Ontario

NATURAL GAS DEMAND SIDE MANAGEMENT TECHNICAL RESOURCE MANUAL

Version 6.0

Date: December 16, 2021

Ontario Natural Gas Demand Side Management Technical Resource Manual

Introduction

This TRM is a document that provides essential information and source materials underpinning prescribed energy savings assumptions and/or calculations for a number of energy efficient technologies that are or may be in the future promoted by the Ontario gas utilities' energy efficiency programs.

The efficiency measures addressed by the TRM are prescriptive and quasi-prescriptive measures that lend themselves to standardized assumptions and algorithms, and for which estimated average savings can be determined to be reasonably accurate.

The assumptions and algorithms represent accepted engineering practice and have been substantiated with third party sources and data specific to Ontario and/or geographic areas with similar climates, to the extent possible and when applicable.

Natural gas savings are reported in gross cubic meters (m^3) of natural gas. Additional electric and water impacts have been included where applicable. Measure life and incremental cost have also been provided. The measures are organized by market, measure category, and end-use.

This TRM includes measures that have been considered by the utilities or might be considered in the future. It should be noted that the TRM is a technical reference document and as such inclusion in the TRM does not imply that it is appropriate to include a measure in the utilities' portfolio in a given program year.

Version History

The TRM is a dynamic document that will be periodically updated with new information supported by substantiated references. The TRM Version Date and Revision History table presented below briefly summarizes the history of the evolution of the introductory sections of the TRM. Similar tables summarize the development of assumptions for each individual measure in the technical sections of the TRM.

Date	Version	Reasons for Update
December 21, 2016	1.0	Original developed by Energy and Resource Solutions (ERS) and filed with the OEB. The TRM was commissioned by the Technical Evaluation Committee (TEC)[1], and was managed by a sub-committee of the TEC.
December 22, 2017	2.0	Update by the OEB's Evaluation Contractor (DNV GL and Dunsky) with input from the Evaluation Advisory Committee (EAC)[2]; the following measures were updated or added: • Commercial Incremental Energy Recover Ventilator (ERV), 55% Efficiency Baseline • Commercial Incremental ERV, No ERV Baseline • Commercial Incremental Heat Recovery Ventilation (HRV), 55% Efficiency Baseline • Commercial Incremental HRV, No HRV Baseline • Commercial Pedestrian Air Curtains with Vestibule
November 30, 2018	3.0	Update by the OEB's Evaluation Contractor (DNV GL and Dunsky) with input from the Evaluation Advisory Committee (EAC); the following measures were updated or added: • Commercial Demand Control Ventilation - Retrofit/Time of Natural Replacement/New Construction, Office/Retail Space • Commercial Demand Control Ventilation - Retrofit/Time of Natural Replacement/New Construction, Other Space Types • Commercial HVLS (High Volume Low Speed) Destratification Fans – New Construction/Retrofit • Multi-Residential Low-Flow Showerheads – New Construction • Residential Low-Flow Showerheads – New Construction Update to the Common Assumptions table input variables: heating hours per year and heating days per year; the following measures that reference these input variables received minor updates: • Commercial Air Curtains • Commercial Pedestrian Air Curtains with Vestibule • Commercial Incremental Energy Recovery Ventilator (ERV) 55% Efficiency Baseline • Commercial Incremental ERV, No Baseline • Commercial Incremental Heat Recovery Ventilator (HRV), 55% Efficiency Baseline • Commercial Incremental HRV, No Baseline • Residential Pipe Wrap

[1] The TEC consisted of utility representatives from each of Union Gas and Enbridge Gas Distribution as well as intervenor representatives and independent members with technical expertise. In its role to establish DSM technical and evaluation standards for natural gas utilities in Ontario, the TEC commissioned the development of the original TRM.

[2] The OEB outlined a structure to evaluate the results of Natural Gas Demand Side Management (DSM) programs from 2015 to 2020. The EAC will provide input and advice to the OEB on the evaluation and audit of DSM results. The committee will consist of representatives from non-utility stakeholders, independent experts, staff from the Independent Electricity System Operator (IESO), and observers from the Environmental Commissioner of Ontario and the Ministry of Energy, all working with OEB staff.

December 20, 2019	4.0	Update by the OEB's Evaluation Contractor (DNV GL and Dunsky) with input from the Evaluation Advisory Committee (EAC); the following measures were updated or added: • Commercial Air Curtains Shipping and Receiving – Dock-in (New Construction/Retrofit) • Commercial Air Curtains Shipping and Receiving – Drive-in (New Construction/Retrofit) • Commercial Air Curtains – Pedestrian Doors (New Construction/Retrofit) • Commercial Dock Door Seals (Retrofit) • Residential High Efficiency Condensing Furnace Measure (New Construction/Time of Natural Replacement) Update to the Common Assumptions table input variables: specific heat of air, OA temperature heating system enabled, space temperature setpoint, inside enthalpy for heating and cooling season, average outdoor relative humidity for heating season, and outdoor enthalpy for heating season. The following measures that reference these input variables received minor updates: • Commercial Incremental Energy Recovery Ventilator (ERV) 55% Efficiency Baseline • Commercial Incremental ERV, No Baseline • Commercial Incremental Heat Recovery Ventilator (HRV), 55% Efficiency Baseline • Commercial Incremental HRV, No Baseline The following measures were retired: • ENERGY STAR Clothes Washers • Commercial Pre-rinse Spray Nozzle (New Construction/Time of Natural Replacement/Retrofit
November 12, 2020	5.0	The OEB's Evaluation Contractor (DNV GL and Dunsky), with input from the Evaluation Advisory Committee (EAC), updated or added the following measures: • Commercial ENERGY STAR Convection Ovens – New Construction and Time of Natural Replacement • Commercial ENERGY STAR Rack Oven – New Construction and Time of Natural Replacement • Residential Low Income Programmable Thermostats – Retrofit • Residential/Low Income Heat Reflector Panels – Retrofit

December 16, 2021		The OEB's Evaluation Contractor (DNV and Dunsky), with input from the Evaluation Advisory Committee (EAC), updated or added the following measures: • Commercial Condensing Unit Heater – New Construction/Time of Natural Replacement • Commercial ENERGY STAR Combi-Ovens - New Construction/Time of Natural Replacement • Commercial Ozone Laundry - New Construction/ Retrofit • Commercial ENERGY STAR Convection Oven - New Construction/Time of Natural Replacement • Commercial ENERGY STAR Dishwashers – New Construction /Time of Natural Replacement • Multi-Residential – Low-Flow Showerheads – New Construction • Multi-Residential – Low-Flow Showerheads – Retrofit • Commercial – ENERGY STAR Rack Oven– New Construction/Time of Natural Replacement The following measures were retired: • Commercial – Infrared (Ir) Heaters <300kbtu/Hr – New Construction • Commercial – Infrared (Ir) Heaters <300kbtu/Hr – Retrofit

Purpose of the TRM

The objectives of the TRM are as follows:

- ❑ Provide transparent, standardized (where applicable), and substantiated assumptions and/or calculation algorithms for efficiency measure savings, costs and lifetimes, as well as their underlying sources.
- ❑ For each measure, establish the conditions under which the savings or other assumptions apply.
- ❑ Provide a basis from which stakeholders, such as utility/program administrators and independent third parties, can estimate the savings achieved for the Ontario energy efficiency portfolios.
- ❑ Support cost-effectiveness calculations for projects undertaken and funded by the utility efficiency programs.[3]
- ❑ Provide access to a chronology of the changes over time to measure assumptions – including the rationale used to support changes.

The purpose of the TRM does not include:

- ❑ Determination of free ridership or spillover values as they are more a function of program design than they are of technology specific factors.
- ❑ Recommendation of potential energy efficiency measures to utilities.
- ❑ Recommendation of program design structures or features.
- ❑ Methodologies for determining the potential savings for custom measures.

Measure Outline

Each measure follows a consistent format that includes the following components.

Version Date and Revision History

This section tracks the history of the measure development, including when the measure documentation was filed and approved by the OEB as well as classification for its application (see table below).

Version Date and Revision History	
Version	
OEB Filing Date	
OEB Approval Date	
Sector → End Use → Technology → Measure Category	

[3] The TRM includes several, but not all of the key inputs to be used in such calculations. Specifically, annual savings (gas, electric and water), incremental costs and measure lives are included, but net-to-gross ratios, non-measure (program) costs and avoided costs are not included.

Sector

"Sector" refers to the market categories (Residential, Multi-Residential, Commercial[4]) for which the measure substantiation document applies.

- **Commercial:** A location providing goods and services such as businesses or institutions, e.g. retail, hospitals, universities, etc. Industrial facilities are also included in this category; however, industrial process improvements are typically custom measures and not addressed by the TRM.
- **Multi-residential:** According to Ontario Regulation 282/98, the multi-residential property class is property used for residential purposes that has seven or more self-contained units,[5]
- **Residential:** According to Ontario Regulation 282/98, the residential property class is property used for residential purposes that has less than seven self-contained units.[6] Typically this includes single detached, semi-detached, row house and/or duplex.

Though Low-Income is a market type and not a market sector, it is appropriate to provide a definition for clarity as all substantiation documents apply to the Low-Income market unless otherwise noted.

***Low-Income**:* Low income residential utility customers face a much higher 'energy burden' (i.e. percent of household income devoted to energy costs) than median and higher income households. The OEB Guidelines (EB-2014-0134) provide additional detail around eligibility criteria for low-income utility customers in Section 6.4 on page 8.

End Use

"End Use" refers to service provided by the equipment (e.g. space heating, water heating, or food service).

Technology

"Technology" refers to the type of equipment (e.g. Adaptive Thermostat).

Measure Category

"Measure category" refers to the general decision types outlined in the OEB Filing Guidelines to the Demand Side Management Framework for Natural Gas Distributors (2015-2020). These decision types characterize how savings and costs are estimated relative to a frame of reference or "base case" that specifies what would have happened in the absence of the utility program. The decision types are defined as follows:

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[4] All Commercial sub docs apply to the Industrial market unless otherwise noted.

[5] https://www.ontario.ca/laws/regulation/980282#BK4

[6] Ibid

• **Early Replacement:** a measure category where a utility energy efficiency program has caused a customer to replace operable equipment with a higher efficiency alternative (also referred to as advancement).[7]

Example: An operating unit heater is replaced with a more efficient radiant heater.

• **Natural Replacement:** a measure category where the equipment is replaced on failure or where a utility energy efficiency program has not influenced the customer decision to replace but once the decision has been made, the utility program influences a higher efficiency alternative.

Example – An operational gas water heater is replaced because of visible rust, and a more efficient water heater, promoted by the program, is installed.

• **New Construction:** efficiency measures in new construction or major renovations, whose baseline would be the relevant code or standard market practice.

Example – A project design team, influenced by the program, specifies a high efficiency boiler rather than the least cost code compliant, or predominant industry practice, option.

• **Retrofit:** a measure category that includes the addition of an efficiency measure to an existing facility such as insulation or air sealing to control air leakage.

Example – An ozone treatment system is added to an existing commercial laundry system in order to facilitate using lower water temperatures.

Note - A single substantiation document may be applicable to multiple categories, and will be identified as such.

Substantiation Document Summary Table

Each substantiation document includes a summary table (see Table 1) outlining critical prescribed savings values or quasi-prescriptive savings factors, key measure parameters, incremental cost, measure life, and applicability factors.

[7] Some customers replace equipment when their existing equipment fails. For a variety of reasons (e.g. concern about energy or maintenance costs, better integration with other building systems, a desire to be able to plan for downtime rather than react to an emergency, etc.), other customers replace equipment before it fails. The key to an “early replacement” designation is that the utility program caused something to be replaced before it otherwise would have been.

Table 1. Measure Key Data

Parameter	Definition
Measure Category	Retrofit, early replacement, new construction, or time of natural replacement. These terms are defined in the Measure Categorization section.
Baseline Technology	The existing condition, code compliant, or standard practice measure depending upon the measure category.
Efficient Technology	The installed high efficiency measure as described in the substantiation document
Market Type	Commercial, Residential, Multi-Residential
Annual Natural Gas Savings	Expressed in cubic meters for prescriptive measures. Expressed as a savings factor (e.g. m3/lb) for quasi-prescriptive measures.
Annual Electric Impacts	Expressed in kWh for applicable measures. Positive values indicate savings. Negative values (-) indicate penalties.
Annual Water Impacts	Expressed in litres for applicable measures.
Measure Life	The length of time that a measure is expected to be functional and performing as predicted.
Incremental Cost ($)	The incremental cost is the difference in cost between the high efficiency technology and the baseline technology. The incremental cost includes incremental installation costs where appropriate.
Restrictions	Describes any limitations to the applicability of the measure's prescribed savings or relationships, such as minimum size or applicable building types.

Overview
This section introduces the technology, describes the energy savings strategy of the measure, and lists other descriptive details.

Application
This section describes market sector or other parameters where the technology in question may be applied. For example, it could address the history of code changes and why the substantiation document savings only apply to homes of a certain vintage or businesses of a certain size. It commonly relates to the restriction section in the summary table.

Baseline Technology
This section provides a definition of the efficiency level of the baseline equipment used to determine energy savings beyond baseline, including any standards or ratings if appropriate. The baseline also may include statements regarding the presumed type of equipment that will be replaced or upgraded. For example, the baseline equipment for commercial infrared heaters is presumed to be a unit heater as opposed to a central system. It may also include statements regarding part-load conditions.[8]

[8] Part-load performance is the ability of the system to handle energy use at conditions lower than the rated capacity of equipment. For example, a boiler may be sized to meet a maximum capacity to meet the load during the coldest day of the year. However, during warmer

Table 2 for each measure summarizes the baseline technology.

Table 2. Baseline for Energy Conservation Measure

Scenario	Requirement
Type of measure	Baseline Efficiency

Efficient Technology

This section provides a definition of the criteria for the efficient equipment used to determine the delta energy savings including any standards or ratings if appropriate. Table 3 for each measure summarizes the efficient technology.

Table 3. Efficient Technology for Energy Conservation Measure

Scenario	Requirement
Type of measure or equipment	Minimum level of efficiency

Energy Impacts

This section identifies the type of energy impacts resulting from implementing the measure (e.g. natural gas savings, electric impacts (savings/penalties)), and explains how this measure causes the change, in narrative form.

Natural Gas Savings Algorithm

This section presents the algorithm(s) utilized to estimate the natural gas savings for the measure. In some cases, the algorithms are used to derive an average natural gas savings for the measures, while for other measures (i.e. quasi-prescriptive) the algorithm(s) represent the derivation of a gas savings factor to be used given certain project assumptions.

Electric and/or Water Savings Algorithm

This section outlines the approach for determining any secondary impacts on other resources, such as electricity and water, and is included as needed.

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temperatures, the equipment will operate at some part-load depending on its ability to turn down to a lower firing rate. The operation and efficiency of the boiler will vary depending on the load conditions.

Assumptions
This section provides a reference table listing key assumptions that impact the measure savings analysis (e.g. hours of operation, equivalent full-load hours, weather criteria, load factors). For some measures, additional assumptions regarding hours of operation or the amount of time equipment or appliances are being used is provided, as applicable. It also provides references for the assumptions used in the measure analysis.

Savings Calculation Example
This section provides an example of a savings calculation. In the case of a quasi-prescriptive measure, application of the associated savings factor is explained.

Uses and Exclusions
This section outlines circumstances where a prescribed savings value is not appropriate.

Measure Life
This section provides the technology's measure life and any qualifying circumstances (e.g. evidence of regular maintenance).

Incremental Cost
This section describes the technology's incremental cost and any additional considerations pertaining to its determination. Incremental cost is dependent on the measure category. The utilities follow the OEB Guidelines' (EB-2014-0134) direction regarding the application of incremental costs as outlined in Section 9.1.1- Net Equipment Costs (pg. 26/27). The incremental cost has been indexed to 2015 and is expressed in Canadian dollars.

References
This TRM aims to provide best available and substantiated information collected at the time of its production. References (many available online) to documents are provided for each key assumption. Examples of references deemed appropriate for this TRM include:
- Efficiency program evaluations conducted both in Ontario and other jurisdictions within Canada and United States;
- Government studies on the performance and/or cost of efficiency technologies – within Ontario, other parts of Canada, the U.S. or outside North America when applicable;
- Other published research on the performance and cost of efficiency measures; within Ontario, other parts of Canada, the U.S. or outside North America when applicable;

Information collected directly from key technology manufacturers and/or other parts of the supply chain for the technology in Ontario (e.g. distributors, contractors, etc.)

Additional TRM Notes
This TRM includes prescribed (prescriptive and quasi-prescriptive) savings estimates that are expected to serve as average, representative values for the province of Ontario. All information

is presented on a per-measure basis. In using the measure-specific information in this TRM, it is important to keep the following notes in mind:

- Measure lives serve to represent the Ontario market and include measure persistence unless otherwise noted.

- In general, the baselines included in the TRM are intended to reflect average practices and conditions in Ontario.

Common Assumptions Table

Where assumptions are shared between multiple technologies, they have been gathered in a Common Assumptions Table. Among these common assumptions, London, Ontario was selected as a default climate zone, due to its elevation and annual average temperature cycle.

In addition to weather-related assumptions, the common assumptions include efficiencies for different types of equipment, common conversions, local conditions that would impact measures like average water temperature, heat content of natural gas, etc.

The Common Assumptions Table is reviewed and updated following a defined review process, which outlines frequency, a workplan to identify and prioritize assumptions and steps to update. The review process ensures assumptions used across all the measures are up to date and reflect current minimum equipment efficiency standards, building codes, studies, and programs.

Gas Properties/Physics Properties/Energy Conversions				
Input Variable	**Assumption**	**Units**	**Source / Comments**	**Affected Subdocs**
Energy density of natural gas	35,738	Btu/m^3 mmBtu/m^3 m^3/mmBtu MJ/m^3	RATE CHANGE #94, EB-2011-0354/EB-2013-0295 The source of the heat content for natural gas is the rate case as approved by the OEB	All Measures
Conversions				
Conversion of Btu/kWh	3,412	Btu/kWh	https://www.extension.iastate.edu/agdm/wholefarm/pdf/c6-86.pdf	All Measures
Conversion of kW/HP	0.7457	kW/HP	https://www.extension.iastate.edu/agdm/wholefarm/pdf/c6-86.pdf	All Measures
Physics Properties				
Acceleration due to gravity	32.2 ft/sec^2 (9.8 mps)	ft/sec^2	http://www.engineeringtoolbox.com/accelaration-gravity-d_340.html	Commercial Air Curtains

Fluid Properties				
Property	**Assumption**	**Units**	**Source / Comments**	**Affected Subdocs**
Specific heat capacity of water	1.00	Btu/lb ˚F	CSA P.3-04 Standard, Testing Method for Measuring Energy Consumption and Determining Efficiencies of Gas-Fired Storage Water Heaters.	Residential Tankless Water Heater Commercial ENERGY STAR Dishwasher Residential High Efficiency Water Heater
Density of water (@ 100 F)	8.29	lb/gal (US gallons)	http://www.engineeringtoolbox.com/water-specific-volume-weight-d_661.html	Residential Tankless Water Heater Commercial ENERGY STAR Dishwasher Residential High Efficiency Water Heater
Density of exhaust air (@ 72 F, 50% RH)	0.074	lb_m/ft^3	Air density calculated based on space temperature temperature setpoint in the common assumptions below. Exhaust air will be at the space conditions. Based on approach in ASHRAE Systems and Equipment Handbook 2012, Chapter 26	Commercial ERV Commercial HRV
Density of outdoor air for heating season	0.078	lb_m/ft^3	Average value calculated based on weather data CWEC data for London, ON (2016).Relative to a 55°F balance point	Commercial Air Curtains for Pedestrian door Commercial Air Curtains for Shipping & Receiving door Commercial Dock Door Seals
	1.256	kg/m^3		
Density of outdoor air for cooling season	0.073	lb_m/ft^3	Average value calculated based on weather data CWEC data for London, ON (2016).Relative to a 72°F balance point	Commercial Air Curtains for Pedestrian door Commercial Air Curtains for Shipping & Receiving door Commercial Dock Door Seals
	1.163	kg/m^3		
Specific heat of air	0.240	Btu/lb_m	2018 ASHRAE Handbook Fundamentals, Chapter 16 (IP Edition)	Commercial Air Curtains for Pedestrian door Commercial Air Curtains for Shipping & Receiving door Commercial Dock Door Seals Commercial HRV
	1,000	J/(kg·K)	2018 ASHRAE Handbook Fundamentals, Chapter 16 (SI Edition)	

Building Use and Occupancy				
Input Variable	**Assumption**	**Units**	**Source / Comments**	**Affected Subdocs**
Average single family residential household size	2.9	residents/ household	Calculated by taking the weighted average of all single-family homes, including detached, semi-detached, row house and duplex. https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/dt-td/Rp-eng.cfm?TABID=2&LANG=E&APATH=3&DETAIL=0&DIM=0&FL=A&FREE=0&GC=0&GID=1161871&GK=0&GRP=1&PID=109536&PRID=10&PTYPE=109445&S=0&SHOWALL=0&SUB=0&Temporal=2016&THEME=116&VID=0&VNAMEE=&VNAMEF=&D1=0&D2=0&D3=0&D4=0&D5=0&D6=0	Residential Showerheads (Single and Multiresidential) Residential Faucet Aerators (Kitchen and Bathroom) Residential High Efficiency Water Heater
Average multi-residential household size	1.90	residents/ household	Calulcated by determining the weighted average between buildings over 5 stories and buildings of five stories or less. https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/dt-td/Rp-eng.cfm?TABID=2&LANG=E&APATH=3&DETAIL=0&DIM=0&FL=A&FREE=0&GC=0&GID=1161871&GK=0&GRP=1&PID=109536&PRID=10&PTYPE=109445&S=0&SHOWALL=0&SUB=0&Temporal=2016&THEME=116&VID=0&VNAMEE=&VNAMEF=&D1=0&D2=0&D3=0&D4=0&D5=0&D6=0	Residential Showerheads (Single and Multiresidential)
Food service days per year	344.0	days	Value updated based on results of Ontario market end-user survey included in Frontier Energy's Technology Assessment Report: Commercial Gas ENERGY STAR Combi Ovens.	Commercial Cooking Measures (Underfired Broilers, Steamers, Fryers, and Convection Ovens) Commercial ENERGY STAR Dishwasher

Weather/Water Assumptions				
Input Variable	**Assumption**	**Units**	**Source / Comments**	**Affected Subdocs**
Average city or inlet water temperature	9.39 C (48.9 F)	deg C (deg F)	Average of findings in two studies, adjusted for Toronto water inlet temperature. Mayer, P. W. et al, Residential Indoor Water Conservation Study: Evaluation of High Efficiency Indoor Plumbing Fixture Retrofits in Single-Family Homes in East Bay Municipal Utility District Service Area, 2003 and Skeel, T. and Hill, S. Evaluation of Savings from Seattle's "Home Water Saver" Apartment/Condominium Program, 1994. Both cited in: Summit Blue (2008).From Faucet Aerator (Residential Bathroom)	Residential Tankless Water Heater Residential Faucet Aerators (Kitchen and Bathroom) Residential High Efficiency Water Heater Commercial Ozone Laundry

Water Heating Assumptions/Setpoints					
Input Variable		**Assumption**	**Units**	**Source / Comments**	**Affected Subdocs**
Domestic hot water factory set tank temperature	Commercial (for some facility types)	60 C (140F)	deg C (deg F)	Ontario Building Code, Section 9.31.6.1. Hot water temperature. http://www.buildingcode.online/2133.html.	Commercial ENERGY STAR Dishwasher
	Residential	48.9 C (120F)	deg C (deg F)	CPSC safety alert recommends users set water heaters to 120 F - https://www.cpsc.gov/s3fs-public/5098-Tap-Water-Scalds.pdf?m._5xOy.uwIEj8j_PNhlzcDfcLWoPdqJ#:~:text=The%20U.S.%20Consumer%20Product%20Safety,degree%20water%20for%20two%20seconds. 2017 Natural Resources LEEP report on water heating systems uses 49 Celcius - https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/pdf/16-426_Builder-Guide_E_ACC.PDF	Residential Tankless Water Heater Residential Faucet Aerators (Kitchen and Bathroom) Residential High Efficiency Water Heater
Natural gas storage tank water heater	Recovery Efficiency (Residential)	78.68%		Average from all models listed on NRCan. (2014).	Residential Faucet Aerators (Kitchen and Bathroom) Residential Pipe Wrap
	Thermal Efficiency (Commercial)	83.0%		Average of standard efficiency of units shipped in 2009, Caneta Research Inc., "Report For Baseline Information - TRM Development, page 5," Caneta Research, Inc, Mississauga, Ontario, August 19, 2013	Commercial ENERGY STAR Dishwasher Commercial Ozone Laundry

Space Conditioning Assumptions/Setpoints				
Input Variable	**Asssumption**	**Units**	**Source / Comments**	**Affected Subdocs**
Commercial heating system efficiency (Air Systems)	80%	Thermal Efficiency	ASHRAE 90.1-2004, ASHRAE 90.1-2007, ASHRAE 90.1-2010, for units below 225 MBH (Table 6.8.1E)	Commercial Kitchen DCV Commercial DCV Commercial Destratification Fans Commercial Air Curtains Commercial ERV Commercial HRV
Heating System Enabled (F)	12.78 C (55 F)	deg C (deg F)	Based on engineering judgment, professional experience with building design, and discussion from both ASHRAE Handbook 2013 and the Nexant ERV-HRV 2010 report: "Historically, heating degree days were reported on a 65°F basis (HDD65) due to poor insulation and low internal gains in a space... A newer building will have an even lower balance temperature with the current value of 50°F, since it will have improved insulation resulting in less heatloss." (Nexant ERV-HRV 2010 report pg. 6-40) ERS assumed a 55F balance temperature to be representative of all building types.	Commercial DCV
OA temperature heating system enabled	34.8	°F	Average London, ON outside dry bulb temperature when temperature drops below 55°F (balance point) based on CWEC data for London, ON (2016).	Commercial Air Curtains for Pedestrian door Commercial Air Curtains for Shipping & Receiving door Commercial Dock Door Seals Commercial ERV Commercial HRV
	1.6	°C		
	494.5	R		
	274.7	K		
Outside enthalpy for heating season	11.82	Btu/lb	Based on OA-heating = 34.8°F and RH= 76.6%. These are the Average London, ON outside dry bulb temperature and Average outside RH respectively, when temperature drops below 55°F. Weather data source: CWEC data for London, ON (2016))	Commercial ERV
Heating Hours per year*	5,293	hours	Relative to a 55F balance point. Based on CWEC data for London, ON (2016). Heating hours per year is the number of hours during the year when a heating system may be enabled due to the outdoor temperature being below the balance point. The balance point is the outdoor temperature at which the heating system will be enabled because the internal gains and the building losses are at equal. Below this temperature, heat must be added to the building to maintain the indoor temperature.	Residential Pipe Wrap Commercial Destratification Fans Commercial HRV Commercial ERV

