulate fan speed and exhaust flow between full rated capacity when high levels of contaminants are present and minimum flow when no contaminants are detected.

Energy savings are associated with reductions in fan power, space heating, and space cooling loads.

APPLICATION

This measure applies to new commercial kitchen exhaust hoods with rated capacity of not more than 15,000 CFM, equipped with DCV systems as described above. Spaces must be heated with natural gas to qualify for this measure.

BASELINE TECHNOLOGY

A new constant volume kitchen exhaust hood with rated capacity not greater than 15,000 CFM.

EFFICIENT TECHNOLOGY

The efficient technology is a commercial kitchen demand control ventilation system with rated capacity not greater than 15,000 CFM, consisting of sensor(s) that determine the level of contaminant in the exhaust air stream, a controller that processes inputs from the sensor(s), and variable frequency drives that receive a signal from the controller and modulate the exhaust and make up air fans to optimize flow rates.

ENERGY IMPACTS

The reduction in the requirement for make-up air results in natural gas savings during the heating season and electric energy savings during the cooling season. In addition, there is significant electric energy savings associated with reduced fan speeds. There is no water usage impact associated with this measure.

NATURAL GAS SAVINGS ALGORITHMS

Natural gas savings result from reduced exhaust and corresponding make-up air flow rates. The deemed savings values reported in Table 1 are derived using accepted engineering principles and empirical data taken from published case studies representing nineteen commercial kitchen DCV installations. [2] [3] [4] [5]

Because the savings are directly dependent upon hood exhaust capacity expressed in CFM, deemed saving values are provided for three ranges of size, with the deemed savings value based on the midpoint of flow range category.[1]

Data from the case studies includes measured average fan input power data for operation under constant volume (baseline) conditions and with DCV systems installed (efficient case). This data was used in conjunction with the fan affinity laws to calculate the average the percent reduction in fan speed and air flow for the nineteen installations as follows.

$\%\,Flow\ Reduction = ((Flow\ Baseline - Flow\ EE)/Flow\ Baseline) \times 100\%$

$\%\,Flow\ Reduction = (1 - (Flow\ EE/Flow\ Baseline)) \times 100\%$

Affinity law: $(Flow\ Efficient\ /\ Flow\ Baseline)^3 = (FP_{efficient}/FP_{baseline})$, or

$(Flow\ Efficient\ /\ Flow\ Baseline) = (FP_{efficient}/FP_{baseline})^{0.333}$

Substituting leads to: $$\%\,Flow\ Reduction = \left[1 - \left(\frac{FP_{efficient}}{FP_{baseline}}\right)^{0.333}\right] \times 100\%$$

Where,

$\%\,Flow\ Reduction$ = The average % reduction in the exhaust flow rate resulting from the DCV installation (% of baseline flow)

$FP_{baseline}$ = The average total, (exhaust hood and make up air) fan power for the baseline condition. (kW)

$FP_{efficient}$ = The average total, (exhaust hood and make up air) fan power for the efficient case. (kW)

This resulted in a percent reduction in flow for each of the nineteen case studies ranging from 12% to 38% with an overall weighted average percent reduction of 25.1%.

The overall average heating load associated with the introduction of outside air was determined using an Outdoor Air Load Calculator tool [6], developed by The Food Service Technology Center. Annual heating loads expressed in BTU per CFM of outside air were determined using

[1] Because hood with capacity less than 1,000 cfm are rarely installed, the midpoint of the 0 - 5,000 CFM category was set at 3,000 cfm.

climate data representing London, Ontario and North-Bay, Ontario, with heating season temperature set-points of 22.2⁰C (72⁰F), and a daily operating schedule of 6:00 AM through 10:00 PM.

A 2014 distribution of kitchen DCV projects provided by the utilities reflected approximately 70% of installations in areas represented by the London weather data, with 30% represented by North-Bay. These values were used with the London and North-Bay annual heating load to derive a weighted-average annual heating load value of 159,733 BTU per CFM.

This value was used in the following equation to derive deemed natural gas savings values for each of the three kitchen exhaust hood size categories.

$$NG\ Savings = \frac{(OAHL \times Capacity \times \%\ Flow\ Reduction)}{(Eff_{heating} \times EC_{NG})}$$

Where,

$NG\ Savings$	= Deemed annual natural gas savings (m^3)
$OAHL$	= The weighted average annual outdoor air heating load (BTU/Year per CFM)
$Capacity$	= The midpoint of the kitchen hood size range (CFM)
$\%\ Flow\ Reduction$	= The average % reduction in the exhaust flow rate resulting from the DCV installation (% of baseline flow)
$Eff_{heating}$	= Efficiency of the space heating system (80%)
EC_{NG}	= Energy content of natural gas (35,738 BTU/m^3)

This equation was used to calculate the natural gas savings for the midpoint of each kitchen hood capacity category as shown in Table 2 below.

Table 2. Natural Gas Savings

Hood Capacity (CFM)	Deemed Savings (m^3 per Year)
3,000	4,207
7,500	10,517
12,500	17,579

Electric Savings Algorithms

Electric energy savings associated with this measure primarily result from a reduction in fan energy associated with VFD controlled modulation of the exhaust hood and make-up air fans.

Additional electric savings result from reduced cooling load associated with a decrease in outside air introduced to the space during the cooling season.

Data reflecting system capacities and average baseline fan energy for the case-studies referenced above revealed a relatively consistent increase in fan power relative to system capacity. The baseline values were plotted against system capacity and revealed a roughly linear relationship described by the following equation.

$$Fan\ Input\ Power_{baseline} = 0.73010 \times System\ Capacity - 0.78175$$

Where,

$Fan\ Input\ Power_{baseline}$ = The baseline unitary input power (kW)
$System\ Capacity$ = The rated capacity of the kitchen exhaust hood (CFM)

This equation was used to calculate the baseline input fan power for the midpoint of each kitchen hood capacity category as shown in Table 3 below.

Table 3. Baseline Input Fan Power

Hood Capacity (CFM)	Baseline Input Fan Power (kW)
3,000	1.41
7,500	4.69
12,500	8.34

The values from table two, the average 25.1% flow reduction derived above, and the fan affinity laws were then used to predict the average input power with the DCV system installed, for the midpoint of each capacity category using the following equation.

$$FP_{efficient} = FP_{baseline} \times (1 - \%Flow\ Reduction)^3$$

Where,

$FP_{efficient}$ = The average total, (exhaust hood and make up air) fan power for the efficient case. (kW)
$FP_{baseline}$ = The average total, (exhaust hood and make up air) fan power for the baseline condition. (kW)
$\%\ Flow\ Reduction$ = The average % reduction in the exhaust flow rate resulting from the DCV installation (% of baseline flow)

The annual fan power savings for each exhaust hood capacity category was then calculated as follows:

$$FP\ Savings = \left(FP_{baseline} - FP_{efficient}\right) \times Annual\ Hours$$

Substituting the above equation for $FP_{efficient}$ leads to the following:

$$FP\ Savings = (FP_{baseline} - FP_{baseline} \times (1 - \%Flow\ Reduction)^3) \times Annual\ Hours$$

Where,

$FP\ Savings$	= The deemed annual fan power electric savings (kWh/Year)
$FP_{efficient}$	= The average total, (exhaust and make up air) fan power for the efficient case. (kW)
$FP_{baseline}$	= The average total, (exhaust and make up air) fan power for the baseline condition. (kW)
$Annual\ Hours$	= The annual operating hours of the system (5,840 Hours/Year)[2]

The resulting deemed fan power savings are shown in Table 4 below.

Table 4. Deemed Fan Power Savings

Hood Capacity (CFM)	Deemed Savings (kWh/year)
3,000	4,774
7,500	15,881
12,500	28,240

Cooling season energy savings are calculated in the same manner as the heating season savings with cooling equipment efficiency and electricity energy content substituted for the heating efficiency and natural gas energy content values. The algorithm is as follows.

$$Cooling\ Savings = \frac{(OACL\ X\ Capacity \times \%\ Flow\ Reduction)}{(Eff_{cooling} \times EC_{Elec})}$$

Where,

$Cooling\ Savings$	= Deemed annual cooling energy savings (kWh)
$OACL$	= The weighted average annual outdoor air cooling load (BTU/Year per CFM)
$Capacity$	= The midpoint of the kitchen hood size range (CFM)
$\%\ Flow\ Reduction$	= The average % reduction in the exhaust flow rate resulting from the DCV installation (% of baseline flow)
$Eff_{cooling}$	= Efficiency of the space cooling equipment (COP = 3.81)
EC_{elec}	= Energy content of electricity (3,413 BTU/kWh)

[2] Sixteen hours per day, seven days per week is the assumed operating hours from the previous version of substantiation sheets. Data from the nineteen case studies referenced earlier supports this assumption.

The resulting savings for each exhaust hood size category were added to the fan power savings to derive the overall electric deemed savings values reflected in Table 5 below. These values are added to the fan savings from Table 3 to derive the total deemed electric savings reported in Table 1.

Table 5. Deemed Fan Power Savings

Hood Capacity (CFM)	Deemed Savings (kWh/year)
3,000	166
7,500	413
12,500	689

LIST OF ASSUMPTIONS

Table 6 provides a list of assumptions utilized in the measure savings algorithms provided above and leading to the deemed savings values listed in Table 1.

Table 6. General Assumptions

Variable	Definition	Value	Inputs	Source
%Flow Reduction	The average reduction in exhaust hood flow rate as a % of rated capacity	25.1%	Derived from empirical fan input power data from nineteen case studies.	[2] [3] [4] [5]
Unitary Fan Input Power $_{baseline}$	Baseline fan input power per CFM of exhaust hood capacity	0.00073 × 1000 CFM - 0.78715	Derived from empirical fan input power data from nineteen case studies.	[2] [3] [4] [5]
OAHL	The annual outdoor air heating load for the service territory. (BTU/CFM)	159,733 BTU/CFM	Weather data for London and North Bay, specified operating hours	[6]
OACL	The annual outdoor air cooling load for the service territory. (BTU/CFM)	2,856 BTU/CFM	Weather data for London and North Bay, specified operating hours	[6]
$Eff_{Heating}$	Heating equipment efficiency	80%		Common Assumptions
$Eff_{Cooling}$	Cooling System Efficiency	13 SEER 3.81 COP		[7]
EC_{NG}	Natural Gas Energy Content	35,738 BTU/m^3		Common Assumptions
EC_{Elec}	Electricity Energy Content	3,413 BTU/kWh		Common Assumptions

Variable	Definition	Value	Inputs	Source
Annual Hours	Annual Operating Hours	5,840	16 hours per day, consistent with nineteen case studies	[2] [3] [4] [5]

SAVINGS CALCULATION EXAMPLE

The example below illustrates how deemed savings values are calculated for the 5,000 - 10,000 CFM exhaust hood size category.

Capacity = Midpoint of size category: 7,500 CFM

$$NG\ Savings = \frac{(OAHL\ X\ Capacity\ \times\ \%\ Flow\ Reduction)}{(Eff_{heating}\ \times\ EC_{NG})}$$

= (159,733 BTU/ CFM × 7,500 CFM × 25.1%)/ (80.0% × 35,738 BTU/m^3)

= 10,517 m^3 per year

$$FP\ Savings = (FP_{baseline} - FP_{baseline}\ \times\ (1 - \%Flow\ Reduction)^3)\ \times\ Annual\ Hours$$

= (4.69 kW – 4.69 kW × (1 – 25.1%)^3 × 5,840 hours per year

= 15,881 kWh per year

$$Cooling\ Savings = \frac{(OACL\ X\ Capacity\ \times\ \%\ Flow\ Reduction)}{(Eff_{cooling} \times\ EC_{Elec})}$$

= (2,856 BTU/CFM × 7,500 CFM × 25.1%) / (3.81 × 3,413 BTU/kWh)

= 413 kWh per year

USES AND EXCLUSIONS

This measure applies to new commercial kitchen exhaust hoods with rated capacity of not more than 15,000 CFM that are equipped with DCV systems as described above. Spaces must be heated with natural gas to qualify for this measure.

Projects for new DCKV system of greater than 15,000 CFM rated capacity should be reviewed under custom project guidelines.

"Short-circuit" hoods that utilize the hood as a plenum for unconditioned make-up air are not eligible for this measure.

MEASURE LIFE

The measure life is 15 years. [8][3]

INCREMENTAL COST

Cost data provided for ten of the nineteen case studies reflected an average installed measure cost of $1.11 per CFM of hood capacity for retrofit installations [2] [3] [4] [5]. There was no breakdown between equipment and installation and no data reflecting incremental cost for new installations could be located. One resource [4] estimated the incremental cost for new installation at 50% of the average retrofit cost. Applying 50% of the average total cost from the ten retrofit case studies to the midpoint of the three size categories leads to the incremental cost values reported here.

Table 7: Incremental Cost Values

Category	Incremental Cost
Up to 5,000 CFM	$1,665
5,001 – 10,000 CFM	$4,162
10,001 – 15,000 CFM	$6,938

REFERENCES

[1] Consortium for Energy Efficiency, "Commercial Kitchen Ventilation - An Energy Efficiency Program Administrator's Guide to Demand Control Ventilation," Consortium for Energy Efficiency, Boston, MA, 2010.

[2] D. Fisher, "Future of DCV for Commercial Kitchens," *ASHRAE Journal,* no. February 2013, pp. 48 - 54, 2013.

[3] Food Service Technology Center, "Demand Control Ventilation in Commercial Kitchens - An Emerging Technology Case Study - FSTC Report 5001-06.13," Fisher Nickel, Inc., San Ramon, CA, 2006.

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[5] Southern California Edison - Design and Engineering Services, "Demand Control Ventilation for Commercial Kitchen Hoods," Southern California Edison, Rosemead, CA, 2009.

[6] Food Service Technology Center, "Food Service Technology Center - Outdoor Air Load Calculator," Fisher-Nickel, Inc. - for Pacific Gas and Electric, 2014. [Online]. Available: http://www.fishnick.com/ventilation/oalc/. [Accessed 3 November 2014].

[3] Measure life documentation for Kitchen DCV was not found. The CPUC DEER database provides measure life of 15 years for VFDs controlled with CO^2 sensors.

[7] Ministry of Municipal Affairs and Housing-Building and Development Branch, "Supplemental Standard SB-10 (Energy Efficiency Supplement)," Ministry of Municipal Affairs and Housing, Toronto, 2011.

[8] California Public Utilities Commission, "DEER2014 EUL Table Update," 4 February 2014. [Online]. Available: http://www.deeresources.com/. [Accessed 18 August 2014].

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CONDENSING MAKE-UP AIR UNIT – NEW CONSTRUCTION OR TIME OF NATURAL REPLACEMENT

Version Date and Revision History	
Draft date	2/25/2015
Version history	v.2
Effective date	TBD
End date	N/A
Commercial → Condensing Make-Up Air Unit (MUA) → New Construction or Time of Natural Replacement	

Table 1 below provides a summary of the key measure parameters, with a deemed savings coefficient.

Table 1. Measure Key Data

Parameter	Definitions		
Measure Category	New Construction (NC) or Time of Natural Replacement (TNR)		
Base Technology	80% Thermal Efficiency Conventional Make-Up Air Unit		
Efficient Technology	≥ 90% Thermal Efficiency, Condensing Make-Up Air Unit		
Market Type	Commercial		
Annual Natural Gas Savings Rate (m^3/CFM)	**Condensing MUA Type**	**Commercial**	**Multi-Residential and Long Term Care**
	Constant Speed	0.407	0.919
	2 Speed	1.22	2.45
	VFD	2.03	3.00
Average Annual Electric Savings (kWh/CFM)	Constant Speed	0	0
	2 Speed	1.24	1.61
	VFD	2.04	2.30
Measure Life	20 Years		
Incremental Cost	**Constant Speed**	**2 Speed**	**VFD**
	$870+$0.66/CFM	$870+$1.01/CFM	$870+$1.02/CFM

Parameter	Definitions
Restrictions	Only condensing make-up air units installed in commercial, multi residential or long term care facilities are eligible for the incentive. Applies to air flows up to 14,000 CFM and systems with Demand Control Ventilation will not qualify.

OVERVIEW

The measure is for the installation of natural gas condensing make-up air (MUA) units with a thermal efficiency of 90% or higher in commercial buildings. Similar to condensing furnaces, high efficiency make-up air units achieve savings through the utilization of a sealed, super insulated combustion chamber, more efficient burners, and multiple heat exchangers that remove a significant portion of the waste heat from the flue gasses. Because multiple heat exchangers are used to remove waste heat from the escaping flue gas, most of the vapor in the flue gas condenses and must be drained.

The measure also covers 2 speed and variable speed equipped models. MUAs with the ability to modulate incoming outside air during periods of reduced occupation reduce fuel consumption by reducing load on the equipment.

APPLICATION

The measure is for the installation of condensing make-up air units which have efficiencies that are higher than code requires. Commercial make-up air units are performance rated by their thermal efficiency (TE). This is a measure of the operating efficiency of the make-up air unit and is defined as the energy out, or the energy transferred to the hot air, divided by the energy in, or the energy contained within the fuel.

BASELINE TECHNOLOGY

Canada's Energy Efficiency Regulations require that new commercial (≥ 225,000 Btu/hr) hot air heating equipment have a rated thermal efficiency (TE) of at least an 80% [1]. For NC/TNR installations, the baseline technology is considered to be the minimum efficiency required by the regulations effective January 1, 2014.

Table 2. Baseline

Type	Thermal Efficiency
Gas Make-Up Air Unit	80%

Efficient Technology

The efficient technology is a condensing make-up air unit with a thermal efficiency rating equal to, or higher than 90%. This is typically the minimum efficiency available for a condensing make-up air unit [2] [3].

Table 3. Efficient Technology

Type	Thermal Efficiency
Gas Condensing Make-Up Air Unit	≥ 90%

Energy Impacts

The primary energy impact associated with the installation of condensing make-up air unit in this service territory is a reduction in natural gas usage resulting from the unit's improved efficiency.

There are electrical savings impacts associated with the measure when the unit installed is equipment with two speed or variable speed capability. These options also lead to additional savings from reducing the outside air during heating and cooling seasons.

No water consumption impacts are associated with this measure.

Natural Gas Savings Algorithms

The measure gas savings are calculated using an assumed load profile for each type of equipment, typical meteorological year 2 (TMY2) data for London, Ontario [4], and the difference in assumed efficiencies for the equipment. The assumed load profiles were developed by Agviro Inc. [5] and are shown in Table 5 in the "List of Assumptions" section. The binned weather data is shown in Table 6.

The deemed natural gas savings factor attributed to this measure is calculated using the following formulas:

$$Heat\ Load\ Rate = \sum_{5^\circ}^{T_o} 1.08 \frac{Btu}{hr\ {}^\circ F\ CFM} \times bin \times (T_s - T_o)$$

And,

$$NG\ Savings\ Factor = \frac{Heat\ Load\ Rate}{35{,}738 \frac{Btu}{m^3}} \times \left(\frac{V_{Base}}{TE_{base}} - \frac{V_{EE}}{TE_{EE}}\right)$$

where,

$Heat\ Load\ Rate$ = Annual heating load per CFM of MAU rated air flow capacity assuming no modulation (Btu/yr/CFM)

$1.08 \frac{Btu}{hr\ °F\ CFM}$	= Volumetric heat capacity, see common assumptions table
bin	= Annual hours in each five degree temperature bin[1] (hr/yr), see Table6 (use appropriate column for appropriate building type)
T_s	= Supply air temperature set point (°F), see Table 4
T_o	= Outside air temperatures (°F), see Table 6
$NG\ Savings\ Factor$	= Annual gas savings factor resulting from installing the new condensing MUA (m^3/yr)/CFM
V_{Base}	= Baseline fan motor speed (%), see Table 5
V_{EE}	= Energy efficient fan motor speed (%), see Table 5
$35{,}738 \frac{Btu}{m^3}$	= Conversion of rated heating capacity from Btu/hr to m^3/hr, common assumptions table
TE_{base}	= Baseline equipment thermal efficiency (%), see Table 2
TE_{EE}	= Efficient equipment thermal efficiency (%), see Table 3

ELECTRIC ENERGY SAVINGS

Electric energy savings are achieved if the MUA are equipped with 2 stage or VFD fan motor controls. The savings factors in Table 1 are averaged across all fan sizes from Table 7.

The electric savings from reducing the speed of a motor is derived using affinity laws. Affinity laws describe the relationship between motor power and speed, which say that the power output of a motor theoretically has a cubic relationship with motor speed. In actuality there are losses and the exponent defining the relationship is typically somewhere between 2.0 and 3.0 [6]. For this review, a value of 2.5 was used.

In addition there are losses inherent to the VFD that must be accounted for. These are typically larger at lower motor sizes and lower speeds, but are typically less than 10%. For this review a penalty of 5% was taken for all VFD applications [7].

The savings are calculated from the daily load profiles in Table 5 by assuming the profile is valid for the entire year. This utilizes the following equation which is summed over the hours of the day. The methodology of this equation is to calculate motor power consumption at each hour of the day, assuming constant speed for the hour and multiply by 365 for a full year of operation. This assumes that the daily load profile in Table 5 is accurate for all days of the year [8].

[1] Tabulated from TMY2 weather data for London, Ontario from: http://apps1.eere.energy.gov/buildings/energyplus/cfm/weather_data3.cfm/region=4_north_and_central_america_wmo_region_4/country=3_canada/cname=CANADA#instructions

$$Motor\ kWh\ Rate = \sum_{h=1}^{24\ hrs} (V_h - V_h{}^x) \times 365\frac{days}{yr} \times \frac{hp}{(\eta - VFD_p)} \times 0.746\frac{kW}{hp} \div CFM$$

Where,

$Motor\ kWh\ Rate$	= Annual electric savings rate due to the motor modulation (kWh/CFM)
V_h	= Speed of the motor for each hour of the day (%), see Table 5
x	= Affinity law exponent, see Table 4
$365\frac{days}{yr}$	= Number of days in the year
hp	= Power input of the fan motor (hp), see Table 7
η	= Fan motor efficiency (%), see Table 4
VFD_p	= Penalty for the VFD (%), see Table 4
$0.746\frac{kW}{hp}$	= Conversion from hp to kW
CFM	= CFM of MUA (ft^3/min), see Table 7

Added to this, are the cooling energy savings that are derived from reduced ventilation loads using 2-speed and VFD options. These are calculated similarly to the natural gas savings by summing the cooling load in British Thermal Units and applying a cooling system efficiency using the following formula.

$$Cooling\ Load\ Rate = \left(\sum_{5°}^{T_o} 1.08\frac{Btu}{hr\ °F\ CFM} \times bin \times (T_o - T_s) \right)$$

And,

$$Cool\ kWh\ Rate = Cooling\ Load\ Rate\ \times (V_{Base} - V_{EE}) \div 12{,}000\frac{Btu}{ton} \times\ 0.924\frac{kW}{ton}$$

Where,

$Cool\ kWh\ Rate$	= The annual cooling load per CFM of MAU rated air flow capacity assuming no modulation (Btu/yr/CFM)
$1.08\frac{Btu}{hr\ °F\ CFM}$	= Volumetric heat capacity, see common assumptions table
bin	= Annual hours in each five degree temperature bin[2] (hr/yr), see Table 5
T_s	= Supply air temperature set point (°F), see Table 4

[2] Tabulated from TMY2 weather data for London, Ontario from: http://apps1.eere.energy.gov/buildings/energyplus/cfm/weather_data3.cfm/region=4_north_and_central_america_wmo_region_4/country=3_canada/cname=CANADA#instructions

T_o	= Outside air temperatures (°F), see Table 6
$Cool\ kWh\ Rate$	= The electrical cooling savings rate per CFM of MAU rated air flow capacity assuming no modulation (kWh/yr/CFM)
V_{Base}	= Baseline fan motor speed (%), see Table 5
V_{EE}	= Energy efficient fan motor speed (%), see Table 5
$12{,}000\frac{Btu}{ton}$	= Conversion of Btus to tons of cooling
$0.924\frac{kW}{ton}$	= Assumption for efficiency of MUA cooling across all equipment types (kW/ton), see Table 4

The total electric savings rate is then calculated by adding the electric savings rate from the motor and from the reduced cooling load.

$$kWh\ Savings\ Rate = Motor\ kWh\ Rate + Cool\ kWh\ Rate$$

Where,

$kWh\ Savings\ Rate$	= Total electrical savings rate per CFM (kWh/yr/CFM)
$Motor\ kWh\ Rate$	= Annual electric savings rate due to the motor modulation (kWh/CFM)
$Cool\ kWh\ Rate$	= The electrical cooling savings rate per CFM of MAU rated air flow capacity assuming no modulation (kWh/CFM)

LIST OF ASSUMPTIONS

The assumptions used to calculate the deemed savings coefficient are shown in Tables 4.

Table 4. Assumptions

Variable	Definition	Inputs	Source
T_s	Supply air temperature set point	72 °F	Common assumptions table
	Specific heat of air times density of air times 60 minutes per hour	1.08 Btu/(hr-°F-CFM)	Common assumptions table
x	Affinity law exponent	2.5	[9]
VFD_p	Percent penalty for VFD losses	5%	[7]
η	Fan motor efficiency	90%	[10]
	Assumption for efficiency of MUA cooling across all equipment types	0.924 kW/ton	[11]

The load profiles used for the natural gas and electric savings calculations are shown in Table 5.

Table 5. Load Profiles for Multi-Residential/Long Term Care and Commercial Facilities [5]

Hour of the Day	Load Profiles					
	Healthcare and Hotels			Commercial		
	Base	2 stage	VFD	Base	2 stage	VFD
1	100%	50%	50%	0%	0%	0%
2	100%	50%	50%	0%	0%	0%
3	100%	50%	50%	0%	0%	0%
4	100%	50%	50%	0%	0%	0%
5	100%	50%	50%	0%	0%	0%
6	100%	50%	50%	0%	0%	0%
7	100%	100%	100%	0%	0%	0%
8	100%	100%	100%	0%	0%	0%
9	100%	100%	70%	100%	75%	50%
10	100%	100%	70%	100%	75%	50%
11	100%	100%	70%	100%	75%	50%
12	100%	100%	100%	100%	75%	50%
13	100%	100%	100%	100%	75%	50%
14	100%	100%	70%	100%	75%	50%
15	100%	100%	70%	100%	75%	50%
16	100%	100%	70%	100%	75%	50%
17	100%	100%	100%	100%	75%	50%
18	100%	100%	100%	100%	75%	50%
19	100%	100%	100%	100%	75%	50%
20	100%	100%	100%	100%	75%	50%
21	100%	50%	50%	0%	0%	0%
22	100%	50%	50%	0%	0%	0%
23	100%	50%	50%	0%	0%	0%
24	100%	50%	50%	0%	0%	0%
Average Air Flow[3]	**100.0%**	**79.2%**	**71.7%**	**100%**	**75%**	**50%**

Table 6 shows the binned weather data.

Table 6. Binned Weather Data for London Ontario [4]

Midpoint Temperature (°F) of 5°F bin (+2.5°F, -2.5°F)	Hours In Each Bin (all hours of the year)[4] (hours) – Multi-Residential and Long-Term Care	Hours In Each Bin (8am to 8 pm)[5] (hours) – Commercial
97.5 (36.4°C)	0	0
92.5 (33.6°C)	8	8
87.5 (30.8°C)	59	59
82.5 (28.1°C)	225	216
77.5 (25.3°C)	407	378
72.5 (22.5°C)	593	385

[3] Only during hours that ventilation is being provided.
[4] Hours of operation based on multi-residential and long-term care load profile.
[5] Hours of operation based on commercial load profile.

Midpoint Temperature (°F) of 5°F bin (+2.5°F, -2.5°F)	Hours In Each Bin (all hours of the year)[4] (hours) – Multi-Residential and Long-Term Care	Hours In Each Bin (8am to 8 pm)[5] (hours) – Commercial
67.5 (19.7°C)	772	401
62.5 (16.9°C)	717	293
57.5 (14.2°C)	758	317
52.5 (11.4°C)	649	298
47.5 (8.6°C)	625	269
42.5 (5.8°C)	643	268
37.5 (3.1°C)	697	294
32.5 (0.3°C)	672	307
27.5 (-2.5°C)	649	304
22.5 (-5.3°C)	501	259
17.5 (-8.1°C)	352	159
12.5 (-10.8°C)	237	107
7.5 (-13.6°C)	122	47
2.5 (-16.4°C)	61	9
-2.5 (-19.2°C)	13	2
-7.5 (-21.9°C)	0	0
Heating Degree $Hours_{72}$	218,846 hr °F	96,948 hr °F
Cooling Degree $Hours_{72}$	5,976 hr °F	5,618 hr °F

The assumed fan horsepower for each fan size is shown in Table 7.

Table 7. Fan Size and Associated Fan Power [5]

Fan Flow (CFM)	Fan power (hp)
1,700	1
3,300	2
6,000	3
9,000	5
14,000	8.5

SAVINGS CALCULATION EXAMPLE

The example below shows how to calculate gas savings achieved from installing one 1,700 CFM condensing MUA equipped with a VFD in a commercial building.

The heat load rate is calculated first and the sum of the bin hours times the temperature difference is shown.

$$Heat\ Load\ Rate = 1.08\frac{Btu}{hr\ °F\ CFM} \times 96{,}948\ hr\ °F = 104{,}704\frac{Btu}{CFM}$$

And the calculation for the natural gas savings factor then becomes,

$$NG\ Savings\ Factor = \frac{104{,}704\ Btu/CFM}{35{,}738\frac{Btu}{m^3}} \times \left(\frac{100\%}{80\%} - \frac{50\%}{90\%}\right) = 2.03\frac{m^3}{CFM}$$

Therefore, annual natural gas savings are:

$$Annual\ NG\ Savings = 1{,}700\ CFM \times 2.03 \frac{m^3}{CFM} = 3{,}451\ m^3$$

The annual motor electric savings are calculated also from a summation, which is not easily shown explicitly, but is shown in equation form here,

$$Motor\ kWh\ Rate = \sum_{h=1}^{24\ hrs} \left(V_h - {V_h}^{2.5}\right) \times 365 \frac{days}{yr} \times \frac{1\ hp}{90\% - 5\%} \times 0.746 \frac{kW}{hp} \div 1700\ CFM$$
$$= 1.86 \frac{kWh}{CFM}$$

The electric savings from the reduced cooling load are calculated similarly to those for the natural gas savings, but using cooling system efficiencies instead of heating system efficiencies.

$$Cooling\ Load\ Rate = \left(1.08 \frac{Btu}{hr\ °F\ CFM} \times 5{,}618\ hr\ °F\right) = 6{,}067 \frac{Btu}{CFM}$$

And,

$$Cool\ kWh\ Rate = 6{,}067 \frac{Btu}{CFM} \times (100\% - 50\%) \div 12{,}000 \frac{Btu}{ton} \times\ 0.924 \frac{kW}{ton} = 0.23 \frac{kWh}{CFM}$$

The total electrical savings rate is then:

$$kWh\ Savings\ Rate^{6} = 1.86 \frac{kWh}{CFM} + 0.23 \frac{kWh}{CFM} = 2.10 \frac{kWh}{CFM}$$

There for the annual electric savings are:

$$Annual\ kWh\ Savings = 1{,}700\ CFM \times 2.10 \frac{kWh}{CFM} = 3{,}562\ kWh$$

USES AND EXCLUSIONS

To qualify for this measure the condensing MUA must be gas-fired, have a thermal efficiency of at least 90% and be installed in a new commercial facility or replace failed equipment.

MEASURE LIFE

The ASHRAE handbook states that the typical design life of commercial heating equipment is 20 years [12].

[6] Note, this value was calculated for the entire range of assumed horsepower sizes and averaged to get 1.60kWh/CFM. Individual sizes vary from the average slightly.

INCREMENTAL COST

The incremental costs were developed in a study by Agviro Inc. for use by Enbridge Union and Union Gas on a per CFM basis as:

Table 8. Incremental Costs [5]

Condensing MUA	Condensing MUA and 2 Speed Motor	Condensing MUA and VFD Motor
$870+$0.66/CFM	$870+$1.01/CFM	$870+$1.02/CFM

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Commercial Condensing Storage Water Heaters

New Construction / Time of Natural Replacement

DATE: May 19, 2015

TO: Ontario TEC Sub-Committee

FROM: ERS

RE: Commercial Condensing Storage Water Heater

The following TRM measure covers commercial condensing storage water heaters for new construction and time of natural replacement.

CONDENSING STORAGE GAS WATER HEATERS – NEW CONSTRUCTION/TIME OF NATURAL REPLACEMENT

Version Date and Revision History	
Draft date	5/19/2015
Version history	v. 1
Effective date	TBD
End date	N/A
Commercial ->Condensing Storage Water Heater -> New Construction Commercial ->Condensing Storage Water Heater -> Time of Natural Replacement	

Table 1 provides a –summary of the key measure parameters and deemed savings coefficients.

Table 1. Measure Key Data

Parameter	Definition			
Measure category	New Construction (NC)			
	Time of Natural Replacement (TNR)			
Baseline technology	Non-condensing storage water heater Greater than 75 kBtu/hr. input Estimated overall efficiency of units shipped = 80.1%			
Efficient technology	Condensing storage water heater Greater than 75 kBtu/hr. input Estimated overall efficiency of units shipped = 94.5%			
Market type	Commercial			
Deemed savings factors		**Low Utilization Application***	**Medium Utilization Application***	**High Utilization Application***
	Natural gas impacts	1.36 m^3 per kBtu/hr. input	2.22 m^3 per kBtu/hr. input	3.09 m^3 per kBtu/hr. input
	*See Table 3 for utilization categories by facility type			
Measure life	15 years			
Incremental cost	250 KBtu/hr input rating and below	$2,215		
	Above 250 KBtu/hr input rating	$3,816		
Restrictions	This measure applies to the installation of condensing natural gas storage water heaters in commercial facilities.			

OVERVIEW

The measure consists of the installation of natural gas fueled condensing storage water heaters for hot water production in commercial facilities. Non-condensing storage water heaters are not eligible under this measure.

Natural gas fueled non-condensing commercial storage water heaters typically consist of an insulated storage tank and a vented burner. The burner is typically located at the bottom of the tank with a flue running straight up and exiting at the top of the tank. This allows for some cooling of the exhaust gas and associated transfer of energy to the hot water.

A primary difference in the design of condensing storage water heaters is the inclusion of a secondary heat exchanger. The exhaust is routed through this secondary heat exchanger before exiting the tank. This further cools the exhaust to the point where water vapor contained in the exhaust gas condenses, transferring the heat of vaporization to the water in the tank, and significantly improving efficiency.

The condensate removed from the flue gases is corrosive, so the heat exchanger and condensate drain system must be constructed of non-corrosive material adding, to the cost of the unit.

The deemed savings values reported in Table 1 result from the differential in the shipment weighted average thermal efficiency values derived by Caneta Research Inc. as part of a 2009 study. [1] The values were calculated using manufacturers published thermal efficiency data for both condensing and non-condensing storage units and market share information provided by the Consortium for Energy Efficiency.

There is continuous heat loss from the tanks of the storage water heater to the surrounding space. The magnitude of this storage or stand-by loss is largely dependent upon the size of the storage tank and the level of tank insulation, and does not differ between condensing and non-condensing models.

The natural gas savings algorithm and the associated variables are presented in the Natural Gas Savings Algorithm section.

APPLICATION

This measure provides incentives for installing natural gas condensing storage water heaters in commercial facilities for either the new construction or time of natural replacement measure category. The units provide service hot water for entire commercial facilities, or in some cases for selected loads within the facility.

BASELINE TECHNOLOGY

The baseline technology for this measure is a natural gas fueled non-condensing, power-vented, storage water heater. or greater, providing the service hot water needs for all or portions of commercial facilities.

Table 1 provides the shipment weighted average thermal efficiency for non-condensing storage water heaters meeting these criteria.

EFFICIENT TECHNOLOGY

The high efficiency technology is a natural gas fueled condensing storage water heater. Condensing storage water heaters with input rating of 200 kBtu/hr. or greater are considered commercial units, but smaller units are frequently installed in commercial facilities to serve all of the service water needs or selected end uses. Units with input ratings of 75 kBtu/hr. or greater are eligible for this measure.

Table 1 provides the shipment weighted average thermal efficiency of condensing storage water heaters from the Caneta report referenced earlier.

ENERGY IMPACTS

Natural gas savings are achieved as a result of the higher overall average thermal efficiency of the condensing storage units.

The natural gas algorithms and the associated variables are presented in the Natural Gas Savings Algorithm section.

There are no electric or water consumption impacts associated with this measure.

NATURAL GAS SAVINGS ALGORITHMS

Shipment-weighted overall average efficiency values for non-condensing and condensing storage water heaters are as shown in Table 2. The values are based on manufacturers published efficiency ratings and market share data obtained in a 2009 study completed for Union Gas. **[1]**

Table 2. Shipment-Weighted Average Commercial Storage Water Heater Thermal Efficiencies

Type	Average Efficiency
Non-Condensing	80.1%
Condensing	94.5%

The 2011 ASHRAE HVAC Applications Handbook provides typical peak hourly demand and average daily hot water consumption data for several building types. [2] A 2012 Enbridge Gas funded study [3] indicates that water heaters are generally sized based on peak 15-minute demands with an oversizing factor applied. The same study includes data indicating the peak 15-minute demand can be estimated as 140% of the peak hourly demand. These values were used to derive Equivalent Full Load Hours (EFLH) values using the following algorithm.

$$EFLH = Demand_{avg.\ daily} \times \frac{1}{Demand_{peak\ 15\ minute} \times OS_{factor}} \times Days\ per\ year$$

Where,

$EFLH$ = The annual EFLH (hours/year)

$Demand_{avg.\ daily}$ = The reported average daily service hot water demand for a specific building type (US gallon/occupant-day) [2]

$Demand_{peak\ 15\ minute}$ = The peak 15-minute service hot water demand for a specific building type (US gallon/occupant-hour) [2] [3]

OS_{factor} = Typical storages water heater oversizing factor relative to 15-minute peak demand (130%) [3]

$Days\ per\ year$ = The number of days per year when the facility is operational

Table 3 provides the EFLH values derived from this data and a description of typical building types and end uses for each utilization category.

Table 3. Utilization Categories and EFLH Values

Category	EFLH	Typical End Uses	Facility Types
Low Utilization	271	Lavatories (hand washing), kitchenette, custodial uses	Elementary schools, office, retail, churches
Medium Utilization	442	Low to moderate use showers, fast food kitchen	Secondary schools, fast food restaurant, dormitories, other
High Utilization	614	High use showers, full commercial kitchen, laundry	Fitness center, full service restaurant, hotels, in patient health care, multi-residential

These average thermal efficiencies and EFLH values are used to derive deemed savings values representing the annual natural gas savings (m^3 per kBtu/hr. input rating) associated with the increase in the thermal efficiency values for each utilization category based on the following algorithm.

$$Deemed\ Natural\ Gas\ Savings = EFLH \times (\frac{\eta_{proposed}}{\eta_{baseline}} - 1)/NG_{ec}$$

Where,

Deemed Natural Gas Savings Factor	=Annual natural gas savings factor expressed as m^3 per kBtu/hr. input rating of condensing storage water heater
EFLH	=Annual Equivalent Full Load Hours for the utilization category (hours) (see Table 3)
$\eta_{proposed}$	=The weighted shipment average thermal efficiency for condensing storage water heaters (see Table 2)
$\eta_{baseline}$	=The weighted shipment average thermal efficiency for non-condensing storage water heaters (see Table 2)
NG_{ec}	= Natural gas energy content (35.738 kBtu/m^3)

The resulting deemed savings factors are provided in Table 4 below:

Table 4. Natural Gas Savings Resulting from Condensing Storage Water Heaters

Category	Savings
Low Utilization	1.36 m^3 per kBtu/hr. input
Medium Utilization	2.22 m^3 per kBtu/hr. input
High Utilization	3.09 m^3 per kBtu/hr. input

LIST OF ASSUMPTIONS

Table 5 provides a list of assumptions utilized in the measure savings algorithms to derive the deemed savings factors listed in Tables 1 and 4 above.

Table 5. General Assumptions

Variable	Definition	Inputs	Source/Comments
EFLH	Annual equivalent full load hours of operation	Typical peak and hourly average hot water consumption values	Based on data from the ASHRAE HVAC Application Handbook [2] as shown in EFLH formula in the Natural Gas Savings Algorithm section.
$\eta_{proposed}$ & $\eta_{baseline}$	Shipment weighted average thermal efficiency of proposed and baseline units	Results of baseline study	Caneta Research Inc. [4]
NG_{ec}	Energy content of natural gas	35.738 kBtu/ m^3	Common Assumptions Table

SAVINGS CALCULATION EXAMPLE

The example below illustrates how savings would be calculated for a condensing storage water heater with rated input capacity of 400 kBtu/hr. in a full service restaurant.

Table 3 above indicates that installation in a full service restaurant is in the high utilization category, with a deemed savings value from Table 1 of 3.09 m^3 per kBtu/hr. rated input capacity.

Annual natural gas savings attributed to this high utilization category installation is calculated as:

$$3.09\, m^3 \Big/ \frac{kBtu}{hr} \times 400 \frac{kBtu}{hr} = 1{,}236\, m^3$$

USES AND EXCLUSIONS

Natural gas-fueled condensing storage water heaters installed in commercial facilities and serving all or part of the service water heating load qualify for this measure. The measure type must be new construction or time of natural replacement installation where the preexisting unit was a natural gas non-condensing power-vented storage unit.

MEASURE LIFE

The measure life is 15 years. [5]

INCREMENTAL COST

There are several sources of information reflecting incremental cost associated with residential condensing water heaters but no previous studies reflecting commercial installations were located.

The incremental cost of equipment reported in Table 6 below resulted from an internet search of manufacturers and retailers websites. Retail pricing data for forty condensing and non-condensing units of various size showed relative consistent incremental equipment cost delta ranging between $1,600 and $2,000 for units under 250 KBtu/hr input capacity, with a significant increase to around $3,000 for units with input capacity in excess of 250 Btu/hr. Table 6 reflects the average incremental equipment cost for units in each of these size categories. The incremental installation cost is taken from an incremental cost study completed for six efficiency programs in the northeast US during 2011 [6], and is consistent with data from other studies.

Table 6. Condensing Water Heater incremental Cost[1]

Input Rating	Incremental Cost of Equipment	Incremental Cost of Installation[2]	Total Incremental
250 KBtu/hr and below	CAD $2,079 [7] [8] [9]	$136 [6]	$2,215
Above 250 kBtu/hr	CAD $3,680 [7] [8] [9]	$136 [6]	$3,816

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COMMERCIAL - CONDENSING UNIT HEATER - NEW CONSTRUCTION OR TIME OF NATURAL REPLACEMENT

Version Date and Revision History	
Draft date:	3/24/15
Effective date:	TBD
End date:	TBD
Commercial→ Condensing Unit Heater→ New Construction or Time of Natural Replacement	

Table 1 below provides a summary of the key measure parameters, with quasi-prescriptive deemed savings based on the rated input of the unit.

Table 1. Measure Key Data

Parameter		**Definitions**		
Measure Category		New Construction (NC) or Time of Natural Replacement (TNR)		
Base Technology		80% Thermal Efficiency, 78% Annual Efficiency		
Efficient Technology		90% Thermal Efficiency, 89% Annual Efficiency		
Market Type		Commercial		
Gas Savings		NC	5.92 m^3 per kBtu/hr input rating	
		TNR	7.89 m^3 per kBtu/hr input rating	
Electric Energy Penalty (kWh/year)		**30 – 100 kBtu/hr**	**125 – 200 kBtu/hr**	**225 – 300 kBtu/hr**
	NC	222 kWh	398 kWh	410 kWh
	TNR	296 kWh	530 kWh	546 kWh
Measure Life		18 years		
Incremental Cost		$12.90 per kBtu/hr input rating		
Restrictions		Must be a new commercial installation of a condensing unit heater		

Overview

The measure is for the installation of a condensing unit heater in commercial facilities. A condensing unit heater is a power-vented unit with a primary, non-condensing heat exchanger, followed by a secondary heat exchanger in which waste heat from the flue gases is recovered. As heat is extracted from the flue gases, resulting condensate of some of the water vapor present in the flue gases occurs. To avoid damage to the unit heater from the corrosive condensate, the heat exchanger is made of a corrosion-resistant material (e.g., stainless steel) and has a condensate drain connection. [1]

The anticipated savings from this measure are calculated utilizing a deemed algorithm. The algorithm and the associated variables are presented in the sections "Natural Gas Savings and Electric Energy Savings Algorithms".

Application

The measure covers the installation of condensing unit heaters in commercial settings. Condensing unit heaters are rated by their thermal efficiency, which is a measure of the operating efficiency of the unit. Thermal efficiency is defined as the energy out, or the energy contained in the hot air, divided by the energy in, or the energy contained within the fuel.

Baseline Technology

Canadian building code requires unit heaters to be manufactured with at least 80% thermal efficiency, which is assumed to be the baseline for the measure shown in Table 2 [2]. The annual efficiency was estimated from the thermal efficiency using the ASHRAE 103 AFUE estimation software [1].

Table 2. Baseline for Condensing Unit Heaters

Type	Efficiency
Non-Condensing Unit Heater	80% Thermal Efficiency [2]
	78% Annual Efficiency [1]

EFFICIENT TECHNOLOGY

The efficient technology is considered to be a condensing unit heater with a thermal efficiency of 90% shown in Table 3. The annual efficiency was estimated from the thermal efficiency using the ASHRAE 103 AFUE estimation software [1].

Table 3. Efficient Technology for Condensing Unit Heater

Type	Efficiency
Condensing Unit Heater	90% Thermal Efficiency
	89% Annual Efficiency [1]

ENERGY IMPACTS

The primary energy impact associated with the installation of condensing boilers in this service territory is a reduction in natural gas usage resulting from the furnace's improved efficiency. There is an electric energy usage increase resulting from using a higher capacity vent motor on the condensing unit heaters compared with standard unit heaters. No water consumption impacts are associated with this measure.

NATURAL GAS SAVINGS ALGORITHMS

The measure gas savings are calculated using an assumption for the equivalent full load hours (EFLH) and the difference in assumed efficiencies for the equipment. The EFLH assumption was derived utilizing bin data for the London, Ontario location with an oversizing factor of 25%. The savings factor calculated in this section and presented in Table 1 needs to be multiplied by the input capacity of the condensing unit heater to get annual savings for the measure.

The deemed natural gas savings factor attributed to this measure is calculated using the following formula:

$$NG\ Savings\ Factor = \frac{EFLH}{35.738\frac{kBtu}{m^3}} \times \left(\frac{AE_{EE}}{AE_{base}} - 1\right)$$

where,

$NG\ Savings\ Factor$ = Annual gas savings (m^3/yr per kBtu/hr of new unit heater input capacity)

$EFLH$	= Equivalent full load hours (hr/yr), see Table 4
$35.738 \frac{kBtu}{m^3}$	= Conversion of rated heating capacity from kBtu to m3, common assumptions table
AE_{base}	= Baseline equipment annual efficiency (%), see Table 2
AE_{EE}	= Efficient equipment annual efficiency (%), see Table 3

Electric Energy Penalty Algorithms

Condensing unit heaters use more electricity than comparably sized non-condensing units. The measure electric energy penalty is calculated using the same assumption for EFLH as used in the natural gas savings and shown in Table 4. The electric consumption assumptions are shown in Table 5.

The deemed electric energy penalty value attributed to this measure is calculated using the following formula:

$$Annual\ kWh\ Penalty = EFLH \times (Elect_{base} - Elect_{EE})$$

where,

$Annual\ kWh\ Penalty$	= annual electric energy penalty resulted from installing the new unit heater (kWh/yr)
$EFLH$	= Equivalent full load hours (hr/yr), see Table 4
$Elect_{base}$	= Power consumption of the baseline unit (kW), see Table 4
$Elect_{EE}$	= Power consumption of the condensing unit heater (kW), see Table 5

List of Assumptions

The assumptions used to calculate the deemed savings coefficient are shown in Table 4.

Table 4. Assumptions List

Variable	Definition	Inputs	Source
$EFLH_{NC}$	Equivalent full load hours for a unit heater – new construction	1,500 hrs	Common Assumptions Table
$EFLH_{TNR}$	Equivalent full load hours for a unit heater –	2,000 hrs	Common

Variable	Definition	Inputs	Source
	time of natural replacement		Assumptions Table

The average electrical consumption values in Table 5 are researched from power ratings for a variety of units.

Table 5. Average Electrical Consumption [1]

Size Range	Baseline (kW)	Efficient (kW)
30 – 100 kBtu/hr	0.155	0.303
125 – 200 kBtu/hr	0.392	0.657
225 – 300 kBtu/hr	0.747	0.1020

SAVINGS CALCULATION EXAMPLE

The example below shows how to calculate gas savings achieved from installing one condensing unit heater with a rated input of 162.5 kBtu/hr in a new building.

$$NG\ savings\ factor = \frac{1{,}500\frac{hr}{yr}}{35.738\frac{kBtu}{m^3}} \times \left(\frac{89\%}{78\%} - 1\right) = 5.92 \text{ per kBtu/hr input}$$

$$Annual\ NG\ savings = 5.92\frac{\frac{m^3}{yr}}{\frac{kBtu}{hr}} \times 162.5\frac{kBtu}{hr} = 962\frac{m^3}{yr}$$

The annual electric penalty is:

$$Annual\ kWh\ Penalty = 1{,}500\ hrs \times (0.392 - 0.657)\ kW = 398\ kWh$$

USES AND EXCLUSIONS

To qualify for this measure the condensing unit heater must be gas-fired, be installed in commercial facilities, and meet or exceed the minimum efficiency as shown in section “Efficient Technology” above.

MEASURE LIFE

The measure life attributed to this measure is 18 years [5] [6].

INCREMENTAL COST

The incremental cost of buying a condensing instead of non-condensing unit heater is $12.90 per kBtu/hr was developed by researching costs from manufacturers and online stores [1].

REFERENCES

[1] Natural Gas Technologies Centre, "DSM Opportunities Associated with Unit Heaters," Union Gas, Boucherville, QC, 2009.

[2] Province of Ontario, "Ontario Regulation 404/12, Energy Efficiency Appliances and Products, Schedule 3, Section 1.1.iv.," Government of Canada, Consolidation period from 31 March 2014. [Online]. Available: http://www.e-laws.gov.on.ca/download/elaws_regs_120404_e.doc. [Accessed Sept 2014].

[3] Davis Energy Group, "Analysis of Standard Options for Unit Heaters and Duct Furnaces," 8 pages, 2004.

[4] NGTC, "NGTC Review (No. 123807-02) - Unit Heaters Savings (Retainer Task for Union Gas," 9 pages, 2007.

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[6] NRCan, "Canada's Energy Effiency Regulations: Gas Fired Unit Heaters," Canadian Government, Apr 2007. [Online]. Available: http://www.nrcan.gc.ca/energy/regulations-codes-standards/bulletins/7195. [Accessed Oct 2014].

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Commercial Infrared Heaters - New Construction

DATE: 5/1/2015

TO: Ontario TEC Sub-committee

FROM: ERS

RE: Commercial Infrared Heaters: New Construction

This section addresses the installation of infrared heaters in new construction projects for commercial buildings. Sources used in the development of this measure include:

- Enbridge substantiation sheet provided by the TEC
- ASHRAE 2008 Handbook, Chapter 15
- Manufacturer SpaceRay's infrared heater engineering manual
- Buckley and Seel's 1988 infrared heater case study
- Natural Resources Canada website
- Infrared heater manufacturer websites
- Nexant DSM gas measure market characterization report

The savings for the measure have been revised in light of the equivalent full load hour calculations submitted that were originally derived in the 2004 Agviro study of the measure.

COMMERCIAL INFRARED (IR) HEATERS < 300KBTU/HR – NEW CONSTRUCTION

Version Date and Revision History	
Draft date:	5/1/2015
Effective date:	TBD
End date:	TBD
Commercial→ Infrared Heater→ New Construction	

Table 1 provides a summary of the key measure parameters with deemed savings coefficients.

Table 1. Measure Key Data

<table>
<tr><th>Parameter</th><th colspan="2">Definitions</th></tr>
<tr><td>Measure Category</td><td colspan="2">New Construction (NC)</td></tr>
<tr><td>Base Technology</td><td colspan="2">Unit Heater</td></tr>
<tr><td>Efficient Technology</td><td colspan="2">Infrared Heater (Single-Stage, Two-Stage and High Intensity)</td></tr>
<tr><td>Market Type</td><td colspan="2">Commercial Space Heating</td></tr>
<tr><td rowspan="2">Annual Gas Savings Rate</td><td>Single-Stage and High Intensity</td><td>8.6 m³ per kBtu/hr of IR heater input capacity</td></tr>
<tr><td>Two Stage</td><td>9.8 m³ per kBtu/hr of IR heater input capacity</td></tr>
<tr><td rowspan="4">Annual Electric Savings</td><td>Infrared Input Rating (kBtu/hr)</td><td>Electric Savings (kWh)</td></tr>
<tr><td>< 50</td><td>0 kWh</td></tr>
<tr><td>50 – 165</td><td>225 kWh</td></tr>
<tr><td>165 - 300</td><td>510 kWh</td></tr>
<tr><td>Measure Life</td><td colspan="2">17 years</td></tr>
<tr><td>Incremental Cost</td><td colspan="2">$9.47 CAD per kBtu/hr of IR heater input capacity</td></tr>
<tr><td>Restrictions</td><td colspan="2">The installed equipment must be less rated at less than 300 kBtu/hr</td></tr>
</table>

OVERVIEW

Natural gas fired infrared (IR) heaters use radiant tube emitters or ceramic/steel emitters (high intensity) as the body by which to transmit infrared energy and heat. Gas is burned to heat the emitter which radiates energy to the floor and other objects in the room.

IR heaters heat more efficiently than conventional forced air systems, such as unit heaters, for several reasons. First, they directly heat the objects in the space through infrared radiant energy, including the floor slab, which then radiate heat back into the air space. Because the people in the room are directly being heated, comfort levels can be achieved at a lower air temperature than with forced hot air systems.

Conventional systems heat the air flowing into the room but because heated air is less dense than the existing cool air, it rises to the ceiling and stratifies, gradually working its way down to the floor level. The floor slab and equipment act as heat sinks causing the ceiling level to be much warmer than the floor area. The result is that a forced hot air system needs to work harder than the infrared heater to heat the same space and IR heaters produce a more uniform space temperature by heating the floor and objects first.

Infrared heaters use smaller fans for the same rated capacity compared to a conventional system because conventional systems use fans to circulate the air through the space and infrared heaters use fans only to induce combustion draft.

Infrared heaters are significantly more efficient that conventional forced hot air systems because of differences in the way heat is distributed and additional losses associated with the forced hot air systems as discussed above. According to a study by Agviro, an infrared heater will have an output at full load of 85% its conventional counterpart for the same space heating capacity [1] [2]. This is often referred to as the compensation factor [3]. The 2012 ASHRAE handbook states that IR heaters produce savings of at least 15% [2] based on a study performed by Buckley and Seel in 1988 that found savings to typically be between 15% and 20% [4]. Although some manufacturers claim performance of IR heaters to be dependent on mounting height, ASHRAE has found IR heater savings to be independent of mounting height.

There are three primary types of infrared heaters, single stage, high intensity, and two-stage. The operation of all three types is essentially the same, but high intensity heaters utilize materials such as ceramics that can withstand higher operating temperatures, and two-stage heaters have controls to optimize performance at two levels of output. Because of their controls, two-stage heaters have better compensation factors then single stage or high intensity heaters.

APPLICATION

The measure covers the installation of infrared heaters in commercial settings. Infrared heaters are regulated by the CSA 2.35b standard, which requires that they convert at least 35% of the input fuel energy to radiant energy [5]. This is called the IR efficiency or the radiant efficiency and is not the same as thermal efficiency, which is a measure of the heating energy out over the fuel energy in. Thermal efficiency of an IR heater is higher than the radiant efficiency because the radiant efficiency does not include all heat delivered to the space, but only includes the radiant component. As such, thermal efficiency is used as the performance metric for savings calculations.

Baseline Technology

Ontario Regulation 404/12 requires unit heaters to be manufactured with at least 80% thermal efficiency, which is assumed to be the baseline for the measure [6].

Table 2. Assumed Baseline Technology

Type	Efficiency
Conventional Unit Heater	80% Thermal Efficiency [6] [7]

Efficient Technology

The efficient technology is an infrared heater.

Table 3. Efficient Technology for Infrared Heaters [1] [2] [4] [8]

Type	Compensation Factor	Thermal Efficiency
Infrared Heater Single Stage and High Intensity	0.85	82%
Infrared Heater Two Stages	0.83	82%

Energy Impacts

Natural gas savings are achieved through four mechanisms:

1. Objects are directly heated instead of the air around them.
2. Less air stratification for more uniform heating of the space.
3. Smaller fans and less stratification which reduces air infiltration changes.
4. Minor electricity savings because of the smaller fans in IR heaters compared to equally sized unit heaters or the blowers in forced hot air systems.

All of these factors are included in the compensation factor.

NATURAL GAS SAVINGS ALGORITHMS

The natural gas savings from installing an IR heater instead of a conventional unit heater can be calculated as a function of the compensation factor discussed in the measure overview and the thermal efficiencies assumed. This document is based on a compensation factor of 0.85 for single and high intensity and 0.83 for two-stage. The savings are directly proportional to the assumed effective full load hours of operation and the installed capacity of the equipment [3] [2] [4] [8].

The following is a derivation of the natural gas savings from installing an IR heater where,

$NG\ Savings$	= Natural gas savings from installing an IR heater (kBtu)
$NG\ Conv$	= Natural gas consumption of the conventional heater (kBtu)
$NG\ IR$	= Natural gas consumption of the IR heater (kBtu)
$EFLH$	= Equivalent full load hours (hrs)[1]
$Input, Output_{Conv}$	= Input/output of the conventional heater (kBtu/hr)
$Input, Output_{IR}$	= Input/output of the IR heater (kBtu/hr)
$Comp$	= Compensation factor for the IR heater (%)

$$(1)\ NG\ Savings = NG\ Conv - NG\ IR$$

$$(2)\ NG\ Conv = Input_{Conv} \times EFLH$$

$$(3)\ NG\ IR = Input_{IR} \times ELFH$$

Substituting equations (2) and (3) into equation (1) results in:

$$(4)\ NG\ Savings = Input_{Conv} \times EFLH - Input_{IR} \times ELFH$$

The natural gas inputs to the IR heater can be defines as:

$$(5)\ Input_{Conv} = \frac{Output_{Conv}}{\eta_{conv}}$$

$$(6) Input_{IR} = \frac{Output_{IR}}{\eta_{IR}}$$

The IR heater output is shown by the following relationship:

$$(7)\ Output_{IR} = Output_{Conv} \times Comp$$

Substituting equation (7) into equation (6):

$$(8) Input_{IR} = \frac{Output_{Conv} \times Comp}{\eta_{IR}}$$

[1] Note, that the EFLH is assumed to be equal for both conventional and the IR heaters.

Then, substituting equations (8) and (5) into equation (4) yields:

$$(9)\ NG\ Savings = \frac{Output_{Conv}}{\eta_{conv}} \times EFLH - \frac{Output_{Conv} \times Comp}{\eta_{IR}} \times ELFH$$

Simplifying the relationships:

$$(10)\ NG\ Savings = Output_{Conv} \times EFLH \times (\frac{1}{\eta_{conv}} - \frac{Comp}{\eta_{IR}})$$

Multiplying through by $\frac{\eta_{IR}}{\eta_{IR}} \times \frac{Comp}{Comp}$ results in::

$$(11)\ NG\ Savings = Output_{Conv} \times EFLH \times (\frac{1}{\eta_{conv}} \times \frac{\eta_{IR}}{\eta_{IR}} \times \frac{Comp}{Comp} - \frac{\cancel{Comp}}{\cancel{\eta_{IR}}} \times \frac{\cancel{\eta_{IR}}}{\eta_{IR}} \times \frac{Comp}{\cancel{Comp}})$$

When this relationship is simplified, the equation results in:

$$(12)\ NG\ Savings = \frac{Output_{Conv} \times Comp}{\eta_{IR}} \times EFLH \times (\frac{\eta_{IR}}{\eta_{conv} \times Comp} - 1)$$

Substituting equation (7) into equation (12) to replace the conventional system output equals:

$$(13)\ NG\ Savings = \frac{Output_{IR}}{\eta_{IR}} \times EFLH \times (\frac{\eta_{IR}}{\eta_{conv} \times Comp} - 1)$$

Substituting equation (6) into equation (13) into the $Output_{IR}$ term results in:

$$(14)\ NG\ Savings = Input_{IR} \times EFLH \times (\frac{\eta_{IR}}{\eta_{conv} \times Comp} - 1)$$

Both sides of equation 14 are divided by the infrared heater input to get the natural gas savings factor, which is the annual natural gas energy savings rate, in m^3 natural gas savings per kBtu/hr input capacity of the IR heater:

$$NG\ Savings\ Factor = \frac{NG\ Savings}{Input_{IR}} = \frac{\cancel{Input_{IR}}}{\cancel{Input_{IR}}} \times EFLH \times (\frac{\eta_{IR}}{\eta_{conv} \times Comp} - 1)$$

Finally, the savings factor is divided by the heat content of natural gas to convert to savings on a volumetric basis:

$$NG\ Savings\ Factor = \frac{EFLH}{35.738 \frac{kBtu}{m^3}} \times (\frac{\eta_{IR}}{\eta_{Conv} \times Comp_{ss,ts}} - 1)$$

where,

$NG\ Savings\ Factor$	= Annual gas savings rate resulting from installing the new IR heater (m^3/yr/(kBtu/hr))
$EFLH$	= Equivalent full load hours of operation, Table 4
$35.738 \frac{kBtu}{m^3}$	= Conversion from Btu/hr to m^3/hr, common assumptions table

$Comp_{ss,ts}$ = Compensation factor for the IR heaters, where *ss* designates single stage or high intensity heaters, and *ts* indicates two-stage heaters (%), Table 4

η_{Conv} = Thermal efficiency of the conventional heater (%), Table 2

η_{IR} = Thermal efficiency of the infrared heater (%), Table 3

ELECTRIC ENERGY SAVINGS ALGORITHMS

The estimated electricity savings are grouped into three bins corresponding to heater capacity ranges. The savings are calculated using assumed fan power values that were estimated from values provided by several major manufacturers. Multiplying the fan power times the equivalent full load hours of operation calculates approximate annual electricity consumption.

$$Annual\ kWh\ Savings = EFLH \times (kW_{Conv} - kW_{IR})$$

Where,

$Annual\ kWh\ Savings$ = Annual electrical savings from installing the new IR heater (kWh)

kW_{Conv} = Conventional heater fan horsepower converted to kW, Table 4

$EFLH$ = Equivalent full load hours of operation, Table 4

kW_{IR} = IR heater fan horsepower converted to kW, Table 4

LIST OF ASSUMPTIONS

The IR system type is presumed to be direct-fired with combustion products vented to the outside.

Table 4 shows the list of assumptions utilized in the measure savings algorithms.