Heating days per year	221	days	Relative to a 55F balance point. Based on CWEC data for London, ON (2016).	Commercial Air Curtains
Effective full load heating hours commercial New Construction*	1,500	hrs	25%Oversized_Infrared Analysis (Agviro Replicated) - with notes and Toronto March 4 2009 -.xls The full load heating hours is the number of hours during the year for which a heating system must operate at full load under design conditions or the peak capacity, in order for the system to satisfy the annual heating requirements of a new building.	Commercial Condensing Unit Heater Commercial Infrared Heaters
Effective full load heating hours commercial Retrofit*	2,000	hrs	25%Oversized_Infrared Analysis (Agviro Replicated) - with notes and Toronto March 4 2009 -.xls The full load heating hours is the number of hours during the year for which a heating system must operate at full load under design conditions or the peak capacity, in order for the system to satisfy the annual heating requirements of an average existing building.	Commercial Condensing Unit Heater Commercial Infrared Heaters
Rooftop Unit Cooling System Efficiency	13 SEER (3.81 COP - Converted to COP by dividing SEER by 3.412 kBtu/kWh)	kBtu/kWh	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	Commercial Air Curtains for Pedestrian door Commercial Kitchen DCV Commercial Air Curtains for Shipping & Receiving door Commercial Dock Door Seals
Space Temperature Setpoint	72.0	°F	Accepted based on engineering judgement. Typical conditions used in design projects. (Based on technical bulletin, ASHRAE 55-2013 notes that for thermal comfort purposes, temperature could range from between approximately 67 and 82 °F - https://www.ashrae.org/File%20Library/docLib/Technology/FAQs2014/TC-02-01-FAQ-92.pdf) Is used in examples: (http://www.climatemaster.com/downloads/lc1019-ashrae-journal-climatemaster-gshp-vs-VRF_article.pdf, p.7) (Energy Management Handbook, Wayne C. Turner, Steve Doty, p. 335)	Commercial Condensing Make-Up Air Unit Commercial DCV Commercial Air Curtains for Pedestrian door Commercial ERV Commercial HRV
	22.2	°C		
	531.7	R		
	295.4	K		
Space Temperature Setpoint- warehouse type of building	69.0	°F	Based on average of data from Enbridge custom projects	Commercial Destratification Fans Commercial Air Curtains- Shipping & Receiving Commercial Dock Door Seals
	20.6	°C		
	528.7	R		
	293.7	K		
OA temperature cooling system enabled	77.0	°F	Average London, ON outside dry bulb temperature when temperature is above 72°F based on CWEC data for London, ON (2016)	Commercial Air Curtains for Pedestrian door Commercial Air Curtains for Shipping & Receiving door ommercial Dock Door Seals
	25.0	°C		
	536.7	R		
	298.1	K		
Inside enthalpy for heating and cooling season	22.72	Btu/lb	Enthalpy at 72°F and 30% R.H. (ASHRAE Standard 62.1-2013 recommends that relative humidity in occupied spaces be controlled to less than 65% to reduce the likelihood of conditions that can lead to microbial growth. https://www.ashrae.org/File%20Library/docLib/Technology/FAQs2014/TC-02-01-FAQ-92.pdf)	Commercial ERV
Inside enthalpy for heating and cooling season- warehouse type of building	21.46	Btu/lb	Enthalpy at 69°F and 30% R.H. (ASHRAE Standard 62.1-2013 recommends that relative humidity in occupied spaces be controlled to less than 65% to reduce the likelihood of conditions that can lead to microbial growth. https://www.ashrae.org/File%20Library/docLib/Technology/FAQs2014/TC-02-01-FAQ-92.pdf)	Commercial Air Curtains- Shipping & Receiving Commercial Dock Door Seals
Outside enthalpy for cooling season	30.95	Btu/lb	Based on OA-cooling = 77.0°F and RH= 57.6%. These are the Average London, ON outside dry bulb temperature and Average outside RH respectively, when temperature is above 72°F. Weather data source: CWEC data for London, ON (2016)	Commercial Pedestrian Air Curtains Commercial Air Curtains- Shipping & Receiving Commercial Dock Door Seals
Cooling hours per year	965.0	hours/yr	Relative to a 72°F balance point- cooling and based on CWEC data for London, ON (2016).	Commercial Pedestrian Air Curtains Commercial Air Curtains- Shipping & Receiving Commercial Dock Door Seals
Cooling days per year	40.0	days/yr		
Average outdoor relative humidity for cooling season	57.6	%	Average London, ON Relative Humidity when outside dry bulb temperature is above 72°F based on CWEC data for London, ON (2016).	Commercial Pedestrian Air Curtains Commercial Air Curtains- Shipping & Receiving Commercial Dock Door Seals
Average outdoor relative humidity for heating season	76.6	%	Average London, ON Relative Humidity when outside dry bulb temperature drops below 55°F (balance point) based on CWEC data for London, ON (2016).	Commercial ERV

This update includes the following Measure Assumptions:

1. Residential Adaptive Thermostat (New Construction/Retrofit)
2. Residential High Efficiency Condensing Furnace (New Construction/Time of Natural Replacement)
3. Residential High Efficiency Water Heaters (New Construction)
4. Residential Low-Flow Showerheads (New Construction)
5. Residential Low-Flow Showerheads (Retrofit)
6. Residential Low Flow Faucet Aerators (Retrofit)
7. Residential Pipe Wrap (Retrofit)
8. Residential Programmable Thermostat (Retrofit)
9. Residential Tankless Water Heater (New Construction/Time of Natural Replacement)
10. Residential Low Income Heat Reflector Panels
11. Commercial – Air Curtains For Shipping and Receiving Doors “Dock-In”– New Construction/Retrofit
12. Commercial – Air Curtains for Shipping and Receiving Doors “Drive-In”– New Construction/Retrofit
13. Commercial – Air Curtains for Pedestrian Doors– New Construction/Retrofit
14. Commercial Condensing Make Up Air Unit (New Construction/Time of Natural Replacement)
15. Commercial Condensing Storage Gas Water Heater (New Construction/Time of Natural Replacement)
16. Commercial Condensing Unit Heater (New Construction/Time of Natural Replacement)
17. Commercial Demand Control Ventilation (New Construction/ Retrofit/Time of Natural Replacement)
18. Commercial Demand Control Ventilation (Expanded Space Types - New Construction/Retrofit/Time of Natural Replacement)
19. Commercial Destratification Fans (New Construction/Retrofit)
20. Commercial – Dock Door Seals (Retrofit)
21. Commercial Energy Recovery Ventilator (55% effectiveness baseline)
22. Commercial Energy Recovery Ventilator (No ERV baseline)
23. Commercial ENERGY STAR Convection Oven (New Construction/Time of Natural Replacement)
24. Commercial ENERGY STAR Dishwasher (New Construction/Time of Natural Replacement)
25. Commercial ENERGY STAR Fryer (New Construction/Time of Natural Replacement)
26. Commercial ENERGY STAR Steam Cooker (New Construction/Time of Natural Replacement)
27. Commercial Heat Recovery Ventilator (55% effectiveness baseline)
28. Commercial Heat Recovery Ventilator (No HRV baseline)
29. Commercial High Efficiency Condensing Furnace (New Construction/ Time of Natural Replacement

30. Commercial High Efficiency Under-Fired Broiler (New Construction/Time of Natural Replacement)
31. Commercial Multi-Residential Showerhead (New Construction)
32. Commercial Multi-Residential Showerhead (Retrofit)
33. Commercial Ozone Laundry (New Construction/Retrofit)
34. Commercial Condensing Tankless Gas Water Heater (New Construction/ Time of Natural Replacement)
35. Commercial Kitchen Demand Controlled Ventilation (New Construction/Time of Natural Replacement)
36. Commercial Kitchen Demand Controlled Ventilation (Retrofit)
37. Commercial ENERGY STAR Rack Ovens (New Construction/Time of Natural Replacement)
38. Commercial – ENERGY STAR Combi Oven– New Construction/Time of Natural Replacement

RESIDENTIAL – ADAPTIVE THERMOSTATS – NEW CONSTRUCTION/RETROFIT

Version Date and Revision History	
Version	1
OEB Filing Date	Dec 21, 2016
OEB Approval Date	
Residential → Space Heating → Adaptive Thermostats → New Construction/Retrofit	

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

Table 1. Measure Key Data

Parameter	Definition	
Measure Category	Retrofit (R) New Construction (NC)	
Baseline Technology	Non-Programmable (NPT) or Programmable Thermostat (PT)	
Efficient Technology	Adaptive Thermostat	
Market Type	Residential	
Annual Natural Gas Savings (m^3)	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
Annual Electrical Cooling Savings (kWh)	Retrofit – Retail Purchase	176 kWh
	Retrofit (Direct Install)	235 kWh
	New Construction	206 kWh
Measure Life	15 years	
Incremental Cost ($ CAD)	Retrofit	$300
	New Construction	$200
Restrictions	This measure requires that one adaptive thermostat would replace a conventional programmable or non-	

Parameter	Definition
	programmable thermostat serving one single zone heating appliance.

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 AND ELECTRIC 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

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[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.

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.

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.

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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.

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/ft² was applied against the average house size of 1,812 ft² [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 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 m³.[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/ ft² to the square footage of the new construction archetype (2,185 ft²), cooling load is estimated to be 1,282 kWh/year. Applying the 16% savings to this amount from

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[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.

[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.

the Cadmus Report [3] results in an estimated electric cooling savings of 205 kWh for new homes with central air conditioning.

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

ASSUMPTIONS

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

Table 3. 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 i
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

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Residential – High Efficiency Condensing Furnace – New Construction/Time of Natural Replacement

Version Date and Revision History	
Version	2
OEB Filing Date	Dec 20, 2019
OEB Approval Date	
Residential → Space Heating → High Efficiency Condensing Furnace → New Construction/Time of Natural Replacement	

Table 1 below provides a summary of the key measure parameters and a savings coefficient.

Table 1. Measure Key Data

Parameter	Definitions	
Measure Category	New Construction (NC) Time of Natural Replacement (TNR)	
Baseline Technology	95% AFUE	
Efficient Technology	97% AFUE	
Market Type	Residential	
Annual Natural Gas Savings Rate (m^3/kBtu/hr)	New Construction	0.343 m^3 per kBtu/hr of input capacity
	Time of Natural Replacement	0.446 m^3 per kBtu/hr of input capacity
Measure Life	18 years	
Incremental Cost ($ CAD)	$188	
Restrictions	Installed equipment must have at least a 97% AFUE. This measure is restricted to central air furnaces in residential homes. In addition to residential type dwellings, this measure is also applicable to multi-residential dwellings where each home is served by a dedicated standalone furnace(s)	

OVERVIEW

The measure is for the installation of condensing furnaces with an AFUE of 97% or higher in 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.

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 central forced air furnaces have at least a 95% rated annual fuel utilization efficiency (AFUE) [1]. The baseline technology is the minimum efficiency required by the regulations established December 12, 2019.

Table 2. Baseline Technology

Type	AFUE
Gas Condensing Furnace	95%

EFFICIENT TECHNOLOGY

The efficient technology is a furnace with an AFUE rating equal to, or higher than 97%.

Table 3. Efficient Technology

Type	AFUE
Gas Condensing Furnace	97%

ENERGY IMPACTS

The primary energy impact associated with the installation of condensing furnaces is a reduction in natural gas usage resulting from improved efficiency.

Canada's Energy Efficiency Regulations now require that new residential furnace fans have a Fan Efficiency Rating (FER), rated in Watts/cfm [2]. In order to comply with the regulation, it will, in most cases, require a change from a permanent split capacitor (PSC) motor to an electronically commutated motor (ECM). 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]. No water consumption 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[1], 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[2].

The 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)

[1] The Caneta Research report provides EFLH values for 6 different houses in London Ontario. The 6 homes include a mix of new construction and existing, 2 archtypes (townhouse and detached), and 3 square footages (1250, 2000, 3000). A representative EFLH for NC and TNR is calculated using the Caneta Research report along with additional data from NRCan [13] and Statistics Canada [14] regarding the prevalence of, and average size of, townhomes and detached homes in Ontario.

[2] 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 savings by 5% if output capacity is the basis.

$35.738\frac{kBtu}{m^3}$	= Conversion of rated heating capacity from input kBtu/hr to m^3/hr
$AFUE_{EE}$	= Efficient equipment AFUE (%)
$AFUE_{base}$	= Baseline equipment AFUE (%)

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	NC	583 hours	[4] based on homes in London Ontario, adjusted to reflect average Ontario home square footage
		TNR	757 hours	

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 in a newly constructed home. 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.

$$NG\ savings\ factor = \frac{583 hours}{35.738\frac{kBtu}{m^3}} \times \left(\frac{97\%}{95\%} - 1\right) = \frac{0.343\ m^3}{\frac{kBtu}{hr}}$$

And,

$$Annual\ NG\ savings = \frac{0.343\ m^3}{\frac{kBtu}{hr}} \times 110\frac{kBtu}{hr} = 38\ m^3$$

USES AND EXCLUSIONS

To qualify for this measure the condensing furnaces must be gas-fired, have an AFUE of at least 97%, and be installed in a residential home. In addition to residential type dwellings, this measure is also applicable to multi-residential dwellings where each home is served by a dedicated standalone furnace(s).

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 $188[3] based on the average difference in incremental cost between 95 AFUE and 97 AFUE residential furnaces. [9]

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RESIDENTIAL – HIGH EFFICIENCY GAS STORAGE WATER HEATERS – NEW CONSTRUCTION

Version Date and Revision History	
Version	1
OEB Filing Date	Dec 21, 2016
OEB Approval Date	
Residential → Water Heating → High Efficiency Gas Storage Water Heaters → New Construction	

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

Table 1. Measure Key Data

Parameter	Definition	
Measure Category	New Construction (NC)	
Baseline Technology	ENERGY STAR power vented storage tank water heater	Energy factor of 0.67
Efficient Technology	High efficiency storage water heater	Energy factor of 0.80
Market Type	Residential	
Annual Natural Gas Savings (m^3)	68.3 m^3	
Measure Life	16 years	
Incremental Cost ($ CAD)	$545	
Restrictions	This measure is restricted to new construction installations in residential homes.	

OVERVIEW

This measure is for the installation of a new high efficiency gas storage water heater in the case of residential new construction.

There are two major categories of water heating equipment for domestic use: storage water heaters, which keep a supply of hot water in a tank, and those that do not store hot water and only heat water when it is needed.

Gas storage water heaters can further be differentiated by natural draft or power vented flue gas exhaust. A power vent is a fan that speeds the exhaust of combustion gases, which increases efficiency, which increases overall performance but requires additional capital cost. An ENERGY STAR power vent storage water heater is considered the baseline for this measure.

Storage water heaters have a lower capital cost than on-demand water heaters, but they also have standby heat losses associated with continuously maintaining water stored at high temperatures. Higher efficiency storage water heaters have tanks with generous amounts of insulation to reduce these losses and more efficient gas burners than standard efficiency storage water heaters.

APPLICATION

This measure focuses on high efficiency gas storage water heaters that have efficiencies above the basic code requirements (new construction projects or time of natural replacement) in a residential setting.

Gas storage water heaters are performance rated using an energy factor (EF). The EF is a measure of efficiency and it can be defined as the total energy delivered as hot water divided by the total energy consumed by the water heater over a 24-hour period in simulated use.

These ENERGY STAR units have an EF of 0.67 and the ability to produce at least 67 US gallons per hour of hot water after warm-up. This measure is intended to provide an incentive to install the highest efficiency power vented water heaters with an EF of 0.80 or greater. The energy consumption of high efficiency water heaters is calculated based on the daily and annual water consumption of a household (according to the number of people in the household) extrapolated from a hot water consumption research study undertaken by Natural Resources Canada (NRCan) [1]. Tank volume capacity requirements are associated with the number of occupants and what is standard issue according to the manufacturers, e.g., a typical family of three to four people would warrant a 50-US gallon tank in order to meet the hot water demand for the household.

BASELINE TECHNOLOGY

For the new construction market, the ENERGY STAR rated power vented storage water heaters are considered baseline because experience indicates that this is a popular choice amongst homebuilders today in order to achieve an efficiency level that falls within the OBC SB-12 required compliance path as referenced in Table 2.1.1.2.A of that supplementary standard. [2] [3] A gas storage water heater with a minimum EF to qualify for ENERGY STAR is shown in Table 1.

Table 1. Baseline Technology

Type	Water Heater Input (Btu/hr)	EF
Gas storage water heater	<75,000	0.67

EFFICIENT TECHNOLOGY

A high efficiency gas storage heater with a minimum energy factor is shown in Table 2.

Table 2. Efficient Technology

Type	Water Heater Input (Btu/hr)	Minimum EF
Gas storage water heater	<75,000	0.80

ENERGY IMPACTS

Natural gas savings are achieved due to the difference in efficiencies between a high efficiency option and the baseline efficiency gas storage water heaters. The higher-efficiency equipment is typically able to both heat and store hot water more efficiently than the standard equipment.

There is a small amount of electrical savings for this measure, which have been shown to be negligible (<1 kWh annually) in the calculations.

NATURAL GAS SAVINGS ALGORITHMS

The following algorithms are referenced from the DOE Water Heater Analysis Model (WHAM) [4] and were used to calculate the stipulated gas impact in cubic meters per year and electric impact in kWh per year.

The total annual energy consumption for the water heater, Q_{In}, is calculated with the inlet water temperature specific to Ontario installations derived from the reference provided in Table 4 below. The total annual natural gas consumption of the water heater is the total annual energy consumption of the unit converted from British thermal units (Btus) to meters cubed.

The energy consumption of the high efficiency water heaters is calculated based on the daily and annual water consumption of a household (according to the number of people in the household) extrapolated from a hot water consumption research study undertaken by NRCan [5]. Tank volume capacity requirements are associated with the number of occupants and what is standard issue according to the manufacturers, e.g., a typical family of three to four people would warrant a 50-US gallon tank in order to meet the hot water demand for the household.

$$Q_{Out} = \rho \times V \times C_P \times (T_F - T_I)$$

where,

Q_{Out} = Energy required to heat tap water to tank temperature (Btu/day)

ρ = The density of water (lb/gal)

V = The daily drawn water (gal/day)

C_P = The specific heat of water (Btu/lb °F)

T_F = The water tank temperature (°F)

T_I = The inlet water temperature to the water heater (°F)

$$Q_{In} = 365 \times (\frac{Q_{Out}}{RE} + UA \cdot (T_{Tank} - T_{Amb}) \times \left(24 - \frac{Q_{Out}}{RE \cdot P_{On}}\right))$$

where,

Q_{In} = The total annual water-heater energy consumption (Btu/year)

Q_{Out} = Energy required to heat tap water to tank temperature (Btu/day)

RE = Recovery efficiency

UA = Standby heat-loss coefficient

T_{Tank} = Average tank temperature (°F)

T_{Amb} = Ambient air temperature (°F)

P_{On} = Water heater input rate (kBtu/hr)

$$Annual\ NG\ consumption = Q_{In}$$

$$Annual\ NG\ savings = Annual\ NG\ consumption\ (baseline) - Annual\ NG\ consumption\ (high\ efficiency)$$

ASSUMPTIONS

Table 4 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 4. Assumptions

Variable	Definition	Inputs		Source/Comments
		Base Efficiency	High Efficiency	
	Average single family residential household size	2.9		Common assumptions table
C_p	Specific heat capacity of water	1.00 Btu/lb ˚F		Common assumptions table
ρ	Density of Water	8.29 lb/gal		Common assumptions table
V	Daily drawn water	42 US gallons		[5]
RE	Recovery efficiency	0.78	0.90	[6]
UA	Standby heat-loss coefficient	5.78		[4]
T_{Amb}	Ambient air temperature	67.5°F (19.7˚C)		[7]
T_{In}	Average city or inlet water temperature	48.9°F (9.39˚C)		Common assumptions table
T_{Tank}	Domestic hot water factory set tank	120°F (48.9˚C)		Common assumptions table

Variable	Definition	Inputs		Source/Comments
		Base Efficiency	High Efficiency	
	temperature			
P_{on}	Water heater input rate ()	44.89 kBtu/hr	40.00 kBtu/hr	[6]
	Tank size	50 US gallons		[5]
	Energy density of natural gas	35,738 m^3/Btu		Common assumptions table

SAVINGS CALCULATION EXAMPLE

The example below illustrates how the savings value is determined for a retrofit installation of a high efficiency storage tank hot water heater. For this example, it will be assumed that the equipment is sized for installation in a household size of three, which is the average household size in Ontario.

Q_{out} can be calculated with actual values for the daily drawn water volume and inlet temperature, but similarly to above. This value is the same for both the baseline and the high efficiency technology:

$$Q_{Out} = 8.30 \times 30 \times 1.00 \times (120°F - 48.9°F) = 17{,}442\ Btu$$

Using Q_{Out}, the total annual water heater energy consumption can be calculated as Q_{In} for both the baseline and the high efficiency equipment:

$$Q_{In\ base} = 365/1000 \times \left(\frac{17{,}442}{0.784} + 5.78 \times (120°F - 67.5°F) \times \left(24 - \frac{17{,}442}{0.784 \cdot 44{,}894}\right)\right)$$
$$= 14{,}145\ kBtu$$

Similarly,

$$Q_{In\ HE} = 11{,}724\ kBtu$$

Now the Q_{In} for the baseline and high efficiency technology can be subtracted and converted to meters cubed of natural gas savings.

$$Annual\ NG\ savings = 14{,}145 - 11{,}724 = 2{,}420\ kBtu$$

$$Annual\ NG\ savings = 2{,}420\ kBtu \times \frac{1{,}008}{35{,}738} = 68.3\ m^3$$

USES AND EXCLUSIONS

This measure requires that the gas storage water heaters be of a nominal input of 75 KBtu/hr or less and also be of the highest power vented efficiency or at least 0.80 EF.

Measure Life

The measure life is 16 years [8].

Residential high efficiency water heaters have a highly variable life expectancy because maintenance and water quality factors, such as hardness, can have a great effect on the equipment's lifetime [9] [10]. Most water heaters used in the Enbridge and Union areas are provided through water heater rental businesses and are therefore constructed of higher durability than standard units for purchase. This measure is also for the highest-efficiency units, which will have a more durable construction than standard units. Considering this, the lifetime referenced, though it's at the high end for typical residential units, is appropriate.

Incremental Cost

The average approximate incremental cost, including installation, for a 40 to 50 US-gallon storage tank water heater is $545[1],[2]

Note: At this point there is only one manufacturer of water heaters that meet the high efficiency criteria, but the units are sold under different trade names.

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RESIDENTIAL – LOW-FLOW SHOWERHEADS – NEW CONSTRUCTION

Version Date and Revision History	
Version	2.0
OEB Filing Date	November 30, 2018
OEB Approval Date	
Residential/Low-Income → Water Heating →Low-flow Showerheads→ New Construction	

Table 1 provides a summary of the key measure parameters and savings values based on the efficient technology.

Table 1. Measure Key Data

Parameter	Definitions	
Measure Category	New Construction (NC)	
Baseline Technology	2.0 gpm	
Efficient Technology	1.5 gmp	
	1.25 gpm	
Market Type	Residential	
Annual Natural Gas Savings per Showerhead (m^3)	***Efficient Technology***	***Savings***
	1.25 gpm	16.9 m^3
	1.5 gpm	11.3 m^3
Annual Water Savings per Showerhead (liters)	1.25 gpm	9,119 liters
	1.5 gpm	4,860 liters
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	None.	

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 2.0 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. There is reduction in water consumption associated with this measure.

NATURAL GAS SAVINGS ALGORITHM

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 in each household was 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.

$$Annual\ energy\ savings\ \left(\frac{m^3}{yr}\right) = 44\ \frac{\frac{m^3}{yr}}{gpm} \times\ (baseline\ rated\ gpm - high\ efficiency\ gpm)$$

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 in the SAS study 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:

$$\frac{Annual\ energy\ savings}{showerhead}\left(\frac{m^3}{yr}\right) = 21.4\ \frac{\frac{m^3}{yr}}{gpm} \times\ (baseline\ rated\ gpm - high\ efficiency\ gpm)$$

Because the population in the study had an average of 2.75 people per household as compared to 2.9 people per single family household based on census data, it is necessary to adjust the usage to reflect this.

$$\frac{Annual\ energy\ savings}{showerhead}\left(\frac{m^3}{yr}\right) = 21.4\ \frac{\frac{m^3}{yr}}{gpm} \times\ (baseline\ rated\ gpm - high\ efficiency\ gpm) \times \frac{2.9\ people}{2.75\ people}$$

[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). [3]

[2] The savings presented here are from a SAS study, which analyzed consumption of households over two years, beginning in 2007. [2]

$$\frac{Annual\ energy\ savings}{showerhead}\left(\frac{m^3}{yr}\right) = 22.5\ \frac{\frac{m^3}{yr}}{gpm} \times\ (baseline\ rated\ gpm - high\ efficiency\ gpm)$$

WATER SAVINGS ALGORITHM

The water savings were calculated using the following algorithm:

$$Savings = Ppl \times Sh \times 365\frac{days}{year} \times T \times (Fl_{base} - Fl_{eff}) \times 3.785\frac{L}{gal} \times PSA$$

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)

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

[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.

ASSUMPTIONS

Table 7 provides a list of constants and assumption used in the derivation of the water savings values.

Table 7 Assumptions

Assumption	Value	Source
Average person per single detached house (2006)	2.9	Common assumptions table
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]
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 2.0 gpm showerhead with a 1.5 gpm showerhead,

$$Annual\ energy\ savings\ (m^3/yr)\ = 22.5\ \frac{m^3/yr}{gpm} x\ (baseline\ rated\ gpm - high\ efficiency\ gpm)$$

$$Annual\ energy\ savings\ (m^3/yr\ )\ = 22.5\ \times\ (2.0 - 1.5)$$

$$Annual\ energy\ savings = 11.3\frac{m^3}{yr}$$

Water Savings

$$Savings = 2.9\frac{people}{residence} \times 0.75\frac{\frac{showers}{person}}{day} \times 7.6\frac{mins}{shower} \times 365\frac{days}{year} \times \left(1.78\ \frac{gallons}{min}\ -\ 1.5\ \frac{gallons}{min}\right) \times 3.785\frac{liters}{gal} \times 76\%\ showerheads\ affected\ in\ each\ residence = 4{,}860\frac{liters}{year}$$

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. 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.

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RESIDENTIAL – LOW-FLOW SHOWERHEADS – RETROFIT

Version Date and Revision History	
Version	1.0
OEB Filing Date	Dec 21, 2016
OEB Approval Date	
Residential/Low-Income → Water Heating →Low-flow Showerheads→ Retrofit	

Table 1 provides a summary of the key measure parameters and savings values based on the efficient technology.

Table 1. Measure Key Data

Parameter	**Definitions**	
Measure Category	Retrofit (R)	
Baseline Technology	2.5 gpm	
Efficient Technology	1.5 gmp	
	1.25 gpm	
Market Type	Residential	
Annual Natural Gas Savings per Showerhead (m^3)	***Efficient Technology***	***Savings***
	1.25 gpm	28.2 m^3
	1.5 gpm	22.5 m^3
Annual Water Savings per Showerhead (liters)	1.25 gpm	13,885 liters
	1.5 gpm	9,546 liters
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	None.	

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. There is reduction in water consumption associated with this measure.

Natural Gas Savings Algorithm

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 in each household was 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.

$$Annual\ energy\ savings\ \left(\frac{m^3}{yr}\right) = 44\ \frac{\frac{m^3}{yr}}{gpm} \times\ (baseline\ rated\ gpm - high\ efficiency\ gpm)$$

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 in the SAS study 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:

$$\frac{Annual\ energy\ savings}{showerhead}\ \left(\frac{m^3}{yr}\right) = 21.4\ \frac{\frac{m^3}{yr}}{gpm} \times\ (baseline\ rated\ gpm - high\ efficiency\ gpm)$$

Because the population in the study had an average of 2.75 people per household as compared to 2.9 people per single family household based on census data, it is necessary to adjust the usage to reflect this.

$$\frac{Annual\ energy\ savings}{showerhead}\ \left(\frac{m^3}{yr}\right) = 21.4\ \frac{\frac{m^3}{yr}}{gpm} \times\ (baseline\ rated\ gpm - high\ efficiency\ gpm) \times \frac{2.9\ people}{2.75\ people}$$

$$\frac{Annual\ energy\ savings}{showerhead}\ \left(\frac{m^3}{yr}\right) = 22.5\ \frac{\frac{m^3}{yr}}{gpm} \times\ (baseline\ rated\ gpm - high\ efficiency\ gpm)$$

[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]

WATER SAVINGS ALGORITHM

The water savings were calculated using the following algorithm:

$$Savings = Ppl \times Sh \times 365\frac{days}{year} \times T \times (Fl_{base} - Fl_{eff}) \times 3.785\frac{L}{gal} \times PSA$$

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)

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:

$$As - Used\ Flow\ Rate^{3} = 0.542 \times Nominal\ Flow\ Rate + 0.691 \text{ [4]}$$

Where,

$As - Used\ Flow\ Rate$	= Actual flow of installed showerhead
$Nominal\ Flow\ Rate$	= Rated flow listed on the showerhead

ASSUMPTIONS

Table 7 provides a list of constants and assumption used in the derivation of the water savings values.

[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.

Table 7 Assumptions

Assumption	Value	Source
Average person per single detached house (2006)	2.9	Common assumptions table
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]
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,

$$Annual\ energy\ savings\ (m^3/yr) = 22.5\ \frac{m^3/yr}{gpm} x\ (baseline\ rated\ gpm - high\ efficiency\ gpm)$$

$$Annual\ energy\ savings\ (m^3/yr) = 22.5 \times (2.5 - 1.5)$$

$$Annual\ energy\ savings = 22.5 \frac{m^3}{yr}$$

Water Savings

$$Savings = 2.9 \frac{people}{residence} \times 0.75 \frac{\frac{showers}{person}}{day} \times 7.6 \frac{mins}{shower} \times 365 \frac{days}{year} \times \left(2.05 \frac{gallons}{min} - 1.5 \frac{gallons}{min}\right) \times 3.785 \frac{liters}{gal} \times 76\%\ showerheads\ affected\ in\ each\ residence = 9{,}546 \frac{liters}{year}$$

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. 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.

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RESIDENTIAL – LOW FLOW FAUCET AERATORS –RETROFIT

Version Date and Revision History	
Version	1
OEB Filing Date	Dec 21, 2016
OEB Approval Date	
Residential → Water Heating → Low-Flow Bathroom and Kitchen Faucet Aerators → Retrofit	

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

Table 1. Measure Key Data

Parameter	Definition		
Measure Category	Retrofit (R)		
Baseline Technology	Standard flow bathroom and kitchen aerators	2.2 gpm (8.35 lpm)	
Efficient Technology	Low flow bathroom and kitchen aerators.	1.0 gpm (3.8 lpm)	1.5 gpm (5.7 lpm)
Market Type	Residential, Multiresidential		
		1.0 gpm Aerator	**1.5 gpm Aerator**
Annual Natural Gas Savings (m^3)	Bathroom aerator	6.40 m^3	3.73 m^3
	Kitchen aerator	19.82 m^3	11.56 m^3
Annual Water Savings (liters)	Bathroom aerator	2,501 liters	1,459 liters
	Kitchen aerator	7,742 liters	4,516 liters
Measure Life	10 years		
Incremental Cost ($ CAD)	$1.14 – Kitchen $0.60 - Bathroom		
Restrictions	Existing residential homes with natural gas fired water heaters		

OVERVIEW

The measure consists of installing either 1.0 or 1.5 gpm aerators on bathroom and kitchen faucets in residential dwellings. The aerators are provided to the dwelling occupants at no cost by the participating utility.

Reduction in water and natural gas consumption result from the measure. The magnitude of the site specific savings is heavily dependent upon human behavior and will vary significantly between sites. The savings algorithm and the resulting savings values are based on data and assumptions representing typical consumption patterns, inlet and outlet water temperatures, flow rates, and water heating equipment efficiencies. These factors are taken from studies that have been previously completed and are referenced in this document.

APPLICATION

This measure applies to the installation of 1.0 and 1.5 gpm bathroom faucet aerators in the residential settings. The measure is applicable to retrofit installation in existing facilities with natural gas fueled domestic water heating. The measure is also applicable to new construction with distribution through participating building contractors.

BASELINE TECHNOLOGY

The baseline technology is defined as an aerator with a flow rate of 2.2 gpm (8.3 lpm). This value is reflected in the Ontario Building Code and is consistent with the maximum allowable flow rate for all faucet aerators manufactured or sold in the United States after Jan 2014, as specified by US Energy Policy Act of 1992. [1]

Table 2. Baseline Technology

Type	Maximum Flow Rate
Code compliant faucet aerator	2.2 gpm (8.35 lpm)

EFFICIENT TECHNOLOGY

The high efficiency technology is a low flow aerator with a rated flow of 1.5 gpm (5.7 lpm) or less at a water pressure of 60 psi. [2]

Table 3. Efficient Technology

Type	Maximum Flow Rate
Low-flow faucet aerator	1.5 gpm (5.7 lpm)

ENERGY IMPACTS

This measures results in a reduction in water and natural gas consumption. The reduction in - water consumption is a function of the baseline and efficient flow rates and typical per capita use patterns. Natural gas savings are dependent upon these factors, the % of the flow reduction represented by heated water, typical entering and leaving hot water temperatures, and water heater efficiencies.

WATER AND NATURAL GAS SAVINGS ALGORITHMS

The measure savings are calculated using the following algorithms:

$$W_{savings} = Fu \times Ppl \times Dr\% \times Fa\% \times \left(\frac{Fl_{base} - Fl_{eff}}{Fl_{base}}\right) \times 3.78\frac{liters}{gallon} \times 365\frac{days}{year}$$

Where,

$W_{savings}$	=	Annual water savings (liters)
Fu	=	Faucet use per capita (gallons)
Ppl	=	Number of people per household
$Dr\ \%$	=	Percentage of flow that goes straight down the drain (%) This is the proportion of water use that depends on faucet on-time, such as when rinsing a toothbrush, as opposed to being dependent on the volume of water drawn, such as when filling a basin.
$Fa\ \%$	=	Single faucet use (bathroom or kitchen) as a % of total household faucet use (%)
Fl_{base}	=	Rated flow of baseline equipment (gpm)
Fl_{eff}	=	Rated flow of efficient equipment (gpm)

Once the reduction in water consumption is determined for each aerator, natural gas savings can be calculated using this water savings value and the following formula.

$$NG_{savings} = W_{savings} \times 8.33\frac{BTU}{gallon - °F} \times \%_{hot} \times (T_{out} - T_{in}) \times \frac{\left(\frac{1}{RE}\right)}{35{,}738\ BTU\ per\ m^3}$$

Where,

$NG_{savings}$	=	Annual natural gas savings (m^3)
$W_{savings}$	=	Annual water savings from equation above (gallons/year)
$\%_{hot}$	=	% of aerator flow that is heated by water heater
T_{out}	=	Water temperature leaving the water heater (°F)
T_{in}	=	Water temperature entering the water heater (°F)
RE	=	Water heater recovery efficiency factor (%)

ASSUMPTIONS

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

Table 4. Assumptions

Parameter	Description	Value	Source
Fu	Faucet use per capita	10.9 gallons / day (41.29 liters / day)	[3]
Ppl	Average people per household	2.9 people per household	Common assumptions table
Dr %	Percentage of flow that goes directly down the drain[1]	70% - bathroom 50% - kitchen	[4]
Fa %	The percentage to total faucet flow represented by each faucet	15% bathroom (per faucet) 65% kitchen faucet	[4]
T_{in}	Average city or inlet water temperature	9.39°C (48.9°F)	Common assumptions table
T_{hot}	Domestic hot water factory set tank temperature	48.9°C (120°F)	Common assumptions table
$\%_{hot}$	% of aerator flow that is heated	46%	[5] [6]
RE	Recovery Efficiency	78.68%	Common assumptions table

SAVINGS CALCULATION EXAMPLE

Inserting values from the list of assumptions provided in Table 4 into the water savings equation above leads to a water consumption reduction for a single 1.5 gpm bathroom aerator of:

10.9 gallon/day per person × 2.9 people × 70% × 15% × (2.2 – 1.5) / 2.2) × 365 days/year × 3.785 liters/gallon = **1,459 liters/year** (385.4 gallons per year)

Inserting the water savings value, temperatures and water heater recovery efficiency into the natural gas savings equation leads to annual natural gas savings of:

[1] There is no research data on the percentage of water that flows straight down the drain. Assuming that it's probably not all straight down the drain nor is it all batch use for kitchen faucets, a range of 25% to 75% was assumed with 50% as the point estimate. For bathroom faucets, one would expect less batch use than in the kitchen, but not 0% so the range was set from 50% to 90% straight down the drain, with 70% as the point estimate.

385.4 gallons / year × 46% heated water × 8.33 BTU / gallon - °F × (120 - 48.9) ^{0}F / 78.68% / 35,738 BTU/m^{3} = **3.73 m^{3} natural gas**

Uses and Exclusions

To qualify for this measure aerators must meet the maximum flow requirement listed in Table 3, and be installed in new or existing residential dwellings equipped with natural gas fueled water heaters.

Measure Life

The measure life attributed to this measure is 10 years. [7]

Incremental Cost

Table 5 presents the measure incremental cost.

Table 5. Incremental Cost [8]

Boiler Rated Input (Btu/h)	Incremental Cost ($)
High Efficiency Aerator	$1.14 – Kitchen $0.60 - Bathroom

The cost is equipment cost associated with bulk purchases by the participating utility for direct distribution to residential end users.

References

[1] Province of Ontario, "Ontario Regulation 332/12, Building Code Act of 1992, Section 7.6.4.1," Consolidation Period 1 January 2014. [Online]. Available: https://www.ontario.ca/laws/regulation/120332. [Accessed 18 August 2014].

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[8] A. Solhdoust, "Union Gas internal data on aerator cost provided to ERS," September 25, 2014.

RESIDENTIAL – PIPE WRAP – RETROFIT

Version Date and Revision History	
Version	1.1 (minor update)
OEB Filing Date	November 30, 2018
OEB Approval Date	
Residential → Water Heating → Pipe Wrap → Retrofit	

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

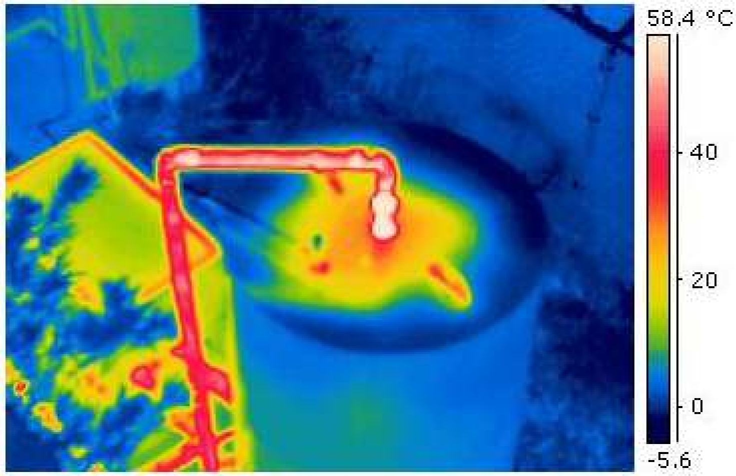
Table 1. Measure Key Data

Parameter	Definition
Measure Category	Retrofit
Baseline Technology	No existing pipe wrap
Efficient Technology	Pipe wrap
Market Type	Residential
Annual Natural Gas Savings Rate (m^3/ft)	3.64 m^3/ft.
Measure Life	15 years [1]
Incremental Cost ($ CAD)	$0.39 per foot
Restrictions	This measure is restricted to retrofit installations in residential homes. The savings are applicable for pipe wrap of up to two meters (6.56 ft) in length.

OVERVIEW

This measure provides the gas savings estimate and costs of insulating hot water pipes for conventional gas hot water storage tanks in a residential retrofit type of application. Figure 1 illustrates the heat loss phenomenon. Natural gas savings are calculated using an engineering algorithm and are reported in meters cubed per linear foot (m^3/ft).

Figure 1: Temperature of Hot Water Pipe Exiting Water Heater[1]



APPLICATION

This measure is for pipe-wrap for domestic hot water heating systems in residential homes.

BASELINE TECHNOLOGY

The baseline case is a hot water pipe without pipe wrap insulation. The R-value is shown in Table 2.

Table 2. Baseline Technology

Type	Value
No pipe wrap	R-0.435 [2]

This value is based on the heat transfer between water and air through copper with a heat transmission coefficient U-2.3 Btu/ft^2·°F·h.

EFFICIENT TECHNOLOGY

The energy efficient case is a hot water pipe with pipe wrap insulation. The R-value of the pipe wrap is shown in Table 3.

Table 3. Efficient Technology

Type	Value
Added pipe wrap insulation (R_{Post})	R_{Pre} + R-4.35[2] [3]

[1] Photograph by Dylan Pankow. Downloaded from https://www.flickr.com/photos/cbcthermal/1475767378/in/photostream/ on 8/1/2014.

[2] Added insulation has an U-value of 0.230 BTU-in/hr-ft^2 -°F

This value is based on a nominal ½-inch diameter copper pipe with ½-inch polyethylene insulation.[3]

ENERGY IMPACTS

Natural gas savings are achieved due to the difference in thermal resistance (R) between the energy efficient pipe wrap and the baseline condition of zero pipe wrap. The insulated pipe wrap reduces the rate of heat flow between the hot water in the pipe and the ambient air surrounding the pipe. This reduction of heat loss with insulated pipes can raise water supply temperature 1.1 ˚C-2.2 ˚C (2°F–4°F) [4] as compared with uninsulated pipes.

NATURAL GAS SAVINGS ALGORITHMS

The following algorithm is referenced from the Home Energy Services Impact Evaluation [5] and was used to calculate the stipulated gas impact. The total annual gas savings per linear foot, *S*, is calculated based on the difference in R values as shown in Table 4 below.

$$S = \frac{\left[\left(\frac{1}{R_{pre}} - \frac{1}{R_{post}}\right) \times C_{pipe} \times \left(T_{pipe} - T_{amb}\right) \times 8760 \times TRF\right]}{RE \times 35{,}738 \frac{Btu}{m^3}}$$

where,

- S = Annual gas savings (m^3/ft)
- R_{pre} = R-value of baseline equipment ($ft^2 \cdot °F \cdot h/Btu$)
- R_{post} = R-value of efficient equipment ($ft^2 \cdot °F \cdot h/Btu$)
- C_{pipe} = Circumference of the outlet water pipe (ft)
- T_{pipe} = Temperature of the outlet water pipe (°F)
- T_{amb} = Ambient air temperature (°F)
- TRF = Thermal regain factor, which discounts savings because reducing heat loss to conditioned space in the heating season is not beneficial[4]

$$TRF = \left[1 - \left(Regain \times \frac{Heating\ Hours\ per\ Year}{Total\ Hours\ per\ Year}\right)\right]$$

[3] The cited reference is web available and includes the material conductivity. The equivalent R-value can be calculated from radial heat loss equation and was also provided in a separate company spec sheet of the same name and title as the cited spec sheet, but that is not available on line.

[4] Regain is a function of both space type and insulation level. Adding insulation to pipes in fully conditioned space with thermostatically controlled heating systems saves no energy in the heating season because the water heater waste heat offsets heating system energy (Regain=100%). While most water heaters are located within insulated space in Ontario, no data was found on the proportions of them in spaces heated with thermostatically controlled systems versus those in unconditioned or semi-conditioned space. In lieu of this the average value calculated for Massachusetts in [5] was used. For simplification, the analysis does not consider interactive effects with semi-conditioned spaces warmed with electric resistance spot heaters.

RE = Water heater recovery efficiency

$$S = \frac{\left[\left(\frac{1}{0.435} - \frac{1}{4.785}\right) \times 0.164 \times (120 - 67.5) \times 8760 \times \left[1 - \left(0.58 \times \frac{5{,}293}{8{,}760}\right)\right]\right]}{0.7868 \times 35{,}738}$$

$$Annual\ NG\ savings = 3.64\ m^3/ft$$

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. Assumptions

Variable	Definition	Value	Source/Comments
R_{pre}	R-value of baseline equipment	0.435 ft²·°F·h/Btu	[2]
R_{post}	R-value of efficient equipment (baseline + additional insulation)	4.785 ft²·°F·h/Btu	Sum of baseline equipment R and pipe wrap R. [3]
C_{pipe}	Circumference of outlet water pipe	0.164 ft	Based on copper pipe with ½-inch nominal 5/8-inch actual outside diameter [3]
T_{pipe}	Domestic hot water factory set tank temperature	120°F (48.9˚C)	Common assumptions table (no heat trap)
T_{amb}	Ambient air temperature	67.5°F (19.7˚C)	[6]
$Regain$	Regain	0.58	[5]
RE	Recovery efficiency	78.68%	Common assumptions table
	Energy density of natural gas	35,738 Btu/m³	Common assumptions table
	Total hours per year	8,760	
	Heating hours per year	5,293	Common assumptions table

The savings are applicable for pipe wrap of up to two meters (6.56 ft) in length.

SAVINGS CALCULATION EXAMPLE

The example below illustrates how the savings value is determined for a pipe wrap retrofit installation on a residential hot water heater for a two meter (6.56 ft) length of pipe. For this example, it will be assumed that the equipment is sized for installation in a household size of 2.9, which is the average household size in Ontario.

$$Annual\ NG\ savings = 3.54 \frac{m^3}{ft} \times 6.56\ ft = 23.9m^3$$

MEASURE LIFE

The measure life is 15 years [1].

INCREMENTAL COST

The average approximate incremental cost, assuming homeowner installation, of pipe wrap on a hot water outlet pipe is approximately $0.39 per foot [7]. [5]

REFERENCES

[1] GDS Associates, Inc., "Measure Life Report Residential and Commercial/Industrial Lighting and HVAC Measures," p. A-3, June 2007.

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RESIDENTIAL - LOW INCOME – PROGRAMMABLE THERMOSTATS – RETROFIT

Version Date and Revision History	
Version	1.1 (minor change)
OEB Filing Date	November 3, 2020
OEB Approval Date	November 12, 2020
Residential → Space Heating → Programmable Thermostats → Retrofit	

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

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 - Low Income
Annual Natural Gas Savings (m^3)	46 m^3
Measure Life	15 years
Incremental Cost	$97
Restrictions	Limited to replacement in situations where existing thermostat is identified as non-programmable. This measure is an option only available under the low-income program.

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 residential low-income 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 since 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).[1] [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 m^3/yr.

Table 2. Enbridge Existing Single Family Home Space Heating Gas Use[2] [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.[3] [5] [6]. The most common presumption for technical savings potential is 8°F setback. Therefore, the technical savings potential is 8%.

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[1] 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.

[2] 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.

[3] 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.

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.[4] [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”[5] [10]
- 38% do not use them to reduce temperature at night[6] [11]
- 60% on hold (low income-specific)[7] [10]

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[4] 1.49 hr. /week / (8 hr. /day * 7 days/wk.) nominal presumed extra setback hours per week per technical potential basis = 3%.

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

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

[7] 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).

- Unquantified impact due to poor usability of conventional programmable thermostats.[8] [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[9] [13]
- 0% effect on net unit energy consumption (UEC) [10] [14]
- (18%) savings[11]
- 6.8% savings[12] [15]
- 3.6% savings[13]

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

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

[10] "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.

[11] 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.

[12] 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. [18]

[13] *Programmable Thermostats Report to KeySpan Energy Delivery on Energy Savings and Cost Effectiveness* GDS Associates. , 2002, as cited in Cadmus (2012). Not found on line. This value also recommended by Cadmus for MA.

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

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

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. 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:

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

$$NG\ Savings = 2{,}172\ {m^3}/{year} \times 2.1\% = 46\ {m^3}/{year}$$

USES AND EXCLUSIONS

This measure requires that the thermostat have two programming modes for weekday and weekend. This measure is limited to replacement in situations where the existing thermostat is identified as non-programmable and is an option only available under the low-income program.

MEASURE LIFE

The measure life for this measure is 15 years. [16]

INCREMENTAL COST

The cost of a programmable thermostat is $97. [14] [16]

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

Version Date and Revision History	
Version	1
OEB Filing Date	Dec 21, 2016
OEB Approval Date	
End date	N/A
Residential → Water Heating → Tankless Water Heater → New Construction/Time of Natural Replacement	

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

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 Natural Gas Savings (m^3)	High Efficiency Non-Condensing Tankless: 88.8 m^3
	Condensing Tankless: 128.0 m^3
Measure Life	20 years
Incremental Cost ($ CAD)	High Efficiency Non-Condensing Tankless = $1,667
	Condensing Tankless = $2,066
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 1. Baseline Technology

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 2. Efficient Technology

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 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].

$$Annual\ NG\ Savings\ = \frac{DHWload}{35.738\frac{kBtu}{m^3}} \times \left(\frac{1}{EF_{baseline}} - \frac{1}{EF_{EE}}\right)$$

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
$EF_{baseline}$	= The assumed baseline storage water heater EF
EF_{EE}	= The assumed tankless water heater EF
$dailyDHW$	= The average daily Canadian DHW consumption (US Gallons)
$365\frac{days}{yr}$	= Days in a year
ρ	= Density of water (lb/US gallon)
C_p	= Specific heat of water (Btu/lb/°F)
T_s	= Average temperature of DHW (°F)
T_c	= Average temperature of city supply water (°F)

ASSUMPTIONS

Table 4 provides a list of assumptions utilized in the measure savings algorithms to derive the savings values listed in Table 1 above.

Table 4. 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	8.29 lb/US Gal	Common assumptions table
C_p	Specific heat of water	1 Btu/lb/°F	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
	Energy density of natural gas	35,738 Btu/m^3	Common assumptions table

SAVINGS CALCULATION EXAMPLE

The example below illustrates how the savings were calculated. The annual domestic hot water heating load can be calculated using the average daily household DHW consumption in Canada.

$$DHWload = 54\,\frac{US\ Gal}{day} \times 365\,\frac{days}{yr} \times 1\,\frac{Btu}{lb°F} \times 8.29\,\frac{lb}{US\ gal} \times (120\ °F - 48.9\ °F)/1000$$
$$= 11{,}608\ kBtu/yr$$

The natural gas savings for a non-condensing tankless water heater can then be calculated from the difference in equipment efficiencies as:

$$Natural\ Gas\ Savings\ = \frac{11{,}617\ kBtu/yr}{35.738\,\frac{kBtu}{m^3}} \times \left(\frac{1}{0.67} - \frac{1}{0.82}\right) = 88.8\ m^3/yr$$

And the natural gas savings for a condensing tankless water heater can be calculated similarly as:

$$\boldsymbol{Natural\ Gas\ Savings\ = \frac{11,617\ kBtu/yr}{35.738\,\frac{kBtu}{m^3}} \times \left(\frac{1}{0.67} - \frac{1}{0.91}\right) = 128.0\ m^3/yr}$$

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 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 5.

Table 5. Incremental Cost[1]

Type	Material	Installation	Total
Non-Condensing	$767	$900	$1,667
Condensing	$1,166	$900	$2,066

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RESIDENTIAL/LOW INCOME – HEAT REFLECTOR PANELS – RETROFIT

Version Date and Revision History	
Version	1.1 (minor change)
OEB Filing Date	November 3, 2020
OEB Approval Date	November 12, 2020
Residential/Low-Income → Space Heating →Heat Reflector Panels→ Retrofit	

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

Table 1. Measure Key Data

Parameter	Definitions	
Measure category	Retrofit	
Baseline technology	No heat reflector panel installed behind radiator	
Efficient technology	Heat reflector panel installed behind radiator	
Market type	Residential/Low Income	
Annual natural gas savings per single family household (m^3)	***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.	
Restrictions	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 be 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 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.

$$Annual\ energy\ savings\ (m^3/year) = Average\ annual\ consumption\ \ (m^3/year) * Average\ change\ in\ consumption\ due\ to\ heat\ reflector\ panels\ (\%)$$

Assumptions

Table 3 provides a list of constants and assumption used in the derivation of the 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	[3]

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,

$$Annual\ energy\ savings\ (m^3/year)$$
$$= Average\ annual\ consumption\ \ (m^3/year)$$
$$*\ Average\ change\ in\ consumption\ due\ to\ heat\ reflector\ panels\ (\%)$$

$$= 3{,}493\ \ m^3/year * \ 4.1\%$$

$$Annual\ energy\ savings = 143.2\ \ m^3/year$$

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 [4]

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.

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COMMERCIAL – AIR CURTAINS FOR SHIPPING AND RECEIVING DOORS "DOCK-IN"– NEW CONSTRUCTION/RETROFIT

Version Date and Revision History	
Version	3
OEB Filing Date	January 8, 2020
OEB Approval Date	January 9, 2020
Commercial → Space Heating → Air Curtains for Shipping and Receiving Doors "Dock-in" → New Construction/Retrofit	

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

Table 1. Measure Key Data

Parameter	Definition			
Measure Category	New Construction (NC) Retrofit (R)			
Baseline Technology	No Air Curtain			
Efficient Technology	Air curtain that meets the minimum standards of the Air Movement and Control Association International, Inc. (AMCA)			
Market Type	Commercial			
Annual Natural Gas Savings (m^3/yr per door)	**8' x 8'**	**8' x 9'**	**8' x 10'**	**10' x 10'**
	4,713	4,845	4,941	5,517
Annual Electric Impacts (kWh/yr per door)	-1,688	-1,630	-1,576	-2,838
Measure Life	15 years			
Incremental Cost ($ CAD)	**8' x 8'**	**8' x 9'**	**8' x 10'**	**10' x 10'**
	$5,663			$6,345
Restrictions	This measure is restricted to the installation of Air Curtains on shipping and receiving doors classified as "Dock-in" door as described on this document. If other mechanisms that combat infiltration at the shipping/receiving door are present, such as door seals, this measure is not eligible. In addition, the docking area must be directly heated by natural gas fueled equipment during winter months and the inside temperature of the area must be maintained at a comfortable level while docking doors are used.			

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. This airflow prevents outdoor air infiltration (heat, moisture, dust, fumes, insects), while also permitting an unobstructed entryway for goods. Figure 1 illustrates the schematic design for a typical air curtain installation at a shipping and receiving door.