Table 4. Conversion Factors

Variable	Definition	Value		Source
$Comp_{ss,ts}$	Compensation factors	$Comp_{ss}$	0.85	[2] [4] [8]
		$Comp_{ts}$	0.83	
$EFLH$	Equivalent full load hours	1,500 hours		Common Assumptions Table
kW_{Conv}	Conventional fan kW draw	< 50 kBtu/hr	0.02 kW	[9]
		50 – 1650 kBtu/hr	0.19 kW	

Variable	Definition	Value		Source
		> 165 kBtu/hr	0.43 kW	
kW_{IR}	IR heater fan kW draw	< 50 kBtu/hr	0.02 kW	[9]
		50 – 165 kBtu/hr	0.04 kW	
		> 165 kBtu/hr	0.09 kW	

Savings Calculation Example

The following example shows how energy savings are calculated for a 100 kBtu/hr input single stage IR heater to be installed at 30 ft from floor in a new building starting with the calculation of the savings factor in Table 1.

$$NG\ Savings = \frac{1{,}500\ hours}{35.738 \frac{kBtu}{m^3}} \times \left(\frac{82\%}{80\% \times 85\%} - 1\right) = 8.64 \frac{m^3}{\frac{kBtu}{hr}}$$

The annual natural gas savings can be calculated as:

$$NG\ Savings = 8.64 \frac{m^3}{\frac{kBtu}{hr}} \times 100 \frac{kBtu}{hr} = 864\ m^3$$

The annual electrical savings can be calculated as:

$$Annual\ kWh\ Savings = 1{,}500\ hrs \times (0.19\ kW - 0.04\ kW) = 225\ kWh$$

Uses and Exclusions

To qualify for this measure the infrared heaters must be of a rated capacity less than 300 kBtu/hr.

Measure Life

The measure life attributed to this measure is 17 years [10].

Incremental Cost

The incremental cost is $9.47 CAD / (kBtu/hr IR input capacity) [11].

References

[1] Agviro, "Assessment of Average Infrared Heater Savings," 2004.

[2] ASHRAE, "HVAC Systems and Equipment, Chapter 16, page 1," 2012.

[3] SpaceRay, "Infrared Heating Engineering Manual," 11 2004. [Online]. Available: www.spaceray.com/pdf/infrared-heating_engineering-manual_0305.pdf. [Accessed 11 2013].

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COMMERCIAL INFRARED HEATERS - RETROFIT

DATE: 5/1/2015

TO: Ontario TEC Sub-committee

FROM: ERS

RE: Commercial Infrared Heaters: Retrofit

This section addresses the installation of infrared heaters in retrofit projects for commercial buildings. Sources used in the development of this measure include:

- Enbridge substantiation sheet provided by the TEC
- ASHRAE 2008 Handbook, Chapter 15
- Manufacturer SpaceRay's infrared heater engineering manual
- Buckley and Seel's 1988 infrared heater case study
- Natural Resources Canada website
- Infrared heater manufacturer websites
- Nexant DSM gas measure market characterization report

COMMERCIAL INFRARED (IR) HEATERS < 300 KBTU/HR – RETROFIT

Version Date and Revision History	
Draft date:	5/1/2015
Effective date:	TBD
End date:	TBD
Commercial→ Infrared Heater→ Retrofit	

Table 1 provides a summary of the key measure parameters with deemed savings coefficients.

Table 1. Measure Key Data

<table>
<tr><th>Parameter</th><th colspan="2">Definitions</th></tr>
<tr><td>Measure Category</td><td colspan="2">Retrofit</td></tr>
<tr><td>Base Technology</td><td colspan="2">Unit Heater</td></tr>
<tr><td>Efficient Technology</td><td colspan="2">Infrared Heater (Single-Stage, Two-Stage and High Intensity)</td></tr>
<tr><td>Market Type</td><td colspan="2">Commercial Space Heating</td></tr>
<tr><td rowspan="2">Annual Gas Savings Rate</td><td>Single-Stage and High Intensity</td><td>11.5 m³ per kBtu/hr of IR heater input capacity</td></tr>
<tr><td>Two-Stage</td><td>13.1 m³ per kBtu/hr of IR heater input capacity</td></tr>
<tr><td rowspan="4">Annual Electric Savings</td><td>Infrared Input Rating (kBtu/hr)</td><td>Electric Savings (kWh)</td></tr>
<tr><td>< 50</td><td>0 kWh</td></tr>
<tr><td>50 – 165</td><td>300 kWh</td></tr>
<tr><td>165 - 300</td><td>1,040 kWh</td></tr>
<tr><td>Measure Life</td><td colspan="2">17 years</td></tr>
<tr><td>Incremental Cost</td><td colspan="2">$25.50 CAD per kBtu/hr of IR heater input capacity</td></tr>
<tr><td>Restrictions</td><td colspan="2">The installed equipment must be less rated at less than 300 kBtu/hr</td></tr>
</table>

OVERVIEW

Natural gas fired infrared (IR) heaters use radiant tube emitters or ceramic/steel emitters (high intensity) as the body by which to transmit infrared energy and heat. Gas is burned to heat the emitter which radiates energy to the floor and other objects in the room.

IR heaters heat more efficiently than conventional forced air systems, such as unit heaters, for several reasons. First, they directly heat the objects in the space through infrared radiant energy, including the floor slab, which then radiate heat back into the air space. Because the people in the room are directly being heated, comfort levels can be achieved at a lower air temperature than with forced hot air systems.

Conventional systems heat the air flowing into the room but because heated air is less dense than the existing cool air, it rises to the ceiling and stratifies, gradually working its way down to the floor level. The floor slab and equipment act as heat sinks causing the ceiling level to be much warmer than the floor area. The result is that a forced hot air system needs to work harder than the infrared heater to heat the same space and IR heaters produce a more uniform space temperature by heating the floor and objects first.

Infrared heaters use smaller fans for the same rated capacity compared to a conventional system because conventional systems use fans to circulate the air through the space and infrared heaters use fans only to induce combustion draft.

Infrared heaters are significantly more efficient that conventional forced hot air systems because of differences in the way heat is distributed and additional losses associated with the forced hot air systems as discussed above. According to a study by Agviro, an infrared heater will have an input at full load of 85% its conventional counterpart for the same space heating capacity [1]. This is often referred to as the compensation factor [2]. The 2012 ASHRAE handbook states that IR heaters produce savings of at least 15% [3] based on a study performed by Buckley and Seel in 1988 that found savings to typically be between 15% and 20% [4]. Although some manufacturers claim performance of IR heaters to be dependent on mounting height, ASHRAE has found IR heater savings to be independent of mounting height.

There are three primary types of infrared heaters, single stage, high intensity, and two-stage. The operation of all three types is essentially the same, but high intensity heaters utilize materials such as ceramics that can withstand higher operating temperatures, and two-stage heaters have controls to optimize performance at two levels of output. Because of their controls, two stage heaters have better compensation factors then single stage or high intensity heaters.

APPLICATION

The measure covers the installation of infrared heaters in commercial settings. Infrared heaters are regulated by the CSA 2.35b standard, which requires that they convert at least 35% of the input fuel energy to radiant energy [5]. This is called the IR efficiency or the radiant efficiency and is not the same as thermal efficiency, which is a measure of the heating energy out over the fuel energy in. Thermal efficiency of an IR heater is higher than the radiant efficiency because the radiant efficiency does not include all heat delivered to the space, but only includes the radiant component. As such, thermal efficiency is used as the performance metric for savings calculations.

BASELINE TECHNOLOGY

Ontario Regulation 404/12 requires unit heaters to be manufactured with at least 80% thermal efficiency, which is assumed to be the baseline for the measure [6].

Table 2. Assumed Baseline Technology

Type	Efficiency
Conventional Unit Heater	80% Thermal Efficiency [6] [7]

EFFICIENT TECHNOLOGY

The efficient technology is an infrared heater.

Table 3. Efficient Technology for Infrared Heaters [1] [3] [4] [8]

Type	Compensation Factor	Thermal Efficiency
Infrared Heater Single-Stage and High Intensity	0.85	82%
Infrared Heater Two-Stages	0.83	82%

ENERGY IMPACTS

Natural gas savings are achieved through four mechanisms:

1. Objects are directly heated instead of the air around them.
2. Less air stratification for more uniform heating of the space.
3. Smaller fans and less stratification which reduces air infiltration changes.
4. Minor electricity savings because of the smaller fans in IR heaters compared to equally sized unit heaters or the blowers in forced hot air systems.

All of these factors are included in the compensation factor.

NATURAL GAS SAVINGS ALGORITHMS

The natural gas savings from installing an IR heater instead of a conventional unit heater can be calculated as a function of the compensation factor discussed in the measure overview and the thermal efficiencies assumed. This document is based on a compensation factor of 0.85 for single and high intensity and 0.83 for two-stage. The savings are directly proportional to the assumed effective full load hours of operation and the installed capacity of the equipment [2] [3] [4] [8].

The following is a derivation of the natural gas savings from installing an IR heater where,

$NG\ Savings$	= Natural gas savings from installing an IR heater (kBtu)
$NG\ Conv$	= Natural gas consumption of the conventional heater (kBtu)
$NG\ IR$	= Natural gas consumption of the IR heater (kBtu)
$EFLH$	= Equivalent full load hours (hrs)[1]
$Input, Output_{Conv}$	= Input/output of the conventional heater (kBtu/hr)
$Input, Output_{IR}$	= Input/output of the IR heater (kBtu/hr)
$Comp$	= Compensation factor for the IR heater (%)

$$(1)\ NG\ Savings = NG\ Conv - NG\ IR$$

$$(2)\ NG\ Conv = Input_{Conv} \times EFLH$$

$$(3)\ NG\ IR = Input_{IR} \times ELFH$$

Substituting equations (2) and (3) into equation (1) results in:

$$(4)\ NG\ Savings = Input_{Conv} \times EFLH - Input_{IR} \times ELFH$$

The natural gas inputs to the IR heater can be defines as:

$$(5)\ Input_{Conv} = \frac{Output_{Conv}}{\eta_{conv}}$$

$$(6) Input_{IR} = \frac{Output_{IR}}{\eta_{IR}}$$

The IR heater output is shown by the following relationship:

$$(7)\ Output_{IR} = Output_{Conv} \times Comp$$

Substituting equation (7) into equation (6):

$$(8) Input_{IR} = \frac{Output_{Conv} \times Comp}{\eta_{IR}}$$

Then, substituting equations (8) and (5) into equation (4) yields:

$$(9)\ NG\ Savings = \frac{Output_{Conv}}{\eta_{conv}} \times EFLH - \frac{Output_{Conv} \times Comp}{\eta_{IR}} \times ELFH$$

Simplifying the relationships:

[1] Note, that the EFLH is assumed to be equal for both conventional and the IR heaters.

$$(10)\ NG\ Savings = Output_{Conv} \times EFLH \times (\frac{1}{\eta_{conv}} - \frac{Comp}{\eta_{IR}})$$

Multiplying through by $\frac{\eta_{IR}}{\eta_{IR}} \times \frac{Comp}{Comp}$ results in::

$$(11)\ NG\ Savings = Output_{Conv} \times EFLH \times (\frac{1}{\eta_{conv}} \times \frac{\eta_{IR}}{\eta_{IR}} \times \frac{Comp}{Comp} - \frac{\cancel{Comp}}{\cancel{\eta_{IR}}} \times \frac{\cancel{\eta_{IR}}}{\eta_{IR}} \times \frac{Comp}{\cancel{Comp}})$$

When this relationship is simplified, the equation results in:

$$(12)\ NG\ Savings = \frac{Output_{Conv} \times Comp}{\eta_{IR}} \times EFLH \times (\frac{\eta_{IR}}{\eta_{conv} \times Comp} - 1)$$

Substituting equation (7) into equation (12) to replace the conventional system output equals:

$$(13)\ NG\ Savings = \frac{Output_{IR}}{\eta_{IR}} \times EFLH \times (\frac{\eta_{IR}}{\eta_{conv} \times Comp} - 1)$$

Substituting equation (6) into equation (13) into the $Output_{IR}$ term results in:

$$(14)\ NG\ Savings = Input_{IR} \times EFLH \times (\frac{\eta_{IR}}{\eta_{conv} \times Comp} - 1)$$

Both sides of equation 14 are divided by the infrared heater input to get the natural gas savings factor, which is the annual natural gas energy savings rate, in m^3 natural gas savings per kBtu/hr input capacity of the IR heater:

$$NG\ Savings\ Factor = \frac{NG\ Savings}{Input_{IR}} = \frac{\cancel{Input_{IR}}}{\cancel{Input_{IR}}} \times EFLH \times (\frac{\eta_{IR}}{\eta_{conv} \times Comp} - 1)$$

Finally, the savings factor is divided by the heat content of natural gas to convert to savings on a volumetric basis:

$$NG\ Savings\ Factor = \frac{EFLH}{35.738 \frac{kBtu}{m^3}} \times (\frac{\eta_{IR}}{\eta_{Conv} \times Comp_{ss,ts}} - 1)$$

where,

$NG\ Savings$	= Annual gas savings rate resulting from installing the new IR heater (m^3/yr/(kBtu/hr))
$EFLH$	= Equivalent full load hours of operation, Table 4
$35.738 \frac{kBtu}{m^3}$	= Conversion from kBtu/hr to m^3/hr, common assumptions table
$Comp_{ss,ts}$	= Compensation factor for the IR heaters, where *ss* designates single stage or high intensity heaters, and *ts* indicates two-stage heaters (%), Table 4
η_{Conv}	= Thermal efficiency of the conventional heater (%), Table 2
η_{IR}	= Thermal efficiency of the infrared heater (%), Table 3

ELECTRIC ENERGY SAVINGS ALGORITHMS

The estimated electricity savings are grouped into three bins corresponding to heater capacity ranges. The savings are calculated using assumed fan power values that were estimated from values provided by several major manufacturers. Multiplying the fan power times the effective full load hours of operation calculates approximate annual electricity consumption.

$$Annual\ kWh\ Savings = EFLH \times (kW_{Conv} - kW_{IR})$$

Where,

$Annual\ kWh\ Savings$ = Annual electrical savings from installing the new IR heater (kWh)

kW_{Conv} = Conventional heater fan horsepower converted to kW, Table 4

$EFLH$ = Equivalent full load hours of operation, Table 4

kW_{IR} = IR heater fan horsepower converted to kW, Table 4

LIST OF ASSUMPTIONS

The IR system type is presumed to be direct-fired with combustion products vented to the outside.

Table 4 shows the list of assumptions utilized in the measure savings algorithms.

Table 4. Conversion Factors

Variable	Definition	Value		Source
$Comp_{ss,ds}$	Compensation factors	$Comp_{ss}$	0.85	[3] [4] [8]
		$Comp_{ts}$	0.83	
$EFLH$	Equivalent full load hours	2,000 hours		Common Assumptions Table
kW_{Conv}	Conventional fan kW draw	< 50 kBtu/hr	0.02 kW	[9]
		50 – 165 kBtu/hr	0.19 kW	
		> 165 kBtu/hr	0.43 kW	
kW_{IR}	IR heater fan kW draw	< 50 kBtu/hr	0.02 kW	[9]
		50 – 165 kBtu/hr	0.04 kW	
		> 165 kBtu/hr	0.09 kW	

SAVINGS CALCULATION EXAMPLE

The following example shows how energy savings are calculated for a 100 kBtu/hr input single stage IR heater to be installed at 30 ft from floor in an existing warehouse starting with the calculation of the savings factor in Table 1.

$$NG\ Savings = \frac{2{,}000\ hours}{35.738\frac{kBtu}{m^3}} \times \left(\frac{82\%}{80\% \times 85\%} - 1\right) = 11.52\frac{m^3}{\frac{kBtu}{hr}}$$

The annual natural gas savings can be calculated as:

$$NG\ Savings = 11.52\frac{m^3}{\frac{kBtu}{hr}} \times 100\frac{kBtu}{hr} = 1{,}152\ m^3$$

The annual electrical savings can be calculated as:

$$Annual\ kWh\ Savings = 2{,}000\ hrs \times (0.19\ kW - 0.04\ kW) = 300\ kWh$$

USES AND EXCLUSIONS

To qualify for this measure the infrared heaters must be of a rated capacity less than 300 kBtu/hour.

MEASURE LIFE

The measure life attributed to this measure is 17 years [10].

INCREMENTAL COST

The incremental cost is $25.50 CAD / (kBtu/hr IR input capacity) [11].

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COMMERCIAL PRE-RINSE SPRAY NOZZLE - NEW CONSTRUCTION/TIME OF NATURAL REPLACEMENT

Version Date and Revision History	
Draft Date:	4/21/2015
Effective Date:	TBD
End Date:	TBD
Commercial → Pre-Rinse Spray Nozzle → New Construction/Time of Natural Replacement	

Table 1 below provides a summary of the key measure parameters, with deemed savings coefficients differentiated by facility type.

Table 1. Measure Key Data

Parameter	Definitions		
Measure Category	New Construction (NC)		
	Time of Natural Replacement (TNR)		
Base Technology	Standard Pre-Rinse Spray Nozzle/Valve supplied with hot water from natural gas fueled water heaters.	Flow rate of 6.1 liters/minute (1.6 GPM) or greater	
Efficient Technology	Low-Flow Pre-Rinse Spray Nozzles supplied with hot water from natural gas fueled water heaters.	Flow rate of 2.4 liters/minute (0.64 GPM) or less	
Market type	Commercial		
Annual Natural Gas Savings	Full Service Restaurant	472 m^3/year	
	Limited Service (Fast Food Restaurant)	92 m^3/year	
	Other	111 m^3/year	
Utilization and Water Savings	Full Service Restaurant	447.3 hours/year	97,529 Liter/year
	Limited Service (Fast Food Restaurant)	87.6 hours/year	19,100 Liters/year
	Other	105.6 hour/year	23,025 Liters/year

Parameter	Definitions
Measure Life	5 years
Incremental Cost	Utility to use actual per unit cost in the year when savings are claimed. Likewise, installation costs to be determined similarly, based on utility in-field experience.

OVERVIEW

Pre-rinse spray nozzles (PRSNs) are commonly utilized in commercial kitchens to remove food waste from dishes and cookware prior to cleaning in the dishwasher, using a pressurized flow of hot water. The nozzles are part of pre-rinse assemblies and typically consist of a spray nozzle, a squeeze handle actuator, an insulated grip, and a dish guard bumper.

Studies have concluded that PRSNs can account for up to 1/3 of the total water consumption in a typical commercial kitchen. [1]

APPLICATION

This measure provides incentives for installing low-flow PRSNs, designed to provide sustained levels of performance with reduced flow of hot water.

BASELINE TECHNOLOGY

The baseline technology for the purpose of calculating energy savings is a PRSN with flow rate of 1.6 GPM.

The 2005 EPAct legislation required all spray nozzles manufactured for sale in the United States to have flow rates of 1.6 GPM of less. While this legislation does not specifically pertain to Canadian sales, it does have an impact on the availability of new PRSNs in Ontario. Because the legislation has been in effect for a period of time exceeding the accepted measure life, it is reasonable to accept the 2005 EPAct standard as the baseline condition for all categories.

Table 2. Baseline PRSN Requirements

Type	Requirement
2005 EPAct compliant PRSN	Flow rate of 6.1 L/Minute (1.6 GPM)

EFFICIENT TECHNOLOGY

Low-flow PRSNs that meet the requirements as shown in Table 3 are supplied with hot water produced by natural gas fueled water heaters.

Table 3. Efficient PRSN Requirements

Type	Requirement
Low-Flow PRSN	Flow rate of 2.4 L/minute (0.64 GPM) or less

ENERGY IMPACTS

The primary energy impact associated with the installation of low–flow PRSN is natural gas savings associated with a reduction in hot-water consumption. Table 1 above provides deemed annual savings coefficients, differentiated by the type of facility.

Water consumption impacts are also provided in Table 1.

NATURAL GAS SAVINGS ALGORITHM

The measure savings are deemed based on the facility type and the values provided in Table 1.

The algorithm leading to the deemed savings values first calculates the reduction in water consumption, and then determines the natural gas savings attributable to this reduction. Equations leading the deemed savings values are as described below.

$$W_{savings} = \left(Flow_{baseline} - Flow_{efficient}\right) \times 60\frac{Minutes}{Hour} \times Utilization$$

where,

$W_{savings}$ = annual reduction in water consumption (liters/year)

$Flow_{baseline}$ = the defined baseline flow from Table 2. (liters/minute)

$Flow_{efficient}$ = the defined efficient flow from Table 3. (liters/minute)

$Utilization$ = the annual hours of utilization from Table 1 (hours/year)

The deemed annual natural gas savings is then calculated as:

$$NG_{savings} = W_{savings} \times \%_{hot} \times Cp_{water} \times (T_{out} - T_{in}) \times \frac{\frac{1}{Eff_{wh}}}{NG_{ec}}$$

where,

$NG_{savings}$ = annual natural gas savings (m^3/year)

$W_{savings}$ = annual reduction in water consumption calculated above (liters/year)

$\%_{hot}$ = % of total PRSN flow from hot water supply (69%)

Cp_{water} = specific heat of water (8.2 Btu/gal-°F)

T_{out} = average water heater set-point (140ºF, 60ºC)

T_{in} = average water heater inlet temperature (48.9ºF, 9.4°C,)

Eff_{wh} = average water heater recovery efficiency (78.7%)

NG_{ec} = Average energy content of natural gas (35,738 Btu/m^3)

LIST OF ASSUMPTIONS

The assumptions used to calculate the deemed savings coefficients are shown in Table 1.

Table 5. Assumptions List

Parameter	Value	Source/Comments
Utilization – Full Service Restaurants	447.3 hours / year	[2]
Utilization – Limited Service (Fast Food) Restaurants	87.6 hours / year	[2]
Utilization – Other	105. 6 hours / year	[2]
% Hot Water to Supplied to PRSN	69%	[2]
Specific Heat of Water (in applicable temperature range)	8.2 Btu/Gal-°F	[3]
Water Heater Inlet Water Temperature	9.4°C (48.9°F)	Common assumptions
Water Heater Set-Point	60°C (140°F)	Common assumptions
Water Heater Efficiency	78.7%	Common assumptions
Energy Content of Natural Gas	35,738 Btu/m3	Common assumptions

SAVINGS CALCULATION EXAMPLE

The example below illustrates how the deemed savings value is determined for a PRSN installed at a full service restaurant:

$$NG_{savings} = W_{savings} \times \%_{hot} \times Cp_{water} \times (T_{out} - T_{in}) \times \frac{\frac{1}{Eff_{wh}}}{NG_{ec}}$$

$$= \frac{97{,}529\,\frac{liters}{year}}{3.785\,\frac{liters}{gal}} \times 69\% \times 8.2\,\frac{Btu}{Gal - °F} \times (140°F - 48.9°F) \times \frac{\frac{1}{78.7\%}}{35{,}738\,\frac{Btu}{m^3}} = 472\,\frac{m^3}{year}$$

USES AND EXCLUSIONS

To qualify for this measure the PRSN must meet or exceed the minimum efficiency as defined in the above section "Efficient Technology." Service/Domestic hot water must be provided by a natural gas fueled water heater.

MEASURE LIFE

The measure life attributed to this measure is 5 years. [4] [5] [6]

INCREMENTAL COST

Table 6 presents the measure incremental cost.

Table 6. Measure Incremental Cost

Measure Category	Incremental Cost ($)
New Construction or Time of Natural Replacement	Utility to use actual per unit cost in the year when savings are claimed. Likewise, installation costs to be determined similarly, based on utility in-field experience.

REFERENCES

[1] US Environmental Protection Agency, "Pre-Rinse Spray Valve Field Study Report," US Environmental Protection Agency - WaterSense Program, Washington.

[2] Energy Profiles Ltd., "Deemed savings For (Low Flow) Pre-Rinse Nozzles," Energy Profiles Ltd., Ontario, 2009.

[3] Engineering Toolbox, "http://www.engineeringtoolbox.com/water-thermal-properties-d_162.htm," Engineering Toolbox, 2013.

[4] Energy Profiles Ltd., "Deemed savings For (LowFlow) Pre-Rinse Nozzles," Energy Profiles Ltd., Ontario, 2009.

[5] US Department of Energy, "How to Buy a Low-Flow Pre-Rinse Spray Valve," US Department of Energy, Federal Energy Management program, Washington.

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Commercial Pre-Rinse Spray Nozzle – Retrofit/Early Replacement

DATE: 4/21/2015

TO: Ontario TEC Committee

FROM: ERS

RE: Pre-Rinse Spray Nozzle – Retrofit/Early Replacement

This TRM section is based on review and validation of information provided in two separate substantiation sheets describing the Pre-Rinse Spray Nozzle (PRSN) measure. The most significant discrepancy in the information provided by the two substantiation sheets[1] is the flow rate associated with the baseline PRSN, with one sheet reflecting 11.4 liters / minute (3.0 GPM), while the other reflects 6.1 liters / minute (1.6 GPM).

Review of related literature by ERS revealed compliance with the 2005 EPAct legislation requires that new PRSNs have flow rates of 6.1 L/Minute (1.6 GPM) or less. While compliance with this US legislation does not apply to units purchased in Ontario, it does influence the manufacture and availability of units, and it is therefore reasonable to use this value as the baseline for *New Construction* and *Time of Natural Replac*ement category types. Also, because this legislation has been in effect for longer than the accepted measure life of 5 years, it is also reasonable to apply this value to the *Retrofit* and *Early Replacement* categories.

[1] EB-2011-0295 Exhibit B, Tab 2, Page 231-237

COMMERCIAL PRE-RINSE SPRAY NOZZLE – RETROFIT/EARLY REPLACEMENT

Version Date and Revision History	
Draft Date:	4/21/2015
Effective Date:	TBD
End Date:	TBD
Commercial → Pre-Rinse Spray Nozzle→ Retrofit/Early Replacement	

Table 1 below provides a summary of the key measure parameters, with deemed savings coefficients differentiated by facility type.

Table 1. Measure Key Data

Parameter	Definitions		
Measure Category	Retrofit (R)		
	Early Replacement (ER)		
Base Technology	Standard Pre-Rinse Spray Nozzle/Valve supplied with hot water from natural gas fueled water heaters.	Flow rate of 6.1 liters/minute (1.6 GPM) or greater	
Efficient Technology	Low-Flow Pre-Rinse Spray Nozzles supplied with hot water from natural gas fueled water heaters.	Flow rate of 2.4 liters/minute (0.64 GPM) or less	
Market type	Commercial		
Annual Natural Gas Savings	Full Service Restaurant	472 m^3/year	
	Limited Service (Fast Food Restaurant)	92 m^3/year	
	Other	111 m^3/year	
Utilization and Water Savings	Full Service Restaurant	447.3 hours/year	97,529 Liters/year
	Limited Service (Fast Food Restaurant)	87.6 hours/year	19,100 Liters/year
	Other	105.6 hour/year	23,025 Liters/year
Measure Life	5 years		
Incremental Cost	Utility to use actual per unit cost in the year when savings are claimed. Likewise, installation costs to be determined similarly, based on utility in-field experience.		

OVERVIEW

Pre-rinse spray nozzles (PRSNs) are commonly utilized in commercial kitchens to remove food waste from dishes and cookware prior to cleaning in the dishwasher, using a pressurized flow of hot water. The nozzles are part of pre-rinse assemblies and typically consist of a spray nozzle, a squeeze handle actuator, an insulated grip, and a dish guard bumper.

Studies have concluded that PRSNs can account for up to 1/3 of the total water consumption in a typical commercial kitchen. [1]

APPLICATION

This measure provides incentives for installing low-flow PRSNs, designed to provide sustained levels of performance with reduced flow of hot water.

BASELINE TECHNOLOGY

The baseline technology for the purpose of calculating energy savings is a PRSN with flow rate of 1.6 GPM.

The 2005 EPAct legislation required all spray nozzles manufactured for sale in the United States to have flow rates of 1.6 GPM of less. While this legislation does not specifically pertain to Canadian sales, it does have an impact on the availability of new PRSNs in Ontario. Because the legislation has been in effect for a period of time exceeding the accepted measure life, it is reasonable to accept the 2005 EPAct standard as the baseline condition for all categories.

Table 2. Baseline PRSN Requirements

Type	Requirement
2005 EPAct compliant PRSN	Flow rate of 6.1 L/Minute (1.6 GPM)

EFFICIENT TECHNOLOGY

Low-flow PRSNs that meet the requirements as shown in Table 3 are supplied with hot water produced by natural gas fueled water heaters.

Table 3. Efficient PRSN Requirements

Type	Requirement
Low-Flow PRSN	Flow rate of 2.4 L/minute (0.64 GPM) or less

Energy Impacts

The primary energy impact associated with the installation of low–flow PRSN is natural gas savings associated with a reduction in hot-water consumption. Table 1 above provides deemed annual savings coefficients, differentiated by the type of facility.

Water consumption impacts are also provided in Table 1.

Natural Gas Savings Algorithm

The measure savings are deemed based on the facility type and the values provided in Table 1.

The algorithm leading to the deemed savings values first calculates the reduction in water consumption, and then determines the natural gas savings attributable to this reduction. Equations leading the deemed savings values are as described below.

$$W_{savings} = \left(Flow_{baseline} - Flow_{efficient}\right) \times 60\frac{Minutes}{Hour} \times Utilization$$

where,

$W_{savings}$	= annual reduction in water consumption (liters/year)
$Flow_{baseline}$	= the defined baseline flow from Table 2. (liters/minute)
$Flow_{efficient}$	= the defined efficient flow from Table 2. (liters/minute)
$Utilzation$	= the annual hours of utilization from Table 1 (hours/year)

The deemed annual natural gas savings is then calculated as:

$$NG_{savings} = W_{savings} \times \%_{hot} \times Cp_{water} \times (T_{out} - T_{in}) \times \frac{\frac{1}{Eff_{wh}}}{NG_{ec}}$$

where,

$NG_{savings}$	= annual natural gas savings (m^3/year)
$W_{savings}$	= annual reduction in water consumption calculated above (liters/year)
$\%_{hot}$	= % of total PRSN flow from hot water supply (69%)
Cp_{water}	= specific heat of water (4,186 Joules/Kg-ºC)
T_{out}	= average water heater set-point (60ºC, 140ºF)

T_{in} = average water heater inlet temperature (9.4ºC, 48.9ºF)

Eff_{wh} = average water heater recovery efficiency (78.7%)

NG_{ec} = Average energy content of natural gas (35.7MJ/m^3)

LIST OF ASSUMPTIONS

The assumptions used to calculate the deemed savings coefficients are shown in Table 1.

Table 5. Assumptions List

Parameter	Value	Source/Comments
Utilization – Full Service Restaurants	447.3 hours / year	[2]
Utilization – Limited Service (Fast Food) Restaurants	87.6 hours / year	[2]
Utilization – Other	105. 6 hours / year	[2]
% Hot Water to Supplied to PRSN	69%	[2]
Specific Heat of Water (in applicable temperature range)	8.2 Btu/Gal - ºF	[3]
Water Heater Supply Water Temperature	9.4°C (48.9 ºF)	Common assumptions
Water Heater Set-Point	60°C (140 ºF)	Common assumptions
Water Heater Efficiency	78.7%	Common assumptions
Energy Content of Natural Gas	35,738 Btu/m^3	Common assumptions

SAVINGS CALCULATION EXAMPLE

The example below illustrates how the deemed savings value is determined for a PRSN installed at a full service restaurant:

$$NG_{savings} = W_{savings} \times \%_{hot} \times Cp_{water} \times (T_{out} - T_{in}) \times \frac{\frac{1}{Eff_{wh}}}{NG_{ec}}$$

$$= \frac{97{,}529\,\frac{liters}{year}}{3.785\,\frac{liters}{gal}} \times 69\% \times \frac{Btu}{Gal - °F} \times (140°F - 48.9°F) \times \frac{\frac{1}{78.7\%}}{35{,}738\,\frac{Btu}{m^3}} = 472\,\frac{m^3}{year}$$

USES AND EXCLUSIONS

To qualify for this measure the PRSN must meet or exceed the minimum efficiency as defined in the above section "Efficient Technology." Service/Domestic hot water must be provided by a natural gas fueled water heater.

MEASURE LIFE

The measure life attributed to this measure is 5 years. [4] [5] [6]

INCREMENTAL COST

Table 5 presents the measure incremental cost by measure category.

Table 6. Measure Incremental Cost

Measure Category	Incremental Cost ($)
Retrofit or Early Replacement	Utility to use actual per unit cost in the year when savings are claimed. Likewise, installation costs to be determined similarly, based on utility in-field experience.

REFERENCES

[1] US Environmental Protection Agency, "Pre-Rinse Spray Valve Field Study Report," US Environmental Protection Agency - WaterSense Program, Washington.