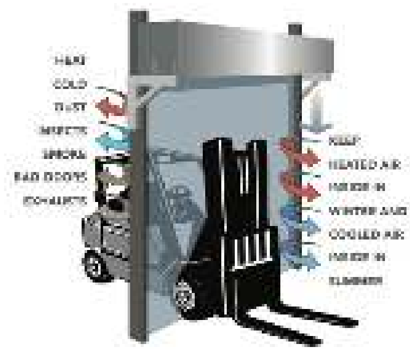

Figure 1. Air Curtain Installation [1]

The air curtains serve to reduce the infiltration of outdoor air at the entrance points consequently reducing the heating and cooling requirements. The Natural Gas and Electrical savings are calculated using engineering best practices algorithm from ASHRAE and are reported in (m^3/yr per door) and in kilowatt hours per year per door (kWh/yr per door) respectively.

APPLICATION

This measure provides incentives for installing air curtains on Shipping and Receiving doors of commercial facilities and specifically for "Dock-in" doors.
Dock-in door: trailers docked with bumpers stops at the doorway. Typical arrangement for these doors is 4ft off the ground. Figure 2 illustrates the typical arrangement for Dock-in doors.

Figure 2 Example of "Dock-in" Shipping and Receiving doors

[1] Illustration downloaded from https://www.northerndocksystems.com/air-barriers/ on 10/24/2019.

Baseline Technology

The current baseline is a doorway without an air curtain, as shown in Table 2.

Table 2. Baseline Technology

Scenario	Requirement
All	Exterior doorway without air curtain

Efficient Technology

Air curtains that meet the requirements as shown in Table 3:

Table 3. Efficient Technology

Scenario	Requirement
All	Air Curtain that has been tested in accordance with ANSI/AMCA 220 [1]

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 annual energy savings per door, differentiated by door type.

There is an electric penalty associated with the addition of an air curtain due to the air curtain's fan. In air-conditioned spaces, the overall electric penalty is reduced due to a reduced air-conditioning load. No water consumption impacts are associated with this measure.

Natural Gas Savings Algorithm

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. In order to characterize the natural gas savings, the calculation approach from ASHRAE Fundamentals Chapters 16 and 26 have been applied.

1. **Calculation of the infiltration across gaps**

Infiltration into a building is introduced by pressure differences across the envelope caused by driving forces (wind and stack effects), specific gap geometry, general building leakage and mechanical system. For uniform indoor air temperatures, the formulas for pressure across a building gap for a given time period are given below. [2]

Wind pressure Effect: $$P_U = \rho_o \frac{{U_H}^2}{2}$$

Stack Effect: $$P_T = g\rho_o \left[\frac{(T_i - T_o)}{T_i}\right]$$

Pressure difference across each gap: $$\Delta p = s^2 W_p P_U + HP_T + \Delta p_I$$

Where:

P_U	=	Reference wind parameter (Pa)
ρ_o	=	Density of outdoor air (kg/m³)
U_H	=	Local average wind speed (m/s)
P_T	=	Stack effect parameter (Pa/m)
g	=	Gravitational acceleration (m/s²)
T_o	=	OA temperature heating system enabled (K)
T_i	=	Space Temperature Setpoint (K)
Δp	=	Pressure difference across each gap (Pa)
s	=	Shelter factor applicable to the given gap (dimensionless)
W_p	=	Wind surface pressure coefficient (dimensionless)
H	=	Gap height relative to the neutral pressure plane (m)
Δp_I	=	Pressure that acts to balance inflows and outflows, including mechanical systems (Pa)

1a. Calculation of the gap height relative to the neutral pressure plane

$$H = n_p - \left(d_p + \frac{h_d}{2}\right)$$

Where:

n_p	=	The neutral pressure plane (m) [2]
d_p	=	The typical dock position off the ground (m)
h_d	=	Door height (m)

2. Calculation of the airflow through openings [2]

[2] Assumed location of the neutral pressure plane half of the average building height = 13.5 ft (4.11m)

Airflow through openings: $$Q = C_{dh} A \sqrt{\left(\frac{2\Delta p}{\rho_o}\right)}$$

Discharge coefficient for openings: $$C_{dh} = 0.40 + 0.0045|T_i - T_0|$$

Where:

Q	=	Total airflow rate through the doorway- heating season (m³/s)
C_{dh}	=	Discharge coefficient for openings during heating season (dimensionless)
A	=	Cross sectional area of dock door opening (m²)

2a. Calculation of the cross-sectional area of opening

Figure 3 Illustrates the schematics of the opening area

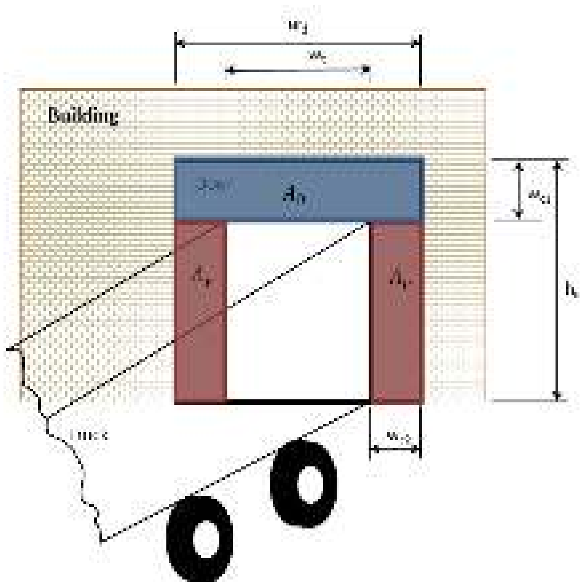

Figure 3 Dock Door opening area

$$A = A_v + A_h$$

$$A_v = 2 \times (h_d - w_{c1}) \times w_{c2}$$

$$A_h = w_d \times w_{c1}$$

Where:

A_v	=	Vertical gap area (m^2)
h_d	=	Door height (m)
w_{c1}	=	Gap between the top of the truck and the top of the dock door (m)
w_{c2}	=	Gap between the side of the truck and the side of the dock door (m)
A_h	=	Horizontal gap area (m^2)
w_d	=	Door width (m)
A	=	Total gap area per door dock (m^2)

3. Calculation of the energy required (natural gas)

$$q_s = Q\rho_0 C_p (T_i - T_o)$$

Where:

q_s	=	Sensible heat load (W)
C_p	=	Specific heat of air (J/(kg.K)

4. Calculation of the natural gas savings

$$NG = 3.412 \times \frac{q_s}{35{,}738} \times HR \times \frac{day_{hs}}{Eff} \times E$$

Where:

NG	=	Annual Natural Gas Savings (m^3/yr per door)
HR	=	Hour per day that the door is open (hr/day)
day_{hs}	=	Heating days per year (day/year)
Eff	=	Heating System efficiency (dimensionless)
E	=	Air Curtain effectiveness (dimensionless)
35,738	=	Energy density of natural gas (Btu/m^3)
3.412	=	Conversion factor from Watt to Btu/hr (1 Watt = 3.412 Btu/hr)

ELECTRIC SAVINGS ALGORITHM

Electricity impact is determined by the total electric effect during heating and cooling season. This is the sum of all effects described below: Electrical penalty - heating season due to the operation of the fan on the air curtain, Electrical saving - cooling season due to the reduction of cooling load (infiltration reduction) and Electrical penalty - cooling season due to the operation of the fan on the air curtain.

1. **Calculation of the electrical penalty - heating season due to the operation of the fan on the air curtain**

$$E_{fan-h} = -HP \times 0.7457 \times HR \times day_{hs}$$

Where:

E_{fan-h}	=	Electrical Penalty- Heating Season due to the operation of the fan on the air curtain (kWh/yr)
HR	=	Hour per day that the door is open (hr/day)
$\mathrm{day_{hs}}$	=	Heating days per year (day/year)
HP	=	Air curtain fan electric input power (hp)
0.7457	=	Conversion factor (1 horsepower = 0.7457 kilowatt)

2. **Calculation of the electrical saving - cooling season due to the reduction of cooling load (infiltration reduction)**

$$E_{savings} = \frac{q_c}{SEER} \times E \times HR \times day_{cs} \times \frac{1}{1000}$$

Where:

$E_{savings}$	=	Electrical Savings- Cooling Season due to the reduction of cooling load (kWh/yr)
q_c	=	Rate of heat transfer through doorway without vestibule (Btu/hr)
SEER	=	Energy efficiency ratio of cooling system (kBtu/kWh)
day_{cs}	=	Cooling days per year (day/year)
1,000	=	Conversion factor (1,000 Btu = 1 kBtu)

$$q_c = 60 \times \rho_o \times Q_{Ac} \times (h_{oc} - h_{ic})$$

Where:

60	=	Conversion factor (min/hr)
Q_{Ac}	=	Total airflow rate through the doorway- cooling season (CFM)
h_{oc}	=	Outside enthalpy-cooling season (Btu/lb)
h_{ic}	=	Inside enthalpy-cooling season (Btu/lb)

ρ_o = Density of dry air (lbm/ft³)

$$Q_{Ac} = 2{,}119 \times A \times C_{dc} \times \sqrt{\frac{2\Delta p_c}{\rho_o}}$$

Where:

2,119 = Conversion factor (1 m3/s = 2119 CFM)

A = opening area (m²)

C_{dc} = Discharge coefficient for openings during cooling season (dimensionless)

ρ_o = Density of dry air (kg/m³)

Wind pressure Effect:

$$P_{Uc} = \rho_o \frac{U_{Hc}^{2}}{2}$$

Stack Effect:

$$P_{Tc} = g\rho_o \left[\frac{(T_{oc} - T_i)}{T_{oc}}\right]$$

Pressure difference across each gap:

$$\Delta p_c = s^2 W_{pc} P_{Uc} + H \times P_{Tc} + \Delta p_I$$

Where:

P_{Uc} = Reference wind parameter - cooling season (Pa)

U_{Hc} = Local average wind speed - cooling season (m/s)

P_{Tc} = Stack effect parameter - cooling season (Pa/m)

T_{oc} = OA temperature heating system enabled - cooling season(K)

Δp_c = Pressure difference across each gap - cooling season (Pa)

W_{pc} = Wind surface pressure coefficient - cooling season (dimensionless)

3. Calculation of the electrical penalty - cooling season due to the operation of the fan on the air curtain

$$E_{fan-c} = -HP \times 0.7457 \times HR \times day_{cs}$$

Where:

E_{fan-c} = Electrical Penalty- Cooling Season due to the operation of the fan on the air curtain (kWh/yr)

HR = Hour per day that the door is open (hr/day)

day_{cs} = Cooling days per year (day/year)

HP = Air curtain fan electric input power (hp)

0.7457 = Conversion factor (1 horsepower = 0.7457 kilowatt)

4. **Calculation of the total electrical impact**

$$E_t = E_{fan-h} + E_{savings} + E_{fan-c}$$

Where:

E_t = Total electrical impact due to the operation of the air curtain (kWh/yr)

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. Assumptions

Variable	Definition	Value and Unit	Source/Comments
ρ_0	Density of outdoor air (heating season)	1.256 kg/m³ (0.078 lb_m/ft^3)	Common assumptions table[3]
	Density of outdoor air (cooling season)	1.163 kg/m³ (0.073 lb_m/ft^3)	Common assumptions table
T_i	Space temperature setpoint-warehouse type of building	69°F (293.7K)	Common assumptions table
T_o	OA temperature heating system enabled	34.8°F (274.7K)	Common assumptions table
T_{oc}	OA temperature cooling system enabled	77.0°F (298.1K)	Common assumptions table
s	Shelter factor	0.7	Based on Shelter Class 3 [2] [3]
W_p	Wind surface pressure coefficient for heating season	0.12	Calculated value based on and approach in [2] and based on CWEC weather data for London, ON (version 2016)
W_{pc}	Wind surface pressure coefficient for cooling season	0.19	
w_{c1}	Gap width between the top of the truck and the top of the dock door	8.88 in (0.23 m)	Calculated based on standard truck [4] and standard door sizes

[3] Pending Ontario TRM v4 approval-common assumption table

Variable	Definition	Value and Unit	Source/Comments
w_{c2}	Gap width between the side of the truck and the side of the dock door	16.71 in (0.42 m)	
C_p	Specific heat of air	1,000 J/(kg·K)	Common assumptions table
h_{ic}	Inside enthalpy for cooling season	21.46 Btu/lb	Common assumptions table
h_{oc}	Outside enthalpy for cooling season	30.95 Btu/lb	Common assumptions table
HR	Hour per day door is open	7.23 hr/day	[3]
U_H	Average wind velocity for heating season	2.60 m/s (5.81 mph)	Calculated using the wind profile law [3] and based on CWEC weather data for London, ON (2016)
U_{Hc}	Average wind velocity for cooling season	2.82 m/s (6.31 mph)	
	Average building height	27ft (8.2m)	[3]
C_{dh}	Discharge coefficient for opening during heating season	0.49	Calculated using ASHRAE algorithm [2] and based on CWEC weather data for London, ON (version 2016)
C_{dc}	Discharge coefficient for opening during cooling season	0.38	
E	Effectiveness of air curtain	70% (Range between 60% - 80%)	[5]
Eff	Commercial heating system efficiency	80%	Common assumptions table
SEER	Commercial cooling system efficiency	13 kBtu/kWh	Common assumptions table
g	Acceleration due to gravity	9.81 m/s^2 (32.2 ft/sec^2)	Common assumptions table
	Airflow rate conversion from m^3/s to CFM	2,119 CFM/m^3/s	[6]
	Energy density of natural gas	35,738 Btu/m^3	Common assumptions table
	Conversion from HP to kWh	0.7457 kW/HP	Common assumptions table
day_{hs}	Heating days per year	221	Common assumptions table
day_{cs}	Cooling days per year	40	Common assumptions table

Variable	Definition	Value and Unit				Source/Comments
Variable	Definition	Door size (W' x H')				Source/Comments
		8x8	8x9	8x10	10x10	
h_d	Dock door height (ft)	8	9	10	10	Based on standard door sizes
w_d	Dock door width (ft)	8	8	8	10	
HP	Air curtain horsepower	2	2	2	3	[7]

SAVINGS CALCULATION EXAMPLE

The example below illustrates the annual natural gas savings and electrical impact values for the installation of air curtains on two of the shipping & receiving doors ("Dock-in" doors) in a retail store. The sizes of the door are: 8′x8′ and 8′x10′

Annual Natural Gas Savings:

1 (8′x8′) + 1 (8′x10′) = 4,713 m^3/yr + 4,941 m^3/yr = 9,654 m3/yr

Annual Electrical Impact:

1 (8′x8′) + 1 (8′x10′) = -1,688 + -1,576 = -3,264 kWh/yr

The total annual natural gas savings is 9,654 m3/yr and the total electrical impact is -3,264 kWh/yr/

USES AND EXCLUSIONS

This measure is restricted to the installation of Air Curtains on shipping and receiving doors classified as Dock-in door as described on this document. If other mechanisms that combat infiltration at the shipping/receiving door are present, such as door seals, this measure is not eligible. In addition, the docking area must be directly heated by natural gas fueled equipment during winter months and the inside temperature of the area must be maintained at a comfortable level while docking doors are used.

MEASURE LIFE

The measure life is 15 years. [8]

INCREMENTAL COST

The purchase and installation cost for air curtains is summarized in the table below. [9]

Table 5. Incremental Cost

Definition	Door size (W' x H')			
	8x8	8x9	8x10	10x10
Ave. product cost	$2,902	$2,902	$2,902	$3,584
Ave. Installation cost[4]	$2,761	$2,761	$2,761	$2,761
Ave. Total cost	$5,663	$5,663	$5,663	$6,345

REFERENCES

[1] I. Air Movement and Control Association International, "ANSI/AMCA Standard 220-05 (R2012)," March 29, 2012.

[2] ASHRAE Handbook Fundamentals (SI edition) Chapter 16, 2018.

[3] Enbridge Gas Inc., "Technology Assessment- Dock Door Seals," OEB, Chatham, ON, 2019.

[4] "cerasis 2015 Trailer Guide," 2015. [Online]. Available: https://cerasis.com/wp-content/uploads/2015/08/2015TrailerGuide.pdf. [Accessed 10 10 2019].

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[6] "The Engineering ToolBox," [Online]. Available: https://www.engineeringtoolbox.com/flow-units-converter-d_405.html. [Accessed 10 10 2019].

[7] L. Edge, "Marley Design and Application Guide, Air Curtains- High velocity series," 2019. [Online]. Available: https://www.marleymep.com/system/files/node/file/field-file/QMark%20HIGH%20VELOCITY%20Sellsheet.pdf. [Accessed 10 10 2019].

[8] MichaelsEnergy, "Final Report: Custom Measure Life Review (Michaels No.:06717AAN)," OEB, Toronto, 2018, May 10.

[9] Northern Dock Systems, "Incremental cost data-Request a quote," Mississauga, 2019.

[4] Installation cost includes mechanical and electrical costs.

COMMERCIAL – AIR CURTAINS FOR SHIPPING AND RECEIVING DOORS "DRIVE-IN"– NEW CONSTRUCTION/RETROFIT

Version Date and Revision History	
Version	1
OEB Filing Date	January 8, 2020
OEB Approval Date	January 9, 2020
Commercial → Space Heating → Air Curtains for Shipping and Receiving Doors "Drive-in" → New Construction/Retrofit	

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

Table 1. Measure Key Data

Parameter	Definition					
Measure Category	New Construction (NC) Retrofit (R)					
Baseline Technology	No Air Curtain					
Efficient Technology	Air curtain that meets the minimum standards of the Air Movement and Control Association International, Inc. (AMCA)					
Market Type	Commercial					
Annual Natural Gas Savings (m^3/yr per door)	**10' x 10'**	**12' x 12'**	**14' x 14'**	**16' x 16'**	**18' x 18'**	**20' x 20'**
	4,844	5,753	6,504	7,081	7,459	7,605
Annual Electric Impacts (kWh/yr per door)	540	843	772	987	488	596
Measure Life	15 years					
Incremental Cost ($ CAD)	**10' x 10'**	**12' x 12'**	**14' x 14'**	**16' x 16'**	**18' x 18'**	**20' x 20'**
	$6,345	$11,158	$14,159	$22,226	$24,699	$45,256
Restrictions	This measure is restricted to the installation of Air Curtains on shipping and receiving doors classified as "Drive-in" door as described on this document. If other mechanisms that combat infiltration at the shipping/receiving door are present, such as door seals, this measure is not eligible. In addition, the docking area must be heated directly by natural gas fueled equipment during winter months and the inside temperature of the area must be maintained at a comfortable level while docking doors are used.					

Overview

Air Curtains are typically mounted above doorways. They separate indoor and outdoor environments with a stream of air strategically engineered to strike the floor with a particular velocity while setting the blower to an optimal position which determines the effectiveness of the air curtain. This airflow prevents outdoor air infiltration (heat, moisture, dust, fumes, insects), while also permitting an unobstructed entryway for goods. Figure 1 illustrates the schematic design for a typical air curtain installation at a shipping and receiving door.

Figure 1. Air Curtain Installation [1]

The air curtains serve to reduce the infiltration of outdoor air at the entrance points consequently reducing the heating and cooling requirements. The Natural Gas and Electrical savings are calculated using engineering best practices algorithms from ASHRAE and are reported in (m^3/yr per door) and in kilowatt hours (kWh/yr per door) respectively.

Application

This measure provides incentives for installing air curtains on Shipping and Receiving doors of commercial facilities and specifically for “Drive-in” doors.
Drive-in door: the door opens and closes to allow traffic to enter the bay. Typical arrangement for these doors is at ground level. Figure 2 illustrates the typical arrangement for Drive-in doors.

Figure 2 Example of "Drive-in" Shipping and Receiving doors[2]

[1] Illustration downloaded from https://www.northerndocksystems.com/air-barriers/ on 10/24/2019.
[2] Illustration downloaded from https://www.overheaddoor.com/rolling-steel-service-doors-626 on 10/24/2019

BASELINE TECHNOLOGY

The current baseline is a doorway without an air curtain, as shown in Table 2.

Table 2. Baseline Technology

Scenario	Requirement
All	Exterior doorway without air curtain

EFFICIENT TECHNOLOGY

Air curtains that meet the requirements as shown in Table 3:

Table 3. Efficient Technology

Scenario	Requirement
All	Air Curtain that has been tested in accordance with ANSI/AMCA 220 [1]

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 annual energy savings per door, differentiated by door size.

There is an electric penalty associated with the addition of an air curtain due to the air curtain's fan. In air-conditioned spaces, the overall electric penalty is reduced due to a reduced air-conditioning load. No water consumption impacts are associated with this measure.

NATURAL GAS SAVINGS ALGORITHM

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. In order to characterize the natural gas savings, the calculation approach from ASHRAE Fundamentals Chapters 16 and 26 have been applied.

1. **Calculation of the infiltration across gaps**

Infiltration into a building is introduced by pressure differences across the envelope caused by driving forces (wind and stack effects), specific gap geometry, general building leakage and mechanical system. For uniform indoor air temperatures, the formulas for pressure across a building gap for a given time period are given below. [2]

Wind pressure Effect: $$P_U = \rho_o \frac{{U_H}^2}{2}$$

Stack Effect: $$P_T = g\rho_o \left[\frac{(T_i - T_o)}{T_i}\right]$$

Pressure difference across each gap: $$\Delta p = s^2 W_p P_U + H P_T + \Delta p_I$$

Where:

P_U	=	Reference wind parameter (Pa)
ρ_o	=	Density of outdoor air (kg/m³)
U_H	=	Local average wind speed (m/s)
P_T	=	Stack effect parameter (Pa/m)
g	=	Gravitational acceleration (m/s²)
T_o	=	OA temperature heating system enabled (K)
T_i	=	Space Temperature Setpoint (K)
Δp	=	Pressure difference across each gap (Pa)
s	=	Shelter factor applicable to the given gap (dimensionless)
W_p	=	Wind surface pressure coefficient (dimensionless)
H	=	Gap height relative to the neutral pressure plane (m)
Δp_I	=	Pressure that acts to balance inflows and outflows, including mechanical systems (Pa)

1a. Calculation of the gap height relative to the neutral pressure plane

$$H = n_p - \frac{h_d}{2}$$

Where:

n_p	=	The neutral pressure plane (m)[3]
h_d	=	Door height (m)

2. Calculation of the airflow through openings [2]

Airflow through openings: $$Q = C_{dh} A \sqrt{\left(\frac{2\Delta p}{\rho_o}\right)}$$

[3] Assumed location of the neutral pressure plane half of the average building hight = 13.5 ft (4.11m)

Discharge coefficient for openings: $C_{dh} = 0.40 + 0.0045|T_i - T_0|$

Where:

Q	=	Total airflow rate through the doorway- heating season (m^3/s)
C_{dh}	=	Discharge coefficient for openings during heating season (dimensionless)
A	=	Cross sectional area of opening (m^2)

2a. Calculation of the cross-sectional area of opening

Figure 3 Illustrates the schematics of the opening area

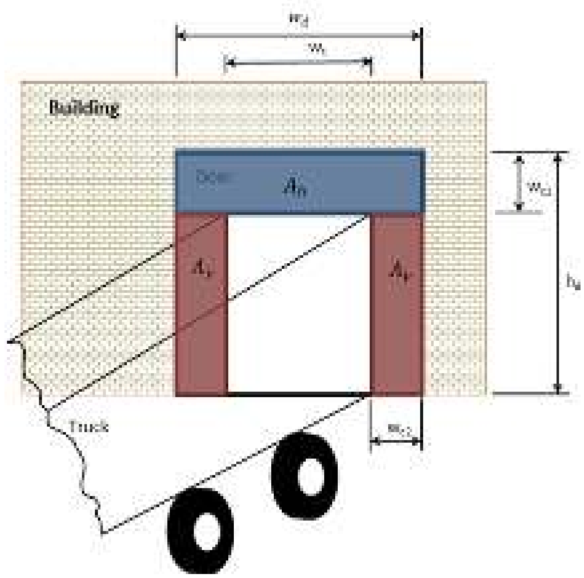

Figure 3 Dock Door opening area

$$A = A_v + A_h$$

$$A_v = 2 \times (h_d - w_{c1}) \times w_{c2}$$

$$A_h = w_d \times w_{c1}$$

Where:

A_v	=	Vertical gap area (m^2)
h_d	=	Door height (m)
w_{c1}	=	Gap between the top of the truck and the top of the dock door (m)

w_{c2}	=	Gap between the side of the truck and the side of the dock door (m)
A_h	=	Horizontal gap area (m^2)
w_d	=	Door width (m)
A	=	Total gap area per door dock (m^2)

3. Calculation of the energy required (natural gas)

$$q_s = Q\rho_0 C_p (T_i - T_o)$$

Where:

q_s	=	Sensible heat load (W)
C_p	=	Specific heat of air (J/(kg.K)

4. Calculation of the natural gas savings

$$NG = 3.412 \times \frac{q_s}{35{,}738} \times HR \times \frac{day_{hs}}{Eff} \times E$$

Where:

NG	=	Annual Natural Gas Savings (m^3/yr per door)
HR	=	Hour per day that the door is open (hr/day)
day_{hs}	=	Heating days per year (day/year)
Eff	=	Heating System efficiency (dimensionless)
E	=	Air Curtain effectiveness (dimensionless)
35,738	=	Energy density of natural gas (Btu/m^3)
3.412	=	Conversion factor from Watt to Btu/hr (1 Watt = 3.412 Btu/hr)

Electric Savings Algorithm

Electricity impact is determined by the total electric effect during heating and cooling season. This is the sum of all effects described below: Electrical penalty - heating season due to the operation of the fan on the air curtain, Electrical saving - cooling season due to the reduction of cooling load (infiltration reduction) and Electrical penalty - cooling season due to the operation of the fan on the air curtain.

1. **Calculation of the electrical penalty - heating season due to the operation of the fan on the air curtain**

$$E_{fan-h} = -HP \times 0.7457 \times HR \times day_{hs}$$

Where:

E_{fan-h}	=	Electrical Penalty- Heating Season due to the operation of the fan on the air curtain (kWh/yr)
HR	=	Hour per day that the door is open (hr/day)
day_{hs}	=	Heating days per year (day/year)
HP	=	Air curtain fan electric input power (hp)
0.7457	=	Conversion factor (1 horsepower = 0.7457 kilowatt)

2. **Calculation of the electrical saving - cooling season due to the reduction of cooling load (infiltration reduction)**

$$E_{savings} = \frac{q_c}{SEER} \times E \times HR \times day_{cs} \times \frac{1}{1000}$$

Where:

$E_{savings}$	=	Electrical Savings- Cooling Season due to the reduction of cooling load (kWh/yr)
q_c	=	Rate of heat transfer through doorway without vestibule (Btu/hr)
SEER	=	Energy efficiency ratio of cooling system (kBtu/kWh)
day_{cs}	=	Cooling days per year (day/year)
1,000	=	Conversion factor (1,000 Btu = 1 kBtu)

$$q_c = 60 \times \rho_o \times Q_{Ac} \times (h_{oc} - h_{ic})$$

Where:

60	=	Conversion factor (min/hr)
Q_{Ac}	=	Total airflow rate through the doorway- cooling season (CFM)
h_{oc}	=	Outside enthalpy - cooling season (Btu/lb)
h_{ic}	=	Inside enthalpy - cooling season (Btu/lb)
ρ_o	=	Density of dry air (lbm/ft^3)

$$Q_{Ac} = 2{,}119 \times A \times C_{dc} \times \sqrt{\frac{2\Delta p_c}{\rho_o}}$$

Where:

2,119	=	Conversion factor (1 m3/s = 2119 CFM)
A	=	opening area (m^2)
C_{dc}	=	Discharge coefficient for openings during cooling season (dimensionless)
ρ_o	=	Density of dry air (kg/m^3)

Wind pressure Effect:

$$P_{Uc} = \rho_o \frac{{U_{Hc}}^2}{2}$$

Stack Effect:

$$P_{Tc} = g\rho_o \left[\frac{(T_{oc} - T_i)}{T_{oc}}\right]$$

Pressure difference across each gap:

$$\Delta p_c = s^2 W_{pc} P_{Uc} + H \times P_{Tc} + \Delta p_I$$

Where:

P_{Uc}	=	Reference wind parameter - cooling season (Pa)
U_{Hc}	=	Local average wind speed - cooling season (m/s)
P_{Tc}	=	Stack effect parameter - cooling season (Pa/m)
T_{oc}	=	OA temperature heating system enabled - cooling season(K)
Δp_c	=	Pressure difference across each crack/gap - cooling season (Pa)
W_{pc}	=	Wind surface pressure coefficient - cooling season (dimensionless)

3. Calculation of the electrical penalty - cooling season due to the operation of the fan on the air curtain

$$E_{fan-c} = -HP \times 0.7457 \times HR \times day_{cs}$$

Where:

E_{fan-c}	=	Electrical Penalty - Cooling Season due to the operation of the fan on the air curtain (kWh/yr)
HR	=	Hour per day that the door is open (hr/day)
day_{cs}	=	Cooling days per year (day/year)
HP	=	Air curtain fan electric input power (hp)
0.7457	=	Conversion factor (1 horsepower = 0.7457 kilowatt)

4. Calculation of the total electrical impact

$$E_t = E_{fan-h} + E_{savings} + E_{fan-c}$$

Where:

E_t = Total Electrical impact due to the operation of the air curtain (kWh/yr)

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. Assumptions

Variable	Definition	Value and Unit	Source/Comments
ρ_0	Density of outdoor air (heating season)	1.256 kg/m^3 (0.078 lb$_m$/ft^3)	Common assumptions table[4]
	Density of outdoor air (cooling season)	1.163 kg/m^3 (0.073 lb$_m$/ft^3)	Common assumptions table
T_i	Space temperature setpoint-warehouse type of building	69°F (293.7K)	Common assumptions table
T_o	OA temperature heating system enabled	34.8°F (274.7K)	Common assumptions table
T_{oc}	OA temperature cooling system enabled	77.0°F (298.1K)	Common assumptions table
s	Shelter factor	0.7	Based on Shelter Class 3 [2] [3]
W_p	Wind surface pressure coefficient for heating season	0.12	Calculated value based on and approach in [2] and based on CWEC weather data for London, ON (version 2016)
W_{pc}	Wind surface pressure coefficient for cooling season	0.19	
w_{c1}	Gap width between the top of the truck and the top of the dock doo	39.8 in (1.01 m)	Calculated based on average traffic characteristics of a sample of 128 survey and adjusted to the %opening of the door
w_{c2}	Gap width between the side of the truck and the side of the dock door	37.2 in (0.94 m)	
C_p	Specific heat of air	1,000 J/(kg·K)	Common assumptions table
h_{ic}	Inside enthalpy for cooling season	21.46 Btu/lb	Common assumptions table
h_{oc}	Outside enthalpy for cooling season	30.95 Btu/lb	Common assumptions table

[4] Pending Ontario TRM v4 approval-common assumption table

Variable	Definition	Value and Unit	Source/Comments
HR	Hour per day door is open	1.70 hr/day	Calculated based on a sample of 128 survey
U_H	Average wind velocity for heating season	2.60 m/s (5.81 mph)	Calculated using the wind profile law [3] and based on CWEC weather data for London, ON (2016)
U_{Hc}	Average wind velocity for cooling season	2.82 m/s (6.31 mph)	
	Average building height	27ft (8.2m)	[3]
C_{dh}	Discharge coefficient for opening during heating season	0.49	Calculated using ASHRAE algorithm [2] and based on CWEC weather data for London, ON (version 2016)
C_{dc}	Discharge coefficient for opening during cooling season	0.38	
E	Effectiveness of air curtain	70% (Range between 60% - 80%)	[4]
Eff	Commercial heating system efficiency	80%	Common assumptions table
SEER	Commercial cooling system efficiency	13 kBtu/kWh	Common assumptions table
g	Acceleration due to gravity	9.81 m/s^2 (32.2 ft/sec^2)	Common assumptions table
	Airflow rate conversion from m^3/s to CFM	2,119 CFM/m^3/s	[5]
	Energy density of natural gas	35,738 Btu/m^3	Common assumptions table
	Conversion from HP to kWh	0.7457 kW/HP	Common assumptions table
day_{hs}	Heating days per year	221	Common assumptions table
day_{cs}	Cooling days per year	40	Common assumptions table

Variable	Definition	Door size (W' x H')						Source/ Comments
		10x10	12x12	14x14	16x16	18x18	20x20	
h_d	Dock door height (ft)	10	12	14	16	18	20	Based on standard door sizes
w_d	Dock door width (ft)	10	12	14	16	18	20	
HP	Air curtain horsepower	3	3	4	4	6	6	[6]

Savings Calculation Example

The example below illustrates the annual natural gas savings and electrical impact values for the installation of air curtains on two of the shipping & receiving doors ("Dock-in" doors) in a retail store. The sizes of the door are: 10'x10' and 14'x14'

Annual Gas Savings:

1 (10'x10') + 1 (14'x14') = 4,844 m^3/yr + 6,504 m^3/yr = 11,348 m3/yr

Annual Electrical Impact:

1 (10'x10') + 1 (14'x14') = 540 + 772 = 1,312 kWh/yr

The total annual gas savings is 11,348 m3/yr and the total electrical savings is 1,312 kWh/yr

Uses and Exclusions

This measure is restricted to the installation of Air Curtains on shipping and receiving doors classified as Drive-in door as described on this document. If other mechanisms that combat infiltration at the shipping/receiving door are present, such as door seals, this measure is not eligible. In addition, the docking area must be directly heated by natural gas fueled equipment during winter months and the inside temperature of the area must be maintained at a comfortable level while docking doors are used.

Measure Life

The measure life is 15 years. [7]

Incremental Cost

The purchase and installation cost for air curtains is summarized in the table below. [8]

Table 5. Incremental Cost

Description	Door size (W' x H')					
	10x10	12x12	14x14	16x16	18x18	20x20
Ave. product cost	$3,584	$8,202	$10,789	$18,856	$20,915	$41,199
Ave. Installation cost[5]	$2,761	$2,956	$3,370	$3,370	$3,784	$4,057
Ave. Total cost	$6,345	$11,158	$14,159	$22,226	$24,699	$45,256

[5] Installation cost includes mechanical and electrical costs

REFERENCES

[1] I. Air Movement and Control Association International, "ANSI/AMCA Standard 220-05 (R2012)," March 29, 2012.

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[3] Enbridge Gas Inc., "Technology Assessment- Dock Door Seals," OEB, Chatham, ON, 2019.

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[5] "The Engineering ToolBox," [Online]. Available: https://www.engineeringtoolbox.com/flow-units-converter-d_405.html. [Accessed 10 10 2019].

[6] L. Edge, "Marley Design and Application Guide, Air Curtains- High velocity series," 2019. [Online]. Available: https://www.marleymep.com/system/files/node/file/field-file/QMark%20HIGH%20VELOCITY%20Sellsheet.pdf. [Accessed 10 10 2019].

[7] MichaelsEnergy, "Final Report: Custom Measure Life Review (Michaels No.:06717AAN)," OEB, Toronto, 2018, May 10.

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COMMERCIAL – AIR CURTAINS FOR PEDESTRIAN DOORS– NEW CONSTRUCTION/RETROFIT

Version Date and Revision History	
Version	2
OEB Filing Date	January 8, 2020
OEB Approval Date	January 9, 2020
Commercial → Space Heating → Air Curtains for Pedestrian doors → New Construction/Retrofit	

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

Table 1. Measure Key Data

Parameter	Definition					
Measure Category	New Construction (NC) Retrofit (R)					
Baseline Technology 1	Door with no Air Curtain or Vestibule					
Baseline Technology 2	Door with no Air Curtain and with Vestibule					
Efficient Technology	Air curtain that meets the minimum standards of the Air Movement and Control Association International, Inc. (AMCA)					
Market Type	Commercial					
	3'x7'	**6'x7'**	**6'x8'**	**2x (3'x7')**	**2x (6'x7')**	**2x (6'x8')**
Annual Natural Gas Saving- without vestibule (m3/yr per door)	845	1,690	1,887	1,690	3,380	3,774
Annual Natural Gas Saving- with vestibule (m3/yr per door)	541	1,082	1,208	1,082	2,164	2,416
Annual Electric Impact- without vestibule (kWh/yr per door)	106	184	215	212	367	431
Annual Electric Impact- with vestibule (kWh/yr per door)	62	96	116	124	192	232
Measure Life	15 years					
	3'x7'	**6'x7'**	**6'x8'**	**2x (3'x7')**	**2x (6'x7')**	**2x (6'x8')**
Incremental Cost ($ CAD)	$1,645	$1,745	$1,745	$3,150	$3,350	$3,350
Restrictions	This measure is restricted to the installation of Air Curtains on Pedestrian doors. In addition: • The space must be heated by natural gas fueled equipment during winter months. • New Construction applications for which the Air Curtains have been installed in lieu of the vestibule are not eligible.					

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. This air flow prevents outdoor air infiltration (heat, moisture, dust, fumes, insects), while also permitting an unobstructed entryway for pedestrians. Figure 1 illustrates the schematic design for a typical air curtain installation at a pedestrian door.

Figure 1. Air Curtain Installation [1]

The units serve to reduce the infiltration of outdoor air at the entrance points and reduce the heating and cooling requirements. The Natural Gas and Electrical Savings are calculated using engineering best practices algorithm from ASHRAE and are reported in meters cubed per year per door (m^3/yr per door) and in kilowatt hours per year per door (kWh/yr per door) respectively.

APPLICATION

This measure provides incentives for installing air curtains on pedestrian doors of commercial facilities

BASELINE TECHNOLOGY

The current baselines are shown in Table 2.

Table 2. Baseline Technology

Scenario	Requirement
Baseline Technology 1	Exterior doorway without vestibule or air curtain
Baseline Technology 2	Exterior doorway with vestibule and no air curtain

[1] Illustration downloaded from http://www.mitzvahengg.com/Non_Re_Circulating_Air_Curtains.htm on 10/14/2014.

Efficient Technology

Air curtains that meet the requirements as shown in Table 3:

Table 3. Efficient Technology

Scenario	Requirement
All	Air Curtain that has been tested in accordance with ANSI/AMCA 220 [1]

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 annual energy savings, differentiated by door type.

There is an electric penalty associated with the addition of an air curtain due to the air curtain's fan. In air-conditioned spaces, the overall electric penalty is reduced due to a reduced air-conditioning load. No water consumption impacts are associated with this measure.

Natural Gas Savings Algorithm

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. In order to characterize the natural gas savings, the calculation approach from ASHRAE Fundamentals Chapters 16 and 26 have been applied.

1. **Calculation of the infiltration across gaps**

Infiltration into a building is introduced by pressure differences across the envelope caused by driving forces (wind and stack effects), specific gap geometry, general building leakage and mechanical system. For uniform indoor air temperatures, the formulas for pressure across a building gap for a given time period are given below. [2]

$$P_U = \rho_o \frac{{U_H}^2}{2}$$

$$P_T = g\rho_o \left[\frac{(T_i - T_o)}{T_i}\right]$$

$$\Delta p = s^2 W_p P_U + H P_T + \Delta p_I$$

Where:

P_U = Reference wind parameter (Pa)

ρ_o	=	Density of outdoor air (kg/m³)
U_H	=	Local average wind speed (m/s)
P_T	=	Stack effect parameter (Pa/m)
g	=	Gravitational acceleration (m/s²)
T_o	=	OA temperature heating system enabled (K)
T_i	=	Space Temperature Setpoint (K)
Δp	=	Pressure difference across each gap (Pa)
s	=	Shelter factor applicable to the given gap (dimensionless)
W_p	=	Wind surface pressure coefficient (dimensionless)
H	=	Gap height relative to the neutral pressure plane (m)
Δp_I	=	Pressure that acts to balance inflows and outflows, including mechanical systems (Pa)

1a. Calculation of the gap height relative to the neutral pressure plane

$$H = n_p - \frac{h_d}{2}$$

Where:

n_p	=	The neutral pressure plane (m)
h_d	=	Door height (m)

2. Calculation of the airflow through openings

$$Q = C_{dh} A \sqrt{\left(\frac{2\Delta p}{\rho_o}\right)}$$

$$C_D = 0.40 + 0.0045|T_i - T_0|$$

Where:

Q	=	Airflow rate (m³/s)
C_{dh}	=	Discharge coefficient for openings during heating season (dimensionless)
A	=	Cross sectional area of opening (m²)

2a. Calculation of the cross-sectional area of opening

$$A = h_d \times w_d \times \%opening$$

Where:

A	=	Total gap area per door dock (m^2)
h_d	=	Door height (m)
w_d	=	Door width (m)
$\%opening$	=	Average % opening area of the door when traffic goes through

3. Calculation of the energy required (natural gas)

$$q_s = Q\rho_0 C_p (T_i - T_o)$$

Where:

q_s	=	Sensible heat load (W)
C_p	=	Specific heat of air (J/(kg.K)

4. Calculation of the natural gas savings for Baseline 1- Door with no Air Curtain and no Vestibule.

$$NG = 3.412 \times \frac{q_s}{35{,}738} \times HR \times \frac{day_{hs}}{Eff} \times E$$

Where:

NG	=	Annual Natural Gas Savings (m^3/yr per door)
HR	=	Hour per day that the door is open (hr/day)
day_{hs}	=	Heating days per year (day/year)
Eff	=	Heating System efficiency (dimensionless)
E	=	Air Curtain effectiveness (dimensionless)
35,738	=	Energy density of natural gas (Btu/m^3)
3.412	=	Conversion factor from Watt to Btu/hr (1 Watt = 3.412 Btu/hr)

5. Calculation of the natural gas savings for Baseline 2- Door with no Air Curtain and with Vestibule.

$$NG = 3.412 \times \frac{(q_b - q_a)}{35{,}738} \times HR \times \frac{day_{hs}}{Eff}$$

$$q_b = q_s \times (1 - VE)$$

$$q_a = q_b \times (1 - E)$$

Where:

NG	=	Annual Natural Gas Savings (m³/yr per door)
q_b	=	Sensible heat load- accounting for vestibule effectiveness (W)
q_a	=	Sensible heat load- accounting for air curtain effectiveness (W)
HR	=	Hour per day that the door is open (hr/day)
day_{hs}	=	Heating days per year (day/year)
Eff	=	Heating System efficiency (dimensionless)
E	=	Air Curtain effectiveness (dimensionless)
VE	=	Vestibule effectiveness (dimensionless)
35,738	=	Energy density of natural gas (Btu/m³)
3.412	=	Conversion factor from Watt to Btu/hr (1 Watt = 3.412 Btu/hr)

ELECTRIC SAVINGS ALGORITHMS

Electricity impact is determined by the total electric effect during heating and cooling season. This is the sum of all effects described below: Electrical penalty - heating season due to the operation of the fan on the air curtain, Electrical saving - cooling season due to the reduction of cooling load (infiltration reduction) and Electrical penalty - cooling season due to the operation of the fan on the air curtain.

1. **Calculation of the electrical penalty - heating season due to the operation of the fan on the air curtain**

$$E_{fan-h} = -HP \times 0.7457 \times HR \times day_{hs}$$

Where:

E_{fan-h}	=	Electrical Penalty- Heating Season due to the operation of the fan on the air curtain (kWh/yr)
HR	=	Hour per day that the door is open (hr/day)
day_{hs}	=	Heating days per year (day/year)
HP	=	Air curtain fan electric input power (hp)
0.7457	=	Conversion factor (1 horsepower = 0.7457 kilowatt)

2. **Calculation of the electrical penalty - cooling season due to the operation of the fan on the air curtain**

$$E_{fan-c} = -HP \times 0.7457 \times HR \times day_{cs}$$

Where:

E_{fan-c}	=	Electrical Penalty- Cooling Season due to the operation of the fan on the air curtain (kWh/yr)
HP	=	Air curtain fan electric input power (hp)
0.7457	=	Conversion factor (1 horsepower = 0.7457 kilowatt)
day_{cs}	=	Cooling days per year (day/year)

3. **Calculation of the electrical saving - cooling season due to the reduction of cooling load (infiltration reduction)**

$$P_{Uc} = \rho_o \frac{{U_{Hc}}^2}{2}$$

$$P_{Tc} = g\rho_o \left[\frac{(T_{oc} - T_i)}{T_{oc}}\right]$$

$$\Delta p_c = s^2 W_{pc} P_{Uc} + H \times P_{Tc} + \Delta p_I$$

Where:

P_{Uc}	=	Reference wind parameter - cooling season (Pa)
U_{Hc}	=	Local average wind speed - cooling season (m/s)
ρ_o	=	Density of dry air (kg/m^3)
P_{Tc}	=	Stack effect parameter - cooling season (Pa/m)
g	=	Gravitational acceleration (m/s^2)
T_{oc}	=	OA temperature heating system enabled - cooling season(K)
T_i	=	Space Temperature Setpoint (K)
Δp_c	=	Pressure difference across each gap - cooling season (Pa)
s	=	Shelter factor applicable to the given gap (dimensionless)
W_{pc}	=	Wind surface pressure coefficient - cooling season (dimensionless)
H	=	Gap height relative to the neutral pressure plane (m)
Δp_I	=	Pressure that acts to balance inflows and outflows, including mechanical systems (Pa)

$$Q_{Ac} = 2{,}119 \times A \times C_{dc} \times \sqrt{\frac{2\Delta p_c}{\rho_o}}$$

Where:

2,119	=	Conversion factor (1 m3/s = 2,119 CFM)
A	=	Opening area (m^2)
C_{dc}	=	Discharge coefficient for openings during cooling season (dimensionless)
ρ_o	=	Density of dry air (kg/m^3)

$$q_c = 60 \times \rho_o \times Q_{Ac} \times (h_{oc} - h_{ic})$$

Where:

q_c	=	Rate of heat transfer through doorway without vestibule - cooling season (Btu/hr)
60	=	Conversion factor (min/hr)
Q_{Ac}	=	Total airflow rate through the doorway- cooling season (CFM)
h_{oc}	=	Outside enthalpy - cooling season (Btu/lb)
h_{ic}	=	Inside enthalpy - cooling season (Btu/lb)
ρ_o	=	Density of dry air (lbm/ft^3)

3a. Calculation of the electrical saving - cooling season due to the reduction of cooling load (infiltration reduction) for Baseline 1. Door with no Air Curtain and no Vestibule

$$E_{savings-1} = \frac{q_c}{SEER} \times E \times HR \times day_{cs} \times \frac{1}{1000}$$

Where:

$E_{savings-1}$	=	Electrical Savings- Cooling Season due to the reduction of cooling load for Baseline 1 (kWh/yr)
q_c	=	Rate of heat transfer through doorway without vestibule - cooling season (Btu/hr)
SEER	=	Energy efficiency ratio of cooling system (kBtu/kWh)
E	=	Air Curtain effectiveness (dimensionless)
HR	=	Hour per day that the door is open (hr/day)

day_{cs}	=	Cooling days per year (day/year)
1,000	=	Conversion factor (1,000 Btu = 1 kBtu)

3b. Calculation of the electrical saving - cooling season due to the reduction of cooling load (infiltration reduction) for Baseline 2. Door with no Air Curtain and with Vestibule

$$E_{savings-2} = \frac{(q_d - q_e)}{SEER} \times HR \times day_{cs} \times \frac{1}{1000}$$

$$q_d = q_c \times (1 - VE)$$

$$q_e = q_d \times (1 - E)$$

Where:

$E_{savings-2}$	=	Electrical Savings- Cooling Season due to the reduction of cooling load for Baseline 2 (kWh/yr)
q_c	=	Rate of heat transfer through doorway without vestibule (Btu/hr)
q_d	=	Sensible heat load cooling season - accounting for vestibule effectiveness (Btu/hr)
q_e	=	Sensible heat load cooling season - accounting for air curtain effectiveness (Btu/hr)
SEER	=	Energy efficiency ratio of cooling system (kBtu/kWh)
E	=	Air Curtain effectiveness (dimensionless)
VE	=	Vestibule effectiveness (dimensionless)
HR	=	Hour per day that the door is open (hr/day)
day_{cs}	=	Cooling days per year (day/year)
1,000	=	Conversion factor (1,000 Btu = 1 kBtu)

4. Calculation of the total electrical impact for Baseline 1

$$E_{t1} = E_{fan-h} + E_{savings-1} + E_{fan-c}$$

Where:

E_{t1} = Total Electrical impact due to the operation of the air curtain (kWh/yr)

5. **Calculation of the total electrical impact for Baseline 2**

$$E_{t2} = E_{fan-h} + E_{savings-2} + E_{fan-c}$$

Where:

E_{t2} = Total Electrical impact due to the operation of the air curtain (kWh/yr)

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. Assumptions

Variable	Definition	Value and Unit	Source/Comments
ρ_o	Density of outdoor air (heating season)	1.256 kg/m^3 (0.078 lb$_m$/ft^3)	Common assumptions table[2]
	Density of outdoor air (cooling season)	1.163 kg/m^3 (0.073 lb$_m$/ft^3)	Common assumptions table
T_i	Space temperature setpoint	72°F (295.4K)	Common assumptions table
T_o	OA temperature heating system enabled	34.8°F (274.7K)	Common assumptions table
T_{oc}	OA temperature cooling system enabled	77.0°F (298.1K)	Common assumptions table
s	Shelter factor	0.7	Based on Shelter Class 3 [2] [3]
W_p	Wind surface pressure coefficient for heating season	0.12	Calculated value based on and approach in [2] and based on CWEC weather data for London, ON (version 2016) [4]
W_{pc}	Wind surface pressure coefficient for cooling season	0.19	
C_p	Specific heat of air	1,000 J/(kg·K)	Common assumptions table
h_{ic}	Inside enthalpy for cooling season	22.72 Btu/lb	Common assumptions table

[2] Pending Ontario TRM v4 approval-common assumption table

Variable	Definition	Value and Unit			Source/Comments
h_{oc}	Outside enthalpy for cooling season	30.95 Btu/lb			Common assumptions table
HR	Hour per day door is open	1.24			Calculated based on door opening frequency and door opening schedule [5]
$\%opening$	Average % opening area of the door when traffic goes through	69%			Calculated based on the average traffic and door dimensions
Variable	**Definition**	**Door size (W' x H')**			**Door size (W' x H')**
		3'x7'	**6'x7'**	**6'x8'**	
h_d	Dock door height (ft)	7	7	8	Based on standard door sizes
w_d	Dock door width (ft)	6	6	6	
HP	Air curtain horsepower	1/15	1/8	1/8	[6]
U_H	Average wind velocity for heating season	2.60 m/s (5.81 mph)			Calculated using the wind profile law [7] and based on CWEC weather data for London, ON (version 2016) [4] [8]
U_{Hc}	Average wind velocity for cooling season	2.82 m/s (6.31 mph)			
	Average building height	27ft (8.2m)			[3]
C_{dh}	Discharge coefficient for opening during heating season	0.49			Calculated using ASHRAE algorithm [2] and based on CWEC weather data for London, ON (version 2016) [4]
C_{dc}	Discharge coefficient for opening during cooling season	0.39			
E	Effectiveness of air curtain	70% (Range between 60% - 80%)			[9]
VE	Effectiveness of vestibule	36%			[5]
Eff	Commercial heating system efficiency	80%			Common assumptions table
$SEER$	Commercial seasonal cooling system efficiency	13 kBtu/kWh			Common assumptions table
g	Acceleration due to gravity	9.81 m/s^2 (32.2 ft/sec^2)			Common assumptions table
	Airflow rate conversion from m^3/s to CFM	2,119 CFM/m^3/s			[10]

Variable	Definition	Value and Unit	Source/Comments
	Energy density of natural gas	35,738 Btu/m^3	Common assumptions table
	Conversion from HP to kWh	0.7457 kW/HP	Common assumptions table
day_{hs}	Heating days per year	221	Common assumptions table
day_{cs}	Cooling days per year	40	Common assumptions table

Savings Calculation Example

The example below illustrates the annual natural gas savings and electrical impact values for the installation of air curtains on two pedestrian doors with vestibules in a retail store. There are two (6′x8′) doors with vestibules.

Annual Natural Gas Savings:

2 (6′x8′) = 2 x 1,208 m^3/yr = 2,416 m3/yr

Annual Electrical Impact:

2 (6′x8′) = 2 x 116 kWh/yr = 232 kWh/yr

The total natural gas savings is 2,416 m3/yr and the total electrical savings is 232 kWh/yr

Uses and Exclusions

This measure is restricted to the installation of Air Curtains on Pedestrian doors. In addition:

- The space must be heated by natural gas fueled equipment during winter months.
- New Construction applications for which the Air Curtain have been installed in lieu of the vestibule are not eligible.

Measure Life

The measure life is 15 years [11].

Incremental Cost

The purchase and installation cost for air curtains is summarized in the table below. [12]

Table 5. Incremental Cost

Definition	Door size (W' x H')					
	3'x7'	6'x7'	6'x8'	2x (3'x7')	2x (6'x7')	2x (6'x8')
Ave. product cost	$400	$500	$500	$800	$1,000	$1,000
Ave. Installation cost[3]	$1,245	$1,245	$1,245	$2,350	$2,350	$2,350
Ave. Total cost	$1,645	$1,745	$1,745	$3,150	$3,350	$3,350

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

Version Date and Revision History	
Version	1
OEB Filing Date	Dec 21, 2016
OEB Approval Date	
Commercial → Space Heating → Condensing Make-Up Air Unit (MUA) → New Construction/Time of Natural Replacement	

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

Table 1. Measure Key Data

Parameter	Definitions		
Measure Category	New Construction (NC) Time of Natural Replacement (TNR)		
Baseline 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
Annual Electric Savings Rate (kWh/CFM)	Constant Speed	0	0
	2 Speed	1.24	1.61
	VFD	2.04	2.30
Measure Life	20 Years		
Incremental Cost ($ CAD)	**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 from 1,500 CFM up to 14,000 CFM. Systems with Demand Control Ventilation will not qualify. Retail is not eligible for this measure. Savings factors are based on base case unit delivering the total fresh air flow from the MUA unit during operation. Air Handling Units (AHU) with return, reheat and cooling are not eligible.

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 Technology

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 natural gas savings are calculated using an assumed load profile for each type of equipment, typical meteorological year 2 (TMY) 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 "Assumptions" section. The binned weather data is shown in Table 6.

The 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 MUA rated air flow capacity assuming no modulation (Btu/yr/CFM)
1.08	= 60 min/hr x 0.239 Btu/ lb_m-F specific heat of air x 0.074 lb_m/ft^3 density of dry air (Btu/hr-F-CFM)
bin	= Annual hours in each five degree temperature bin[1] (hr/yr), see Table 6 (use appropriate column for appropriate building type)
T_s	= Supply air temperature set point (°F)
T_o	= Outside air temperatures (°F)
$NG\ Savings\ Factor$	= Annual gas savings factor resulting from installing the new condensing MUA (m^3/yr)/CFM
V_{Base}	= Baseline fan motor speed (%)
V_{EE}	= Energy efficient fan motor speed (%)
$35{,}738\frac{Btu}{m^3}$	= Conversion of rated heating capacity from Btu/hr to m^3/hr, common assumptions table
TE_{base}	= Baseline equipment thermal efficiency (%)
TE_{EE}	= Efficient equipment thermal efficiency (%)

ELECTRIC SAVINGS ALGORITHM

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].