[2] Energy Profiles Ltd., "Deemed savings For (LowFlow) Pre-Rinse Nozzles," Energy Profiles Ltd., Ontario, 2009.

[3] Engineering Toolbox, "http://www.engineeringtoolbox.com/water-thermal-properties-d_162.htm," Engineering Toolbox, 2013.

[4] Energy Profiles Ltd., "Deemed savings For (Low Flow) Pre-Rinse Nozzles," Energy Profiles Ltd., Ontario, 2009.

[5] US Department of Energy, "How to Buy a Low-Flow Pre-Rinse Spray Valve," US Department of Energy, Federal Energy Management program, Washington.

[6] Quantec, "Comprehensive Assessment of Demand-side Resource Potentials," Pudget Sound Energy, Seattle, 2007-2008.

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RESIDENTIAL PROGRAMMABLE THERMOSTATS RETROFIT

DATE: 5/21/2015

TO: Ontario TEC Committee

FROM: ERS

RE: Programmable Thermostats

In May 2014, ERS recommended that the subcommittee not commission subdocument development on programmable thermostats based on preliminary research finding low savings potential, as reflected in ENERGY STAR's product termination due to low evaluated savings and relatively high naturally occurring adoption in Canada[1] and further suggested new investigation regarding adaptive and web-enabled thermostat measure. ERS essentially repeated the recommendation early in July.[2] Later that month the subcommittee noted that the programmable thermostat is an active measure for Union Gas and therefore needs to be kept on the subdoc list[3], then requested expedited analysis on the relevance (or not) of the measure in August.[4] As a result a memo was written by ERS citing research on programmable thermostats savings.[5] The TEC subcommittee requested that this subdocument be drafted.

[1] Memorandum from ERS to subcommittee, Questions regarding supporting information for measures in development, Part 1, May 6, 2014.
[2] Email from Jon Maxwell to Marc Hull-Jacquin, July 14, 2014.
[3] Email from Marc Hull-Jacquin, July 24, 2014.
[4] Email from Marc Hull-Jacquin, August 15, 2014.
[5] Memorandum from ERS to subcommittee, September 08, 2014.

PROGRAMMABLE THERMOSTATS

Version Date and Revision History	
Draft date	5/21/2015
Version history	v.1
Effective date	TBD
End date	N/A
Residential → Programmable Thermostats → Retrofit	

Table 1 provides a summary of the key measure parameters with a deemed savings coefficient.

Table 1. Measure Key Data

Parameter	Definition
Measure category	Retrofit (R)
Baseline technology	Nonprogrammable thermostat
Efficient technology	Programmable thermostat with at least two programming modes (weekday and weekend)
Market type	Residential
Annual natural gas savings	Natural gas savings = 46 m^3
Measure life	15 years
Incremental cost	$68
Restrictions	None

OVERVIEW

Residential home heating and cooling system thermostats maintain temperature in the spaces by either turning equipment on and off as necessary or modulating the systems to address the heating and cooling loads. Setting the temperatures back when residences are unoccupied or the residents are sleeping presents a significant potential for savings, as it reduces heat loss and allows the heating and cooling systems to operate for shorter periods of time.

APPLICATION

This measure is for the installation of a programmable thermostat in the residential homes in place of nonprogrammable thermostats. Because the 2012 Ontario Building Code requires programmable thermostats in new construction homes this measure is applicable for retrofits only.

BASELINE TECHNOLOGY

The baseline for this measure is a manual thermostat.

EFFICIENT TECHNOLOGY

The efficient technology is a programmable thermostat with at least two programming modes for weekdays and weekends. The thermostat should already have pre-programmed modes from the manufacturer.

ENERGY IMPACTS

Natural gas savings are achieved due to the heating system having to heat at a lower temperature during the evening and unoccupied hours.

There is a small amount of electrical savings for this measure for homes with AC systems. Based on RECS data for the Northeast United states and the TMY3 data for London, Ontario, the cooling hours are very limited for this measure, especially during setback periods.

NATURAL GAS SAVINGS ALGORITHMS

The approach used to calculate savings is to:

(1) Estimate the annual average natural gas heating energy used in Ontario homes.

(2) Calculate the theoretical technical savings potential based on a switch from a fixed setpoint to a programmed night setback, expressed as a percentage of annual heating energy use;

(3) Develop one behavioral factor to discount savings due to the fact that some manual thermostat owners manually reduce their setpoint at night or during unoccupied daytime periods;

(4) Develop a second behavior factor to discount savings due to the fact that some programmable thermostat owners do not program their thermostats as aggressively as the technical savings potential assumes; and

(5) Combine the factors to estimate annual natural gas savings.

Home Energy Use

Enbridge load research data provides estimates of annual natural gas use of existing non-multifamily family homes with natural gas furnaces by furnace type (high, mid and conventional efficiency).[6] [1] The market share of each furnace type is known from Enbridge's 2013 Residential Market Survey. [2] Unknown furnace types were distributed using known furnace type weighting. Based on this data the weighted average (column A * column C) Enbridge space heating single family natural gas use is 2,077 m³/yr.

Table 2. Enbridge Existing Single Family Home Space Heating Gas Use[7] [2] [1]

Furnace Type, by Efficiency	Average Consumption for Furnace Type (m^3) From 2012 Load Research Report (A)	% Furnace Type from 2008 Residential Survey (B)	% Furnace Type Adjusted to Exclude Unknown (C)
High	1,916	52%	61%
Mid	2,248	27%	32%
Conventional	2,698	6%	7%
Unknown		15%	
Weighted Average Consumption / Total %	2,077	100%	100%

Union Gas analysis of a sample of 50 homes found average natural gas use for space heating of 2,315 m^3/yr. [3]

Based on a 60/40 share of customers for Enbridge and Union, respectively [4], the weighted average single family residential home energy use for space heating in Ontario is 2,172 m^3/yr.

Theoretical Technical Savings Potential

A common rule of thumb for thermostat setback savings is 1.8% of annual heating energy use per degree C (1% per degree F) for an 8 hour per night setback adjustment. [8] [5] [6]. The most

[6] Natural gas forced air furnaces comprise approximately 90% of the residential space heating market in Enbridge Service territory. For the purposes of this substantiation document, it is assumed that furnace energy usage is representative of the 10% that use non-furnace gas heating systems.

[7] The "high" and "mid" annual energy use data comes from the Enbridge Gas Distribution Load Research-Strategy, Research and Planning group load research data as presented in Figure 1 of *Enbridge Load Research Newsletter* June 2012. The furnace type population distribution data comes from Residential Market Survey Data 2013, produced for Enbridge Gas Distribution by TNS, slide 41, weighted. Subsequent columns of data are calculated.

[8] This savings fraction can be supported through simple analysis of hourly weather data. Many articles on program thermostat savings potential directly or indirectly cite a 1978 study *Energy Savings through Thermostat Setbacks*, Nelson, Lorne W. and J. Ward MacArthur (1978), ASHRAE Transactions, Volume 83, AL-78-1 (1): 319-333. The article itself was not readily accessible, but the referenced University of Alberta document summarizes it well. The archived but accessible ENERGY STAR programmable thermostat calculator uses this same rule of thumb in citing "Industry data (2004)" and using s 3% savings per degree per 24 hours of reduction, the same as 1% per 8 hours. https://www.energystar.gov/ia/partners/promotions/cool_change/downloads/CalculatorProgrammableThermostat.xls.

common presumption for technical savings potential is 8°F setback. Therefore the technical savings potential is 8%.

Behavior Factor – Baseline

The theoretical technical savings potential is based on the thermostat being set to a constant temperature. Field studies and telephone surveys have found that some residents with manual thermostats set them back at night. This reduces the technical savings potential. Two studies focused on this particular factor and found 44% [7] and 66% [8] of users do this. A third study found that residents with manual thermostats actually set back their temperature 1.49 hours per week more often than those with programmable thermostats, leading to about a (3%) realization rate.[9] [9] The authors speculate that the reason for this is due to factors such as being able to pre-heat the home before awaking with a programmable thermostat. Two of the studies do not quantify the number of degrees of setback. Data from the third study indicates a median of 4 to 5 degrees of night setback for those that manually do so. [7]

If the three values are averaged 71% of the theoretical technical potential is lost due to pre-retrofit behavior mimicking the desired post-retrofit behavior. We discounted this baseline penalty factor by 1/3 based on the professional judgment that the referenced studies did not all directly compare before and after setpoints. We expect that on average both the systematic benefits of programmability and the likelihood of additional degrees of setback when programmed result in some additional savings even for those that previously manually set back their thermostats.

$$Pre-retrofit\ savings\ behavior\ discount\ factor = \left(\frac{44\% + 66\% + 103\%}{3}\right) \times \frac{2}{3} = 47\%$$

where,

Pre-retrofit savings behavior discount factor	= savings reduction due to manual energy efficient behavior such as manual setback in the pre-retrofit case

Behavior Factor – Post-Retrofit

A number of studies have found that programmable thermostat owners do not configure setpoints in such a way that they will achieve the nominal 8% savings presented in the technical potential section. Quantifications of this phenomenon are listed below for programmable thermostat owners and space heating controls:

- 53% set them in “hold mode”[10] [10]
- 38% do not use them to reduce temperature at night[11] [11]

[9] 1.49 hr. /week / (8 hr. /day * 7 days/wk.) nominal presumed extra setback hours per week per technical potential basis = 3%.

[10] Carrier study of 35,471 programmable thermostats in the territories of LIPA, Con Edison, SCE, and SDG&E as cited in [10].

- 60% on hold (low income-specific)[12] [10]
- Unquantified impact due to poor usability of conventional programmable thermostats.[13] [10]

Preprogramming of thermostats helps and was an ENERGY STAR requirement when the label existed, [12] but the majority of owners reprogram or otherwise override the settings from their factory settings. Averaging these three values is a representation of the percentage of savings not realized because of programmable thermostats being used as fixed manual thermostats. The average is 50%. $Post-retrofit\ savings\ behavior\ discount\ factor = \left(\frac{53\%+38\%+60\%}{3}\right) = 50\%$

where,

Pre-retrofit savings behavior discount factor = savings reduction due to inadequate use of the control features of a programmable thermostat

Savings Calculations

Using the behavior adjustment values estimated above and applying them to the theoretical savings, the total savings fraction is 2.1%:

$$Annual\ savings\ fraction = 8\% \times (100\% - 47\%) \times (100\% - 50\%) = 2.1\%$$

For comparison below are findings from prior studies regarding overall savings:

- 0% difference in setpoints on average[14] [13]
- 0% effect on net unit energy consumption (UEC) [15] [14]
- (18%) savings[16]
- 6.8% savings[17] [15]

---

[11] Based on total US homes participating in RECS survey.

[12] Based on on-site inspections of low income residences finding 45% on hold, 30% programmed, and 25% off, not visible, or reported as nonprogrammable (small sample).

[13] Six different studies are cited in Meier, 2010.

[14] "Respondents with programmable thermostats report thermostat setpoints that are not substantially different from those of respondents with manual thermostats"

[15] "Essentially zero," per *Three-Block Regression Analysis Regarding Effects of Programmable Thermostats on Setpoint Behavior and Electric Central Air/Gas Heat UECs*. Prepared for Southern California Edison by Athens Research. 2005, as cited in Dyson, 2005.

[16] It must be noted that this analysis did normalize for home physical characteristics and weather but did not adjust for any characteristic behavioral differences between those with and without programmable thermostat. *Programmable Thermostats Installed into Residential Buildings: Predicting Energy Saving Using Occupant Behavior & Simulation*, prepared for Southern California Edison by James J. Hirsch & Associates. 2004, as cited and described in Dyson, 2005.

- 3.6% savings[18]

Once the annual average residential usage is determined, the annual energy savings due to programmable thermostats (NG Savings, in m^3), are as follows:

$$NG\ Savings = ARSH \times Annual\ savings\ fraction$$

LIST OF ASSUMPTIONS

Table 3 provides a list of assumptions utilized in the measure savings algorithms to derive the stipulated savings values listed in Table 1 above. The algorithms are provided in the following section.

Table 3. General Assumptions

Definition	Inputs	Source/Comments
Annual average residential household space heating natural gas use	2,172 m^3	From utilities surveys and billing analysis (blended value between utilities) as described in the Home Energy Use section above
Annual savings fraction	2.1%	Calculated above

SAVINGS CALCULATION EXAMPLE

The savings for this measure is calculated as follows:

$$NG\ Savings = ARSH \times Annual\ savings\ fraction$$

$$NG\ Savings = 2{,}172\ {}^{m^3}/_{year} \times 2.1\% = 46\ {}^{m^3}/_{year}$$

[17] This report's recommended results are contrary to the others. It is oft-cited and is based on a relatively robust method: Pre- and post-retrofit billing analysis with participants and a nonparticipant control group, with subsequent adjustment and normalization for the presence of other measures, home size, and other factors. The authors used several methods before settling on the preferred one that resulted in the 6.8% savings. One reviewer observed that an alternate approach presented in the report that used a participation indicator (the reviewer's preference) and led to significantly lower savings of 1.7% to 1.8%. For this commentary see Cadmus et al, 2012. [19]

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USES AND EXCLUSIONS

This measure requires that the thermostat have two programming modes for weekday and weekend.

MEASURE LIFE

The measure life for this measure is 15 years. [16]

INCREMENTAL COST

The cost of a programmable thermostat is $68. [16]

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RESIDENTIAL – 95% OR HIGHER EFFICIENCY FURNACE – NEW CONSTRUCTION/TIME OF NATURAL REPLACEMENT

Version Date and Revision History	
Draft date	06/19/2015
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Effective date	TBD
End date	N/A
Residential → Condensing Furnace with Efficiency of 95% or Higher → New Construction/Time of Natural Replacement	

Table 1 below provides a summary of the key measure parameters, with a deemed savings coefficients.

Table 1. Measure Key Data

Parameter	Definitions
Measure Category	New Construction (NC) Time of Natural Replacement
Base Technology	90% AFUE
Efficient Technology	95% AFUE
Market Type	Residential
Annual Natural Gas Savings Factor	1.05 m^3 per $kBtu/hr_{input}$
Measure Life	18 years
Incremental Cost	$528
Restrictions	Installed equipment must have at least a 95% AFUE. This measure is restricted to central air furnaces in residential homes.

OVERVIEW

The measure is for the installation of condensing furnaces with an AFUE of 95% or higher in new residential homes. Condensing gas furnaces achieve savings through the utilization of a sealed, super insulated combustion chamber, more efficient burners, and multiple heat exchangers that remove a significant portion of the waste heat from the flue gasses. As the heat exchangers remove waste heat from the flue gases, the gases condense and the resulting condensate must be drained.

The deemed savings from this measure are calculated utilizing the algorithm and the associated variables presented in the "Natural Gas Savings Algorithm" section.

APPLICATION

The measure is for the installation of condensing furnaces which have efficiencies that are higher than the code requirement for new homes. Residential furnaces (units with capacity of up to 225 kBtu/hr input) are performance rated by their annual fuel utilization efficiency or AFUE. This is a measure of the seasonal performance of the equipment and is more comprehensive than combustion or thermal efficiency measurements.

BASELINE TECHNOLOGY

Canada's Energy Efficiency Regulations require that new residential furnaces have at least a 90% rated annual fuel utilization efficiency (AFUE) [1] [2]. For new construction installations, the baseline technology is considered to be the minimum efficiency required by the regulations established December 31, 2009.

Table 2. Baseline Technology

Type	AFUE
Gas Condensing Furnace	90%

EFFICIENT TECHNOLOGY

The efficient technology is a furnace with an AFUE rating equal to, or higher than 95%. This is the minimum efficiency for an ENERGY STAR furnace in Canada, effective February 1, 2013.

Table 3. Efficient Technology

Type	AFUE
Gas Condensing Furnace	95%

ENERGY IMPACTS

The primary energy impact associated with the installation of condensing furnaces is a reduction in natural gas usage resulting from improved efficiency.

No water consumption or electric energy impacts are associated with this measure.

NATURAL GAS SAVINGS ALGORITHMS

The annual gas savings factor is calculated in the formula below using an assumption for the equivalent full load hours (EFLH), derived by Caneta Research Inc, and the difference in assumed efficiencies for the equipment. The annual natural gas savings for a given size furnace can be calculated by multiplying the rated input of the furnace times the savings factor[1].

The deemed natural gas savings factor attributed to this measure is calculated using the following formula:

$$NG\ savings\ factor = \frac{EFLH}{35.738\,\frac{kBtu}{m^3}} \times \left(\frac{AFUE_{EE}}{AFUE_{base}} - 1\right)$$

where,

$NG\ savings\ factor$	= Annual gas savings factor resulting from installing the new furnace (m^3/yr)/(kBtu/hr)
$EFLH$	= Equivalent full load hours (hrs/yr), see Table 4
$35.738\,\frac{kBtu}{m^3}$	= Conversion of rated heating capacity from input kBtu/hr to m3/hr, common assumptions table
$AFUE_{EE}$	= Efficient equipment AFUE (%), see Table 3
$AFUE_{base}$	= Baseline equipment AFUE (%), see Table 2

ELECTRIC ENERGY SAVINGS

The Ontario Building Code requires that all furnaces installed in new construction homes with permit pull dates after December 31, 2014 use brushless direct current motors (also known as electronically commutated motors, or ECMs). Such motors are significantly more efficient than traditional permanent split capacitor (PSC) type motors. With this code elevation, there is no electricity savings associated with the ECMs often installed with new condensing furnaces [3].

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[1] The Regulations are defined based on Btu/hr of gas input and residential boilers and most commercial heating equipment are also rated based on input capacity. Note that some residential furnace manufacturers rate the capacity based on Btu/hr output. For example, spot checks of manufacturer literature in August 2014 found that Trane, and Bryant publish furnace capacity based on output; Carrier and Rheem list input capacity. Increase the deemed savings by 5% if output capacity is the basis.

List of Assumptions

The assumptions used to calculate the deemed savings coefficient are shown in Table 4.

Table 4. Assumptions

Variable	Definition	Inputs	Source
$EFLH$	Equivalent full load hours	675 hours[2]	[4] based on the average London (Ontario) home

Savings Calculation Example

The example below shows how to calculate gas savings achieved from installing one condensing furnace with a rated input of 110 kBtu/hr. First the calculation of the savings factor is shown and then the calculation of the annual natural gas savings is shown from the savings factor.

$$NG\ savings\ factor = \frac{675\ hours}{35.738 \frac{kBtu}{m^3}} \times \left(\frac{95\%}{90\%} - 1\right) = \frac{1.05\ m^3}{\frac{kBtu}{hr}}$$

And,

$$Annual\ NG\ savings = \frac{1.05\ m^3}{\frac{kBtu}{hr}} \times 110 \frac{kBtu}{hr} = 115\ m^3$$

Uses and Exclusions

To qualify for this measure the condensing furnaces must be gas-fired, have an AFUE of at least 95%, and be installed in a residential home.

Measure Life

The measure life attributed to this measure is 18 years [5] [6]. Expert opinions and studies cited by NRCAN are 15, 18, and 20 years [7]. The ASHRAE handbook states that most heat exchangers have a design life of 15 years and the design life of commercial heating equipment is about 20 years [8]

Incremental Cost

The measure incremental cost is $528, based on the average difference in incremental cost between 90 AFUE and 95 AFUE residential furnaces. The cost estimate is based on

[2] Based on New Construction homes only. See reference 3 for details.

data from a 2011 Northeast Energy Efficiency Partnership EM&V Forum-sponsored study on incremental costs [9] and was escalated by 12.5% to account for four years of inflation and converted to Canadian dollars.

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SHOWERHEADS

Version Date and Revision History	
Draft date	2/16/2015
Effective date	TBD
End date	TBD
Residential/Low-Income → Water Heating →Low flow showerheads→ New Construction/Retrofit	

Table 1 provides a summary of the key measure parameters, with deemed savings values based on the efficient technology.

Table 1. Measure Key Data

Parameter	Definitions	
Measure category	New Construction Retrofit	
Base technology	2.5 gpm	
Efficient technology	1.5 gmp	
	1.25 gpm	
Market type	Residential	
Annual natural gas savings per showerhead	***Efficient Technology***	***Savings***
	1.25 gpm	55 m^3
	1.5 gpm	44 m^3
Annual water savings per showerhead	1.25 gpm	14,363 L
	1.5 gpm	9,875 L
Measure life	10 years	
Incremental cost	Utility to use actual per showerhead cost in the year when savings are claimed. Likewise, installation costs to be determined similarly, based on utility in-field experience.	

OVERVIEW

Hot water heating represents a large share of the energy consumption in homes. One of the simplest ways to reduce hot water heating costs is to reduce the amount of hot water use. Installing low flow showerheads can have a noticeable impact on a residence's hot water consumption. The savings that can be achieved are attractive since this measure is relatively inexpensive and easy to implement.

Low flow showerheads restrict the flow of the water while maintaining the water pressure.

APPLICATION

This measure pertains to the implementation of low flow showerheads in single-family residential homes.

BASELINE TECHNOLOGY

The baseline technology is a showerhead with a flow of 2.5 gpm. [1]

EFFICIENT TECHNOLOGY

The efficient technology is a low-flow showerhead with a flow rate of 1.5 gpm or lower.

ENERGY IMPACTS

The primary energy impact associated with implementation of low-flow showerheads is a reduction in natural gas resulting from a reduction in the hot water consumption. Table 1 in the "Overview" section provides deemed annual savings values (m^3 of natural gas) per showerhead.

There is an additional reduction in water consumption associated with this measure.

NATURAL GAS SAVINGS ALGORITHM

Natural Gas

This algorithm outlines a methodology to determine the energy consumption as a function of a showerhead's rated flow-rate. It is based on the methodology developed by Navigant Consulting using data from a SAS statistical billing analysis study with the specific purpose of determining the impact of low-flow showerheads in Ontario.

The SAS study [2] analyzed the gas consumption in Enbridge territory over the course of two years for 178 households which included a control group, a low-flow group, and a treatment group which had high-flow showerheads in the first year of the study. After a year into the study, showerheads in the treatment group were replaced with low-flow fixtures of 1.25 gpm.

The study resulted in two groups of savings: homes with showerheads that had pre-existing showerheads with full-on flow rates, or nominal/rated flow rates, between 2.0 gpm to 2.5 gpm and homes with showerheads with full-on flow rates greater than 2.5 gpm.

The full-on flow rate groups in the SAS sample and their associated savings levels are shown in Table 2:

Table 2. Savings from SAS Study [2] [3]

Rated Flow Rate	Average of Rated Flow Rates (gpm)[1]	Nominal Rated Flow of Low Flow Showerhead (gpm)	Nominal Flow Reduction (gpm)	Annual Savings (m^3)[2]	Annual Savings Per Nominal GPM Flow Reduction (m^3/gpm)
2.0 to 2.5 gpm	2.40	1.25	1.15	46.4	40.3
>2.5 gpm	3.09	1.25	1.84	87.8	47.7

The average reduction in annual natural gas use is 44.0 m^3 per gpm reduction in rated showerhead flow rate. Using this relationship, the gas savings can be calculated for any combination of baseline and high efficiency showerheads, if rated flow rate is known.

$$Annual\ energy\ savings\left(\frac{m^3}{yr}\right) = 44\ \frac{\frac{m^3}{yr}}{gpm} \times\ (baseline\ rated\ gpm - high\ efficiency\ gpm)$$

WATER SAVINGS

The water savings were calculated using the following algorithm:

$$Savings = Ppl \times Sh \times 365 \times T \times \left(Fl_{base} - Fl_{eff}\right) \times 3.79\frac{L}{gal} \times PSA$$

Where,

$Savings$	= Annual savings in liters
Ppl	=Number of people per household
Sh	= Showers per capita per day
365	= Days per year
T	= Showering time (minutes)
Fl_{base}	= As-used flow rate with base equipment (GPM) – Calculated from equation from Summit Blue Study
Fl_{eff}	= As-used flow rate with efficient equipment (GPM) – Calculated from equation from Summit Blue Study
PSA	=Proportion of showerhead activity in residences affected by replacement (in order to adjust the water savings to account for residences with multiple showerheads)

[1] The average flow rate used here is from actual bag tested flow rate data provided by Enbridge Gas for the corresponding year of the SAS study (2007). [3]

[2] The savings presented here are from a SAS study, which analyzed consumption of households over two years, beginning in 2007. [2]

Fl_{base} and Fl_{eff} are the "as-used" flow rate. The nominal flow-rate is the flow the showerhead will deliver at full flow at 80 psi. However, based on Enbridge flow rate bag test data, the flow for installed fixtures varies from the rated flow rate of the showerhead. [3] [4] [5].

The following regression based on a study in 443 California homes of+ weighted regression analysis of as-used flow compared to full-on flow rate:

$$As - Used\ Flow\ Rate^{3} = 0.542 \times Nominal\ Flow\ Rate + 0.691\ [4]$$

Where,

$As - Used\ Flow\ Rate$ = Actual flow of installed showerhead

$Nominal\ Flow\ Rate$ = Rated flow listed on the showerhead

List of Assumptions

Table 7 provides a list of constants and assumption used in the derivation of the deemed water savings values.

Table 7. Constants and Assumptions

Assumption	Value	Source
Average person per single detached house (2006)	3	Common assumptions table
Showers per capita per day	0.75	[4]
Proportion of showerhead affected by replacement (PSA)	76%	[4]
Average showering time per day per showerhead (minutes)	7.6 minutes	[4]

Savings Calculation Example

The scenario for the gas savings is as follows. A showerhead will be replaced with a 1.5 gpm showerhead for a single family residence.

Natural Gas Savings

Using the equation above for the replacement of a baseline 2.5 gpm showerhead with a 1.5 gpm showerhead,

$$Annual\ energy\ savings\ (m^3/yr)\ = 44\ \frac{m^3/yr}{gpm} x\ (baseline\ rated\ gpm - high\ efficiency\ gpm)$$

$$Annual\ energy\ savings\ (m^3/yr\ )\ = 44\ \times\ (2.5 - 1.5)$$

[3] The lower limit of this equation is 1.25 gpm due to water pressure limitations. As the showerhead flow rate is reduced, the full-on flow will approach the as-used flow since as there is a limit to the acceptable flow-rate. [4] As such, the algorithm assumes that a showerhead with a full-on flow rate of 1.25 gpm also has an as-used flow of 1.25 gpm. Actual flow rates lower that 1.25 gpm can be assumed to result in longer showers, negating additional savings.

$$Annual\ energy\ savings = 44\frac{m^3}{yr}$$

Water Savings

$$Savings = 3.0\frac{people}{residence} \times 0.75\frac{\frac{showers}{person}}{day} \times 7.6\frac{mins}{shower} \times 365\frac{days}{year} \times \left(2.05\ \frac{gallons}{min}\ -\ 1.5\ \frac{gallons}{min}\right) \times 3.785\frac{liters}{gal} \times 76\%\ showerheads\ affected\ in\ each\ residence = 9{,}875\frac{liters}{year}$$

USES AND EXCLUSIONS

To qualify for this measure, low-flow showerheads must be implemented in residential homes.

MEASURE LIFE

The measure life attributed to this measure is 10 years. [4]

INCREMENTAL COST

The incremental cost for this measure could not be determined by looking at big-box retailer data. The driver for higher cost of fixtures is the available features of the showerheads. However, the previous substantiation sheet based the incremental cost on bulk purchases by the utility for program implementation. Since the incremental cost of the measure in the previous substantiation sheet is based on actual cost to the utility, it is the most accurate data. This method is consistent with other TRMs.

Table 8 presents the measure incremental cost.

Table 8. Measure Incremental Cost

Measure Category	Incremental Cost ($)
All measure categories	Utility to use actual per showerhead cost in the year when savings are claimed. Likewise, installation costs to be determined similarly, based on utility in-field experience.

REFERENCES

[1] "Ontario Building Code Act, 1992; Regulation 350/06," Service Ontario, e-Law, Ontario, 1992.

[2] L. Rothman, "SAS PHASE II Analysis for Enbridge Gas Distribution Inc.: Estimating the

Impact of Low-Flow Showerhead Installation," SAS Institute Canada, Toronto, 2010.

[3] Enbridge Gas Ltd. , *Bag Test Benchmarking Research.*

[4] Barkett, Brent; Cook, Gay, "Resource Savings Values in Selected Residential DSM Prescriptive Programs," Summit Blue, Ontario, 2008.

[5] O. Drolet, "Showerheads/Aerators Flow Rate Validation," Natural Gas Technologies Centre, Ontario, 2007.

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TANKLESS GAS WATER HEATERS – NEW CONSTRUCTION/TIME OF NATURAL REPLACEMENT – DOMESTIC HOT WATER

Version Date and Revision History	
Draft date	12/4/2014
Version history	v. 1
Effective date	TBD
End date	N/A
Residential->Tankless Water Heater -> New Construction Residential->Tankless Water Heater -> Time of Natural Replacement	

Table 1 provides a summary of the key measure parameters and deemed savings coefficients.

Table 1. Measure Key Data

Parameter	Definition
Measure category	New Construction (NC)
	Time of Natural Replacement (TNR)
Baseline technology	Storage Water Heater, EF = 0.67
Efficient technology	High Efficiency Non-Condensing Tankless Water Heater, EF = 0.82
	Condensing Tankless Water Heater, EF = 0.91
Market type	Residential
Annual energy savings	High Efficiency Non-Condensing Tankless: 88.7 m^3
	Condensing Tankless: 127.9 m^3
Measure life	20 years
Incremental cost	High Efficiency Non-Condensing Tankless = $1,611
	Condensing Tankless = $2,039
Restrictions	This measure applies to the installation of natural gas tankless water heaters in residential buildings.

OVERVIEW

The measure consists of the installation of natural gas tankless water heaters for domestic hot water production in residential buildings. Natural gas tankless water heaters are available in both condensing and non-condensing models.

Tankless, also called instantaneous or on-demand, water heaters provide hot water without using a storage tank. There is nominal "storage", ranging from 2-10 gallons within the heat exchanger, but this represents 5% or less of the storage tank capacity associated with equivalent storage water heaters. The reduced storage capacity results in the need for higher capacity burners to generate the flow of hot water necessary to serve equivalent peak loads. This translates to higher equipment and installation costs for these units.

The algorithm and the associated variables are presented in the section "Natural Gas Savings Algorithm".

APPLICATION

This measure provides incentives for installing tankless natural gas water heaters in residential buildings for the new construction and TNR measure categories.

Tankless water heaters are performance rated differently depending on their size. Those above 250 kBtu/hr are rated for their thermal efficiency and those below 250 kBtu/hr are rated for their energy factor (EF). The EF is an average daily efficiency that includes all standby or storage losses, while thermal efficiency is a short term measure of the equipment's performance that includes flue losses but no other losses. Residential water heaters are typically smaller than 250 kBtu/hr.

BASELINE TECHNOLOGY

The residential water heater minimum efficiency requirement varies as a function of the prescriptive compliance path chosen from those offered in the Ontario Building Code Supplemental Standard SB-12, Table 2.1.1.2.A. [1] ENERGY STAR rated power vented storage water heaters are considered baseline because experience indicates that prescriptive paths that use this energy factor specification is a popular choice amongst Ontario new homebuilders today in order to comply with code. [2] [3] [4]. A gas storage water heater with a minimum EF to qualify for ENERGY STAR is shown in Table 2 and is assumed to be the baseline in New Construction and TNR installations.

Table 2. Baseline Gas Storage Water Heater

Type	Minimum Energy Factor (EF)
Gas storage water heaters	0.67

Efficient Technology

The high efficiency technology is a natural gas fueled tankless water heater with minimum rated EFs in Table 3. 0.82 is the minimum EF allowable for ENERGY STAR eligibility, which also is the minimum required for Union and Enbridge program incentive eligibility as of October 2014 [4]. 0.91 is the minimum rated EF of a condensing tankless water heater from the Natural Resources Canada (NRCan) list of available products. [5] Both non-condensing and condensing units are eligible for this measure.

Table 3. High Efficiency Water Heater Minimum Efficiency Requirements

Type	Minimum EF
Tankless gas water heater	0.82
Condensing Tankless gas water heater	0.91

Energy Impacts

Natural gas savings are achieved as a result of the higher overall average efficiencies of the tankless units and elimination of storage or standby losses.

There is no water consumption impact associated with this measure and the electric impacts are negligible. Condensing units typically require electricity for powered venting. The baseline in Ontario also is power vented so there is no associated electric energy impact with venting. Some condensing units require small condensate pumps that run for a few minutes a day but this electricity use is not significant.

Natural Gas Savings Algorithms

The deemed natural gas savings are calculated using the algorithms below, which are based on EFs and the average annual DHW heating load. The average annual DHW heating load is derived from a study of hot water use conducted by NRCan, Union Gas, and Caneta Research Inc. who metered a sample of residential hot water heaters in Ontario [6].

$$Annual\ NG\ Savings\ = \frac{DHWload}{35.738\frac{kBtu}{m^3}} \times (\frac{1}{EF_{baseline}} - \frac{1}{EF_{EE}})$$

and,

$$DHWload = dailyDHW \times 365\frac{days}{yr} \times \rho \times C_p \times (T_s - T_c)/1{,}000$$

where,

$Annual\ NG\ Savings$ = Annual natural gas saving (m^3), see Table 1

$DHWload$	= Annual domestic hot water heating load (kBtu), calculated
$35.738\frac{kBtu}{m^3}$	= Conversion from kBtu to m^3 natural gas
$EF_{baseline}$	= The assumed baseline storage water heater EF, see Table 2
EF_{EE}	= The assumed tankless water heater EF, see Table 3
$dailyDHW$	= The average daily Canadian DHW consumption (US Gallons), see Table 4
$365\frac{days}{yr}$	= Days in a year
ρ	= Density of water (lb/US gallon), see Table 4
C_p	= Specific heat of water (Btu/lb/°F), see Table 4
T_s	= Average temperature of DHW (°F), see Table 4
T_c	= Average temperature of city supply water (°F), see Table 4

ELECTRIC PENALTY ALGORITHMS

ELECTRIC IMPACTS ARE NEGLIGIBLE FOR THIS MEASURE

ASSUMPTIONS

Table 4 provides a list of assumptions utilized in the measure savings algorithms to derive the deemed savings values listed in Table 1 above.

Table 4. General Assumptions

Variable	Definition	Inputs	Source/Comments
$dailyDHW$	The average daily DHW consumption	54 US Gallons	NRCan, Union Gas, and Caneta Research Inc. [6]
ρ	Density of water	1 Btu/lb/°F	Common assumptions table
C_p	Specific heat of water	8.28 lb/US Gal	Common assumptions table
T_s	Temperature of DHW water	48.9 °C (120 °F)	Common assumptions table
T_c	Temperature of city supply water	9.3 °C (48.9 °F)	Common assumptions table

SAVINGS CALCULATION EXAMPLE

The example below illustrates how the deemed savings were calculated.

The annual domestic hot water heating load can be calculated using the average daily household DHW consumption in Canada.

$$DHWload = 54\ \frac{US\ Gal}{day} \times 365\frac{days}{yr} \times 1\frac{Btu}{lb°F} \times 8.28\frac{lb}{US\ gal} \times (120\ °F - 48.9\ °F)/1000$$
$$= 11{,}608\ kBtu/yr$$

The natural gas savings for a non-condensing tankless water heater can then be calculated from the difference in equipment efficiencies as:

$$Deemed\ Natural\ Gas\ Savings\ = \frac{11{,}608\ kBtu/yr}{35.738\frac{kBtu}{m^3}} \times \left(\frac{1}{0.67} - \frac{1}{0.82}\right) = 88.7\ m^3/yr$$

And the natural gas savings for a condensing tankless water heater can be calculated similarly as:

$$\boldsymbol{Deemed\ Natural\ Gas\ Savings\ = \frac{11,608\ kBtu/yr}{35.738\frac{kBtu}{m^3}} \times \left(\frac{1}{0.67} - \frac{1}{0.91}\right) = 127.9\ m^3/yr}$$

USES AND EXCLUSIONS

Natural gas-fueled tankless water heaters installed in residential buildings qualify for this measure. The measure type must be new construction or TNR.

MEASURE LIFE

The measure life is 20 years [7].

INCREMENTAL COST

The incremental cost is $1,611 for a non-condensing tankless water heater and $2,039 for a condensing tankless water heater. [8] [9].

REFERENCES

[1] "Building Code Act 1992 - Supplementary Standard SB-12," Ministry of Municipal Affairs and Housing, 15 Mar 2013. [Online]. Available: http://www.mah.gov.on.ca/Asset10095.aspx?method=1. [Accessed 10 Oct 2014].

[2] Sustainable Housing Foundation, *2012 Building Code,* pg 6, 2012.

[3] L. Brydon, *Codes, Standards and Rating Systems: A Path to Sustainability,* pg 34: Reliance, 2009.

[4] Energy Star, "Residential Water Heaters Key Product Criteria," 2014. [Online]. Available: http://www.energystar.gov/index.cfm?c=water_heat.pr_crit_water_heaters. [Accessed 10 Oct 2014].

[5] Natural Resources Canada, "Energy Efficiency Ratings: Search, Water Heaters, Tankless," [Online]. Available: http://oee.nrcan.gc.ca/pml-lmp/index.cfm?action=app.search-recherche&appliance=WATERHEATER_T. [Accessed 4 December 2014].

[6] e. a. M. Thomas, "More Info on Hot Water Use In Canada," ACEEE Hot Water Forum 2010. [Online]. Available: https://www.aceee.org/files/pdf/conferences/hwf/2010/3D_Martin_Thomas.pdf. [Accessed 23 July 2014].

[7] Schonbauer, "Tankless Water Heaters: Do They Really Save Money?," Minnesota Center for Energy and Enviornment, Minneapolis, MN, 2012.

[8] CPUC, "Database for Energy Efficient Resources (DEER)," California Public Utilities Commission, March 5, 2014. [Online]. Available: www.deerresources.com. [Accessed 23 June 2014].

[9] Caneta Research Inc., "Canadian Residential Water Heater Market Assessment Final Report," Ministry of Energy Mines and Petroleum, March 31, 2009.

COMMERCIAL SPACE HEATING – AIR CURTAINS- NEW CONSTRUCTION/RETROFIT

DATE: 11/9/2015

TO: Ontario TEC Committee

FROM: ERS

RE: Air Curtains

The following TRM measure covers the use of air curtains in commercial space heating applications. We have reviewed the documentation provided to us by the TEC, and have verified the accuracy of the engineering algorithms and reasonableness of the assumptions. In addition, we have researched the references provided and have investigated and referenced additional sources of information.

The presented method is a simplified approach using commonly recognized relationships and parameters to accommodate industry standard marketing practice. The estimated energy savings is the difference between the heat lost or gained through the doorway prior to and after installing an air curtain. Five scenarios are evaluated based on available incentives [1]: single doorway, double doorway, and three different sized shipping and receiving doorways. This method uses average outdoor and indoor temperature conditions and average wind velocities associated with the Ontario service territory. The methodology utilizes assumptions that have been adopted by ASHRAE and allows for an estimate of average savings, and the adoption of a reasonable deemed value.

AIR CURTAINS – NEW CONSTRUCTION/RETROFIT

Version Date and Revision History	
Draft date	11/9/2015
Version history	v.1
Effective date	TBD
End date	N/A
Commercial → Space Heating/Cooling → New Construction→ Air Curtains Commercial → Space Heating/Cooling → Retrofit → Air Curtains	

Table 1 provides a summary of the key measure parameters with a deemed savings coefficient.

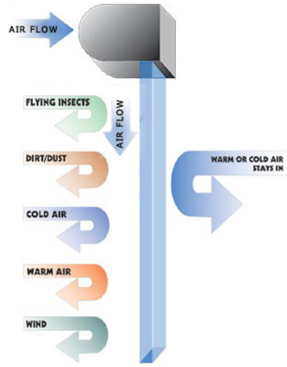
Table 1. Measure Key Data

<table>
<tr><th>Parameter</th><th colspan="9">Definition</th></tr>
<tr><td>Measure category</td><td colspan="9">New Construction/Retrofit</td></tr>
<tr><td>Baseline technology</td><td colspan="9">No air curtain or vestibule</td></tr>
<tr><td>Efficient technology</td><td colspan="9">Air curtain that meets the minimum standards of the Air Movement and Control Association International, Inc. (AMCA)</td></tr>
<tr><td>Market type</td><td colspan="9">Retail, office, and institutional buildings</td></tr>
<tr><td rowspan="3">Annual natural gas savings (m³)</td><td colspan="3">Single Door</td><td colspan="3">Double Door</td><td colspan="3">Shipping and Receiving</td></tr>
<tr><td>7’x3’</td><td>7’x6’</td><td>8’x6’</td><td>2x7’x3’</td><td>2x7’x6’</td><td>2x8’x6’</td><td>8’x8’</td><td>8’x10’</td><td>10’x10’</td></tr>
<tr><td>671</td><td>1,343</td><td>1,622</td><td>1,343</td><td>2,686</td><td>3,243</td><td>12,108</td><td>15,135</td><td>20,796</td></tr>
<tr><td>Annual electricity penalty (kWh)</td><td>137</td><td>78</td><td>58</td><td>273</td><td>156</td><td>115</td><td>613</td><td>1,997</td><td>1,597</td></tr>
<tr><td>Measure life</td><td colspan="9">15 years</td></tr>
<tr><td>Restrictions</td><td colspan="9">This measure is restricted to exterior doors without vestibules in buildings with natural gas heating</td></tr>
<tr><td rowspan="10">Incremental Cost</td><th colspan="4">Air Curtain Type</th><th colspan="5">Approximate Cost</th></tr>
<tr><td colspan="2" rowspan="3">Single door</td><td colspan="2">7’x3’</td><td colspan="5">$1,000</td></tr>
<tr><td colspan="2">7’x6’</td><td colspan="5">$1,400</td></tr>
<tr><td colspan="2">8’x6’</td><td colspan="5">$1,500</td></tr>
<tr><td colspan="2" rowspan="3">Double door</td><td colspan="2">2 x 7’ x 3’</td><td colspan="5">$2,000</td></tr>
<tr><td colspan="2">2 x 7’ x 6’</td><td colspan="5">$2,800</td></tr>
<tr><td colspan="2">2x8’x6’</td><td colspan="5">$3,000</td></tr>
<tr><td colspan="2" rowspan="3">Shipping and receiving</td><td colspan="2">8’ x 8’</td><td colspan="5">$3,500</td></tr>
<tr><td colspan="2">8’ x 10’</td><td colspan="5">$3,500</td></tr>
<tr><td colspan="2">10’ x 10’</td><td colspan="5">$4,500</td></tr>
</table>

OVERVIEW

Air Curtains are typically mounted above doorways and separate indoor and outdoor environments with a stream of air strategically engineered to strike the floor with a particular velocity and position. This air flow prevents outdoor air infiltration (heat, moisture, dust, fumes, insects), while also permitting an unobstructed entryway for pedestrians or goods. Figure 1 illustrates the schematic design for a typical air curtain installation.

Figure 1: Air Curtain Installation[1]



The anticipated savings from this measure will be calculated as a deemed amount of energy savings under heating and cooling conditions for five scenarios; single door, double door, and three different sized shipping and receiving doors. Natural gas savings are calculated using an engineering algorithm and are reported in meters cubed (m^3). Electric savings are calculated using an engineering algorithm and are reported in kilowatt hours (kWh).

Baseline Technology

There are no code standards that require air curtains in Ontario. This may change in the future[2] but the current baseline is a doorway without an air curtain, as shown in Table 2.

Table 2. Baseline Air Curtain

Scenario	Requirement
All	Exterior doorway without vestibule or air curtain

Efficient Technology

Air curtains that meet the requirements as shown in Table 3:

[1] Illustration downloaded from http://www.mitzvahengg.com/Non_Re_Circulating_Air_Curtains.htm on 10/14/2014.

[2] A code change proposal, CE192-13, toward the 2015 International Energy Conservation Code (IECC) was approved at the ICC (Group B) Committee Action Hearings in Dallas on April 27, 2013 and approved at the Final Action Hearings in Atlantic City in October 2013. [2] This standard provides an exception to the requirement for a vestibule if, "Doors that have an air curtain with a minimum velocity of 2 m/s at the floor, have been tested in accordance with ANSI/AMCA 220 and installed in accordance with manufacturer's instructions. Manual or automatic controls shall be provided that will operate the air curtain with the opening and closing of the door. Air curtains and their controls shall comply with Section C408.2.3." [3]

Table 3. Efficient Air Curtain Requirements

Scenario	Requirement
All	Air Curtain that has been tested in accordance with ANSI/AMCA 220 [2]

ENERGY IMPACTS

The primary energy impact associated with the installation of air curtains is a reduction in natural gas usage or electricity resulting from reduced infiltration of cold air or hot air that needs to be heated or cooled when it enters a building. Table 1 provides deemed annual savings coefficients, differentiated by door type.

There is an electric penalty associated with the addition of an air curtain due to the curtain's fan. For air conditioned spaces the reduced air conditioning load is greater than the increased electricity use to operate the air curtain. For spaces without mechanical cooling there is a small electric usage penalty. No water consumption impacts are associated with this measure.

NATURAL GAS SAVINGS ALGORITHMS

Natural gas energy savings are achieved by determining the difference between heat lost at a doorway before and after the addition of an air curtain during the heating season.

$$Annual\ NG\ Savings = \frac{(q_{bc} - q_{ac})}{35.74\ kBtu/m^3} \times HR \times \frac{day_{hs}}{Eff}$$

where,

q_{bc} = Rate of transfer of sensible heat through open doorway (kBtu/hr)

q_{ac} = Rate of transfer of sensible heat through air curtain (kBtu/hr)

HR = Hour per day that door is open, see Table 4

day_{hs} = Heating days per year, see Table 4

Eff = Boiler or furnace heating system efficiency, see Table 4

<u>Heat Transfer at Doorway without Air Curtain for Heating Season</u>:

$$q_{bc} = \frac{1.08\ Btu/(hr \bullet F \bullet CFM) \times Q_A \times (t_{ih} - t_{oh})}{1{,}000}$$

where,

Q_A = Total air flow entering doorway (cfm)

t_{ih} = Inside temperature during heating season (°R), see Table 4

t_{oh} = Outside temperature during heating season (°R), see Table 4

Total air entering doorway is the combination of that caused by wind and thermal forces [3]:

$$Q_A = \sqrt{{Q_w}^2 + {Q_t}^2}$$

To determine the air entering doorway due to wind forces, the following equation is used [3]:

$$Q_w = V_h \times H \times W \times C_v \times 88\ fpm/mph$$

where,

Q_w = Air flow entering doorway due to wind forces (cfm)

V_h = Wind velocity during heating season (mph), see Table 4

H = Height of doorway (ft), see Table 4

W = Width of doorway (ft), see Table 4

C_v = Effectiveness of openings, see Table 4

Air entering doorway due to thermal forces can be calculated as [3]:

$$Q_t = 60\ sec/min \times H \times W \times C_{dh} \times \sqrt{2 \times g \times {}^{H}/_{2} \times \left({}^{(t_{ih} - t_{oh})}/_{t_{ih}}\right)}$$

where,

Q_t = Air flow entering doorway due to thermal forces (cfm)

C_{dh} = Discharge coefficient for opening during heating season (C_{dh} is assumed to be 0.65 for unidirectional flow)

$$C_{dh} = 0.4 + 0.0025 \times (t_{ih} - t_{oh})$$

$$C_{dh} = 0.4 + 0.0025 \times (531.67 - 492.97) = 0.5$$

g = Constant acceleration due to gravity (ft/sec^2), see Table 4

<u>Heat Transfer at Doorway with Air Curtain for Heating Season</u>:

Air curtain effectiveness [4]:

$$q_{ac} = q_{bc} \times (1 - E)$$

where,

E = Air curtain effectiveness (%), see Table 4

ELECTRICITY SAVINGS ALGORITHMS

Electricity savings is achieved by determining the reduced air conditioning load during the summer season less the increased electricity use by the air curtain's fan.

$$Electricity\ Savings\ (\frac{kWh}{hr}) = \left(\frac{(q_{tbc} - q_{tac})}{EER} - (HP \times 0.7457)\right) \times HR \times day_{cs}$$

where,

q_{tbc} = Rate of transfer of total heat through open doorway (kBtu/hr)

q_{tac} = Rate of transfer of total heat through air curtain (kBtu/hr)

EER = Energy efficiency ratio of cooling unit (kBtu/kWh), see Table 4

HP = Air curtain fan electric input power (hp), see Table 4

0.7457 = Unit conversion factor, brake horsepower to electric power (kW/HP)

HR = Hour per day that door is open, see Table 4

day_{cs} = Cooling days per year, see Table 4

<u>Heat Transfer at Doorway without Air Curtain for Cooling Season</u>:

Calculating air flow through the doorway during the cooling season is similar to calculating it for the heating season, but the formula is enthalpy-based instead of dry bulb temperature-based to account for humidity-related load.

Total heat transfer without air curtain:

$$q_{tbc} = \frac{4.5 \times Q_A \times (h_{oc} - h_{ic})}{1{,}000}$$

where,

4.5 = 60 min/hr x 0.075 lb_m/ft^3 density of dry air ($lb\text{-}min/ft^3\text{-}hr$)

Q_A = Same formula as for heating

h_{oc} = Average enthalpy of outside air (Btu/lb)

h_{ic} = Average enthalpy of inside air (Btu/lb)

The values for average wind velocity and the inside and outside air temperatures to calculate Q_A differ as noted in Table 4. Also, C_d for cooling is derived per the following equation, rather than deemed:

C_{dc} = Discharge coefficient for opening during cooling season

$$C_{dc} = 0.4 + 0.0025 \times (t_{ic} - t_{oc})$$

$$C_{dc} = 0.4 + 0.0025 \times (536.87 - 531.67) = 0.41$$

t_{ic} = Inside temperature during cooling season (˚R), see Table 4

t_{oc} = Outside temperature during cooling season (˚R), see Table 4

Heat transfer with the air curtain is as with heating:

$$q_{tac} = q_{tbc} \times (1 - E)$$

LIST OF ASSUMPTIONS

Table 4 provides a list of assumptions utilized in the measure savings algorithm to derive the stipulated savings values listed in Table 1 above.

Table 4. General Assumptions

<table>
<tr><th rowspan="2">Variable</th><th rowspan="2">Definition</th><th colspan="7">Scenario</th><th rowspan="2">Source/Comments</th></tr>
<tr><th colspan="3">Single Door</th><th>Double Doors</th><th colspan="3">Shipping and Receiving</th></tr>
<tr><td>t_{ih}</td><td>Inside temperature for heating season</td><td colspan="7">72°F (22.2˚C)
(531.67˚R)</td><td>Common assumptions table, room setpoint</td></tr>
<tr><td>t_{oh}</td><td>Outside air temperature during heating season</td><td colspan="7">33.3°F (0.7˚C)
(492.97˚R)</td><td>Common assumptions table</td></tr>
<tr><td>t_{ic}</td><td>Inside temperature for cooling season</td><td colspan="7">72°F (22.2˚C)
(531.67˚R)</td><td>Common assumptions table, room setpoint</td></tr>
<tr><td>t_{oc}</td><td>Outside air temperature during cooling season</td><td colspan="7">77.2°F (25.1˚C)
(536.87˚R)</td><td>Common assumptions table</td></tr>
<tr><td>h_{ic}</td><td>Inside enthalpy for cooling season</td><td colspan="7">22.7 Btu/lb</td><td>Common assumptions table</td></tr>
<tr><td>h_{oc}</td><td>Outside enthalpy for cooling season</td><td colspan="7">27.4 Btu/lb</td><td>Common assumptions table</td></tr>
<tr><td>H</td><td>Door height (ft)</td><td>7</td><td>7</td><td>8</td><td>8</td><td>8</td><td>10</td><td>10</td><td>[1]</td></tr>
<tr><td>W</td><td>Door width (ft)</td><td>3</td><td colspan="2">6</td><td>2 x 6</td><td>8</td><td>8</td><td>10</td><td>[1]</td></tr>
<tr><td>HR</td><td>Hour per day door is open</td><td colspan="4">1</td><td colspan="3">5.6</td><td>[5] [6][3],[4]</td></tr>
<tr><td>HP</td><td>Air curtain horsepower</td><td colspan="3">1</td><td>1</td><td>1.5</td><td>3</td><td>3</td><td>[7][5]</td></tr>
<tr><td></td><td>Wind Direction</td><td colspan="7">Diagonal</td><td>Common assumptions table</td></tr>
</table>

[3] Based on an average of warehouse, retail, and grocery store door opening 35% of the way estimated at 5 seconds per opening and approximately 2,000 openings per day. Baseline data approximated from cited reference.

[4] Based on an average of grocery and retail space openings at 5.6 deliveries per day at 60 minutes per delivery. Baseline data approximated from cited reference.

[5] Assumes motor efficiency and load factor are the same, so that nameplate rated output brake horsepower and running input electric power are the same.

Variable	Definition	Scenario			Source/Comments
		Single Door	Double Doors	Shipping and Receiving	
V_h	Average wind velocity for heating season	2.2 mph (3.5 kph)			[8] - Calculated using the wind profile law for the center of the doorway reduced by 25% due to diagonal wind
V_c	Average wind velocity for cooling season	1.8 mph (2.9 kph)			[8] – Calculated using the wind profile law for the center of the doorway reduced by 25% due to diagonal wind
C_{dh}	Discharge coefficient for opening during heating season	0.5			[3]
C_{dc}	Discharge coefficient for opening during cooling season	0.41			[3]
C_v	Effectiveness of openings	0.3			[3] - Assume diagonal wind[6]
E	Effectiveness of air curtain	70% (Range between 60% - 80%)			[4]
Eff	Heating system efficiency	80%			Common assumptions table
EER	Energy Efficiency Ratio for Cooling Unit	9.5 kBtu/kWh			Common assumptions table
g	Acceleration due to gravity	32.2 ft/sec^2 (9.8 mps)			Common assumptions table
c_p	Specific heat of air	1.4			Common assumptions table
	Conversion from mph to fpm	88 fpm/mph			Common assumptions table
	Conversion from Btu to m^3	35.74 kBtu/m^3			Common assumptions table
	Conversion from HP to kWh	0.7457 kW/HP			Common assumptions table
day_{hs}	Heating days per year	232			Common assumptions table
day_{cs}	Cooling days per year	30		0	Common assumptions table

[6] The flow through the inlet will depend on orientation of the doorway; the flow is maximized when the inlet is directly facing the prevailing wind. Wind blowing perpendicularly, directly into a door will result in a Cv of 0.5 to 0.6. Wind blowing diagonally into it will result in a Cv of 0.25 to 0.35. Wind blowing across a doorway will result in lesser Cv due to entrainment, as will the negative pressure on a doorway on the leeward side of a building.

The analysis assumes that the air curtain fan is only on during the heating season for uncooled spaces.

SAVINGS CALCULATION EXAMPLE

The example below illustrates the deemed annual natural gas savings value for a retail space with a single door (6'x8') entrance.

During the heating season it will save gas:

$$Air\ flow\ rate\ Q_A\ from\ wind\ and\ thermal\ forces\ before\ air\ curtain$$

$$= \sqrt{(V_h \times H \times W \times C_v \times 88)^2 + (60 \times H \times W \times C_{dh} \times \sqrt{2 \times g \times {}^{H}\!/_{2} \times \left({}^{(t_{ih} - t_{oh})}\!/_{t_{ih}}\right)})^2}$$

$$= \sqrt{(2.2 \times 8 \times 6 \times 0.3 \times 88)^2 + \left(60 \times 8 \times 6 \times 0.5 \times \sqrt{2 \times 32.2 \times ({}^{8}\!/_{2}) \times \left({}^{(531.67 - 492.97)}\!/_{531.67}\right)}\right)^2}$$

$$Q_A = 6{,}830 cfm$$

$$Heat\ loss\ before\ air\ curtain = \ q_{bc} = \frac{1.08\ \times Q_A \times (t_{ih} - t_{oh})}{1{,}000}$$

$$= \frac{1.08 \times 6{,}830 \times (72 - 33.3)}{1{,}000} = 285\ kBtu/h$$

$$q_{ac} = q_{bc} \times (1 - E) == \ 285\ \times (1 - 0.7) = 86\ kBtu/h$$

$$Annual\ NG\ Savings = \frac{(q_{bc} - q_{ac})}{35.74} \times HR \times \frac{day_{hs}}{Eff} = \frac{(285 -\ 86)}{35.74} \times 1 \times \frac{232}{0.80}\ = 1{,}622\ m3$$

It will also have a negative electric savings due to fan operation:

$$Annual\ Electric\ Impact, Heating\ Season\ = -HP \times 0.7457\ \times HR \times day_{hs}$$

$$= 1 \times 0.7457 \times 1 \times 232\ = -173\ kWh$$

During the cooling season the air curtain will reduce the load on the retail space's HVAC system, saving electricity, which will be partially offset by the air curtain fan operation at the same time.

$$Q_A$$

$$= \sqrt{(1.8 \times 8 \times 6 \times 0.3 \times 88)^2 + \left(60 \times 8 \times 6 \times 0.41 \times \sqrt{2 \times 32.2 \times ({}^{8}\!/_{2}) \times \left({}^{(536.87 - 531.67)}\!/_{536.87}\right)}\right)^2}$$

$$Q_A = 2{,}946\ cfm$$

$$q_{tbc} = \frac{4.5 \times Q_A \times (h_{oc} - h_{ic})}{1{,}000} = \frac{4.5 \times 2{,}918 \times (27.4 - 22.7)}{1{,}000} = 62.3\ kBtu/hr$$

$$q_{tac} = 62.3 \times (1 - 0.7)$$

$$q_{tac} = 18.7\ kBtu/h$$

$$Annual\ Electric\ Impact, Cooling\ Season = \left(\frac{(q_{tbc} - q_{tac})}{EER} - (HP \times 0.7457)\right) \times HR \times day_{cs}$$

$$= \left(\frac{(62.3 - 18.7)}{9.5} - (1 \times 0.7457)\right) \times 1 \times 30\ = 115\ kWh$$

The net annual electricity loss is 58 kWh/yr.

Measure Life

The measure life is 15 years [9].

Incremental Cost

The purchase and installation cost for air curtains is summarized in the table below. [10]

Air Curtain Type		Approximate Cost
Single door	3' x 7'	$1,000
	6' x 7'	$1,400
	6' x 8'	$1,500
Double door	2 x 7' x 3'	$2,000
	2 x 7' x 6'	$2,800
	2 x 6' x 8'	$3,000
Shipping and receiving	8' x 8'	$3,500
	8' x 10'	$3,500
	10' x 10'	$4,500

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DESTRATIFICATION FANS

DATE: 10/27/15

TO: Ontario TEC Committee

FROM: ERS

RE: Destratification Fans

The following TRM measure covers the use of ceiling mounted paddle destratification fans with a minimum diameter of 20 feet, in commercial space heating applications. We have reviewed the documentation provided to us by the TEC, and we have verified the accuracy of the engineering algorithms and reasonableness of the assumptions. In addition, we have researched the references provided and have investigated and referenced available sources of information.

The presented methodology uses commonly recognized relationships and parameters that will be common to most spaces, and are compatible with industry standard marketing practice. It focuses on open warehouse areas with gas fired forced hot air furnaces, including unit heaters. It assumes that, prior to destratification there is a temperature difference between the floor and the underside of the roof, and after destratification the air temperature is uniform within the space. The estimated energy savings is the difference between the heat lost through the roof in each case. This simplified method uses average outdoor and indoor temperature conditions and does not include the influence of infiltration, ventilation or other sources of heat within the space, as these factors are difficult to predict and vary greatly across facilities.

It should be noted that the proposed savings per square foot are low compared to the prior Enbridge substantiation document. The methods used are not directly comparable. The prior subdoc primary savings basis is normalized results from two weeks of metering with and without fans at an example facility.

This method is based on engineering calculations as presented by ASHRAE that center on reduced heat loss through the top of the building. The engineering approach does have in common use of the case study's measured temperature at the ceiling, a key variable, as a representative value.

The information below is not used as a basis for the developed estimates and therefore is not in the subdoc itself but does provide context and comparison, as the group engaged in extensive discussion on both method and parameter values.

For comparison regarding the temperature assumptions, U-value and method,

1. The Minnesota TRM savings uses the same method as the subdoc. Their savings basis is a 10F reduction in ceiling temperature and a 0.08 U-value, of course with their weather. This compares with the Ontario subdoc's latest version difference of 10.6F (86.5F – 75.9F) reduction and 0.107 U-value for existing bldgs. Their method leads to slightly less savings, other parameters being equal. (https://mn.gov/commerce/energy/images/MN-TRM-2014-ver1%252E0.pdf)

For comparison regarding the temperature assumptions,

2. The Naval study mentioned in the TEC subcommittee-ERS call covered two sites. Each had 5F or less in stratification temperature difference between eye level and the ceiling without fans. Fans reduced their ceiling temperatures by 3F and 2F. This would lead to less than 1/3 of the savings as we are using for Ontario, all else being equal. They don't calculate % facility savings but their graphs suggest about 35% for one site and 5% for the other. (http://airiusfans.com/wp-content/uploads/Techval_report.pdf)

3. A manufacturer sales presentation projects ½F to 1F per foot, slightly more than the subdoc's 10.6F over 25 feet (www.zoofans.com/reps/sales_presentation.pdf)

For comparison regarding the temperature assumptions, method and to provide savings fraction data,

4. A NiCor research paper found 11F of stratification with 10F of it eliminated at one site with big fans and about 5F eliminated at a gym with small fans. This is comparable to the Ontario draft. It computed 21% savings at one site and 0% at the other. It goes out of its way to refute a commonly cited 1997 paper that gives CFD-based savings estimates of 13% to 33% (https://www.nicorgasrebates.com/-/media/Files/NGR/PDFs/ETP/1026%20Thermal%20Equalizer%20Destratification%20Fans%20Public%20Project%20Report%20APPROVED%20FINAL%20to%20Nicor%20Gas%2010062014%20REV%202.pdf).

More savings fractions:

5. The 2008 Hunter Douglas, Brampton Ontario study referenced in the subdoc shows 19% savings when 5 fans (with a total area of influence of 7,850 ft2 per fan or 39,250 ft2 reconditioned by the 5 fans) were installed in a 92,483 ft2 building.

6. The 2005 Middletown, NY study referenced in the subdoc shows 26% savings installing 5 fans in a 58,000 ft2 warehouse.

7. The 2010 Poultry Farm by Oli Coe of Farm Energy in UK. Study shows 16% savings by installing destratification fans. It is not clear how many fans, specifications, or area of the building etc. (www.thepoultrysite.com/articles/1960/destratification-fan-study/

DESTRATIFICATION FANS– NEW/RETROFIT

Version Date and Revision History	
Draft date	10/27/2015
Version history	v.1
Effective date	TBD
End date	N/A
Commercial → Space Heating → Destratification Fans → Retrofit Commercial → Space Heating → Destratification Fans → New Construction	

Table 1 provides a summary of the key measure parameters with a deemed savings coefficient.

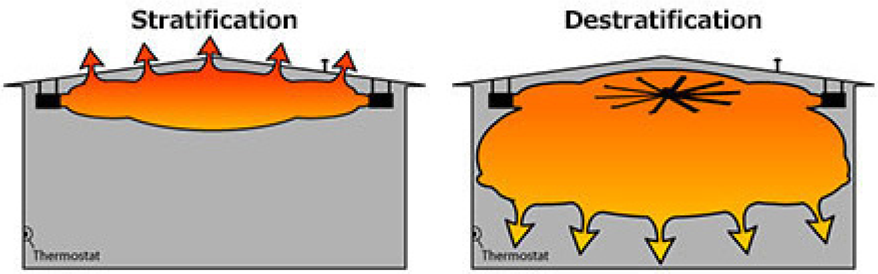
Table 1. Measure Key Data

Parameter	Definition	
Measure category	Retrofit and New Construction	
Baseline technology	No destratification fans	
Efficient technology	Destratification fans	
Market type	Commercial	
Annual natural gas savings (m^3/ fan)	Retrofit	New Construction
	1,734 m^3/fan	583 m^3/fan
Measure life	15 years	
Restrictions	This measure is restricted to fans with a minimum diameter of 20 feet for use in warehousing, manufacturing, industrial or retail buildings with a minimum of 25 foot ceilings and forced air space heating, including unit heaters.	