[1] Tabulated from TMY2 weather data for London, Ontario from: https://energyplus.net/weather-location/north_and_central_america_wmo_region_4/CAN/ON/CAN_ON_London.716230_CWEC

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].

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

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 (%)
x	= Affinity law exponent
$365 \frac{days}{yr}$	= Number of days in the year
hp	= Power input of the fan motor (hp)
η	= Fan motor efficiency (%)
VFD_p	= Penalty for the VFD (%)
$0.746 \frac{kW}{hp}$	= 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 MUA rated air flow capacity assuming no modulation (Btu/yr/CFM)

bin	= Annual hours in each five degree temperature bin[2] (hr/yr), see Table 5
T_s	= Supply air temperature set point (°F)
T_o	= Outside air temperatures (°F)
$Cool\ kWh\ Rate$	= The electrical cooling savings rate per CFM of MUA rated air flow capacity assuming no modulation (kWh/yr/CFM)
V_{Base}	= Baseline fan motor speed (%)
V_{EE}	= Energy efficient fan motor speed (%)
$12{,}000\frac{Btu}{ton}$	= Conversion of Btus to tons of cooling
$0.924\frac{kW}{ton}$	= Assumption for efficiency of MUA cooling across all equipment types (kW/ton)

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 MUA rated air flow capacity assuming no modulation (kWh/CFM)

ASSUMPTIONS

The assumptions used to calculate the 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
x	Affinity law exponent	2.5	[9]
VFD_p	Percent penalty for VFD losses	5%	[7]

[2] Tabulated from TMY2 weather data for London, Ontario from: https://energyplus.net/weather-location/north_and_central_america_wmo_region_4/CAN/ON/CAN_ON_London.716230_CWEC

Variable	Definition	Inputs	Source
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.

[3] Only during hours that ventilation is being provided.

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
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

4 Hours of operation based on multi-residential and long-term care load profile.
5 Hours of operation based on commercial load profile.

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:

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

[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.

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. The unit airflow shall be between 1,500 CFM up to 14,000 CFM. Systems with Demand Control Ventilation will not qualify. Retail is not eligible for this measure.

MEASURE LIFE

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

INCREMENTAL COST

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

Table 8. Incremental Cost [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

REFERENCES

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

Version Date and Revision History	
Version	1
OEB Filing Date	Dec 21, 2016
OEB Approval Date	
Commercial → Water Heating → Condensing Storage Water Heater → New Construction/Time of Natural Replacement	

Table 1 provides a –summary of the key measure parameters and 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. of input Estimated overall efficiency of units shipped = 80.1%		
Efficient Technology	Condensing storage water heater Greater than 75 kBtu/hr. of input Estimated overall efficiency of units shipped = 94.5%		
Market Type	Commercial		
Annual Natural Gas Savings Rate (m^3 per kBtu/hr of rated input)	**Low Utilization Application***	**Medium Utilization Application***	**High Utilization Application***
	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 ($ CAD)	250 KBtu/hr input rating and below	$2,591	
	Above 250 KBtu/hr input rating	$4,464	
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 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, with and input rating of 75 kBtu/hr or greater [2], 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 an input rating of 75 kBtu/hr or greater are eligible for this measure [2]. Units must be certified to the appropriate CSA standard such as: CSA 4.3/ANSI Z21.10.3, or CSA P3-04, DOE 10 CFR Part 430.

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. [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 service hot water demand for a specific building type (US gallon/occupant-hour) [3] [4]

OS_{factor} = Typical storages water heater oversizing factor relative to 15-minute peak demand (130%) [4]

$Days\ per\ year$ = 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 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.

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

Where,

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)
$\eta_{proposed}$	=The weighted shipment average thermal efficiency for condensing storage water heaters
$\eta_{baseline}$	=The weighted shipment average thermal efficiency for non-condensing storage water heaters
NG_{ec}	= Natural gas energy content

The resulting 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

ASSUMPTIONS

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

Table 5. 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 thermal efficiency of proposed and baseline units	Results of baseline study	Caneta Research Inc. [5]
NG_{ec}	Energy density of natural gas	35,738 Btu/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 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. [6]

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 kBtu/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 [7], and is consistent with data from other studies.

Table 6. Incremental Cost[1]

Input Rating	Incremental Cost of Equipment	Incremental Cost of Installation[2]	Total Incremental
250 KBtu/hr and below	CAD $2,432 [8] [9] [10]	$159 [7]	$2,591
Above 250 kBtu/hr	CAD $4,306 [8] [9] [10]	$159 [7]	$4,464

REFERENCES

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COMMERCIAL – CONDENSING UNIT HEATER – NEW CONSTRUCTION/TIME OF NATURAL REPLACEMENT

Version Date and Revision History	
Version	3
OEB Filing Date	December 16, 2021
OEB Approval Date	December 16, 2021
Commercial→ Space Heating → Condensing Unit Heater→ New Construction/Time of Natural Replacement	

Table 1 below provides a summary of the key measure parameters and savings based on the rated input of the unit.

Table 1. Measure Key Data

<table>
<tr><th colspan="2">Parameter</th><th colspan="3">Definitions</th></tr>
<tr><td colspan="2">Measure Category</td><td colspan="3">New Construction (NC)
Time of Natural Replacement (TNR)</td></tr>
<tr><td colspan="2">Baseline Technology</td><td colspan="3">80% Thermal Efficiency, 78% Annual Efficiency</td></tr>
<tr><td colspan="2">Efficient Technology</td><td colspan="3">90% Thermal Efficiency, 89% Annual Efficiency</td></tr>
<tr><td colspan="2">Market Type</td><td colspan="3">Commercial, Multi-residential</td></tr>
<tr><td colspan="2" rowspan="2">Annual Natural Gas Savings Rate (m^3 /kBtu/hr)</td><td>New Construction</td><td colspan="2">5.92 m^3 per kBtu/hr input rating</td></tr>
<tr><td>Time of Natural Replacement</td><td colspan="2">7.89 m^3 per kBtu/hr input rating</td></tr>
<tr><td rowspan="3">Annual Electric Impacts (kWh/year)</td><td></td><th>30 – <125 kBtu/hr</th><th>125 – <225 kBtu/hr</th><th>225 – <325 kBtu/hr</th></tr>
<tr><td>NC</td><td>-222 kWh</td><td>-398 kWh</td><td>-410 kWh</td></tr>
<tr><td>TNR</td><td>-296 kWh</td><td>-530 kWh</td><td>-546 kWh</td></tr>
<tr><td colspan="2">Measure Life</td><td colspan="3">18 years</td></tr>
<tr><td colspan="2">Incremental Cost ($ CAD)</td><td colspan="3">$16.07 per kBtu/hr input rating</td></tr>
<tr><td colspan="2">Restrictions</td><td colspan="3">Must be a new commercial installation of a condensing unit heater</td></tr>
</table>

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, condensation 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 an 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] [3]
	78%Annual Efficiency [1]

EFFICIENT TECHNOLOGY

The efficient technology is 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 unit heaters in this service territory is a reduction in natural gas usage resulting from the unit heater's improved efficiency. Electric energy usage increases because of a higher capacity vent motor used 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. To calculate the annual measure savings, the savings factor calculated in this section and presented in Table 1 must be multiplied by the input capacity of the condensing unit heater.

The 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)
$35.738\,\frac{kBtu}{m^3}$	= Conversion of rated heating capacity from kBtu to m^3
AE_{base}	= Baseline equipment annual efficiency (%)
AE_{EE}	= Efficient equipment annual efficiency (%)

ELECTRIC IMPACT 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 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)

$Elect_{base}$ = Power consumption of the baseline unit (kW)

$Elect_{EE}$ = Power consumption of the condensing unit heater (kW)

LIST OF ASSUMPTIONS

The assumptions used to calculate the 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 – time of natural replacement	2,000 hrs	Common 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 – <125 kBtu/hr	0.155	0.301**
125 – <225 kBtu/hr	0.392	0.657
225 – <325 kBtu/hr	0.747	1.020

*Size range deviates slightly from reference [1] which is based on actual units' sizing and capacities available at the time and should not affect the electrical consumption values.

**Value extrapolated from 125 – 225 kBtu/hr and 225 – 300 kBtu/hr size range.

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.

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

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

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. [4]

Incremental Cost

The incremental cost of buying a condensing instead of non-condensing unit heater is $16.07 per kBtu/hr[1]. [1]

[1] The incremental costs for a condensing unit heater were derived from the NGTC report, reference [1]. All the calculations can be found in the supplementary excel file - 'Unit Heater Incremental Costs Analysis_EGI_2021-10-14.xlsx'. The size ranges used in the substantiation document deviate from the reference. To maintain the assumptions used in the reference and due to a lack of data on the current state of the market, the cost is based on the size ranges reported in the reference document. The cost is however, adjusted for inflation at the rate of 1.85%. Inflation rates retrieved from https://www.bankofcanada.ca/rates/related/inflation-calculator/.

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COMMERCIAL – DEMAND CONTROLLED VENTILATION – NEW CONSTRUCTION/ RETROFIT/TIME OF NATURAL REPLACEMENT

Version Date and Revision History	
Version	2.0
OEB Filing Date	November 30, 2018
OEB Approval Date	
Commercial → Space Heating → Demand Controlled Ventilation→ New Construction/Retrofit/Time of Natural Replacement	

Table 1 provides a summary of the key measure parameters and savings coefficients differentiated by facility type.

Table 1. Measure Key Data

Parameter	Definitions		
Measure Category	New Construction (NC), Retrofit (R), and Time of Natural Replacement (TNR)		
Base Technology	Existing and New single zone, constant volume ventilation system with natural gas-fueled heating	Designed and operating in a manner that provides the minimum outdoor air requirement as specified in Table 6.2.2.1 of ASHRAE Standard 62.1-2013 [1]	
Efficient Technology		Ventilation rate during the occupied periods of the building schedule is modulated in response to actual CO_2 concentrations, as measured with an appropriately located CO_2 sensor.	
Market Type	Commercial		
Annual Natural Gas Savings Rate (m^3/ft^2)	**Space Type**	**Savings**	
	Office	0.112	
	Retail	0.392	
Measure Life	15 years		
Incremental Cost ($)	**Retrofit**	**Time of Natural Replacement/New Construction**	
	$1,050 per zone, assuming one sensor per zone	$750 per zone, assuming one sensor per zone	
Restrictions	This measure is intended for self-calibrating sensors or other types of sensors whose calibration warranty period by the manufacturer is 15 years or more. Multi-zone systems, variable air volume (VAV) systems, or systems equipped with heat recovery capabilities are not eligible for this prescriptive		

Parameter	Definitions
	measure. Applications with free cooling economizers are eligible for this prescriptive measure. For new construction applications, this measure is not eligible to buildings/spaces where DCV is required by current building code.

OVERVIEW

Adequate ventilation of buildings is necessary to remove "pollutants" resulting from activities occurring within the space and maintain acceptable levels of indoor air quality. This ventilation is typically accomplished by introducing a quantity of outside air sufficient to dilute the pollutants, while the same quantity of "contaminated" air is removed from the building through either passive or active means of building exhaust.

The minimum required ventilation rate is typically established during the design process, based on applicable building codes and anticipated occupancy patterns. Consideration is also given to any special building functions expected to generate excessive levels of pollutants (various manufacturing processes, sustained high levels of human activity, etc.).

Heating, cooling, and maintaining acceptable humidity levels for the ventilation air introduced to the space represent a very significant component of the overall building energy consumption. This energy is typically much greater than the sum of all "skin losses" or surface heat transfer from the building. Excessive ventilation can be extremely costly, with little if any associated benefit.

DCV is a control strategy that automatically modulates outside air dampers to control the quantity of outside air introduced to a space based on the "demand" or level of contaminants being produced within the space. In most spaces the optimum ventilation rate fluctuates in direct proportion to occupancy and the level of activity within the space.

There can be many different types of indoor air pollutants specific to the particular building activities. One common pollutant found in all occupied spaces is CO_2, which is produced by humans through respiration. CO_2 levels expressed in parts per million (ppm) have been found to provide a good representation of overall indoor air quality, and except for cases where specific process-related pollutants overshadow their impact, have become the universally accepted controlled variable for DCV systems.

APPLICATION

This measure pertains to the implementation of DCV, based on CO_2 concentrations within the space, for single-zone, constant volume ventilation systems.

Implementation includes the installation of a CO_2 sensor in an appropriate location within the space or in the return air duct. The sensor outputs are provided to an automated control system with a programed sequence of operation that modulates the outside air damper position, controlling the ventilation rate in response to CO_2 concentrations. The controller can be part of the facility's building automation system or an independent control device, integrated within a packaged roof top unit (RTU), air handling unit (AHU), or make-up air unit (MUA).

Installations covered under this TRM section are incorporated as part of either a retrofit into existing functional ventilation systems, as part of a time of natural replacement project, or as part of a new construction project.

DCV can also be implemented for complex ventilation systems, including multi-zone and variable air volume (VAV) systems. However, the Enermodal market research study [2] conducted prior to development of this measure correctly concluded that the relative complexity of the installations and the wide variations in achievable savings make these installations better candidates for custom incentive applications.

BASELINE TECHNOLOGY

The baseline technology is represented by an existing single-zone, constant volume ventilation system, with natural gas-fueled heating, designed and operating in a manner that provides the minimum outdoor air requirement as specified by the data provided in Table 6.2.2.1 of ASHRAE Standard 62.1-2013. [1]

These minimum-design outdoor air ventilation rates are intended to meet ventilation requirements when the space is at the anticipated peak occupancy level. ASHRAE Standard 62.1, Table 6.2.2.1 provides default occupancy density values for various space types along with values representing the minimum ventilation per person and per unit of area served by the system.

The baseline system provides this minimum outdoor air requirement on a continuous basis throughout the occupied periods of the building schedule, and it does not provide ventilation during the unoccupied periods of the building schedule[1]. Table 2 presents the baseline requirements.

Table 2. Baseline Technology

Type	Requirement
Existing single-zone, constant volume ventilation system with natural gas-fueled heating	Designed and operating in a manner that provides the minimum outdoor air requirement as specified in Table 6.2.2.1 of ASHRAE Standard 62.1-2013 [1], on a continuous basis during the occupied periods

[1]Some systems may have a fixed minimum outside air damper position, (typically 5% OA), to allow for a minimum level of ventilation even during unoccupied hours. As long as this minimum is present in both the baseline and efficient scenarios (with DCV implemented), it has no impact on the resulting measure savings.

EFFICIENT TECHNOLOGY

The efficient technology is represented by the baseline ventilation system with an appropriately located CO_2 sensor, a controller, and a control algorithm established to limit the maximum outdoor air ventilation rate to that based on the ASHRAE 62.1, Table 6.2.2.1 prescribed values, equivalent to the continuous occupied period ventilation provided by the baseline system.

The CO_2 sensor measures CO_2 concentrations and provides an output signal to a stand-alone control device specific to the ventilation system. The controller will accept the input from the sensor and generate a corresponding output signal to the outside air damper actuator, adjusting the damper position as described below.

Appendix H of the Enermodal market research study [2] presents the results of a survey of RTU installers representing 1,000 DCV installations. The study confirmed that control algorithms are typically established based on an assumed differential of 700 ppm in CO_2 concentrations of ambient outside air and design condition interior air. Typical ambient air CO_2 concentrations are around 400 ppm, meaning that most systems are calibrated to allow for steady state CO_2 concentrations of up to 1,100 ppm when the space is fully occupied with the outside air dampers at the position intended to allow for the ASHRAE 62.1 prescribed design flow rate. As occupancy declines, the CO_2 concentration drops and the controller reduces the damper opening. With no occupants in the space the CO_2 concentration eventually reaches the outdoor ambient level, at which point the outside air damper is closed, (or in some cases set to a minimum position as described in footnote 1 on the previous page). Table 3 presents the efficient system requirements.

Table 3. Efficient Technology

Type	Requirement
Existing single-zone, constant volume ventilation system with natural gas-fueled heating	Ventilation rate during the occupied periods of the building schedule is modulated in response to actual CO_2 concentrations, as measured with an appropriately located CO_2 sensor

ENERGY IMPACTS

The primary energy impact associated with implementation of DCV in this service territory is lower heating fuel consumption resulting from a reduction in the quantity of outside air introduced to the space during the heating season. Table 1 in the "Overview" section provides annual savings values (m^3 natural gas / ft^2 area served), differentiated by space type. The savings are based on climate data for London, Ontario, which was selected as a proxy city for Ontario based on a weighted average analysis of Ontario's 10 largest cities, provided by Enbridge Gas. The spreadsheet analysis used population and degree data obtained from online sources and was validated as part of the review for this measure. [3] [4] [5]

Extensive analysis completed by Enermodal Engineering as part of a market research study [2] led to the conclusion that in Ontario the cooling season energy impact (electric energy savings) occurs only during a limited number of hours when the space requires cooling and outdoor air temperature is warmer than the space temperature. The Excel-based tool developed by Enermodal Engineering and used to derive the savings values provided in Table 1 predicted cooling season electric savings equivalent to less than 1% of the projected heating natural gas savings. The predicted electric energy savings by the model is small enough to be within the level of precision that could reasonably be attained by the savings algorithm leading to the prediction.[2]

There is no water consumption impact associated with this measure.

Natural Gas Savings Algorithm

As part of the Enermodal market research study [2], a spreadsheet tool was developed to predict annual natural gas savings for spaces of various types and sizes in selected locations throughout the Enbridge-Union Gas service territories. The tool is based on the algorithm described below.

The spreadsheet tool's multi-step algorithm is used to predict annual energy savings for spaces with varying end uses and sizes in five different climate zones. The results were calibrated against eQUEST-DOE-2 [6] building simulation model results for seventy-five combinations of building types, sizes, and climate zones.

The specific steps in the spreadsheet algorithm are as follows:

1. Determine the maximum anticipated occupancy and the associated design minimum outside air flow rate in CFM that is required by code [1]. This represents the baseline condition whenever the space is occupied.

$$Flow_{Design} = Occ_{Design} \times \frac{SF}{1000} \times Rp + SF \times Ra$$

where,

$Flow_{Design}$	= The design ventilation rate in expressed (CFM)
Occ_{Design}	= The design occupants per 1000 square feet (from ASHRAE 62.1, Table 6.2.2.1)
SF	= The area of zone served (ft^2)
Rp	= The occupant ventilation rate, CFM per person (from ASHRAE 62.1, Table 6.2.2.1)
Ra	= The area ventilation rate, CFM per square foot (from ASHRAE 62.1, Table 6.2.2.1)

[2] A reduction of the system peak electrical demand could result if space occupancy during the peak period is lower than the peak occupancy levels defined by ASHRAE 62.1 table 6.2.2.1.

2. Apply the appropriate occupancy schedule [7] and determine space occupancy and the associated outside air flow rate (CFM) on an hourly basis for the efficient case condition during occupied periods with DCV implemented.

$$Flow_{efficienct\ case} = Occ_{Design} \times \%\ Occ \times \frac{SF}{1000} \times Rp + SF \times Ra$$

where,

$Flow_{efficient\ caset}$ = The hourly efficient case ventilation rate in expressed (CFM)

$\%\ Occ$ = The value taken from US DOE commercial reference building typical occupancy schedule for the specified space type

When the space is unoccupied the outside air flow is assumed to be zero for both the baseline and efficient case scenario.

3. Use typical hourly weather data [8] (dry-bulb temperature, humidity ratio, and outdoor air pressure) to calculate the density of air (lb/ft^3) on an hourly basis and determine the resulting mass flow rate (lb/min).

$$M = Density_{Air} \times Flow_{Hourly} \times 60\ min/hour$$

where,

M = The hourly mass flow rate of air (lbs/hour)

$Density_{Air}$ = The density calculated from typical weather data representing each hour in the specific climate zone (lb/ft$^{3)}$

$Flow_{Hourly}$ (CFM) = The flow rate calculated in the above equations for each hour of the year

4. Subtract the hourly outdoor air temperature from the desired supply air temperature to determine the need for heating and the temperature rise (°F) required for each hour and calculate the thermal energy requirement.

$$Q = M \times Cp_{Air} \times \Delta T$$

where,

Q = The thermal energy requirement (Btu/hour)

Cp_{Air} = The specific heat of air (Btu/lb-°F)

ΔT = The difference between average hourly outdoor temperature and supply air temperature (°F)

5. Divide the hourly thermal energy requirement by the typical heating system efficiency to calculate the hourly average input energy (m^3) for the baseline and efficient case conditions.

$$NG_{Hourly} = \frac{Q}{35{,}738 \cdot Heating\ system\ efficiency}$$

where,

NG_{Hourly} = The hourly natural gas consumption (m³)

$Heating\ system\ efficiency$ = The average heating system efficiency

35,738 = Energy density of natural gas (Btu/m³)

6. Sum the hour results to determine the annual energy input (kWh) of the baseline and efficient case conditions and deduct the annual efficient case energy input from the baseline value to determine the predicted annual savings in m³ of natural gas.

$$Annual\ savings = \sum_{0}^{8760} NG_{efficiennt\ case} - \sum_{0}^{8760} NG_{Baseline}$$

where,

$Annual\ savings$ = The annual natural gas savings (m³/year)

$\sum_{0}^{8760} NG_{efficient\ case}$ = The summation of the efficient case hourly natural gas consumption

$\sum_{0}^{8760} NG_{Baseline}$ = The summation of the baseline hourly natural gas consumption

The results were normalized to derive the annual savings per square foot of area served for the typical climate zone represented by London, Ontario presented in Table 1.

The savings values (m³ / ft²) derived from the spreadsheet tool and reflected in Table 1 are then used to calculate and report project specific savings as follows:

$$Savings_{NG} = Savings \times Zone\ area$$

where,

$Savings_{NG}$ = The annual natural gas savings (m³)

$Savings$ = The savings value for the space type and climate zone from Table 1 (m³ / ft²)

$Zone\ area$ = The area of the zone served by the RTU, AHU, or MUA (ft²)

ASSUMPTIONS

Table 4 provides a list of constants and assumption used in the derivation of the savings values. Because duct runs for single-zone RTUs are generally short and/or within the conditioned space, this value also represents a reasonable estimate of system efficiency.

Table 4. Assumptions

Parameter	Value	Units	Reference
Space temperature setpoint	72	°F	Common assumptions table

OA temperature heating system is enabled	55	°F	Common assumptions table
Commercial heating system efficiency	80%	%	Common assumptions table
Energy density of natural gas	35,738	Btu/m³	Common assumptions table
Conversion factor for the specific heat of air	1 Btu/lb·°F = 4186.8 J/kg·K		Converting between commonly used Units

SAVINGS CALCULATION EXAMPLE

The example below illustrates how the savings value is determined for a DCV installation for a 10,000 ft² office single zone area.

$$Savings_{NG} = Savings \times Zone\ area$$

$$= 0.112\ m^3/ft^2 \ X\ 10{,}000\ ft^2$$

$$= 1{,}120\ m^3 \text{ per year}$$

USES AND EXCLUSIONS

To qualify for this measure, DCV must be implemented for a single-zone, constant volume ventilation system, with natural gas fueled heating that previously operated to provide constant ventilation meeting the minimum outdoor air requirements specified by ASHRAE 62.1 Table 6.2.2.1.

Multi-zone systems, VAV systems, or systems equipped with energy or heat recovery capabilities are not eligible for this prescriptive measure.

This measure is intended for self-calibrating sensors or other types of sensors whose calibration warranty period by the manufacturer is 15 years or more.

MEASURE LIFE

The standard measure life attributed to this measure is 15 years. [9] The 15 year measure life is intended for self-calibrating sensors or other types of sensors whose calibration warranty period by the manufacturer is 15 years or more.

Although physical components of the ventilation system can be expected to last longer, energy savings persist only as long as sensors and other components of the DCV system remain in calibration and functioning as intended.

Self-calibrating sensors are widely available and used in prescriptive applications as covered by this substantiation document. The calibration warranty period for these sensors are 15 years or more, depending upon the manufacturer.

Incremental Cost

Table 5 presents the measure incremental cost.

Table 5. Measure Incremental Cost [2]

Measure Category	Cost Component	Incremental Cost ($)
Retrofit – Single Zone	Equipment	$750
	Installation	$300
	Total	**$750 + $300 = $1,050**
Time of Natural replacement – Single Zone Replacement/ New Construction	Equipment	$750
	Total	**$750**

References

[1] ASHRAE, "ANSI/ASHRAE Standard 62.1 - 2013, Table 6.2.1.1, Page 12-16," American Society of Heating, Refrigeration and Air-Conditioning Engineers, Atlanta, 2013.

[2] Enermodal Engineering, "Union Gas Market Research - Demand Controlled Ventilation Systems - Task 6, see page 40 for measure cost data," Enermodal Engineering, Kitchener, Ontario, 2013.

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[9] California Public Utilities Commission: Database for Energy Efficient Resources (DEER) – 2014, Updated-EULrecords_02-05-2014; EUL ID: HVAC-VSD-DCV Available from: http://deeresources.com/files/deerchangelog/deerchangelog.html

COMMERCIAL – DEMAND CONTROLLED VENTILATION – NEW CONSTRUCTION RETROFIT/TIME OF NATURAL REPLACEMENT

Version Date and Revision History	
Version history	1.0
OEB Filing Date	November 30, 2018
OEB Approval Date	
End date	
Commercial → Space Heating → Demand Controlled Ventilation → New Construction/Retrofit/Time of Natural Replacement	

Table 1 provides a summary of the key measure parameters and savings coefficients differentiated by facility type.

Table 1: Measure Key Data

Parameter	Definitions	
Measure category	New Construction (NC), Retrofit (R), and Time of Natural Replacement (TNR)	
Baseline Technology	Existing and New single-zone, constant volume ventilation system with natural gas-fueled heating	Designed and operating in a manner that provides the minimum outdoor air requirement as specified in Table 6.2.2.1 of ASHRAE Standard 62.1-2013 [1]
Efficient technology		Ventilation rate during the occupied periods of the building schedule is modulated in response to actual CO_2 concentrations, as measured with an appropriately located CO_2 sensor.
Market type	Commercial	
Annual Natural Gas Savings (m^3/ft^2)	**Space Type**	**Savings**
	Primary/Secondary School Gymnasium	1.484
	Post-Secondary School Classroom	0.601
	Community Center Meeting Space	0.441
	Exercise Center/Sports Arena	0.435
	Senior/Nursing/Long-Term Care Facility (Common Areas)	0.636
	Cinemas and Performing Arts	1.690
	Hotel Conference Rooms	1.043
Measure life	15 years	

Incremental Cost ($)	**Retrofit**	**Time of Natural Replacement/New Construction**
	$1,050 per sensor, assuming one sensor per zone	$750 per sensor, assuming one sensor per zone
Restrictions	This measure is intended for self-calibrating sensors or other types of sensors whose calibration warranty period by the manufacturer is 15 years or more. Multi-zone systems, variable air volume (VAV) systems, or systems equipped with heat recovery capabilities are not eligible for this prescriptive measure. Applications with free cooling economizers are eligible for this prescriptive measure. For new construction applications, this measure is not eligible to buildings/spaces where DCV is required by current building code.	