OVERVIEW

This measure is for the installation of destratification fans in new and retrofit commercial types of applications. Figure 1 illustrates air mixing and resulting uniform air temperature distribution caused by the destratification fans. Natural gas savings are calculated using an engineering algorithm and are reported in meters cubed per square foot of roof area (m^3/ft^2).

Figure 1: Stratification vs. Destratification1



Baseline Technology

The baseline case is a space with no destratification fans or other mechanisms that combat destratification, such as radiant heaters and high velocity vertical throw unit heaters

Efficient Technology

The energy efficient case is a space with destratification fans.

Energy Impacts

Stratification can result in ceiling temperatures as much as 10°C higher than temperatures at floor level [1]. As a result, thermostats are typically set higher to maintain temperatures which are comfortable for employees near the floor which in turn results in greater gas usage for heating. Destratification fans are designed to move large volumes of air at slow rates. This air churning moves the warmer air near the ceiling downward which equalizes the temperature within the space and also benefits the employees comfort levels on the floor. Depending on the size of the space, destratification fans can reduce ceiling temperatures by an average of 4°C and increase floor temperatures by an average of 1.5°C resulting in an overall temperature profile difference of less than 0.5°C [1]. Natural gas savings are achieved due to the difference in heat loss through the roof before and after destratification.

No water consumption impacts are associated with this measure. Any electrical costs associated with the operation of the destratification fans would be offset by the reduced use of auxiliary heating equipment such as blower motors on space heating equipment [1].

[1] Photograph downloaded from http://www.allseasonshire.eu/blog/thermal-destratification-explained/ on 10/1/2014.

NATURAL GAS SAVINGS ALGORITHMS

The following algorithm was used to calculate the stipulated gas impact in cubic meters per fan. The total gas savings, *NG Savings*, is calculated based on the difference in heat loss through the roof before and after destratification. [2]

$$NG\ Savings = q_{bd} - q_{ad}$$

The heat loss per unit roof area through the roof before destratification is calculated in the following equation:

$$q_{bd} = U \times A \times (t_{ib} - t_o)$$

where,

q_{bd} = Heat loss through the roof before destratification (Btu/h)

U = Average heat transfer coefficient for the roof (Btu /ft^2·°F·h), see Table 4

A = Area of roof influenced by destratification fans (ft^2)

t_{ib} = Temperature on underside of roof before destratification (°F), see Table 4

t_o = Outside air temperature (°F), see Table 4

The heat loss per unit roof area through the roof after destratification is calculated in the following equation:

$$q_{ad} = U \times A \times (t_{ia} - t_0)$$

where,

q_{ad} = Heat loss through the roof after destratification (Btu/ft^2·h)

U = Average heat transfer coefficient for the roof (Btu /ft^2·°F·h), see Table 4

A = Area of roof influenced by destratification fans (ft^2)

t_{ia} = Average indoor air temperature after destratification (°F) [2]

$$t_{ia} = \frac{(t_{ib} \times H_{ah}) + (t_f \times H_{bh})}{(H_{ah} + H_{bh})} = \frac{(86.5 \times 8) + (72 \times 22)}{(22 + 8)} = 75.9\text{°F}$$

where,

t_{ib} = Temperature on underside of roof before destratification (°F), see Table 4

H_{ah} = Height above heaters to roof (ft), see Table 4

t_f = Thermostat temperature setting (°F), see Table 4

H_{bh} = Height below heaters to floor (ft), see Table 4

Simplifying the equations to calculate the annual natural gas savings factor per unit area, the following equation is used:

$$NG\ Savings = \frac{hrs_{hs} \times U \times (t_{ib} - t_{ia}) \times 7{,}850 \frac{ft^2}{fan}\ \ Roof}{35{,}738 \frac{Btu}{m^3} \times \eta} + \frac{hrs_{hs} \times Uwall \times (t_{iib} - t_{ia}) \times Area\ of\ influence\ of\ fan\ in\ contact\ with\ exterior\ wall \frac{ft^2}{fan}}{35{,}738 \frac{Btu}{m^3} \times \eta}\ Wall$$

where,

NG savings = Annual gas savings per unit area (m^3/fan)

hrs_{hs} = Heating season hours for this location (h), see Table 4

η = Efficiency of gas furnace, see Table 4

The calculated annual savings factor - Retrofit:

$$NG\ savings = \frac{5{,}567 \times 0.107 \times (86.5 - 75.9) \times 7{,}850}{35{,}738 \times 0.8} = 1{,}734 \frac{m^3}{fan}$$

The calculated annual savings factor – New Construction:

$$NG\ savings = \frac{5{,}567 \times 0.036 \times (86.5 - 75.9) \times 7{,}850}{35{,}738 \times 0.8} = 583 \frac{m^3}{fan}$$

List of Assumptions

Table 4 provides a list of assumptions utilized in the measure savings algorithm to derive the stipulated savings values listed in Table 1 above.

Table 4. General Assumptions

Variable	Definition	Value		Source/Comments
hrs_{hs}	Heating hours per year	5,567		Based on TMY3 data for London, ON and on heating hours below 55°F (12.8 ˚C)
U	Average heat	Retrofit	New Construction	Codes and engineering judgment [2]

[2] The substantiation document roof U-value should reflect the average of all buildings that receive this measure. No survey data on Ontario warehouse roof U-values was available. The current (IEC-2012) code minimum U-value for new construction is 0.032 Btu/°F·h·ft² [6]. ASHRAE 90.1-1999 cites 0.036 Btu/°F·h·ft² for prescriptive use [7]. In the 1990's the ASHRAE-based code requirement was less stringent, 0.084 Btu/°F·h·ft² [8], and before this code was in effect average U-values likely were higher due to roof penetration. Insulation has been added to some older warehouses that have been re-roofed. Also, the

Variable	Definition	Value		Source/Comments
	transfer coefficient for the roof	0.107 Btu/°F·h·ft^2 (0.51 W/m^2·K)	0.032 Btu/°F·h·ft^2 (0.51 W/m^2·K)	
t_{ib}	Temperature on underside roof deck before destratification	86.5 °F		Based on a temperature gradient of 0.426 ˚Cft calculated for 25 feet between the thermostat and the ceiling [1]
t_f	Thermostat temperature setting	72°F (22.2˚C)		Common assumptions table, room setpoint
H_{ah}	Height above heaters to roof	8 ft		Minimum requirements are 8 feet from floor or ceiling [3]
H_{bh}	Height below heaters to floor	22 ft		Minimum requirements are 8 feet from floor or ceiling [3]
	Effective area covered by fan	7,850 ft^2		[1]
η	Efficiency of gas furnace	0.80		Common assumptions table
	Conversion from Btu to m^3	35,738 Btu/m^3		Common assumptions table

The roof area upon which the savings is based may not exceed the manufacturer-rated maximum floor area covered by the destratification fans at their installed height.

This measure is restricted to fans with a minimum diameter of 20 feet for use in warehousing, manufacturing, industrial or retail buildings with a minimum of 30 foot ceilings and forced air space heating, including unit heaters. [4]

Savings Calculation Example - Retrofit

The example below illustrates the deemed savings value for five (5) twenty foot paddle destratification fans in an existing commercial warehouse. The room has a 30 foot ceiling and a gas furnace set at 72°F (22.2 ˚C).

$$Annual\ NG\ savings = \ 1{,}734 \frac{m^3}{fan} \times 5 fans = 8{,}670\ m^3$$

savings calculated in this set of algorithms are based solely on reducing heat loss through the roof. There will be additional savings due to reduced heat loss through the upper part of the walls and possibly due to less stack effect-related infiltration. After consideration of all of these factors, engineering judgment was used estimate an average roof U-value (and effectively the overall UA) of 0.107 Btu/°F·h·ft^2.

SAVINGS CALCULATION EXAMPLE – NEW CONSTRUCTION

The example below illustrates the deemed savings value for six (6) twenty-four foot paddle destratification fans to be installed in a commercial warehouse under construction. The room has a 30 foot ceiling and a gas furnace set at 72°F (22.2 ˚C).

$$Annual\ NG\ savings = \ 583\frac{m^3}{fan} \times 6fans = 3{,}498\ m^3$$

MEASURE LIFE

The measure life is 15 years [5].

INCREMENTAL COST

The purchase and installation cost for destratification fans will vary depending on the available electrical infrastructure and the need for specialty lifts for high ceilings. The approximate incremental cost (for equipment and installation) of a 24 foot destratification fan is $6,100 [2].

REFERENCES

[1] Cold Weather Destratification Energy Savings of a Warehousing Facility, "Hunter Douglas Monitoring Results," May 2008.

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Commercial – 95% Or Higher Efficiency Furnaces – New Construction

DATE: 1/29/2015

TO: Ontario TEC Sub-committee

FROM: ERS

RE: Commercial – 95% Or Higher Efficiency Furnaces – New Construction and Time of Natural Replacement

The following TRM measure covers condensing furnaces for commercial new construction and time of natural replacement applications. We have reviewed the documentation provided to us by the TEC, and we have verified the accuracy of the engineering algorithms and reasonableness of the assumptions. In addition, we have researched the references provided and have investigated and referenced available sources of information.

The presented method uses a straightforward method similar to the approach for the residential furnaces and is based on assumptions for efficiencies and equivalent full load hours (EFLH). We have researched commercial EFLH and at this point have not been able to find a better source than the values derived for commercial boilers in the 2012 AMEC report cited in the references.

Also, although commercial furnaces are generally recognized as greater than 225 kBtu/hr by regulation, ENERGY STAR and NRCan, there are no furnaces available with condensing efficiencies at this size range as verified on the AHRI and NRCan databases. Because of this, the measure is directed to furnaces smaller than 225 kBtu/hr, which are governed by residential regulation, but installed in commercial installations.

95% or Higher Efficiency Furnace – New Construction and Time of Natural Replacement

Version Date and Revision History	
Draft date	1/29/2015
Version history	v.1
Effective date	TBD
End date	N/A
Commercial → 95% or Higher Efficiency Furnaces → New Construction (NC) and Time of Natural Replacement (TNR)	

Table 1 below provides a summary of the key measure parameters, with a deemed savings coefficient.

Table 1. Measure Key Data

Parameter	Definitions
Measure Category	New Construction (NC) and Time of Natural Replacement (TNR)
Baseline Technology	90% AFUE
Efficient Technology	≥ 95% AFUE
Market Type	Commercial
Annual Natural Gas Savings	2.33 m^3 per kBtu/hr input capacity – NC
	3.11 m^3 per kBTU input capacity - TNR
Measure Life	18 years
Incremental Cost ($)	$346
Restriction	Must have a rated efficiency of at least 95% and must be a standalone furnace

Overview

The measure is for the installation of high efficiency condensing furnaces with an annual fuel utilization efficiency (AFUE) of 95% or higher in commercial buildings. High efficiency gas furnaces achieve savings through the utilization of a sealed, super insulated combustion chamber, more efficient burners, and multiple heat exchangers that remove a significant portion of the waste heat from the flue gasses. Because multiple heat exchangers are used to remove waste heat from the escaping flue gasses, most of the flue gasses condense and must be drained.

APPLICATION

The measure is for the installation of condensing furnaces which have efficiencies that exceed code requirements. Commercial furnaces are typically categorized as being of an input capacity greater than 225 kBtu/hr and are performance-rated by their thermal efficiency. Investigation into the commercial furnace market shows that furnaces greater than 225 kBtu/hr are not made with efficiencies greater than 82% [1]. Because there is no large, high efficiency commercial furnace equipment, this measure is intended to support the purchase of smaller, less than 225 kBtu/hr, high efficiency furnaces.

Furnaces less than 225 kBtu/hr are performance rated by their annual fuel utilization efficiency or AFUE. This is a measure of the seasonal performance of the equipment and is a more comprehensive system efficiency than combustion or thermal efficiency measurements.

BASELINE TECHNOLOGY

Canada's Energy Efficiency Regulations require that new furnaces under 225 kBtu/hr have at least a 90% AFUE [2]. For new construction installations, the baseline technology is considered to be the minimum efficiency required by the regulations established December 31, 2009.

Table 2. Baseline Technology AFUE

Type	AFUE
Gas Condensing Furnace	90%

EFFICIENT TECHNOLOGY

The efficient technology is a condensing furnace with a thermal efficiency rating equal to, or higher than 95%. This is the minimum efficiency for an ENERGY STAR furnace in Canada, effective February 1, 2013 [3].

Table 3. Efficient Technology AFUE

Type	AFUE
Gas Condensing Furnace	95%

ENERGY IMPACTS

The primary energy impact associated with the installation of condensing furnaces in this service territory is a reduction in natural gas usage resulting from the furnace's improved efficiency.

No water consumption or electric impacts are associated with this measure.

Natural Gas Savings Algorithms

The measure gas savings are calculated using an assumption for the equivalent full load hours (EFLH), derived by AMEC, and the difference in assumed efficiencies for the equipment. The annual natural gas savings for a given size furnace can be calculated by multiplying the rated input of the furnace times the savings factor[1].

The deemed natural gas savings factor attributed to this measure is calculated using the following formula:

$$NG\ Savings\ Factor = \frac{EFLH}{35.738\frac{kBtu}{m^3}} \times \left(\frac{AFUE_{EE}}{AFUE_{base}} - 1\right)$$

where,

$NG\ Savings\ Factor$	= Annual gas savings per input capacity resulting from installing the new furnace (m^3/yr)/(kBtu/hr)
$EFLH$	= Equivalent full load hours (hrs), see Table 4
$35.738\frac{kBtu}{m^3}$	= Conversion of rated heating capacity from input kBtu/hr to m^3/hr, common assumptions table
$AFUE_{base}$	= Baseline equipment thermal efficiency (%), see Table 2
$AFUE_{EE}$	= Efficient equipment thermal efficiency (%), see Table 3

Electric Energy Savings

The Ontario Building Code requires that all furnaces installed in new construction with permit pull dates after December 31, 2014 use brushless direct current motors (also known as electronically commutated motors, or ECMs). Such motors are significantly more efficient than traditional permanent split capacitor (PSC) type motors. With this code elevation there is no electricity savings associated with the ECMs often installed with new condensing furnaces [4].

List of Assumptions

The assumptions used to calculate the deemed savings coefficient are shown in Table 4.

[1] The Regulations are defined based on Btu/hr of gas input and residential boilers and most commercial heating equipment are also rated based on input capacity. Note that some furnace manufacturers rate the capacity based on Btu/hr output. For example, spot checks of manufacturer literature in August 2014 found that Trane, and Bryant publish furnace capacity based on output; Carrier and Rheem list input capacity. Increase the deemed savings by 5% if output capacity is the basis.

Table 4. Assumptions

Variable	Definition	Inputs	Source
$EFLH$	Equivalent full load hours	1,500 hrs - NC	Common assumptions
		2000 hrs - TNR	

*

Savings Calculation Example

The example below shows how to calculate gas savings achieved from installing one condensing furnace with a rated input of 110 kBtu/h from the deemed savings factor in Table 1.

$$NG\ Savings\ Factor = \frac{1{,}500 hrs}{35.738 \frac{kBtu}{m^3}} \times \left(\frac{95\%}{90\%} - 1\right) = \frac{2.33\ (m^3/yr)}{\frac{kBtu}{hr}}$$

And,

$$Annual\ NG\ savings = \frac{2.33 \left(\frac{m^3}{yr}\right)}{\frac{kBtu}{hr}} \times 110 \frac{kBtu}{hr} = 256\ m^3$$

Uses and Exclusions

To qualify for this measure the condensing furnaces must be gas-fired, have an AFUE of at least 95% and be installed in a new commercial facility. The measure applies to standalone furnaces and not to heating systems that are part of rooftop units or to unvented make-up air heaters.

Measure Life

The measure life attributed to this measure is 18 years [5] [6]. Expert opinions and studies cited by NRCAN are 15, 18, and 20 years [7]. The ASHRAE handbook states that most heat exchangers have a design life of 15 years and the design life of commercial heating equipment is about 20 years [8]

Incremental Cost

The measure incremental cost is $346, based on the average difference in incremental cost between 90 AFUE and 94 AFUE residential furnaces. The cost estimate is based on data from a 2011 Northeast Energy Efficiency Partnership EM&V Forum-sponsored study on incremental costs [9]and was escalated by 12.5% to account for four years of inflation.

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COMMERCIAL SPACE HEATING – HEAT RECOVERY VENTILATION (HRV) – NEW CONSTRUCTION AND RETROFIT (NO HRV BASELINE)

Version Date and Revision History	
Draft date:	11/17/2015
Version history	v.2
Effective date:	TBD
End date:	TBD
Commercial→ Heat Recovery Ventilation→ New Construction Commercial→ Heat Recovery Ventilation→ Retrofit	

Table 1 provides a summary of the key measure parameters with deemed savings coefficients differentiated by level of use the building receives, which in turn dictates the assumed hours of operation for the building.

Table 1. Measure Key Data

Parameter	Definition			
Measure Category	New construction (NC) where no HRV is required by Ontario Building Code			
	Retrofit			
Base Technology	No HRV			
Efficient Technology	HRV with minimum 65% Sensible Heat Recovery Effectiveness at 32°F			
Market Type	Commercial Space Heating			
Annual Gas Savings	**Building Type**	**Gas Savings Rate (m^3/CFM)**	**Group**	**Average Group Gas Savings (m^3/CFM)**
	Multi-Family, Health Care and Nursing Homes	5.00	High Use	5.00
	Hotels	3.58	Medium Use	2.78
	Restaurant	2.59		

	Retail	2.18		
	Office	1.91	Low Use	1.78
	Warehouse	1.82		
	School	1.61		
Annual Electric Penalty[1]	**Building Type**	**Electric Penalty Rate (kWh/CFM)**	**Group**	**Average Group Electric Penalty (kWh/CFM)**
	Multi-Family, Health Care and Nursing Homes	4.62	High Use	4.62
	Hotels	3.30	Medium Use	2.57
	Restaurant	2.39		
	Retail	2.01		
	Office	1.76	Low Use	1.64
	Warehouse	1.68		
	School	1.49		
Measure Life	14 Years			
Incremental Cost	Integrated HRV		Standalone or Bolt-On HRV	
	CA$4.93/CFM		CA$7.64/CFM	
Restrictions	This measure is intended for HRVs with a minimum effectiveness of 65% and installation in buildings where HRVs are not required by building code[2]. For example, new construction health care spaces are not eligible because they require heat recovery per CSA Z317.2-01. This measure applies to buildings where no DCV or schedule setback is required or already exists.			

OVERVIEW

A heat recovery ventilator (HRV) refers to heat exchanger equipment that is designed to transfer sensible heat from the building exhaust air to the outside supply air. The temperature of the outside supply air is raised by the heat transferred from the exhaust air stream within the heat exchanger. By doing so, the amount of heat energy lost through the exhaust air stream is reduced and energy is saved through decreased load on the building heating system [1].

[1] The electric penalty does not apply when the HRV unit is installed as part of an integrated HVAC package.

[2] For buildings where HRVs are required by building code SB-10, please see supporting measure with 50% effectiveness as baseline.

One component of HRVs includes circulation fans, which are typically high efficiency electrically commutated motors. These will consume more electrical energy in cases where HRV unit is added to the existing HVAC system as a standalone or bolt-on unit [1]. No penalty is assigned if the HRV is integrated as part of the HVAC packaged system installed at retrofit or new construction because the higher efficiency of the new fans compensate for the additional static pressure.

An important distinction to make for an HRV is that it does not transfer moisture between the air streams like an energy recovery ventilator would. Figure 1 shows an example and a schematic of a heat recovery ventilator.

Figure 1. Heat Recovery Ventilator[3]

APPLICATION

The measure covers the installation of heat recovery ventilators in commercial settings. The performance of the HRV can be quantified by its sensible effectiveness, which is

[3] From http://www.nfan.co.uk/what_are_heat_recovery_systems, 12/15/2014

defined as the ratio of actual heat energy captured to the maximum heat energy that could be captured. This is a value determined during testing and varies with temperature difference. Sensible heat recovery effectiveness is not to be confused with total effectiveness which is a measure of the heat and moisture transfer. All references to effectiveness within this document refer to sensible effectiveness, not total effectiveness. Other performance parameters to be considered are the pressure drop over the HRV, and the method of frost control for the heat exchanger [2].

BASELINE TECHNOLOGY

The baseline is considered to be a building operating without the use of a HRV as shown in Table 2. This implies that no heat is being recovered between the exhausted inside air and the incoming outside supply air.

Table 2. Baseline for Heat Recovery Ventilators

Type	Efficiency
No HRV	No Heat Recovery

EFFICIENT TECHNOLOGY

The efficient technology is an HRV with an effectiveness of at least 65% as shown in Table 3. Note, ENERGY STAR requires that qualifying HRVs have a minimum rated effectiveness of 60% at -13°F (-25°C) and 65% at 32°F (0°C) [3].

Table 3. Efficient Technology for Heat Recovery Ventilators

Type	Minimum Efficiency
HRV	65% Minimum Sensible Heat Recovery Effectiveness at 32°F

ENERGY IMPACTS

Natural gas savings are achieved because the incoming supply air arrives at the building heating equipment at a higher temperature than it would without an HRV. This means that less energy is required to heat the supply air to the set point temperature.

An electrical penalty is incurred due to the operation of HRV fans or increased load on central fans, except when the HRV is integrated as part of the HVAC package.

NATURAL GAS SAVINGS ALGORITHMS

The following algorithms are used to calculate the gas impact in cubic meters and are formulae from ASHRAE 2012, chapter 26 [2]. The ASHRAE equations make the following assumptions: no vapor condensation within the HRV, no cross leakage, no heat gas from fan motors, and equal supply and exhaust air flow rates.

The energy saved by an HRV is a function of the heat transfer rate through the heat exchanger and the length of time it operates. The heat transfer rate can be calculated from the temperature difference between the supply and exhaust air entering the HRV the average effectiveness of the HRV, the physical properties of air and the flow rate through the HRV. A defrost factor must also be considered to account for the time that exhaust air is diverted through the core in order to prevent freezing, which impedes the operation of the HRV.

$$hrs = Heathrs \times \frac{weeklyhrs}{168\,\frac{hrs}{week}}$$

and,

$$NG\ Savings = hrs \times \frac{60min}{hr} \times \rho \times \frac{\varepsilon}{\eta} \times \frac{C_p}{35{,}738\,\frac{Btu}{m^3}} \times (T_3 - T_1) \times (1 - DF)$$

Where,

hrs	= Annual hours that the HRV is expected to be in use (hours/year)
$Heathrs$	= Number of hours in the heating season (hours/year)
$weeklyhrs$	= Number of weekly operating hours (hours/week)
$168\,\frac{hrs}{week}$	= Number of hours in a week
$NG\ Savings$	= Annual natural gas savings per CFM of HRV (m^3/CFM/year)
$\frac{60min}{hr}$	= Conversion from minutes to hours
ρ	= Density of air at 72°F (lb_m/ft^3) Table
ε	= Average effectiveness of the HRV (%)[4]
η	= The efficiency of the building's heating system (%)
C_p	= Specific heat of air (Btu/lb_m-°F)
$35{,}738\,\frac{Btu}{m^3}$	= Conversion from Btu to m^3 of natural gas
T_3	= Temperature of the inside (exhaust) air entering the HRV (°F)

[4] Note, for this analysis the rated effectiveness is being used as an average effectiveness.

T_1 = Average outside temperature during heating hours (°F)

DF = Defrost control de-rating factor (%)

ELECTRIC ENERGY PENALTY ALGORITHMS) FOR HRVS ADDED TO AN EXISTING SYSTEM)

The electric penalty is based on the ENERGY STAR minimum fan efficiency requirements of 0.83 W/CFM. Using this value, and the calculated hours of HRV operation from the natural gas algorithms, the kWh electric penalty can be calculated using the following equation.

The kWh fan penalty analysis presumes that the system has an automatic bypass damper so that there is no added pressure drop during hours when heat recovery is not needed.

$$kWh\ penalty = 0.83\frac{W}{CFM} \times hrs \div 1000\frac{W}{kW}$$

Where,

$kWh\ penalty$ = The annual electric penalty per CFM of HRV capacity ($kWh/ft^3/min/year$)

$0.83\frac{W}{CFM}$ = Minimum efficacy to be qualified for ENERGY STAR (1.20 CFM/W)

hrs = Annual hours that the HRV is expected to be in use (hours/year)

LIST OF ASSUMPTIONS

Table 4 shows the list of assumptions used in the algorithms sections.

Table 4. Assumptions

Variable	Definition	Value	Source
$Heathrs$	Hours in Heating Season, 55°F Balance Temperature[5]	5,567 hrs	Common assumptions table
ρ	Density of the exhaust air	$0.0741\ lb_m/ft^3$	Common assumptions

[5] The annual heating hours, and average outside air temperature, assume an average building balance temperature of 55°F, which is the temperature at which neither heating nor cooling is required. The actual balance point for a particular application will vary based on building construction, internal loads, HVAC system zoning, and other factors.

Variable	Definition	Value	Source
			table
η	Efficiency of gas fired heating equipment	80%	Common assumptions table
C_p	Specific heat of air	0.240 Btu/lb_m-°F	Common assumptions table
T_1	Average temperature of outside (supply) air during the heating season	33°F	Common assumptions table
T_3	Average temperature of inlet exhaust air	72°F	Common assumptions table
Fan Efficiency	Assumed fan efficiency	0.83 W/CFM	[3]
RH_1	Average outdoor relative humidity	46.7%	[4]
RH_3	Average indoor relative humidity	30%	[6], [2]
DF	Defrost control de-rating factor	5%[6]	[1], [2], [7], [6]

The assumed weekly hours of operation for different building types are given in Table 5.

Table 5. Hours of Weekly Operation [6]

Building Type	Hours of Operation per Week
Multi-Family	168
Health Care	168
Nursing Home	168
Hotel	120
Restaurant	87
Retail	73
Office	64
Warehouse	61

[6] All air-to-air heat recovery equipment requires frost control in colder climates to prevent freeze-up of exhaust air condensate on heat exchanger components. There are different types of frost control methods and depending on the defrost control system, annual heat recovery estimates should be reduced by 5% to 15%.

Building Type	Hours of Operation per Week
School	54

EXAMPLE

For this example it will be assumed that a new health care facility installs a 500 CFM HRV in the London district.

$$hrs = 5{,}567hrs \times \frac{168hrs}{168\frac{hrs}{week}} = 5{,}567hrs$$

and,

$$NG\ Savings = 5{,}567hrs \times \frac{60min}{hr} \times 0.0741\frac{lb_m}{ft^3} \times \frac{65\%}{80\%} \times \frac{0.240\frac{Btu}{lb_m - {}^\circ R}}{35{,}738\frac{Btu}{m^3}} \times (72°F - 33°F)$$
$$\times (1 - 5\%) = 5.00\frac{m^3}{CFM}$$

Therefore,

$$NG\ Savings = 500CFM \times 5.00\frac{m^3}{CFM} = 2{,}500m^3$$

The electrical penalty can be calculated as the following.

$$kWh\ penalty = 500\ CFM \times 0.83\frac{W}{CFM} \times 5{,}567\ hrs \times \frac{1kW}{1000W} = 2{,}310\ kWh$$

USES AND EXCLUSIONS

- The HRV must have an effectiveness of at least 65%.
- Restriction for new building construction: This measure is not applicable to buildings in which an HRV is required by the Ontario Building Code (SB-10) . [8] Note: please see supporting measure that utilizes code minimum as baseline for these scenarios.
- Restriction for new building construction: This measure is not applicable to systems serving health care spaces indicated in Table 1 because heat recovery is required by CSA Z317.2-01

MEASURE LIFE

A 14 year measure life is recommended by DEER, based on KEMA-XENERGY's Retention Study of PG&Es 1996-1997 Energy Incentive Program. This study tracked installed equipment over 6 years and used statistical analysis to calculate EUL [6].

INCREMENTAL COST

Table 6 demonstrates the incremental cost of heat recovery ventilators.

Table 6. Incremental Cost [6] [9]

Measure Type	Cost
Integrated units	CA$4.93/CFM
Bolted-on systems	CA$7.64/CFM

The incremental costs for integrated ERV systems were developed by Nexant in their 2010 review of the measure using RSMeans and other sources. Nexant accounted for inflation rates in their review and the incremental cost developed in that report has further been increased to $3.95/CFM [6] to account for the average inflation rate[7] since 2010. ERS used RSMeans corroborated with manufacturer data to determine the costs for standalone or bolt-on units at $6.12/CFM. The additional cost for standalone or bolt-on units is due to the additional materials and equipment required, as well as the labor associated with integrating the standalone or bolt-on system with the existing ventilation system [9].

[7] 1.82% with data from http://www.inflation.eu/inflation-rates/canada/historic-inflation/cpi-inflation-canada.aspx

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COMMERCIAL SPACE HEATING – ENERGY RECOVERY VENTILATION (ERV) – NEW CONSTRUCTION AND RETROFIT (NO ERV BASELINE)

Version Date and Revision History	
Draft date:	11/17/2015
Effective date:	TBD
End date:	TBD
Commercial→ Energy Recovery Ventilation→ New Construction Commercial→ Energy Recovery Ventilation→ Retrofit	

Table 1 provides a summary of the key measure parameters with deemed savings coefficients differentiated by level of use the building receives, which in turn dictates the assumed hours of operation for the building.

Table 1. Measure Key Data

Parameter	Definitions			
Measure Category	New construction (NC), ERV not required by Ontario Building Code			
	Retrofit			
Base Technology	No ERV			
Efficient Technology	ERV with Minimum 65% Sensible Heat Recovery Effectiveness and 63% Total Energy Recovery Effectiveness at 32°F			
Market Type	Commercial Space Heating			
Annual Gas Savings	**Building Type**	**Gas Savings Rate (m^3/CFM)**	**Group**	**Average Group Gas Savings (m^3/CFM)**
	Multi-Family, Health Care and Nursing Homes	6.64	High Use	6.64
	Hotels	4.74	Medium Use	3.68
	Restaurant	3.43		
	Retail	2.88		
	Office	2.53	Low Use	2.36
	Warehouse	2.41		
	School	2.13		

<table>
<tr><th>Parameter</th><th colspan="4">Definitions</th></tr>
<tr><td rowspan="8">Annual Electric Penalty[1]</td><td>Building Type</td><td>Electric Penalty Rate (kWh/CFM)</td><td>Group</td><td>Average Group Electric Penalty (kWh/CFM)</td></tr>
<tr><td>Multi-Family, Health Care and Nursing Homes</td><td>4.62</td><td>High Use</td><td>4.62</td></tr>
<tr><td>Hotels</td><td>3.30</td><td rowspan="3">Medium Use</td><td rowspan="3">2.57</td></tr>
<tr><td>Restaurant</td><td>2.39</td></tr>
<tr><td>Retail</td><td>2.01</td></tr>
<tr><td>Office</td><td>1.76</td><td rowspan="3">Low Use</td><td rowspan="3">1.64</td></tr>
<tr><td>Warehouse</td><td>1.68</td></tr>
<tr><td>School</td><td>1.49</td></tr>
<tr><td>Measure Life</td><td colspan="4">14 Years</td></tr>
<tr><td rowspan="2">Incremental Cost</td><td colspan="2">Integrated ERV</td><td colspan="2">Standalone or Bolt-On ERV</td></tr>
<tr><td colspan="2">CA$4.49/CFM</td><td colspan="2">CA$7.20/CFM</td></tr>
<tr><td>Restrictions</td><td colspan="4">This measure is intended for ERVs with a minimum effectiveness of 65% and installation in buildings where ERVs are not required by building code [2]. For example, new construction health care spaces are not eligible because they require heat recovery per CSA Z317.2-01. This measure applies to buildings where no DCV or schedule setback is required or already exists.</td></tr>
</table>

OVERVIEW

An energy recovery ventilator (ERV) refers to heat exchanger equipment that is designed to transfer heat and moisture between the building exhaust air and the outside supply air. During the heating season, this raises the temperature of the outside supply air through heat transfer within the heat exchanger and typically adjusts the humidity of the supply air through moisture transfer. By doing so, the amount of energy wasted in heat through the exhaust air stream is reduced and energy is saved through decreased load on the building heating system. ERVs are available as desiccant rotary wheels or membrane plate exchangers. [1].

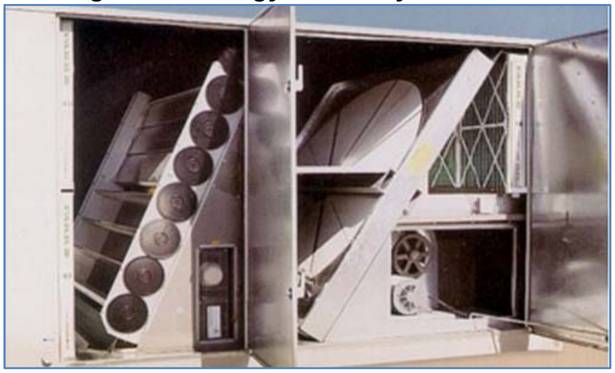
One of the components of ERVs is circulation fans, which are typically high efficiency electrically commutated motors. These will consume more electrical energy in cases where the ERV unit is added to the existing HVAC system as a standalone or bolt-on unit [1]. No penalty is assigned if the ERV is integrated as part of the HVAC packaged

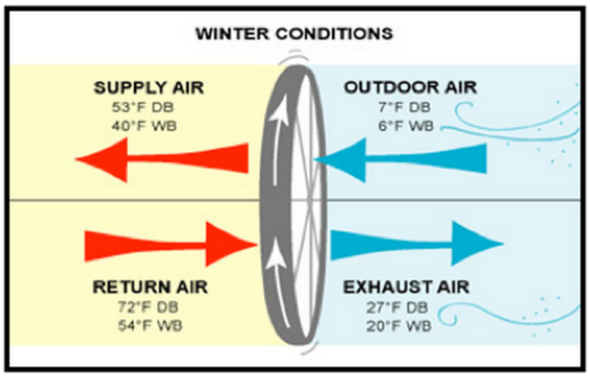
[1] The electric penalty does not apply when the ERV unit is installed as part of an integrated HVAC package.

[2] For buildings where ERVs are required by building code SB-10, please see supporting measure with 50% effectiveness as baseline.

system installed in new construction because the higher efficiency of the new fans compensate for the additional static pressure. Figure 1 is an illustration of a wheel-type energy recovery ventilator and functionality.

Figure 1: Energy Recovery Ventilator[3]





[3] From http://www.acelaenergy.com/aloha/products/energy-recovery/, 12/10/2014.

APPLICATION

The performance of the ERV can be quantified by its total effectiveness, which is a function of both its sensible and latent effectiveness'. Sensible refers to heat transfer and latent refers to moisture transfer. Sensible effectiveness is defined as the ratio of actual heat energy captured to the maximum heat energy that could be captured. Latent effectiveness is defined as the ratio of actual moisture transferred to the maximum moisture that could be transferred. Total effectiveness is defined similarly as the ratio of actual energy transferred to the total energy transferred. These values are determined during testing and both vary with temperature and moisture differences. Other performance parameters to be considered are the pressure drop over the ERV, and the method of frost control **[2]**.

BASELINE TECHNOLOGY

The baseline is considered to be a building operating without the use of an ERV as shown in Table 2. This implies that no energy recovery is taking place between the incoming outside supply air and the exhausting inside air.

Table 2. Baseline for Energy Recovery Ventilators

Type	Efficiency
No ERV	No Energy Recovery

EFFICIENT TECHNOLOGY

The efficient technology is defined as an ERV with a sensible heat recovery effectiveness of at least 65% as shown in Table 3. Note, ENERGY STAR requires that qualifying ERVs have a minimum rated sensible effectiveness of 60% at -13°F (-25°C) and 65% at 32°F (0°C) [3].

Table 3. Efficient Technology for Energy Recovery Ventilators

Type	Efficiency
ERV	65% Minimum Sensible Heat Recovery Effectiveness at 32°F

ENERGY IMPACTS

Natural gas savings are achieved because the supply air arrives at the building heating equipment at a higher enthalpy than it would without an ERV. This means that less energy is required to heat the supply air to the set point temperature.

An electrical penalty is incurred due to the operation of ERV fans or increased load on central fans, except when the ERV is integrated as part of the HVAC package. There are potential cooling electric savings that are possible with an ERV. The ERV pretreats the incoming outdoor air by removing heat and moisture with exhaust air. The potential savings are minimal since there are few hours where this would occur for the London, Ontario climate zone.

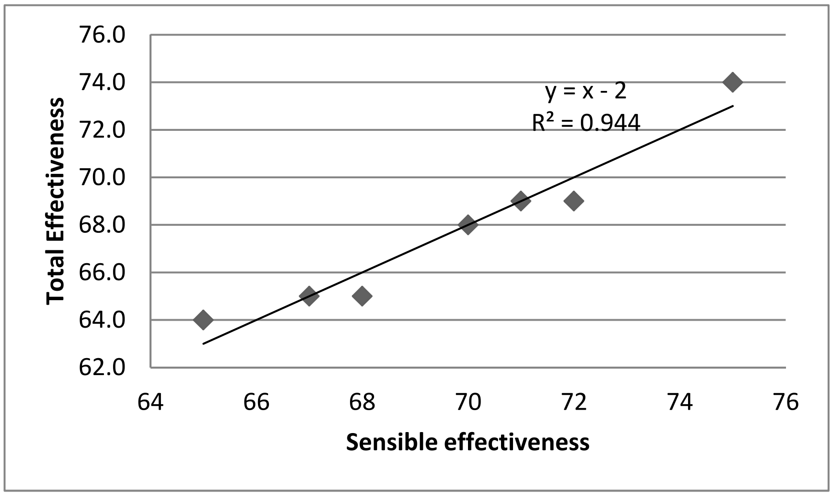
NATURAL GAS SAVINGS ALGORITHMS

The following algorithms are used to calculate the gas impact in cubic meters and are formulae from ASHRAE Heating, Ventilating and Air Conditioning Systems and Equipment Handbook 2012, chapter 26 [2]. The ASHRAE equations make the following assumptions: no vapor condensation within the ERV, no cross transfer of anything but moisture, no heat gains from fan motors, and equal supply and exhaust air flow rates.

The energy saved by an ERV is a function of the heat and moisture transfer rates through the heat exchanger and the length of time it operates. The heat and moisture transfer can be calculated from the enthalpy difference between the supply and exhaust air entering the ERV, the total effectiveness of the ERV, the physical properties of air, and the flow rate through the ERV. A defrost factor must also be considered to account for the time that exhaust air is diverted through the core in order to prevent freezing, which impedes the operation of the ERV.

Since the efficient technology is defined by the sensible heat recovery effectiveness, an assumption for the total recovery effectiveness is needed to calculate the energy savings for the measure. By comparing rated values of sensible heat recovery and total recovery effectiveness from the Air Conditioning, Heating and Refrigeration Institute (AHRI) database, [4] a relationship was developed between the two. This relationship is shown in Figure 2.

Figure 2. Total Effectiveness Versus Sensible Effectiveness



Total recovery effectiveness is approximately two percent less than heat recovery effectiveness. Based on a sensible heat recovery effectiveness of 65%, a total recovery effectiveness of 63% is assumed for the efficient technology in this measure.

The natural gas savings rates in Table 1 are calculated using the following formulae.

$$hrs = Heathrs \times \frac{weekly - hrs}{168\,\frac{hrs}{week}}$$

and,

$$NG\ Savings = hrs \times \frac{60min}{hr} \times \frac{\varepsilon}{\eta} \times \frac{\rho}{35{,}738\,\frac{Btu}{m^3}} \times (h_3 - h_1) \times (1 - DF)$$

Where,

hrs	= Annual hours that the ERV is expected to be in use (hours/year)
$Heathrs$	= Number of hours in the heating season (hours/year)
$weeklyhrs$	= Number of weekly operating hours (hours/week)
$168\,\frac{hrs}{week}$	= Number of hours in a week
$NG\ Savings$	= Annual natural gas savings per CFM of ERV (m^3/CFM/year)
$\frac{60min}{hr}$	= Conversion from minutes to hours
ε	= Total effectiveness of the ERV (%)[4]
η	= The efficiency of the building's heating system (%)

[4] Note, for this analysis the rated total effectiveness is being used as an average total effectiveness.

ρ	= Density of air at 72°F (lb_m/ft^3)	Table
$35{,}738 \frac{Btu}{m^3}$	= Conversion from Btu to m^3 of natural gas	
h_3	= Enthalpy of the inside (exhaust) air entering the ERV (Btu/lb)	
h_1	= Enthalpy of the outside (supply) air entering the ERV (Btu/lb)	
DF	= Defrost control de-rating factor (%)	

Electric Energy Penalty Algorithms (For ERVs Added To An Existing System)

The electric penalty is based on the ENERGY STAR minimum fan efficiency requirements of 0.83 W/CFM. Using this value, and the calculated hours of ERV operation from the natural gas algorithms, the kWh electric penalty can be calculated using the following equation.

The kWh fan penalty analysis presumes that the system has an automatic bypass damper so that there is no added pressure drop during hours when heat recovery is not needed.

$$kWh\ penalty = 0.83 \frac{W}{CFM} \times hrs \div 1000 \frac{W}{kW}$$

Where,

$kWh\ penalty$	= The annual electric penalty per CFM of ERV capacity (kWh/ft³/min/year)
$0.83 \frac{W}{CFM}$	= Minimum efficacy to be qualified for ENERGY STAR (1.20 CFM/W)
hrs	= Annual hours that the ERV is expected to be in use (hours/year)

List of Assumptions

Table 4 shows the list of assumptions used in the algorithms sections.

Table 4. Assumptions

Variable	Definition	Value	Source
$Heathrs$	Hours in Heating Season, 55°F	5,567 hrs	Common

Variable	Definition	Value	Source
	Balance Temperature[5]		assumptions table
ε	Total effectiveness	63%	[4] and analysis in this document
ρ	Density of the exhaust air	0.0741 lb_m/ft^3	Common assumptions table
η	Efficiency of gas fired heating equipment	80%	Common assumptions table
h_1	Average enthalpy of outside (supply) air during the heating season	9.89 Btu/lb	[6], validated against psychrometric chart given rh1 / t1 and rh3 / t3 temperature and humidity (provide below).
h_3	Average enthalpy of inlet exhaust air	22.7 Btu/lb	
Fan Efficiency	Assumed fan efficiency	0.83 W/CFM	[3]
RH_1	Average outdoor relative humidity	46.7%	[5]
RH_3	Average indoor relative humidity	30%	[7], [2]
DF	Defrost control de-rating factor	5%[6]	[1] [2] [8] [7]
	Average temperature of outside (supply) air during the heating season	33°F	Common assumptions table
	Average temperature of inlet exhaust air	72°F	Common assumptions table

[5] The annual heating hours, and average outside air temperature, assume an average building balance temperature of 55°F, which is the temperature at which neither heating nor cooling is required. The actual balance point for a particular application will vary based on building construction, internal loads, HVAC system zoning, and other factors.

[6] All air-to-air heat recovery equipment requires frost control in colder climates to prevent freeze-up of exhaust air condensate on heat exchange components. There are different types of frost control methods and depending on the defrost control system, annual heat recovery estimates should be reduced by 5% to 15%. The cited Nexant document specifically considers the factor for Ontario (p. 6-47 and 6-48) and recommends 5% as a conservative value.

The assumed weekly hours of operation for different building types are given in Table 5.

Table 5. Hours of Weekly Operation [7]

Building Type	Hours of Operation per Week
Multi-Family	168
Health Care	168
Nursing Home	168
Hotel	120
Restaurant	87
Retail	73
Office	64
Warehouse	61
School	54

EXAMPLE

For this example it will be assumed that a new health care facility installs a 500 CFM ERV.

$$hrs = 5{,}567hrs \times \frac{168hrs}{168\frac{hrs}{week}} = 5{,}567hrs$$

and,

$$NG\ Savings = 5{,}567hrs \times \frac{60min}{hr} \times 0.0741\frac{lb_m}{ft^3} \times \frac{63\%}{80\%} \times \frac{1}{35{,}738\frac{Btu}{m^3}} \times \left(22.7\frac{Btu}{lb_m} - 9.89\frac{Btu}{lb_m}\right) \times (1 - 5\%) = 6.64\frac{m^3}{CFM}$$

Therefore,

$$NG\ Savings = 500CFM \times 6.64\frac{m^3}{CFM} = 3{,}320\ m^3$$

The electrical penalty can be calculated as the following.

$$kWh\ penalty = 500\ CFM \times 0.83\frac{W}{CFM} \times 5{,}567\ hrs \times \frac{1kW}{1000W} = 2{,}310\ kWh$$

USES AND EXCLUSIONS

- The ERV must have a sensible heat recovery effectiveness of at least 65%.
- Restriction for New Building Construction: This measure is not applicable to buildings in which an ERV is required by Ontario Building Code (SB-10). Note please see supporting measure that utilizes code minimum as baseline for these scenarios.
- Restriction for New Building Construction: This measure is not applicable to systems serving health care spaces indicated in Table 1 because heat recovery is required by CSA Z317.2-01

MEASURE LIFE

A 14 year measure life is recommended by DEER, based on KEMA-XENERGY's Retention Study of PG&Es 1996-1997 Energy Incentive Program. This study tracked installed equipment over 6 years and used statistical analysis to calculate EUL [7].

INCREMENTAL COST

Table 6 demonstrates the incremental cost of energy recovery ventilators.

Table 6. Incremental Cost [9]

Measure Type	Cost
Integrated units	CA$4.49/CFM
Bolted-on systems	CA$7.20/CFM

The incremental costs were developed by ERS using RSMeans and were corroborated with manufacturer data. The costs for integrated systems were found to be $3.60/CFM for ERVs integrated into HVAC systems and $5.77/CFM for standalone systems [9]. The increased cost from integrated to standalone or bolt-on systems is due to the additional materials and equipment required and the added labor for integrating the standalone or bolt-on system with the existing ventilation system.

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[1] Natural Resources Canada, "Heat/Energy Recovery Ventilators," 2 2012. [Online]. Available: http://oee.nrcan.gc.ca/sites/oee.nrcan.gc.ca/files/files/pdf/publications/HRV_EN.pdf.

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[3] ENERGY STAR, "Technical Specifications for Residential Heat Reocovery Ventilators and Energy Recovery Ventilators," 2012. [Online]. Available: https://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/hrv_erv/herv_prog_req.pdf?feb9-e816. [Accessed Oct 2014].

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Commercial Space Heating – Heat Recovery Ventilation (HRV) – New Construction/Time of Natural Replacement (50% Effectiveness Baseline)

Version Date and Revision History	
Draft date:	11/17/2015
Effective date:	TBD
End date:	TBD
Commercial → Heat Recovery Ventilation → New Construction Commercial → Heat Recovery Ventilation → Time of Natural Replacement	

Table 1 provides a summary of the key measure parameters with deemed savings coefficients.

Table 1. Measure Key Data

Parameter	Definition			
Measure Category	New construction (NC) where HRV is required by Ontario Building Code			
	Time of Natural Replacement (TNR)			
Base Technology	HRV with Minimum 50% Sensible Heat Recovery Effectiveness as per Ontario Building Code 2015			
Efficient Technology	HRV with Minimum 65% Sensible Heat Recovery Effectiveness at 32°F			
	HRV with Minimum 75% Sensible Heat Recovery Effectiveness at 32°F			
	HRV with Minimum 85% Sensible Heat Recovery Effectiveness at 32°F			
Market Type	Commercial Space Heating			
Annual Gas Savings with a HRV with Minimum 65% Sensible Heat Recovery Effectiveness at 32°F	**Building Type**	**Gas Savings Rate (m^3/CFM)** ε_{EE} 1	**Group** ε_{EE}1	**Average Group Gas Savings (m^3/CFM)** ε_{EE} 1
	Multi-Family, Health Care and Nursing Homes	1.16	High Use	1.16
	Hotels	0.83	Medium Use	0.64

Parameter	Definition			
	Restaurant	0.60		
	Retail	0.50		
	Office	0.44	Low Use	0.41
	Warehouse	0.42		
	School	0.37		
Annual Gas Savings with a HRV with Minimum 75% Sensible Heat Recovery Effectiveness at 32°F	**Building Type**	**Gas Savings Rate (m^3/CFM)** ε_{EE} 2	**Group** ε_{EE} 2	**Average Group Gas Savings (m^3/CFM)** ε_{EE} 2
	Multi-Family, Health Care and Nursing Homes	1.93	High Use	1.93
	Hotels	1.38	Medium Use	1.07
	Restaurant	1.00		
	Retail	0.84		
	Office	0.73	Low Use	0.68
	Warehouse	0.70		
	School	0.62		
Annual Gas Savings with a HRV with Minimum 85% Sensible Heat Recovery Effectiveness at 32°F	**Building Type**	**Gas Savings Rate (m^3/CFM)** ε_{EE} 3	**Group** ε_{EE} 3	**Average Group Gas Savings (m^3/CFM)** ε_{EE} 3
	Multi-Family, Health Care and Nursing Homes	2.70	High Use	2.70
	Hotels	1.93	Medium Use	1.50
	Restaurant	1.40		
	Retail	1.17		
	Office	1.03	Low Use	0.96
	Warehouse	0.98		
	School	0.87		
Measure Life	14 Years			
Incremental Cost	CA$1.00 per CFM at ε_{EE} 1			
	CA$2.00 per CFM at ε_{EE} 2			
	CA$3.00 per CFM at ε_{EE} 3			

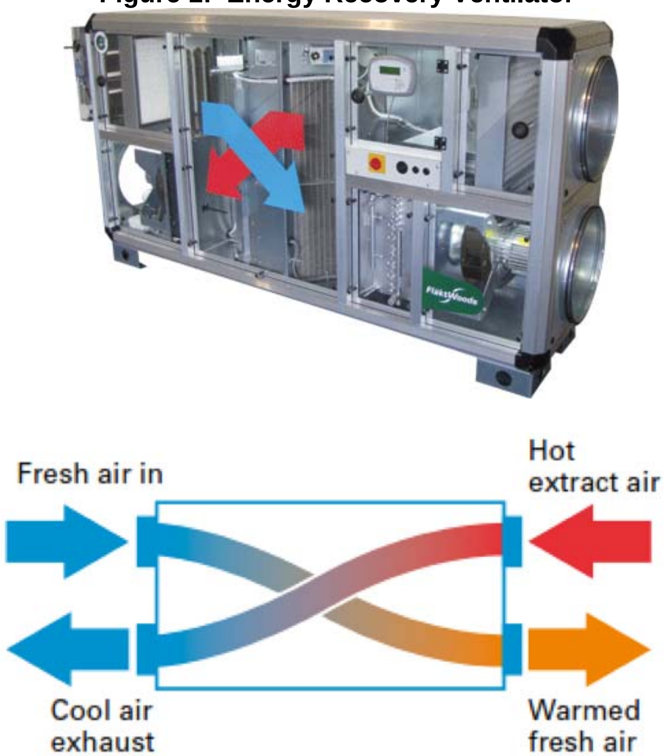
Parameter	Definition
Restrictions	This measure is not eligible in areas where: • 100% fresh air is required, • No recirculation is allowed by codes or standards. For instance: CSA Z317.2_10 (*Special Requirements for Heating, Ventilation, and Air Conditioning (HVAC) Systems in Health Care Facilities*) • Contaminants (gases and vapors) may be present and the HRV may bring them back into the breathing zone • Systems where no DCV or scheduled setbacks are required

OVERVIEW

A heat recovery ventilator (HRV) refers to heat exchanger equipment that is designed to transfer sensible heat from the building exhaust air to the outside supply air. The temperature of the outside supply air is raised by the heat transferred from the exhaust air stream within the heat exchanger. By doing so, the amount of heat energy lost through the exhaust air stream is reduced and energy is saved through decreased load on the building heating system [1].

Figure 1 shows an example and a schematic of an HRV.

Figure 1: Energy Recovery Ventilator[1]



APPLICATION

The measure covers the installation of heat recovery ventilators in commercial settings. The performance of the HRV can be quantified by its sensible effectiveness, which is defined as the ratio of actual heat energy captured to the maximum heat energy that could be captured. This is a value determined during testing and varies with temperature difference. Sensible heat recovery effectiveness is not to be confused with total effectiveness which is a measure of the heat and moisture transfer. All references to effectiveness within this document refer to sensible effectiveness, not total effectiveness. Other performance parameters to be considered are the pressure drop over the HRV, and the method of frost control for the heat exchanger [2].

BASELINE TECHNOLOGY

The baseline is considered to be a building operating with the use of an HRV as per Ontario Building Code (SB-10) and as shown in Table 2. [3]

[1] From http://www.nfan.co.uk/what_are_heat_recovery_systems, 12/15/2014

Table 2. Baseline for Heat Recovery Ventilators

Type	Efficiency
HRV	HRV with 50% Sensible Heat Recovery Effectiveness per Ontario Building Code (OBC)

EFFICIENT TECHNOLOGY

The efficient technology is defined as an HRV with a sensible heat recovery effectiveness of at least 65% as shown in Table 3. Note, ENERGY STAR requires that qualifying HRVs have a minimum rated sensible effectiveness of 60% at -13°F (-25°C) and 65% at 32°F (0°C) [4].

Table 3. Efficient Technology for Heat Recovery Ventilators

Type	Efficiency
HRV $\varepsilon_{EE}1$	Minimum 65% Sensible Heat Recovery Effectiveness at 32°F
HRV $\varepsilon_{EE}2$	Minimum 75% Sensible Heat Recovery Effectiveness at 32°F
HRV $\varepsilon_{EE}3$	Minimum 85% Sensible Heat Recovery Effectiveness at 32°F

ENERGY IMPACTS

Heat is recovered from the outgoing exhaust air and added to the incoming supply air. Natural gas savings are achieved because the incoming supply air arrives at the building heating equipment at a higher temperature than it would without an HRV. This means that less energy is required to heat the supply air to the set point temperature.

NATURAL GAS SAVINGS ALGORITHMS

The following algorithms are used to calculate the gas impact in cubic meters and are formulae from ASHRAE Heating, Ventilating and Air Conditioning Systems and Equipment Handbook 2012, Chapter 26 [2]. The ASHRAE equations make the following assumptions: no vapor condensation within the HRV, no cross leakage, no heat gas from fan motors, and equal supply and exhaust air flow rates.

The energy saved by an HRV is a function of the heat transfer rate through the heat exchanger and the length of time it operates. The heat transfer rate can be calculated from the temperature difference between the supply and exhaust air entering the HRV the average effectiveness of the HRV, the physical properties of air and the flow rate through the HRV. A defrost factor must also be considered to account for the time that exhaust air is diverted through the core in order to prevent freezing, which impedes the operation of the HRV.

The natural gas savings rates in Table 1 are calculated using the following formulae.

$$hrs = Heathrs \times \frac{weeklyhrs}{168\frac{hrs}{week}}$$

and,

$$NG\ Savings = hrs \times \frac{60min}{hr} \times \rho \times \frac{(\varepsilon_{EE-50\%})}{\eta} \times \frac{C_p}{35{,}738\frac{Btu}{m^3}} \times (T_3 - T_1) \times (1 - DF)$$

Where,

hrs	= Annual hours that the HRV is expected to be in use (hours/year)
$Heathrs$	= Number of hours in the heating season (hours/year)
$weeklyhrs$	= Number of weekly operating hours (hours/week)
$168\frac{hrs}{week}$	= Number of hours in a week
$NG\ Savings$	= Annual natural gas savings per CFM of HRV (m^3/CFM/year)
$\frac{60min}{hr}$	= Conversion from minutes to hours
ε_{EE}	= Sensible effectiveness of the high efficient HRV (%)
η	= The efficiency of the building's heating system (%)
C_p	= Specific heat of air (Btu/lb_m-°F)
ρ	= Density of air at 72°F (lb_m/ft^3) Table
$35{,}738\frac{Btu}{m^3}$	= Conversion from Btu to m^3 of natural gas
T_3	= Temperature of the inside (exhaust) air entering the HRV (°F)
T_1	= Average outside temperature during heating hours (°F)
DF	= Defrost control de-rating factor (%)

List of Assumptions

Table 4 shows the list of assumptions used in the algorithms sections.

Table 4. Assumptions

Variable	Definition	Value	Source

Variable	Definition	Value	Source
$Heathrs$	Hours in Heating Season, 55°F Balance Temperature[2]	5,567 hrs	Common assumptions table
$\varepsilon_{EE}1$	Minimum sensible effectiveness	65%	[6] and analysis in this document
$\varepsilon_{EE}2$	Minimum sensible effectiveness	75%	[6] and analysis in this document
$\varepsilon_{EE}3$	Minimum sensible effectiveness	85%	[6] and analysis in this document
ρ	Density of the exhaust air	0.0741 lb_m/ft^3	Common assumptions table
η	Efficiency of gas fired heating equipment	80%	Common assumptions table
C_p	Specific heat of air	0.240 Btu/lb_m-°F	Common assumptions table
DF	Defrost control de-rating factor	0%[3]	[8] [9] [10] [11]
T1	Average temperature of outside (supply) air during the heating season	33°F	Common assumptions table
T3	Average temperature of inlet exhaust air	72°F	Common assumptions table

The assumed weekly hours of operation for different building types are given in Table 5.

Table 5. Hours of Weekly Operation [11]

Building Type	Hours of Operation per Week

[2] The annual heating hours, and average outside air temperature, assume an average building balance temperature of 55°F, which is the temperature at which neither heating nor cooling is required. The actual balance point for a particular application will vary based on building construction, internal loads, HVAC system zoning, and other factors.

[3] All air-to-air heat recovery equipment requires frost control in colder climates to prevent freeze-up of exhaust air condensate on heat exchange components. There are different types of frost control methods and depending on the defrost control system, annual heat recovery estimates should be reduced by 5% to 15%. The cited Nexant document specifically considers the factor for Ontario (p. 6-47 and 6-48) and recommends 5% as a conservative value for the base case scenario.

Building Type	Hours of Operation per Week
Multi-Family	168
Health Care	168
Nursing Home	168
Hotel	120
Restaurant	87
Retail	73
Office	64
Warehouse	61
School	54

EXAMPLE

For this example it will be assumed that a new health care facility installs a 500 CFM HRV with a sensible effectiveness of 75%. In this case the $\varepsilon_{EE}2$ is applicable.

$$hrs = 5{,}567hrs \times \frac{168hrs}{168\frac{hrs}{week}} = 5{,}567hrs$$

and,

$$NG\ Savings = 5{,}567hrs \times \frac{60min}{hr} \times 0.0741\frac{lb_m}{ft^3} \times \frac{75\% - 50\%}{80\%} \times \frac{0.240\frac{Btu}{lb_m - °R}}{35{,}738\frac{Btu}{m^3}}$$
$$\times (72°F - 33°F) \times (1 - 5\%) = 1.93\frac{m^3}{CFM}$$

Therefore,

$$NG\ Savings = 500CFM \times 1.93\frac{m^3}{CFM} = 963\ m^3$$

USES AND EXCLUSIONS

This measure is intended for buildings with an existing HRV, or a new construction building that requires a heat recovery system. For buildings without an existing HRV, or new buildings not requiring a heat recovery system, please see supporting measure with no HRV baseline. Other restrictions include:

- Measure not applicable to areas and rooms where 100% fresh air is required.
- Measure not applicable to areas and rooms where no recirculation is allowed by codes or standards. For instance CSA Z317.2_10 (Special Requirements for Heating, Ventilation, and Air Conditioning (HVAC) Systems in Health Care Facilities).
- Measure not applicable to areas and rooms where contaminants (gases and vapors) may be present and the HRV may bring them back into the breathing zone.
- Measure not applicable to systems where no DCV or scheduled setbacks are required.

MEASURE LIFE

A 14 year measure life is recommended by DEER is based on KEMA-XENERGY's Retention Study of PG&Es 1996-1997 Energy Incentive Program. This study tracked installed equipment over 6 years and used statistical analysis to calculate EUL [11].

INCREMENTAL COST

The incremental costs, representing differences in equipment costs, between baseline units meeting minimum code efficiency and high efficiency units are $1.00 per cfm at 65%, $2.00 at 75%, and $3.00 at 85% efficiency[4] [12] .

[4] Based on a manufacturer's estimate that typical incremental installed cost premium for 85% efficiency heat recovery units are $3.00 /cfm greater than for 50% efficiency units.

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[2] ASHRAE Handbook, "Heating, Ventilating and Air Conditioning Systems and Equipment, 22, 26, and 28," 2012. [Online]. Available: http://handbook.ashrae.org/Handbook.aspx. [Accessed Oct 2014].

[3] "Building Code Act 1992 - Supplementary Standard SB-10," 14 September 2012. [Online].

[4] ENERGY STAR, "Technical Specifications for Residential Heat Reocovery Ventilators and Energy Recovery Ventilators," 2012. [Online]. Available: https://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/hrv_erv/herv_prog_req.pdf?feb9-e816. [Accessed Oct 2014].

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COMMERCIAL SPACE HEATING – ENERGY RECOVERY VENTILATION (ERV) – NEW CONSTRUCTION, TIME OF NATURAL REPLACEMENT (50% EFFECTIVENESS BASELINE)

Version Date and Revision History	
Draft date:	11/17/2015
Effective date:	TBD
End date:	TBD
Commercial → Energy Recovery Ventilation → New Construction Commercial → Energy Recovery Ventilation →Time of Natural Replacement	

Table 1 provides a summary of the key measure parameters with deemed savings coefficients.