OVERVIEW

Buildings require adequate ventilation to remove carbon dioxide and pollutants resulting from activities occurring within the space and maintain acceptable levels of indoor air quality. This ventilation is typically accomplished by introducing a quantity of outside air sufficient to dilute the pollutants, while the same quantity of "contaminated" air is removed from the building through either passive or active means of building exhaust

The minimum required ventilation rate is typically established during the design process based on applicable building codes and anticipated occupancy patterns. Consideration is also given to any special building functions expected to generate higher levels of pollutants, such as various manufacturing processes and sustained high levels of human activity.

Heating, cooling, and maintaining acceptable humidity levels for the incoming ventilation air represent a significant component of the overall building energy consumption. This energy is typically much greater than the sum of all envelope losses or surface heat transfer from the building. Excessive ventilation can be extremely costly, with little if any associated benefit.

Demand control ventilation (DCV) is a control strategy that automatically modulates outside air dampers to control the quantity of outside air being introduced to a space based on the "demand" or the level of contaminants being produced within the space. In most spaces the optimum ventilation rate fluctuates in direct proportion to occupancy and the level of activity within the space.

There can be many different types of indoor air pollutants specific to the particular building activities. One common pollutant found in all occupied spaces is Carbon dioxide (CO_2), which is produced by humans through respiration. CO_2 levels expressed in parts per million (ppm) is a good indicator of overall indoor air quality in most spaces. Exceptions include spaces where specific process-related pollutants dominate. Thus, CO_2 levels, expressed in parts per million (ppm), are typically used as the control variable for DCV systems.

APPLICATION

This measure pertains to the implementation of DCV, based on CO_2 concentrations within the space, for single-zone, constant volume ventilation systems.

Implementation includes the installation of one or more CO_2 sensors in appropriate locations within the space or appropriately located with accessibility in the return air duct. The sensor outputs are provided to an automated control system with a programed sequence of operation that modulates the outside air damper position, controlling the ventilation rate in response to CO_2 concentrations. The controller can be part of the facility's building automation system or an independent control device, integrated within a packaged roof top unit (RTU), air handling unit (AHU), or make-up air unit (MUA).

Installations covered under this TRM section are incorporated as part of either a retrofit into existing functional ventilation systems, as part of a time of natural replacement project, or as part of a new construction project.

DCV can also be implemented for complex ventilation systems, including multi-zone and variable air volume (VAV) systems which are not covered in this substantiation document.

BASELINE TECHNOLOGY

The baseline technology is represented by an existing single-zone, constant volume ventilation system, with natural gas-fueled heating, designed and operating in a manner that provides the minimum outdoor air requirement as specified by the data provided in Table 6.2.2.1 of ASHRAE Standard 62.1-2013. [1]

These minimum-design outdoor air ventilation rates are intended to meet ventilation requirements when the space is at the anticipated peak occupancy level. ASHRAE Standard 62.1, Table 6.2.2.1 provides default occupancy density values for various space types along with values representing the minimum ventilation per person and per unit of area served by the system.

The baseline system provides this minimum outdoor air requirement on a continuous basis throughout the occupied periods of the building schedule, and it does not provide ventilation during the unoccupied periods of the building schedule[1]. Table 2 presents the baseline requirements.

[1] Some systems may have a fixed minimum outside air damper position, (typically 5% OA), to allow for a minimum level of ventilation even during unoccupied hours. As long as this minimum is present in both the baseline and efficient scenarios (with DCV implemented), it has no impact on the resulting measure savings.

Table 2: Baseline Technology

Type	Requirement
Existing single-zone, constant volume ventilation system with natural gas fueled heating	Designed and operating in a manner that provides the minimum outdoor air requirement as specified in Table 6.2.2.1 of ASHRAE Standard 62.1-2013 [1], on a continuous basis during the occupied periods

Efficient Technology

The efficient technology is represented by the baseline ventilation system with appropriately located CO_2 sensors, controllers, and control algorithms established to limit the maximum outdoor air ventilation rate to that based on the ASHRAE 62.1, Table 6.2.2.1 prescribed values, equivalent to the continuous occupied period ventilation provided by the baseline system.

The CO_2 sensors measure CO_2 concentrations and provide an output signal to stand-alone control devices specific to the ventilation system. The controllers will accept the input from the sensors and generate a corresponding output signal to the outside air damper actuators, adjusting the damper positions as necessary. Table 3 presents the efficient system requirements.

Table 3: Efficient Technology

Type	Requirement
Existing single-zone, constant volume ventilation system with natural gas-fueled heating	Ventilation rate during the occupied periods of the building schedule is modulated in response to actual CO_2 concentrations, as measured with an appropriately located CO_2 sensor

Energy Impacts

The primary energy impact associated with implementation of DCV in the EGD-Union Gas service territories is lower heating fuel consumption resulting from a reduction in the quantity of outside air introduced to the space during the heating season. Table 1 provides annual savings values (m^3 natural gas / ft^2 area served) differentiated by space type. The savings are based on climate data for London, Ontario, which was selected as a proxy city for Ontario. [2]

Space cooling affects electricity consumption exclusively and has not been included in this analysis.

There is no water consumption impact associated with this measure.

NATURAL GAS SAVINGS ALGORITHM

The annual natural gas savings calculations for single-zone buildings was based on a spreadsheet tool originally developed as part of the Enermodal DCV market research study [3]. The spreadsheet tool's multi-step algorithm is used to predict annual energy savings for spaces. ICF International [4] has updated and expanded this tool to derive savings for the space types presented in Table 1.

The specific steps in the spreadsheet algorithm are as follows:

1. **Design Airflow:** Determine the maximum anticipated occupancy and the associated design outside airflow rate that is required by code [1] at this peak occupancy. This represents the baseline condition whenever the space is occupied.

$$\mathrm{Flow_{Design}} = \mathrm{Occ_{Design}} \times \frac{\mathrm{A}}{1000} \times \mathrm{Rp} + \mathrm{A} \times \mathrm{Ra}$$

where,

$\mathrm{Flow_{Design}}$	= The design ventilation airflow rate (cfm)
$\mathrm{Occ_{Design}}$	= The design occupants per 1000 ft^2 (from ASHRAE 62.1, Table 6.2.2.1)
A	= The area of zone served (ft^2)
Rp	= The occupant ventilation rate, cfm per person (from ASHRAE 62.1, Table 6.2.2.1)
Ra	= The area ventilation rate, cfm per ft^2 (from ASHRAE 62.1, Table 6.2.2.1)

2. **DCV Airflow:** Apply the appropriate occupancy schedule [4] and determine space occupancy and the associated outside air flow rate (cfm) on an hourly basis for the efficient case condition during occupied periods with DCV implemented.

$$\mathrm{Flow_{DCV}} = \mathrm{Occ_{Design}} \times \%\,\mathrm{Occ} \times \frac{\mathrm{A}}{1000} \times \mathrm{Rp} + \mathrm{A} \times \mathrm{Ra}$$

Where,

$\mathrm{Flow_{DCV}}$	= The hourly efficient case ventilation airflow rate (cfm)
$\%\,\mathrm{Occ}$	= Percent of peak design occupancy, taken from building typical occupancy schedule for the specified space type [4]

3. **Mass flow rate of air:** Use typical hourly weather data [2] including dry-bulb temperature, humidity ratio, and outdoor air pressure to calculate the density of air on an hourly basis and determine the resulting mass flow rate.

$$M = Density_{Air} \times Flow_{Hourly} \times 60\ min/hour$$

where,

M = The hourly mass flow rate of air (lb/hour)

$Flow_{Hourly}$ = The flow rate calculated in the above equations for each hour of the year (cfm)

$Density_{Air}$ = The density calculated from typical weather data representing each hour in the specific climate zone (lb/ft^3)

4. **Thermal Energy Requirement:** Subtract the hourly outdoor air temperature from the desired supply air temperature to determine the need for heating and the temperature rise (°F) required for each hour and calculate the thermal energy requirement.

$$Q = M \times Cp_{Air} \times \Delta T$$

where,

Q = The thermal energy requirement per hour (Btu/hour)

Cp_{Air} = The specific heat of air (Btu/lb-°F)

ΔT = The difference between average hourly outdoor temperature and supply air temperature (°F)

5. **Input Energy Requirement:** Divide the hourly thermal energy requirement by the typical heating system efficiency to calculate the hourly average input energy (m3) for the baseline and efficient case conditions

$$NG_{Hourly} = \frac{Q}{35{,}738 \cdot Eff_{gas}}$$

where,

NG_{Hourly} = The specific heat of air (m^3/hr)

Eff_{gas} = The average heating system efficiency (%)

35,738 = Energy density of natural gas (Btu/m^3)

6. **Annual Savings:** Sum the hourly results to determine the annual energy input of the baseline and efficient case conditions and deduct the annual efficient case energy input from the baseline value to determine the predicted annual savings in m^3 of natural gas.

$$Annual\ savings = \sum_{0}^{8760} NG_{efficiennt\ case} - \sum_{0}^{8760} NG_{Baseline}$$

where,

Annual savings = The annual natural gas savings (m^3/year)

$\sum_0^{8760} NG_{efficient\ case}$ = The sum of the efficient case hourly natural gas consumption

$\sum_0^{8760} \text{NG}_{\text{Baseline}}$ = The sum of the baseline hourly natural gas consumption

7. **Calibration Factors:** ICF employed EnergyPlus models of both a base case and the improved case to estimate the savings from implementing DCV. A standard box modeling approach was used for the creation of all the models. In this approach, a single, rectangular zone was created, and the length, height and width scaled appropriately to be representative of each building type. The appropriate loads, constructions, and schedules were then applied to the zone. Calibration factors were developed based on a comparison of the savings from DCV on a per unit floor area basis. As such, the calibration factors represent the percentage difference in the estimated savings for DCV by the spreadsheet-based analysis and the building energy models developed in EnergyPlus.

$$\text{Annual Gas Savings} = \text{Annual savings} \times \text{Calibration factor}$$

8. **Normalized Savings:** The results were normalized to derive the annual savings per ft^2 of area served for the typical climate zone represented by London, Ontario in Table 1. The savings values (m^3/ft^2) derived from the spreadsheet tool and reflected in Table 1 are then used to calculate and report project specific savings as follows:

$$\text{Savings}_{\text{NG}} = \text{Annual Gas Savings} \times \text{Zone area}$$

where,

$\text{Savings}_{\text{NG}}$ = The annual natural gas savings (m^3/year)

Annual Gas Savings = The annual gas savings value for the space type and climate zone from Table 1 (m^3/ft^2)

Zone area = The area of the zone served by the RTU, AHU, or MUA (ft^2)

ASSUMPTIONS

provides a list of constants and assumptions used in the derivation of the deemed savings values. Because duct runs for single-zone RTUs are generally short and/or within the conditioned space, this value also represents a reasonable estimate of system efficiency.

Table 4: Assumptions

Parameter	Value	Units	Reference
Space temperature setpoint	72	°F	Common assumptions table
OA temperature heating system is enabled	55	°F	Common assumptions table
Commercial heating system efficiency	80%	%	Common assumptions table
Conversion factor for the specific heat of air	1 Btu/lb·°F = 4186.8 J/kg·K		[5] Converting between commonly used Units

Savings Calculation Example

The example below illustrates how the annual gas savings value is determined for the installation of DCV with CO_2 sensors for a 5,000 ft² secondary school gym single zone area with scheduled ventilation.

$$\text{Savings}_{\text{NG}} = \text{Annual Gas Savings} \times \text{Zone area}$$

$$= 1.484\ m^3/ft^2 \times 5{,}000\ ft^2$$

$$= 7{,}420\ m^3 \text{ per year}$$

Uses and Exclusions

To qualify for this measure, DCV must be implemented for a single-zone, constant volume ventilation system with natural gas fueled heating that previously operated to provide constant ventilation meeting at least the minimum outdoor air requirements specified by ASHRAE 62.1 Table 6.2.2.1.

Multi-zone systems, VAV systems, or systems equipped with energy or heat recovery capabilities are not eligible for this prescriptive measure.

This measure is intended for self-calibrating sensors or other types of sensors whose calibration warranty period by the manufacturer is 15 years or more.

Measure Life

The standard measure life attributed to this measure is 15 years. [6] The 15-year measure life is intended for self-calibrating sensors or other types of sensors whose calibration warranty period by the manufacturer is 15 years or more.

Although physical components of the ventilation system can be expected to last longer, energy savings persist only as long as sensors and other components of the DCV system remain in calibration and functioning as intended.

Self-calibrating sensors are widely available and used in prescriptive applications as covered by this substantiation document. The calibration warranty period for these sensors are 15 years or more, depending upon the manufacturer.

INCREMENTAL COST

Table 5 presents the measure incremental cost.

Table 5: Measure Incremental Cost [7]

Measure Category	Cost Component	Incremental Cost ($)
Retrofit – Single Zone	Equipment	$750
	Installation	$300
	Total	**$750 + $300 = $1,050**
Time of Natural replacement – Single Zone Replacement/ New Construction	Equipment	$750
	Total	**$750**

REFERENCES

[1] ASHRAE, "ANSI/ASHRAE Standard 62.1 - 2013, Table 6.2.1.1, Page 12-16," American Society of Heating, Refrigeration and Air-Conditioning Engineers, Atlanta, 2013.

[2] Environment and Natural Resources Canada, "Historical Data," Government of Canada, [Online]. Available: http://climate.weather.gc.ca/historical_data/search_historic_data_e.html. [Accessed 20 04 2018].

[3] E. Engineering, "Union Gas Market Research - Demand Controlled Ventilation Systems - Task 6," Kitchener, Ontario, 2013.

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COMMERCIAL – HVLS (HIGH VOLUME LOW SPEED) DESTRATIFICATION FANS– NEW CONSTRUCTION/RETROFIT

Version Date and Revision History	
Version	2.0
OEB Filing Date	November 30, 2018
OEB Approval Date	
Commercial → Space Heating → HVLS Destratification Fans → New Construction/Retrofit	

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

Table 1. Measure Key Data

Parameter	**Definition**		
Measure Category	New Construction (NC) Retrofit (R)		
Baseline Technology	No destratification system		
Efficient Technology	HVLS destratification fans		
Market Type	Commercial		
Annual Natural Gas Savings (m^3/ fan)	Fan Diameter	New Construction	Retrofit
	20ft	1,472 m^3/ fan	2,029 m^3/ fan
	24ft	2,120 m^3/ fan	2,922 m^3/ fan
Measure Life	15 years		
Incremental Cost ($ CAD)	$7,961		

Parameter	Definition
Restrictions	This measure is restricted to HVLS fans with minimum diameter of 20 feet for use in warehousing type buildings with a minimum of 25-foot ceilings. These spaces affected by destratification fans must be heated by ceiling mounted natural gas forced air space heating systems including unit heaters. In addition, this measure is restricted to heated enclosures (space affected by the destratification) that are floor level thermostatically temperature controlled, and space heating system located at roof level. If other mechanisms that combat destratification such as radiant heaters and/or high velocity vertical throw unit heaters are present, this measure is not eligible. It is assumed that the building is operating without night setbacks The number of fans installed in the space should not exceed: *20ft diameter fan:* building length (ft) x building width (ft) *0.77[1])/7,854 *24ft diameter fan:* building length (ft) x building width (ft) *0.77[1])/11,310

OVERVIEW

This measure is for the installation of large diameter HVLS (High Volume Low Speed) ceiling fans in commercial warehouse-type spaces for both new construction and retrofits applications.

Typically, in warehouse-type spaces, the thermostat is located at floor level where people work, and the unit heater is at ceiling level. As there is a call for heat by the floor level thermostat, heat is introduced into the space by ceiling mounted horizontal flow unit heaters or forced air heaters. Unless there is a means to direct the hot air to the ground, the heated air remains at ceiling level and forms a temperature layer with the warmest air at the ceiling and the coolest at the floor. With air temperature at the ceiling being hotter than air temperature at ground level where the thermostat is located, there is a greater heat loss through the ceiling and walls compared to an evenly mixed air temperature throughout the height of the space.

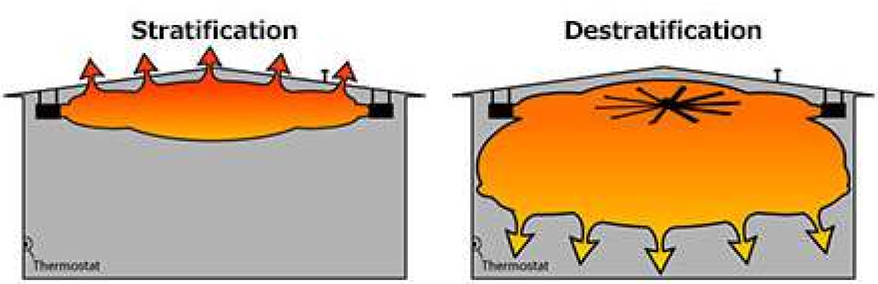
The installation of HVLS destratification fans helps to decrease thermal stratification of the air by pushing the warmer air at the ceiling to the ground creating comfort for the people working

[1] Based on average of data from Enbridge custom projects. On average, 77% of the entire space had been destratified.

while bringing the colder air at ground level to the ceiling to be heated. This convection effect mixes the air in the space reducing thermal stratification and providing comfort at floor level. 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 fan (m3/fan)

Figure 1: Stratification vs. Destratification[2]



APPLICATION

This measure provides incentives for installing HVLS destratification fans in commercial warehouse-type facilities where the space heating system is located near the ceiling level with a thermostat or other temperature-based HVAC control system is in place at the floor level. The units serve to reduce the stratification of heated air in a space with a high ceiling and therefore reduce space heating requirements.

BASELINE TECHNOLOGY

The baseline case is a space without destratification fans nor other mechanisms that combat destratification, such as radiant heaters and/or high velocity vertical throw unit heaters

EFFICIENT TECHNOLOGY

The energy efficient case is a space with HVLS destratification fans.

[2] Photograph downloaded from http://www.allseasonshire.eu/blog/thermal-destratification-explained/ on 10/1/2014.

ENERGY IMPACTS

Stratification can result in ceiling temperatures significantly higher than temperatures at floor level. 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. HVLS 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 benefits the employees comfort levels on the floor. Natural gas savings are achieved due to the difference in heat loss through the roof and walls by conduction and heat loss via infiltration and ventilation 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.

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 heat loss reduction through the roof, walls and infiltrations/ventilation due to the HVLS destratification fan.

$$NG\ Savings = \frac{(\Delta Q_{roof} + \Delta Q_{wall} + \Delta Q_{vent}) \times hrs_{hs}}{ED_{NG} \times \eta}$$

where,

$NG\ Savings$ = Annual Natural Gas Savings (m³/fan)

ΔQ_{roof} = Heat loss reduction through the roof after destratification (Btu/h)

ΔQ_{wall} =Heat loss reduction through exterior walls after destratification (Btu/h)

ΔQ_{vent}= Heat loss reduction via infiltrations/ventilation after destratification (Btu/h)

hrs_{hs} = Annual operating hours based on the heating season (h), see table 4

ED_{NG} = Energy density of natural gas, see table 4

η = Efficiency of gas furnace, see table 4

Heat Loss Reduction Through the Roof

The heat loss reduction through the roof is based on the difference in heat loss through the roof before and after destratification:

$$\Delta Q_{roof} = q_{roof\_bd} - q_{roof\_ad}$$
$$= U_{roof} \times A_{roof\_fan} \times (t_{roof\_ibd} - t_o) - U_{roof} \times A_{roof,fan} \times (t_{roof\_iad} - t_o)$$
$$= U_{roof} \times A_{roof\_fan} \times (t_{roof\_ibd} - t_{roof\_iad})$$

where,

q_{roof_bd} = Heat loss through the roof before destratification (Btu/·h)

q_{roof_ad} = Heat loss through the roof after destratification (Btu/·h)

U_{roof} = Average heat transfer coefficient for the roof (Btu /ft^2·°F·h), see table 4

A_{roof_fan}= Area of roof influenced by destratification fans (ft^2), see table 4

t_o = Outside air temperature (°F), not used in calculation

t_{roof_ibd} = Average temperature of the roof, indoor, before destratification (°F), see table 4

t_{roof_iad} = Average temperature of the roof, indoor, after destratification (°F), see below

To determine the average indoor air temperature at the ceiling before and after destratification, the following equations are used:

$$t_{roof\_iad} = \frac{(t_{roof\_ibd} \times H_{ah}) + (t_{tstat} \times H_{bh})}{(H_{ah} + H_{bh})}$$

where,

t_{roof_ibd} = Temperature at ceiling before destratification (°F), see table 4

t_{tstat} = Thermostat temperature setting (°F), see table 4

H_{ah} = Height above heaters to roof (ft), see table 4

H_{bh} = Height below heaters to floor (ft), see table 4

Heat Loss Reduction Through the exterior walls

The heat loss reduction through the exterior walls is based on the difference in heat loss through the walls before and after destratification:

$$\Delta Q_{wall} = q_{wall\_bd} - q_{wall\_ad}$$

$$= U_{wall} \times (Ratio_{wr} \times A_{roof\_fan}) \times (t_{wall\_ibd} - t_o)$$
$$- U_{wall} \times (Ratio_{wr} \times A_{roof\_fan}) \times (t_{wall\_iad} - t_o)$$

$$= U_{wall} \times (Ratio_{wr} \times A_{roof\_fan}) \times (t_{wall\_ibd} - t_{wall\_iad})$$

where,

q_{wall_bd} = Heat loss through the walls before destratification (Btu/·h)

q_{wall_ad} = Heat loss through the walls after destratification (Btu/·h)

U_{wall} = Average heat transfer coefficient for the walls (Btu /ft²·°F·h), see table 4

$Ratio_{wr}$ = Roof to wall influence ratio, see table 4

t_o = Outside air temperature (°F), not used in calculation

t_{wall_ibd} = Average temperature of the wall, indoor, before destratification (°F), see below

t_{wall_iad} = Average temperature of the wall, indoor, after destratification (°F), see below

To determine the average indoor air temperature at the walls before and after destratification, the following equations are used:

$$t_{wall\_ibd} = t_{roof\_ibd} - \frac{Building_{H\_avg} \times \left(t_{roof\_ibd} - t_{tstat}\right)}{2 \times \left(H_{tstat-roof}\right)}$$

$$t_{wall\_iad} = t_{roof\_iad} - \frac{Building_{H\_avg} \times \left(t_{roof\_iad} - t_{tstat}\right)}{2 \times \left(H_{tstat-roof}\right)}$$

where,

t_{tstat} = Thermostat temperature setting (°F), see table 4

$Building_{H\_avg}$ = Average Building height (ft), see table 4

$H_{tstat-roof}$ = Height above thermostat to roof (ft), see table 4

Heat Loss Reduction via Infiltration and Ventilation

The heat loss reduction via infiltration and ventilation as a result of destratification is based on the stack effect principles and is the difference in heat loss over the entire building shell before and after destratification. Air leakage, through doors, roof penetrations, and building envelope material can be significant in older buildings, whereas newer buildings will have tighter envelopes but have mandatory code requirements to provide ventilation. Destratification results in consistent indoor temperatures generally reducing the indoor temperatures where this leakage or ventilation occurs, resulting in energy savings. Research papers on this subject have stated that "Not accounting for this heat loss due to ventilation in estimating energy savings from destratification can lead to significant errors" [2]

The following equation is used to calculate the savings in ventilation heat loss due to destratification measures within the building. For simplicity an Air-Change-per Hour (ACH) process is used, and it is assumed that infiltration and ventilation is equal on all building envelope surfaces.

$$\Delta Q_{vent} = q_{vent\_bd} - q_{vent\_ad}$$

$$\Delta Q_{vent} = 0.018 \times ACH_n \times A_{roof\_fan} \times Building_{H_{avg}} \times \frac{Ratio_{wr} \times (t_{wall\_ibd} - t_{wall\_iad}) + (t_{roof\_ibd} - t_{roof\_iad})}{(1 + Ratio_{wr})}$$

where

q_{vent_bd} = Heat loss through infiltration before destratification (Btu/·h)

q_{vent_ad} = Heat loss through infiltration after destratification (Btu/·h)

0.018 = Heat capacity of air times 60 minutes (Btu.h/°F.ft^3/h)

ACH_n = Air changes per hour (1/h), see table 4

$Building_{H\_avg}$ = Average Building height (ft), see table 4

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 (Warehouse Type Building)

Variable	Definition	Value	Source/Comments
hrs_{hs}	Heating hours per year	Balance Point 55°F (12.8˚C) 5,293	Based on CWEC data for London, ON (2016). Annual hours on heating hours below 55°F [3]
ED_{NG}	Energy density of natural gas	35,738 Btu/m^3	Common assumptions table
η	Gas fired unit heater rated heating system efficiency	80%	Common assumptions table

Variable	Definition	Value		Source/Comments
		Retrofit	New Construction	
U_{roof}	Average heat transfer coefficient for the roof	0.050 Btu/°F·h·ft² (R-20)	0.025 Btu/°F·h·ft² (R-40)	New Construction based on OBC [4] Retrofit based on Enbridge destratification Custom projects[3]
U_{wall}	Average heat transfer coefficient for the wall	0.062 Btu/°F-h-ft² (R-16)	0.040 Btu/°F-h-ft² (R-25)	
A_{roof_fan}	Area of roof influenced by destratification fans	20ft	24ft	Based on a field study [1] and extrapolated for 24ft.[4]
		7,854ft²	11,310ft²	
$Ratio_{wr}$	Ratio of wall to roof area for subject buildings	0.37		Based on average data from Enbridge destratification Custom projects[5]
t_{roof_ibd}	Average temperature of the roof before destratification	84.66 °F		Based on average of data from Enbridge custom projects
t_{tstat}	Thermostat temperature setting	69°F		Based on average of data from Enbridge custom projects
$H_{tstat-roof}$	Height above thermostat to roof	26ft		Assuming a ceiling height of 31ft[6] [5]
H_{ah}	Height above heaters to roof	8 ft		Minimum requirements are 8 feet from floor or ceiling [6]
H_{bh}	Height below heaters to floor	23 ft		Minimum requirements are 8 feet from floor or ceiling [6]. Assuming a ceiling height of 31ft.
$Building_{H\_avg}$	Average Building height	31 ft		Based on average of data from Enbridge custom projects

3 Data from the Enbridge custom projects (between 2011 and 2018) was used to develop the average insulation level for retrofit building which have utilized the destratification energy savings measure.

4 Extrapolation for 24ft diameter fan is based on the following equation: pi () x (5 x 24/2)²

5 The ratio of wall area divided by roof area used the following average dimensions: Building height = 31 ft, Building width = 299 ft, Building length = 376 ft. The roof area = 112,377 ft², and the Wall area = 41,656 ft²

6 ASHRAE standard 55-2010 indicates that people generally occupy the area between the floor and 6ft level above the floor. It is assumed that thermostats are generally located 5ft above the floor. Based on Enbridge custom projects, the average height of the building is 31ft.