Table 1. Measure Key Data

Parameter	**Definition**			
Measure Category	New Construction (NC) is required by Ontario Building Code			
	Time of Natural Replacement (TNR)			
Base Technology	ERV with Minimum 50% Energy Recovery Effectiveness as per Ontario Building Code 2015			
Efficient Technology	ERV with Minimum 65% Sensible Heat Recovery Effectiveness and 63% Total Energy Recovery Effectiveness at 32°F			
	ERV with Minimum 75% with Sensible Heat Recovery Effectiveness and 73% Total Energy Recovery Effectiveness at 32°F			
	ERV with Minimum 85% Sensible Heat Recovery Effectiveness and 83% Total Energy Recovery Effectiveness at 32°F			
Market Type	Commercial Space Heating			
Annual Gas Savings With a Minimum ERV Sensible Heat Recovery	**Building Type**	**Gas Savings Rate (m^3/CFM)** ε_{EE} 1	**Group** ε_{EE} 1	**Average Group Gas Savings (m^3/CFM)** ε_{EE} 1

Parameter	Definition			
Effectiveness of 65%	Multi-Family, Health Care and Nursing Homes	1.37	High Use	1.37
	Hotels	0.98	Medium Use	0.76
	Restaurant	0.71		
	Retail	0.60		
	Office	0.52	Low Use	0.49
	Warehouse	0.50		
	School	0.44		
Annual Gas Savings With a Minimum ERV Sensible Heat Recovery Effectiveness of 75%	**Building Type**	**Gas Savings Rate (m³/CFM)** ε_{EE} 2	**Group** ε_{EE} 2	**Average Group Gas Savings (m³/CFM)** ε_{EE} 2
	Multi-Family, Health Care and Nursing Homes	2.42	High Use	2.42
	Hotels	1.73	Medium Use	1.34
	Restaurant	1.25		
	Retail	1.05		
	Office	0.92	Low Use	0.86
	Warehouse	0.88		
	School	0.78		
Annual Gas Savings With a Minimum ERV Sensible Heat Recovery Effectiveness of 85%	**Building Type**	**Gas Savings Rate (m³/CFM)** ε_{EE} 3	**Group** ε_{EE} 3	**Average Group Gas Savings (m³/CFM)** ε_{EE} 3
	Multi-Family, Health Care and Nursing Homes	3.48	High Use	3.48
	Hotels	2.48	Medium Use	1.93
	Restaurant	1.80		
	Retail	1.51		
	Office	1.32	Low Use	1.23
	Warehouse	1.26		
	School	1.12		
Measure Life	14 Years			
Incremental Costs	CA$1.00 per CFM at ε_{EE} 1			

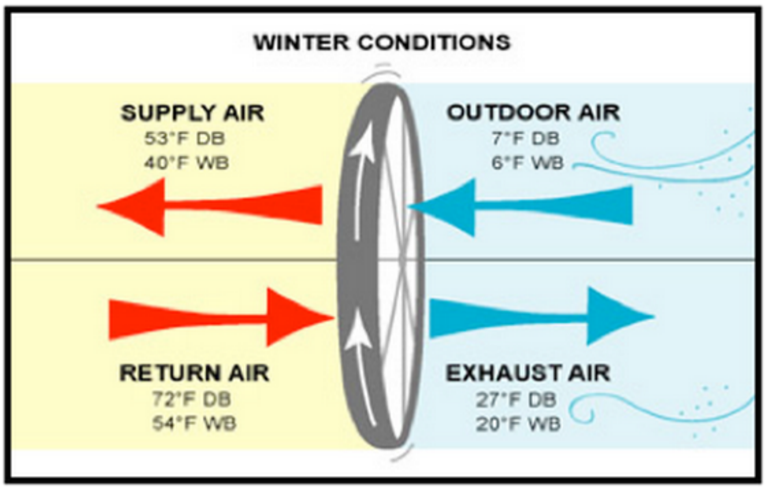
Parameter	Definition
	CA$2.00 per CFM at ε_{EE} 2
	CA$3.00 per CFM at ε_{EE}3
Restrictions	This measure is not eligible in areas where: • 100% fresh air is required, • No recirculation is allowed by codes or standards. For instance CSA Z317.2_10 (*Special Requirements for Heating, Ventilation, and Air Conditioning (HVAC) Systems in Health Care Facilities*), • Contaminants (gases and vapors) may be present and the ERV may bring them back into the breathing zone • no DCV or scheduled setbacks are required

OVERVIEW

An energy recovery ventilator (ERV) refers to heat exchanger equipment that is designed to transfer heat and moisture between the building exhaust air and the outside supply air. During the heating season, this raises the temperature of the outside supply air through heat transfer within the heat exchanger and typically adjusts the humidity of the supply air through moisture transfer. By doing so, the amount of energy wasted in heat through the exhaust air stream is reduced and energy is saved through decreased load on the building heating system. ERVs are available as desiccant rotary wheels or membrane plate exchangers [1].

Figure 1 is an illustration of a wheel-type energy recovery ventilator and functionality.

Figure 1: Energy Recovery Ventilator[1]



[1] From http://www.acelaenergy.com/aloha/products/energy-recovery/, 12/10/2014.

APPLICATION

The performance of the ERV can be quantified by its total effectiveness, which is a function of both its sensible and latent effectiveness. Sensible refers to heat transfer and latent refers to moisture transfer. Sensible effectiveness is defined as the ratio of actual heat energy captured to the maximum heat energy that could be captured. Latent effectiveness is defined as the ratio of actual moisture transferred to the maximum moisture that could be transferred. Total effectiveness is defined similarly as the ratio of actual energy transferred to the total energy transferred. These values are determined during testing and both vary with temperature and moisture differences. Other performance parameters to be considered are the pressure drop over the ERV, and the method of frost control **[2]**.

BASELINE TECHNOLOGY

The baseline is considered to be a building operating with the use of an ERV as per Ontario Building Code (SB-10). [3]

Table 2. Baseline for Energy Recovery Ventilators

Type	Efficiency
ERV	ERV with 50% Energy Recovery Effectiveness per Ontario Building Code (OBC)

EFFICIENT TECHNOLOGY

The efficient technology is defined as an ERV with a sensible heat recovery effectiveness of at least 65% as shown in Table 3. Note, ENERGY STAR requires that qualifying ERVs have a minimum rated sensible effectiveness of 60% at -13°F (-25°C) and 65% at 32°F (0°C) [4].

Table 3. Efficient Technology for Energy Recovery Ventilators

Type	Efficiency
ERV $\varepsilon_{EE}1$	Minimum 65% Sensible Heat Recovery Effectiveness at 32°F
ERV $\varepsilon_{EE}2$	Minimum 75% Sensible Heat Recovery Effectiveness at 32°F

Type	Efficiency
ERV $\varepsilon_{EE}3$	Minimum 85% Sensible Heat Recovery Effectiveness at 32°F

ENERGY IMPACTS

Heat and moisture are recovered from the outgoing exhaust air and added to the incoming supply air. Natural gas savings are achieved because the supply air arrives at the building heating equipment at a higher enthalpy than it would without an ERV. This means that less energy is required to heat the supply air to the set point temperature.

There are potential cooling electric savings that are possible with an ERV. The ERV pretreats the incoming outdoor air by removing heat and moisture with exhaust air. The potential savings are minimal since there are few hours where this would occur for the London, Ontario climate zone.

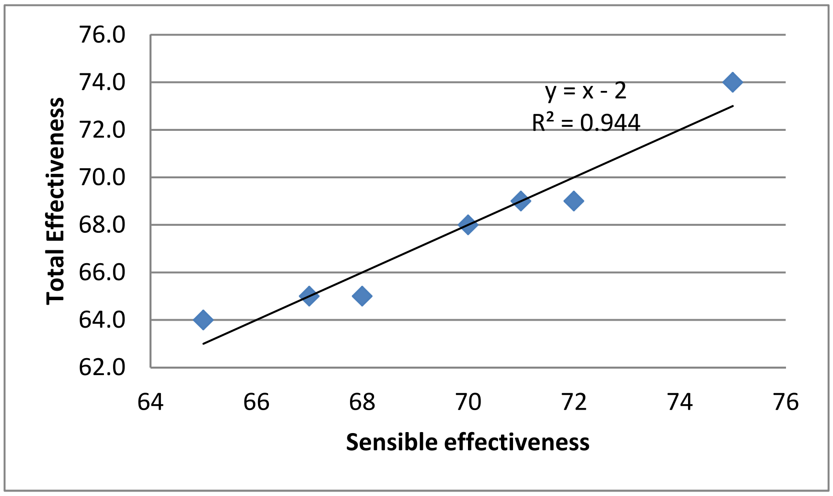
NATURAL GAS SAVINGS ALGORITHMS

The following algorithms are used to calculate the gas impact in cubic meters and are formulae from ASHRAE Heating, Ventilating and Air Conditioning Systems and Equipment Handbook 2012, chapter 26 [2]. The ASHRAE equations make the following assumptions: no vapor condensation within the ERV, no cross transfer of anything but moisture, no heat gains from fan motors, and equal supply and exhaust air flow rates.

The energy saved by an ERV is a function of the heat and moisture transfer rates through the heat exchanger and the length of time it operates. The heat and moisture transfer can be calculated from the enthalpy difference between the supply and exhaust air entering the ERV, the total effectiveness of the ERV, the physical properties of air, and the flow rate through the ERV. A defrost factor must also be considered to account for the time that exhaust air is diverted through the core in order to prevent freezing, which impedes the operation of the ERV.

Since the efficient technology is defined by the sensible heat recovery effectiveness, an assumption for the total recovery effectiveness is needed to calculate the energy savings for the measure. By comparing rated values of sensible heat recovery and total recovery effectiveness from the Air Conditioning, Heating and Refrigeration Institute (AHRI) database, [5] a relationship was developed between the two. This relationship is shown in Figure 2.

Figure 2. Total Effectiveness Versus Sensible Effectiveness



Total recovery effectiveness is approximately two percent less than heat recovery effectiveness. For instance, based on a sensible heat recovery effectiveness of 65%, a total recovery effectiveness of 63% is assumed for the efficient technology in this measure.

The natural gas savings rates in Table 1 are calculated using the following formulae.

$$hrs = Heathrs \times \frac{weeklyhrs}{168\frac{hrs}{week}}$$

and,

$$NG\ Savings = hrs \times \frac{60min}{hr} \times \frac{(\varepsilon_{EE-50\%})}{\eta} \times \frac{\rho}{35{,}738\frac{Btu}{m^3}} \times (h_3 - h_1) \times (1 - DF)$$

Where,

hrs	= Annual hours that the ERV is expected to be in use (hours/year)
$Heathrs$	= Number of hours in the heating season (hours/year)
$weeklyhrs$	= Number of weekly operating hours (hours/week)
$168\frac{hrs}{week}$	= Number of hours in a week
$NG\ Savings$	= Annual natural gas savings per CFM of ERV (m^3/CFM/year)
$\frac{60min}{hr}$	= Conversion from minutes to hours
ε_{EE}	= Total effectiveness of the high efficient ERV (%)[2]
η	= The efficiency of the building's heating system (%)
ρ	= Density of air at 72°F (lb_m/ft^3) Table

[2] Note, for this analysis the rated total effectiveness is being used as an average total effectiveness.

$35{,}738 \frac{Btu}{m^3}$	= Conversion from Btu to m³ of natural gas
h_3	= Enthalpy of the inside (exhaust) air entering the ERV (Btu/lb)
h_1	= Enthalpy of the outside (supply) air entering the ERV (Btu/lb)
DF	= Defrost control de-rating factor (%)

LIST OF ASSUMPTIONS

Table 4 shows the list of assumptions used in the algorithms sections.

Table 4. Assumptions

Variable	Definition	Value	Source
$Heathrs$	Hours in Heating Season, 55°F Balance Temperature[3]	5,567 hrs	Common assumptions table
$\varepsilon_{EE}1$	Total minimum effectiveness	63%	[5] and analysis in this document
$\varepsilon_{EE}2$	Total minimum effectiveness	73%	[5] and analysis in this document
$\varepsilon_{EE}3$	Total minimum effectiveness	83%	[5] and analysis in this document
ρ	Density of the exhaust air	0.0741 lb_m/ft^3	Common assumptions table
η	Efficiency of gas fired heating equipment	80%	Common assumptions table
h_1	Average enthalpy of outside (supply) air during the heating season	9.89 Btu/lb	[7], validated against psychrometric chart given rh1 / T1 and rh3 / T3 temperature and humidity (provide below).
h_3	Average enthalpy of inlet exhaust air	22.7 Btu/lb	
RH_1	Average outdoor relative humidity	46.7%	[6]

[3] The annual heating hours, and average outside air temperature, assume an average building balance temperature of 55°F, which is the temperature at which neither heating nor cooling is required. The actual balance point for a particular application will vary based on building construction, internal loads, HVAC system zoning, and other factors.

Variable	Definition	Value	Source
RH_3	Average indoor relative humidity	30%	[8], [2]
DF	Defrost control de-rating factor	0%[4]	[1] [2] [9] [8]
T1	Average temperature of outside (supply) air during the heating season	33°F	Common assumptions table
T3	Average temperature of inlet exhaust air	72°F	Common assumptions table

The assumed weekly hours of operation for different building types are given in Table 5.

Table 5. Hours of Weekly Operation [8]

Building Type	Hours of Operation per Week
Multi-Family	168
Health Care	168
Nursing Home	168
Hotel	120
Restaurant	87
Retail	73
Office	64
Warehouse	61
School	54

[4] All air-to-air heat recovery equipment requires frost control in colder climates to prevent freeze-up of exhaust air condensate on heat exchange components. There are different types of frost control methods and depending on the defrost control system, annual heat recovery estimates should be reduced by 5% to 15%. The cited Nexant document specifically considers the factor for Ontario (p. 6-47 and 6-48) and recommends 5% as a conservative value for the base case scenario.

EXAMPLE

For this example it will be assumed that a new health care facility installs a 500 CFM ERV with a total effectiveness of 75%. In this case the $\varepsilon_{EE}2$ is applicable.

$$hrs = 5{,}567hrs \times \frac{168hrs}{168\frac{hrs}{week}} = 5{,}567hrs$$

and,

$$NG\ Savings = 5{,}567hrs \times \frac{60min}{hr} \times 0.0741\frac{lb_m}{ft^3} \times \frac{(73\% - 50\%)}{80\%} \times \frac{1}{35{,}738\frac{Btu}{m^3}} \times \left(22.7\frac{Btu}{lb_m} - 9.89\frac{Btu}{lb_m}\right) \times (1 - 5\%) = 2.42\frac{m^3}{CFM}$$

Therefore,

$$NG\ Savings = 500CFM \times 2.42\frac{m^3}{CFM} = 1{,}210\ m^3$$

USES AND EXCLUSIONS

Note measure is intended for buildings with an existing ERV, or new construction buildings required to have a heat recovery system. For buildings without an existing ERV, or new buildings not required to have a heat recovery system, please see supporting measure with no ERV baseline. Also:

- Measure not applicable to areas and rooms where 100% fresh air is required.
- Measure not applicable to areas and rooms where no recirculation is allowed by codes or standards. For instance CSA Z317.2_10 (Special Requirements for Heating, Ventilation, and Air Conditioning (HVAC) Systems in Health Care Facilities).
- Measure not applicable to areas and rooms where contaminants (gases and vapors) may be present and the ERV may bring them back into the breathing zone.
- Measure not applicable to systems where no DCV or scheduled setbacks are required.

MEASURE LIFE

A 14 year measure life is recommended by DEER is based on KEMA-XENERGY's Retention Study of PG&Es 1996-1997 Energy Incentive Program. This study tracked installed equipment over 6 years and used statistical analysis to calculate EUL [8].

INCREMENTAL COST

The incremental costs, representing differences in equipment costs, between baseline units meeting minimum code efficiency and high efficiency units are $1.00 per cfm at 65%, $2.00 at 75%, and $3.00 at 85% efficiency[5] [10]

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[11] ERV/HRV manufacturer, Interviewee, *Incremental costs of installed equipment.* [Interview]. Nov 2015.

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HEAT REFLECTOR PANELS – RETROFIT

Version Date and Revision History	
Draft date	10/08/2015
Effective date	TBD
End date	TBD
Residential/Low-Income → Space Heating →Heat Reflector Panels→ Retrofit	

Table 1 provides a summary of the key measure parameters, with deemed savings values based on the efficient technology.

Table 1. Measure Key Data

Parameter	Definitions	
Measure category	Retrofit	
Base technology	No heat reflector panel installed behind radiator	
Efficient technology	Heat reflector panel installed behind radiator	
Market type	Residential	
Annual natural gas savings per single family household	***Efficient Technology***	***Savings***
	4.1% reduced gas consumption	143.2 m^3
Measure life	25 years	
Incremental cost	Utility to use actual per heat reflector panel cost in the year when savings are claimed. Likewise, installation costs to be determined similarly, based on utility in-field experience.	
Uses and Exclusions	To qualify for this measure, heat reflector panels must be implemented in older single-family residential homes by direct install using certified contractors.	

OVERVIEW

Space heating represents a large share of the energy consumption in homes. For older hydronically (hot water) heated homes, one of the simplest ways to reduce space heating costs is to reduce the amount of heat being absorbed by surrounding walls. Installing heat reflector panels behind radiators can have a noticeable impact on a residence's space heating energy consumption. The savings that can be achieved are attractive since this measure is relatively inexpensive and easy to implement.

A heat reflector panel, attached to the wall behind radiators, reflects heat back into the room that would usually absorbed by the wall. Also, the air trapped behind the radiator prevents conductive heat loss to the exterior.

APPLICATION

This measure pertains to the implementation of heat reflector panels in older (built before 1980) single-family residential homes that have hydronic heating through radiators served by boiler systems.

BASELINE TECHNOLOGY

The baseline technology is an older (built before 1980) single-family residential home with radiant heating and no heat reflector panels attached to the wall behind a radiator.

EFFICIENT TECHNOLOGY

The efficient technology is a saw tooth panel made of clear PVC with a reflective surface attached to the wall behind a radiator. [1]

ENERGY IMPACTS

The primary energy impact associated with implementation of heat reflector panels is a reduction in heat loss through the wall, thus resulting in a reduction in natural gas consumption. Table 1 in the "Overview" section provides deemed annual savings values (m^3 of natural gas) per single family home.

NATURAL GAS SAVINGS ALGORITHM

Results of Load Research Study

This algorithm outlines a methodology to determine the energy consumption as a function of the average boiler consumption of a single-family residence. It is based on a study conducted by Enbridge Gas Distribution Load Research Group in 2007 with the specific purpose of investigating the effects of heat reflector panels on residential heating consumption.

The study examined the gas consumption of boilers before and after the installation of heat reflector panels; the research details and study results were presented by Enbridge Gas Distribution in a 2008 report [2].

Automatic meter reading (AMR) equipment was installed at 31 randomly selected sample sites and boiler consumption was monitored for several weeks. Heat reflector panels were then installed by a panel manufacturer and monitoring of consumption continued. The daily consumption data collected was then separated into two groups: consumption before the installation of the heat reflector panel and consumption after the installation of the heat reflector panel.

Using the daily consumption data, the direction and magnitude of the impact of heat reflector panels was calculated by comparing the pre-installation period use-per-degree-day with the post-installation period use-per-degree-day for each site.

The study concluded that heat reflector panels, on average, reduced gas consumption by 4.1% within the sample. A 90% confidence interval was also computed for the average estimate (yielding a low value of 2.8% and a high value of 5.4%). The study provided 90% confidence that the true average would fall between the provided ranges when inferring from the sample to the population. The study results are summarized in Table 2:

Table 2. Summary of Results from EGD Load Research Group (2007) Study [2]

Number of Sites	31
Study Start Date	November 23, 2007
Study End Date	March 31, 2007
Average Change in Consumption	**-4.1%**
Standard Deviation of the Change	4.4%
90% Confidence Interval (High)	**-5.4%**
90% Confidence Interval (Low)	**-2.8%**

A previous Enbridge Gas Distribution Load Research study conducted in 2006 showed the average annual boiler consumption (with a 90% confidence interval) for a single-family residence to be 3,493 m^3 [2]. Applying the average change in consumption resulting from the Heat Reflector Panel study to an average boiler consumption of 3,493 m^3 resulted in an annual gas consumption savings value of 143.2 m^3.

$$Annual\ energy\ savings\ \left(\frac{m^3}{yr}\right) = Average\ annual\ consumption\ \frac{m^3}{yr} x\ (\%\ average\ change\ in\ consumption\ due\ to\ heat\ reflector\ panels)$$

List of Assumptions

Table 3 provides a list of constants and assumption used in the derivation of the deemed gas consumption savings values.

Table 3. Constants and Assumptions

Assumption	Value	Source
Average annual boiler consumption for an older single family residence (m^3)	3,493	[2]
Minimum space between radiator and the wall (inches)	0.25	[1]

SAVINGS CALCULATION EXAMPLE

The scenario for the gas savings is as follows. A heat reflector panel will be installed by certified contractors in a single-family residence which previously did not have any heat reflector panels.

Natural Gas Savings

Using the equation above for the installation of heat reflector panels compared to a residence not previously having any heat reflector panels,

$$Annual\ energy\ savings\ \left(\frac{m^3}{yr}\right)$$
$$= Average\ annual\ consumption\ \frac{m^3}{yr} x\ (\%\ average\ change\ in\ consumption\ due\ to\ heat\ reflector\ panels)$$

$$Annual\ energy\ savings\ (m^3/yr\ ) = 3{,}493\ \times\ (4.1\%)$$

$$Annual\ energy\ savings = 143.2\frac{m^3}{yr}$$

USES AND EXCLUSIONS

To qualify for this measure, heat reflector panels must be implemented in older single-family residential homes by direct install using certified contractors.

MEASURE LIFE

The measure life attributed to this measure is 25 years [3]

INCREMENTAL COST

The incremental cost for this measure could not be determined by looking at big-box retailer data. However, the previous substantiation sheet based the incremental cost on bulk purchases by the utility for program implementation. Since the incremental cost of the measure in the previous substantiation sheet is based on actual cost to the utility, it is the most accurate data. This method is consistent with other TRMs.

Table 4 presents the measure incremental cost.

Table 4. Measure Incremental Cost

Measure Category	Incremental Cost ($)
All measure categories	Utility to use actual per heat reflector panel cost in the year when savings are claimed. Likewise, installation costs to be determined similarly, based on utility in-field experience.

References

Works Cited

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SHOWERHEADS, MULTI-RESIDENTIAL UNITS

Version Date and Revision History	
Draft date	2/16/2015
Effective date	TBD
End date	TBD
Multi-residential/Low-Income → Water Heating →Low-flow showerheads→ New Construction/Retrofit	

Table 1 provides a summary of the key measure parameters, with deemed savings values based on the efficient technology.

Table 1. Measure Key Data

Parameter	Definitions	
Measure category	New Construction Retrofit	
Base technology	2.5 gpm	
Efficient technology	1.5 gpm	
	1.25 gpm	
Market type	Multi-residential	
Annual natural gas savings per showerhead	***Efficient Technology***	***Savings***
	1.25 gpm	38.3 m^3
	1.5 gpm	30.6 m^3
Annual water savings per showerhead	1.25 gpm	12,105 L
	1.5 gpm	8,322 L
Measure life	10 years	
Incremental cost	Utility to use actual per showerhead cost in the year when savings are claimed. Likewise, installation costs to be determined similarly, based on utility in-field experience.	
Restrictions	This document is applicable to low-flow showerheads that have been installed by way of Direct Installation in multi-residential households where sampling confirms the basecase is equal to or less efficient than 2.5 gpm.	

OVERVIEW

In Multi-residential households, one of the ways to reduce domestic hot water heating costs is to reduce the amount of hot water use. Installing low-flow showerheads can have a noticeable impact on a building's hot water consumption. The savings that can be achieved are attractive since this measure is relatively inexpensive and easy to implement.

Low-flow showerheads restrict the flow of the water while maintaining water pressure.

APPLICATION

This measure pertains to the implementation of low-flow showerheads in multi-residential households.

BASELINE TECHNOLOGY

The baseline technology is a showerhead with a flow of 2.5 gpm. [1]

EFFICIENT TECHNOLOGY

The efficient technology is a low-flow showerhead with a flow rate of 1.5 gpm or lower.

ENERGY IMPACTS

The primary energy impact associated with implementation of low-flow showerheads is a reduction in natural gas resulting from a reduction in the hot water consumption. Table 1 in the "Overview" section provides deemed annual savings values (m^3 of natural gas) per showerhead.

There is an additional reduction in water consumption associated with this measure.

NATURAL GAS SAVINGS ALGORITHM

Natural Gas

This algorithm outlines a methodology to determine the energy consumption as a function of a showerhead's rated flow-rate. It is based on the methodology developed by Navigant Consulting using data from a SAS statistical billing analysis study with the specific purpose of determining the impact of low-flow showerheads for single family homes in Ontario.

The SAS study [2] analyzed the gas consumption in Enbridge territory over the course of two years for 178 single family households which included a control group, a low-flow group, and a treatment group which had high-flow showerheads in the first year of the study. After a year into the study, showerheads in the treatment group were replaced with low-flow fixtures of 1.25 gpm.

The study resulted in two groups of savings: homes with showerheads that had pre-existing showerheads with full-on flow rates, or nominal/rated flow rates, between 2.0 gpm to 2.5 gpm and homes with showerheads with full-on flow rates greater than 2.5 gpm.

The full-on flow rate groups in the SAS sample and their associated savings levels per household are shown in Table 2:

Table 2. Savings from SAS Study [2] [3]

Rated Flow Rate	Average of Rated Flow Rates (gpm)[1]	Nominal Rated Flow of Low-flow Showerhead (gpm)	Nominal Flow Reduction (gpm)	Annual Savings (m^3)[2]	Annual Savings Per Nominal GPM Flow Reduction (m^3/gpm)
2.0 to 2.5 gpm	2.40	1.25	1.15	46.4	40.3
>2.5 gpm	3.09	1.25	1.84	87.8	47.7

The average reduction in annual natural gas use is 44.0 m^3 per gpm reduction in rated showerhead flow rate. Using this relationship, the gas savings can be calculated for any combination of baseline and high efficiency showerheads, if rated flow rate is known. The average number of showers was 2.06 per household. Using this factor, we can adjust the saving to a per showerhead basis.

$$\frac{Annual\ energy\ savings}{showerhead}\left(\frac{m^3}{yr}\right) = \frac{44\ \frac{\frac{m^3}{yr}}{gpm} \times\ (baseline\ rated\ gpm - high\ efficiency\ gpm)}{2.06\,\frac{showerheads}{household}}$$

This results in a savings calculation of:

$$\frac{Annual\ energy\ savings}{showerhead}\left(\frac{m^3}{yr}\right) = 21.4\ \frac{\frac{m^3}{yr}}{gpm} \times\ (baseline\ rated\ gpm - high\ efficiency\ gpm)$$

Based on data from Enbridge Gas (for the 2015 program year)[3], there are 1.02 showerheads per multifamily residence. Furthermore, for multi-residential homes, Navigant Consulting proposed an adjusted savings based on number of occupants per household to reflect differences in patterns of use and have conservatively assumed that, on average, the seasonal efficiency of the gas devices are similar. [4] The average number of people per single home in the referenced study in the treatment group, or where low-flow showerheads were installed, was 2.75 people per household. The average number of people in a multi-residential residence (weighted by type: buildings over 5 stories and (2) for buildings of five stories or less (1.9)) is 1.96 people.

[1] The average flow rate used here is from actual bag tested flow rate data provided by Enbridge Gas for the corresponding year of the SAS study (2007). [4]

[2] The savings presented here are from a SAS study, which analyzed consumption of households over two years, beginning in 2007. [3]

[3] According to Enbridge Gas data for the program year of 2015, as of November 12, 2015, there had been 7,280 showerheads replaced in 7,127 apartments, totaling about 1.02 showers per suite.

The showering behaviors of the residents in single family homes as compared to multifamily home should be similar, if not equal. Rather, the proportion of people per showerhead will be the driving factor in the savings.

$$Multifamily\ Savings\ \times \frac{MF\ People}{SF\ Showers} = Single\ family\ savings\ \times \frac{SF\ People}{SF\ Showers}$$

Based on these factors, the adjustment can be made as follows:

$$Multifamily\ Savings = Single\ family\ savings\ \times \frac{SF\ People}{SF\ Showers} \times \frac{SF\ Showers}{MF\ People}$$

We know the savings per showerhead for single family homes as determined above, thus the relationship reduces to:

$$Multifamily\ Savings = 21.4\ \frac{\frac{m^3}{yr}}{gpm} \times\ (baseline\ rated\ gpm - high\ efficiency\ gpm) \times SF\ People \times \frac{SF\ Showers}{MF\ People}$$

Applying all the factors above: the resulting savings per showerhead for multi-residential is:

$$Multifamily\ Savings = 21.4\ \frac{\frac{m^3}{yr}}{gpm} \times\ (baseline\ rated\ gpm - high\ efficiency\ gpm) \times 2.75\ people \times \frac{1.02\ Showers}{1.96\ People}$$

Resulting in:

$$Multifamily\ Savings = 30.62 \times\ (baseline\ rated\ gpm - high\ efficiency\ gpm)$$

WATER SAVINGS

The SAS study only presented natural gas savings for the region but did not report water savings. Another algorithm was used to determine the water savings:

$$Savings = \frac{Ppl \times 0.68 \times Sh \times 365 \times T \times (Fl_{base} - Fl_{eff}) \times 3.785 \frac{L}{gal} \times PSA}{Number\ of\ Showerheads}$$

Where,

$Savings$	= Annual savings in liters
Ppl	=Number of people per household
Sh	= Showers per capita per day
365	= Days per year

T	= Showering time (minutes)
Fl_{base}	= As-used flow rate with base equipment (GPM) – Calculated from equation from Summit Blue Study
Fl_{eff}	= As-used flow rate with efficient equipment (GPM) – Calculated from equation from Summit Blue Study
Number of Showerheads	=Number of showerheads

Fl_{base} and Fl_{eff} are the "as-used" flow rate. The nominal flow-rate is the flow the showerhead will deliver at full flow at 80 psi. However, based on Enbridge flow rate bag test data, the flow for installed fixtures varies from the rated flow rate of the showerhead. [3] [5] [6].

The following regression based on a study in 443 California homes of+ weighted regression analysis of as-used flow compared to full-on flow rate:

$$As - Used\ Flow\ Rate^{4} = 0.542 \times Nominal\ Flow\ Rate + 0.691\ [5]$$

Where,

$As - Used\ Flow\ Rate$	= Actual flow of installed showerhead
$Nominal\ Flow\ Rate$	= Rated flow listed on the showerhead

LIST OF ASSUMPTIONS

Table 3, provides assumptions used in the natural gas calculation.

Table 3. Constants and Assumptions for Natural Gas Savings Calculation

Assumption	Value	Source
Average persons per multi family residnce (2006)	1.96	Common assumptions table
Average number of showerheads per multi family residence	1.02	Enbridge Gas data
Average number of people per single family residence in SAS study treatment group	2.75	[2]
Average number of showers per single family residence in SAS study treatment group	2.06	[2]

Table 4 provides a list of constants and assumption used in the derivation of the deemed water savings values.

[4] The lower limit of this equation is 1.25 gpm due to water pressure limitations. As the showerhead flow rate is reduced, the full-on flow will approach the as-used flow since as there is a limit to the acceptable flow-rate. [5] As such, the algorithm assumes that a showerhead with a full-on flow rate of 1.25 gpm also has an as-used flow of 1.25 gpm. Actual flow rates lower that 1.25 gpm can be assumed to result in longer showers, negating additional savings.

Table 4. Constants and Assumptions for Water Savings Calculation

Assumption	Value	Source
Average persons per multi family residnce (2006)	1.96	Common assumptions table
Number of showerheads per residence	1.02	Enbridge data
Showers per capita per day	0.75	[5]
Average showering time per day per showerhead (minutes)	7.6 minutes	[5]

SAVINGS CALCULATION EXAMPLE

The scenario for the gas savings is as follows. A showerhead will be replaced with a 1.5 gpm showerhead for a multi-residential residence.

Natural Gas Savings

Using the equation above for the replacement of a baseline 2.5 gpm showerhead with a 1.5 gpm showerhead,

$$Annual\ energy\ savings\ (m^3/yr) = 30.62\ \frac{m^3/yr}{gpm} x\ (baseline\ rated\ gpm - high\ efficiency\ gpm)$$

$$Annual\ energy\ savings\ (m^3/yr\ ) = 30.62 \times\ (2.5 - 1.5)$$

$$Annual\ energy\ savings = 30.6\frac{m^3}{yr}$$

Water Savings

$$Savings = 1.96\frac{people}{residence} \times 0.75\frac{\frac{showers}{person}}{day} \times 7.6\frac{mins}{shower} \times 365\frac{days}{year} \times \left(2.05\ \frac{gallons}{min}\ -\ 1.5\ \frac{gallons}{min}\right) \times 3.785\frac{liters}{gal} \div 1.02 showerheads = 8{,}322\frac{liters}{year}$$

USES AND EXCLUSIONS

This document is applicable to low-flow showerheads that have been installed by way of Direct Installation in multi-residential households where sampling confirms the basecase is equal to or less efficient than 2.5 gpm.

Measure Life

The measure life attributed to this measure is 10 years. [5]

Incremental Cost

The incremental cost for this measure could not be determined by looking at big-box retailer data. The driver for higher cost of fixtures is the available features of the showerheads. However, the previous substantiation sheet based the incremental cost on bulk purchases by the utility for program implementation. Since the incremental cost of the measure in the previous substantiation sheet is based on actual cost to the utility, it is the most accurate data. This method is consistent with other TRMs.

Table 4 presents the measure incremental cost.

Table 5. Measure Incremental Cost

Measure Category	Incremental Cost ($)
All measure categories	Utility to use actual per showerhead cost in the year when savings are claimed. Likewise, installation costs to be determined similarly, based on utility in-field experience.

References

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