Variable	Definition	Value		Source/Comments
ACH_n	Air Changes per hour	Retrofit	New Construction	Retrofit : Based on average of data from Enbridge custom projects NC: base on ASHRAE 62.1, 2013
		0.13	0.12	

SAVINGS CALCULATION EXAMPLE

The example below illustrates the savings value for the installation of a 20ft diameter HVLS destratification fan in a new commercial warehouse. The room has a 31-foot ceiling, the building length = 376 ft, and the building width =299 ft.

Heat Loss Reduction Through the Roof

Calculation of the average indoor air temperature at the ceiling after destratification:

$$t_{roof\_iad} = \frac{(t_{roof\_ibd} \times H_{ah}) + (t_{tstat} \times H_{bh})}{(H_{ah} + H_{bh})}$$

$$= \frac{(84.66°F \times 8ft) + (69°F \times 23ft)}{(8ft + 23ft)} = 73.04°\text{F}$$

Calculation of the heat loss reduction through the roof for a new construction building:

$$\Delta Q_{roof} = U_{roof} \times A_{roof,fan} \times (t_{roof\_ibd} - t_{roof\_iad})$$

$$\Delta Q_{roof} = 0.025 \frac{Btu}{°F}.h.ft^2 \times 7{,}854ft^2 \times (84.66°F - 73.04°F)$$

$$\boldsymbol{\Delta Q_{roof} = 2{,}281\ Btu/h}$$

Heat Loss Reduction Through the Exterior Walls

Calculation of the average indoor air temperature at the walls before and after destratification:

$$t_{wall\_ibd} = t_{roof\_ibd} - \frac{Building_{H\_avg} \times (t_{roof\_ibd} - t_{tstat})}{2 \times (H_{tstat-roof})}$$

$$= 84.66 - \frac{31ft \times (84.66°\text{F} - 69°\text{F})}{2 \times 26ft} = 75.32°\text{F}$$

$$t_{wall\_iad} = t_{roof\_iad} - \frac{Building_{H_{avg}} \times \left(t_{roof\_iad} - t_{tstat}\right)}{2 \times \left(H_{tstat-roof}\right)}$$

$$= 73.04 - \frac{31ft \ \times (73.04°\text{F} - 69°\text{F})}{2 \ \times 26ft} = 70.63°\text{F}$$

Calculation of the heat loss through the walls for a new construction building:

$$\Delta Q_{wall} = U_{wall} \times Ratio_{wr} \ \times A_{roof,fan} \ \times \left(t_{wall_{ibd}} - t_{wall_{iad}}\right)$$

$$\Delta Q_{wall} = 0.040 \frac{Btu}{°\text{F}} \cdot h \cdot ft^2 \times 0.37 \ \times 7{,}854 ft^2 \times (75.32°\text{F} - 70.63°\text{F})$$

$$\Delta Q_{wall} = \mathbf{545\ Btu/h}$$

Heat loss Reduction via Infiltration and Ventilation

Calculation of the heat loss via infiltration for a new construction building:

$$\Delta Q_{vent} \ = \ 0.018 \times ACH_n \times A_{roof\_fan} \times Building_{H_{avg}} \times \frac{Ratio_{wr} \ \times \left(t_{wall\_ibd} - t_{wall\_iad}\right) + \left(t_{roof\_ibd} - t_{roof\_iad}\right)}{(1 + Ratio_{wr}\ )}$$

$$\Delta Q_{vent} \ = \ 0.018 \times 0.12 \times 7{,}854 \times 31ft \ \times \frac{0.37 \ \times (75.32°\text{F} - 70.63°\text{F}) + (84.66°\text{F} - 73.04°\text{F})}{(1 + 0.37)}$$

$$\boldsymbol{\Delta Q_{vent} \ = 5{,}127\ Btu/hr}$$

Natural Gas Savings

$$NG\ Savings = \frac{\left(\Delta Q_{roof} + \Delta Q_{wall} + \Delta Q_{inf}\right) \ \times \ hrs_{hs}}{ED_{NG} \times \eta}$$

$$= \frac{\left(2{,}281 \ \frac{Btu}{h} + 545 \frac{Btu}{hr} + 5{,}127 \frac{Btu}{hr}\right) \ \times \ 5{,}293h}{35{,}738 \frac{Btu}{m^3} \times 0.8}$$

$$\boldsymbol{NG\ Savings = 1{,}472\ m^3/fan}$$

Uses and Exclusions

This measure is restricted to fans with a minimum diameter of 20 feet for use in warehousing-type commercial buildings with a minimum of 25-foot ceiling with space heating provided by unit heaters and an unobstructed thermostat with no other mechanisms that combat stratification, such as radiant heaters and high velocity vertical throw unit heaters.

The number of fans installed in the space should not exceed: building length (ft) x building width (ft) *0.77)/Area influenced by the fan rounded down to the nearest whole number of fans.

Measure Life

The measure life is 15 years [7], [8]

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 destratification fan is $7,961 [2].[7]

[7] XE currency. Converted to CAD based on the Daily Currency Converted for Bank of Canada last 90 days average, as of 08/22/2018 (1.305CAD/US). (https://www.xe.com/fr/currencyconverter/convert/?Amount=1&From=USD&To=CAD)http://www.bankofcanada.ca/rates/exchange/daily-converter/)

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COMMERCIAL – DOCK DOOR SEALS–RETROFIT

Version Date and Revision History	
Version	1
OEB Filing Date	January 8, 2020
OEB Approval Date	January 9, 2020
Commercial → Space Heating → Dock Door Seals → Retrofit	

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

Table 1. Measure Key Data

Parameter	Definition			
Measure Category	Retrofit (R)			
Baseline Technology 1	Dock door with deteriorated seals			
Baseline Technology 2	Dock door without seals			
Efficient Technology	Dock Door Seals as described on this document			
Market Type	Commercial			
	Door size (H' x W')			
	8' x 8'	**8' x 9'**	**8' x 10'**	**10' x 10'**
Annual Natural Gas Saving - Baseline 1 (m^3/yr per door)	1,897	1,977	2,041	1,736
Annual Natural Gas Saving - Baseline 2 (m^3/yr per door)	4,853	4,988	5,087	4,501
Annual Electrical Impact - Baseline 1 (kWh/yr per door)	451	481	509	433
Annual Electrical Impact - Baseline 2 (kWh/yr per door)	1,155	1,214	1,269	1,123
Measure Life	10 years			
Incremental Cost	**Door size (H' x W')**			
	8' x 8'	**8' x 9'**	**8' x 10'**	**10' x 10'**
Incremental cost ($ CAD)- from Baseline 1	$1,425	$1,580	$1,617	$2,968
Incremental cost ($ CAD)- from Baseline 2	$1,263	$1,417	$1,455	$2,615
Restrictions	This measure is restricted to the replacement of existing deteriorated seals or the addition of new seals to existing dock door that do not have any type of seal in place. If other mechanisms that combat infiltration at the shipping/receiving door are present, such as air curtains, this measure is not eligible. In addition, the docking area must be directly heated by natural gas fueled equipment during winter months and the inside temperature of the area must be kept at a comfortable level while docking doors are used.			

OVERVIEW

At the shipping/receiving dock and during loading/uploading operations, the dock door opens, and infiltration losses occur through the gap between the truck and the door. For heated spaces, natural gas savings are achieved when this gap is reduced by replacing deteriorated seals operating beyond their useful life or adding new seals to existing dock doors that do not have them. A review of historical custom project data from the utilities[1] demonstrates a common practice of not replacing dock sealing systems after they have reached the end of their useful service life. For this study, two baselines were defined: dock door with deteriorated seals (baseline 1), and dock door without seals (baseline 2)

The natural gas savings (m^3) are calculated using a combination of field depressurization tests[2] results and engineering calculation approach from ASHRAE Fundamentals Chapters 16 and 24.

APPLICATION

This measure provides incentives for replacing deteriorated seals or adding new seals to existing dock door that do not have any type of seals in place. Two type of seals are recommended based on door size and industry standards (best practices) for effectively reducing the infiltration losses at the shipping and receiving door and during loading/uploading operations.

Compression seals: a wide pad that surrounds the dock is compressed by the trailer "sealing" the gap between the truck and the dock door. This is a fixed pad dock seal with a minimum 40oz vinyl cover. (figure 1)

Shelters-type seals: a curtain-like seal (minimum 40oz vinyl) with a foam frame that compresses against the sides and top of the trailer box. (figure 2)

Figure 1 Compression seals[3]

Figure 2 Shelter-type seals[4]

Compression seals are recommended for the 8′x8′, 8′x9′ and 8′x10′ door sizes while shelter is recommended for 10′x10′ dock doors.

[1] Refers to the former Union Gas Ltd. and Enbridge Gas Distribution (the utilities)
[2] Performed by Enermodal Engineering [2]
[3] Images courtesy of Frommelt Industries of Canada Inc.
[4] Image downloaded from https://www.speedtechequipment.com/used-equipment/ on 10/31/2019

BASELINE TECHNOLOGY

The baseline is shown in Table 2.

Table 2. Baseline Technology

Scenario	Requirement
Baseline Technology 1	Dock door with deteriorated seals
Baseline Technology 2	Dock door without seals

EFFICIENT TECHNOLOGY

Dock door seal for shipping and receiving door that meet the requirements as shown in Table 3:

Table 3. Efficient Technology

Door size (H' x W')	Requirement
8' x '8	Compression-type seal – a wide pad that surrounds the dock is compressed by the trailer “sealing” the gap between the truck and the dock door. This is a fixed pad dock seal with a minimum 40oz vinyl cover
8' x '9	
8' x '10	
10' x '10	Shelters-type seal- a curtain-like seal (minimum 40oz vinyl) with a foam frame that compresses against the sides and top of the trailer box

ENERGY IMPACTS

The technology serves to reduce the infiltration of outdoor air at the entrance points (gap between the dock door and the truck) consequently reducing the heating requirements.

NATURAL GAS SAVINGS ALGORITHMS

In order to characterize the natural gas savings, field depressurization tests results[5] have been combined with the calculation approach from ASHRAE Fundamentals Chapters 16 and 24.

1. **Calculation of the infiltration across small gaps**

Infiltration into a building is introduced by pressure differences across the envelope caused by driving forces (wind and stack effects), specific gap geometry, general building leakage and

[5] Performed by Enermodal Engineering [2]

mechanical system. For uniform indoor air temperatures, the formulas for pressure across a building gap for a given time period are given below. [1]

$$P_U = \rho_o \times \frac{{U_H}^2}{2}$$

$$P_T = g \times \rho_o \times \left[\frac{(T_i - T_o)}{T_i}\right]$$

$$\Delta p = s^2 \times W_p \times P_U + H \times P_T + \Delta p_I$$

Where:

P_U	=	Reference wind parameter (Pa)
ρ_o	=	Density of outdoor air (kg/m^3)
U_H	=	Local average wind speed (m/s)
P_T	=	Stack effect parameter (Pa/m)
g	=	Gravitational acceleration (m/s^2)
T_o	=	OA temperature heating system enabled (K)
T_i	=	Space temperature setpoint for warehouse-type of building (K)
Δp	=	Pressure difference across each gap (Pa)
s	=	Shelter factor applicable to the given gap (dimensionless)
W_p	=	Wind surface pressure coefficient (dimensionless)
H	=	Gap height relative to the neutral pressure plane (m)
Δp_I	=	Pressure that acts to balance inflows and outflows, including mechanical systems (Pa)

2. **Calculation of the airflow through openings** [1]

$$Q = C_{dh} \times A \times \sqrt{\left(\frac{2\Delta p}{\rho_o}\right)}$$

$$C_{dh} = 0.40 + 0.0045 \times |T_i - T_o|$$

Where:

Q	=	Total airflow rate through the doorway- heating season (m^3/s)

C_{dh}	=	Discharge coefficient for openings during heating season (dimensionless)
A	=	Cross sectional area of opening (m^2)

2a. Calculation of the opening area for Baseline 1. Dock door with deteriorated seals

$$A_1 = A_{v1} + A_{h1}$$

$$A_{v1} = 2 \times (h_d - w_c) \times w_c$$

$$A_{h1} = w_d \times w_c$$

Where:

A_{v1}	=	Vertical gap area for Baseline 1 (m^2)
h_d	=	Dock door height (m)
w_c	=	Gap width for Baseline 1 (m)
A_{h1}	=	Horizontal gap area for Baseline 1 (m^2)
w_d	=	Dock door width (m)
A_1	=	Total gap area per door dock for Baseline 1 (m2)

2b. Calculation of the cross-sectional area of opening for Baseline 2. Dock door without seals

$$A_2 = A_{v2} + A_{h2}$$

$$A_{v2} = 2 \times (h_d - w_{c1}) \times w_{c2}$$

$$A_{h2} = w_d \times w_{c1}$$

Where:

A_{v2}	=	Vertical gap area for Baseline 2 (m^2)
w_{c1}	=	Gap between the top of the truck and the top of the dock door for Baseline 2 (m)
w_{c2}	=	Gap between the side of the truck and the side of the dock door for Baseline 2 (m)
A_{h2}	=	Horizontal gap area for Baseline 2 (m^2)

A_2 = Total gap area per door dock for Baseline 2 (m^2)

3. Calculation of the energy required (natural gas)

$$q_s = Q \times \rho_0 \times C_p \times (T_i - T_o)$$

Where:

q_s = Rate of heat transfer through doorway- heating season (W)

C_p = Specific heat of air (J/(kg.K)

Q = Total airflow rate through the doorway- heating season (m^3/s)

T_o = OA temperature heating system enabled (K)

T_i = Space temperature setpoint for warehouse-type of building (K)

4. Calculation of the natural gas savings

$$NG = 3.412 \times \frac{q_s}{35{,}738} \times HR \times \frac{day_{hs}}{Eff} \times E$$

Where:

NG = Annual Natural Gas Savings (m^3/yr per door)

HR = Hour per day that the door is open (hr/day)

day_{hs} = Heating days per year (day/year)

Eff = Heating System efficiency (dimensionless)

E = Dock door seal effectiveness (dimensionless)
E_s compression seals effectiveness and E_c shelter effectiveness

35,738 = Energy density of natural gas (Btu/m^3)

3.412 = Conversion factor from Watt to Btu/hr (1 Watt = 3.412 Btu/hr)

ELECTRIC SAVINGS ALGORITHM

Electrical saving - cooling season due to the reduction of cooling load (infiltration reduction).

$$E_{savings} = \frac{q_c}{SEER} \times E \times HR \times day_{cs} \times \frac{1}{1000}$$

Where:

$E_{savings}$	=	Electrical Savings - Cooling Season due to the reduction of cooling load (kWh/yr)
q_c	=	Rate of heat transfer through doorway without vestibule (Btu/hr)
SEER	=	Energy efficiency ratio of cooling system (kBtu/kWh)
E	=	Dock door seal effectiveness (dimensionless)
day_{cs}	=	Cooling days per year (day/year)
1,000	=	Conversion factor (1,000 Btu = 1 kBtu)

$$q_c = 60 \times \rho_o \times Q_{Ac} \times (h_{oc} - h_{ic})$$

Where:

60	=	Conversion factor (min/hr)
Q_{Ac}	=	Total airflow rate through the doorway- cooling season (CFM)
h_{oc}	=	Outside enthalpy - cooling season (Btu/lb)
h_{ic}	=	Inside enthalpy - cooling season (Btu/lb)
ρ_o	=	Density of dry air (lbm/ft^3)

$$Q_{Ac} = 2{,}119 \times A \times C_{dc} \times \sqrt{\frac{2\Delta p_c}{\rho_o}}$$

Where:

2,119	=	Conversion factor (1 m^3/s = 2119 CFM)
A	=	opening area (m^2)
C_{dc}	=	Discharge coefficient for openings during cooling season (dimensionless)
ρ_o	=	Density of dry air (kg/m^3)

$$P_{Uc} = \rho_o \times \frac{{U_{Hc}}^2}{2}$$

$$P_{Tc} = g \times \rho_o \times \left[\frac{(T_{oc} - T_i)}{T_{oc}}\right]$$

$$\Delta p_c = s^2 \times W_{pc} \times P_{Uc} + H \times P_{Tc} + \Delta p_I$$

Where:

P_{Uc}	=	Reference wind parameter-cooling season (Pa)
ρ_o	=	Density of dry air (kg/m^3)
U_{Hc}	=	Local average wind speed-cooling season (m/s)
P_{Tc}	=	Stack effect parameter - cooling season (Pa/m)
g	=	Gravitational acceleration (m/s^2)
T_{oc}	=	OA temperature heating system enabled - cooling season(K)
T_i	=	Space temperature setpoint for warehouse - type of building (K)
Δp_c	=	Pressure difference across each gap - cooling season (Pa)
s	=	Shelter factor applicable to the given gap (dimensionless)
W_{pc}	=	Wind surface pressure coefficient - cooling season (dimensionless)
H	=	Gap height relative to the neutral pressure plane (m)
Δp_I	=	Pressure that acts to balance inflows and outflows, including mechanical systems (Pa)

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. Assumptions

Variable	Definition	Value and Unit	Source/Comments
ρ_0	Density of outdoor air (heating season)	1.256 kg/m^3 (0.078 lb_m/ft^3)	Common assumptions table[6]
	Density of outdoor air (cooling season)	1.163 kg/m^3 (0.073 lb_m/ft^3)	Common assumptions table
T_i	Space temperature setpoint-warehouse type of building	69°F (293.7K)	Common assumptions table

[6] Pending Ontario TRM v4 approval-common assumption table

Variable	Definition	Value and Unit	Source/Comments
T_o	OA temperature heating system enabled	34.8°F (274.7K)	Common assumptions table
T_{oc}	OA temperature cooling system enabled	77.0°F (298.1K)	Common assumptions table
s	Shelter factor	0.7	Based on Shelter Class 3 [2]
W_p	Wind surface pressure coefficient for heating season	0.12	Calculated value based on and approach in [1] and based on CWEC weather data for London, ON (version 2016) [3]
W_{pc}	Wind surface pressure coefficient for cooling season	0.19	
w_c	Gap width between the sides of the truck and the sides of the door (top and sides) for Baseline 1	4.21 in (0.11 m)	Based on average of data from the utilities dock door seals custom projects [2]
w_{c1}	Gap width between the top of the truck and the top of the dock doo	8.88 in (0.23 m)	Calculated based on standard truck [4] and standard door sizes [2]
w_{c2}	Gap width between the side of the truck and the side of the dock door	16.71 in (0.42 m)	
C_p	Specific heat of air	1,000 J/(kg·K)	Common assumptions table
h_{ic}	Inside enthalpy for cooling season	21.46 Btu/lb	Common assumptions table
h_{oc}	Outside enthalpy for cooling season	30.95 Btu/lb	Common assumptions table
HR	Hour per day door is open	7.23 hr/day	[2]
U_H	Average wind velocity for heating season	2.60 m/s (5.81 mph)	Calculated using the wind profile law [2] and based on CWEC weather data for London, ON (version 2016) [3]
U_{Hc}	Average wind velocity for cooling season	2.82 m/s (6.31 mph)	
H^*	Average building height	27ft (8.2m)	[2]
C_{dh}	Discharge coefficient for opening during heating season	0.49	Calculated using ASHRAE algorithm [1]and based on CWEC weather data for

Variable	Definition	Value and Unit	Source/Comments
C_{dc}	Discharge coefficient for opening during cooling season	0.38	London, ON (version 2016) [3]
E	Effectiveness of compression seals	72%	[2]
	Effectiveness of shelters	57%	
Eff	Commercial heating system efficiency	80%	Common assumptions table
SEER	Commercial cooling system efficiency	13 kBtu/kWh	Common assumptions table
g	Acceleration due to gravity	9.81 m/s² (32.2 ft/sec²)	Common assumptions table
	Airflow rate conversion from m³/s to CFM	2,119 CFM/m³/s	[5]
	Energy density of natural gas	35,738 Btu/m³	Common assumptions table
	Conversion from HP to kWh	0.7457 kW/HP	Common assumptions table
day_{hs}	Heating days per year	221	Common assumptions table
day_{cs}	Cooling days per year	40	Common assumptions table

Variable	Definition	Door size (W' x H')				Source/Comments
		8x8	8x9	8x10	10x10	
h_d	Dock door height (ft)	8	9	10	10	Based on standard door sizes
w_d	Dock door width (ft)	8	8	8	10	

SAVINGS CALCULATION EXAMPLE

The example below illustrates the annual natural gas savings for a retail store that replaced the existing deteriorated seals on 2 of their 8′x 8′ shipping & receiving dock doors with new compression seals.

Nat. Gas savings = 2 (8′x8′) = 1,897 m3/yr per door x 2 doors = 3,794 m3/yr

Electrical savings = 2 (8′x8′) = 451 kWh/yr per door x 2 doors = 902 kWh/yr

The total annual natural gas savings is 3,794 m3/yr and the total electrical savings is 902 kWh/yr

USES AND EXCLUSIONS

This measure is restricted to the replacement of existing seals or the addition of new seals to existing dock door that do not have any type of seal in place. If other mechanisms that combat infiltration at the shipping/receiving door are present, such as air curtains, this measure is not eligible. In addition, the docking area must be directly heated by natural gas fueled equipment during winter months and the inside temperature of the area must be maintained at a comfortable level while docking doors are used.

MEASURE LIFE

The measure life is 10 years. [6]

INCREMENTAL COST

The purchase and installation cost for dock door seals is summarized in the table below. [7]

Table 5. Incremental Cost

Description	Door size (W' x H')			
	8x8	8x9	8x10	10x10
Seal cost ($ CAD)	$775.20	$929.63	$967.07	$1,788.41
Installation cost- Baseline 1	$650.00	$650.00	$650.00	$1,179.30
Installation cost- Baseline 2	$487.50	$487.50	$487.50	$826.90
Total incremental cost ($ CAD) - Retrofit	$1,425	$1,580	$1,617	$2,968
Total incremental cost ($ CAD) - New Install	$1,263	$1,417	$1,455	$2,615

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Commercial – Incremental Energy Recovery Ventilation (ERV) (55% Effectiveness Baseline) – New Construction/Time of Natural Replacement

Version Date and Revision History	
Version	2.2 (minor update)
OEB Filing Date	December 20, 2019
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Commercial → Space Heating → Incremental Energy Recovery Ventilation → New Construction/Time of Natural Replacement	

Table 1 provides a summary of the key measure parameters and 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)			
Baseline Technology	ERV with Minimum 55% Energy Recovery Effectiveness as per Ontario Building Code 2017, Supplement SB-10 January 1, 2017			
Efficient Technology	ERV with Minimum 65% Sensible Heat Recovery Effectiveness[1] 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			
Measure Efficiency	**Building Type**	**Gas Savings Rate (m³/working CFM),** ε_{EE} 1	**Group**	**Average Group Gas Savings (m³/working CFM)**

Parameter	Definition			
Annual Gas Savings Rate with a Minimum ERV Sensible Heat Recovery Effectiveness of 65%, ε_{EE} 1 (m³/ working CFM)[2]	Multi-Family, Health Care and Nursing Homes	0.85	High Use	0.85
	Hotels	0.61	Medium Use	0.47
	Restaurant	0.44		
	Retail	0.37		
	Office	0.32	Low Use	0.30
	Warehouse	0.31		
	School	0.27		
Measure Efficiency	**Building Type**	**Gas Savings Rate (m³/working CFM), ε_{EE} 2**	**Group**	**Average Group Gas Savings (m³/working CFM)**
Annual Natural Gas Savings with a Minimum ERV Sensible Heat Recovery Effectiveness of 75%, ε_{EE} 2 (m³/ working CFM)[1]	Multi-Family, Health Care and Nursing Homes	1.70	High Use	1.70
	Hotels	1.22	Medium Use	0.95
	Restaurant	0.88		
	Retail	0.74		
	Office	0.65	Low Use	0.61
	Warehouse	0.62		
	School	0.55		
Measure Efficiency	**Building Type**	**Gas Savings Rate (m³/working CFM), ε_{EE} 3**	**Group**	**Average Group Gas Savings (m³/working CFM)**
Annual Natural Gas Savings with a Minimum ERV Sensible Heat Recovery Effectiveness of	Multi-Family, Health Care and Nursing Homes	2.56	High Use	2.56
	Hotels	1.83	Medium Use	1.42
	Restaurant	1.32		
	Retail	1.11		

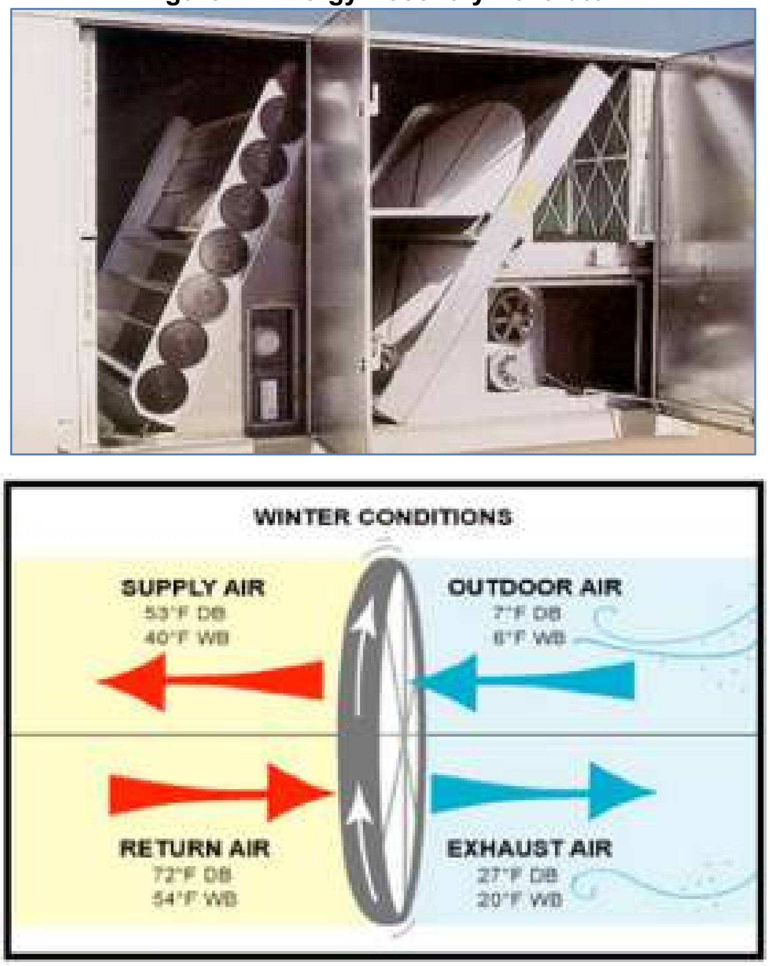
Parameter	Definition			
85%, ε_{EE} 3 (m³/ working CFM)[1]	Office	0.97	Low Use	0.91
	Warehouse	0.93		
	School	0.82		
Measure Life	14 Years			
Incremental Costs ($ CAD)	\$1.00 per CFM at ε_{EE} 1			
	\$2.00 per CFM at ε_{EE} 2			
	\$3.00 per CFM at ε_{EE}3			
Restrictions	This measure is not eligible in areas where: • The ERV unit has a sensible effectiveness of less than 65% at 32°F, • 100% of the exhaust air must be evacuated from the building in order to avoid cross contamination, and therefore 100% fresh air is required such as described in OBC section 1.1.1.4. • No recirculation is allowed by codes or standards. For instance, any limitations as per 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 • Systems where DCV or scheduled setbacks are used during operated hours[3]			

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[4]



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 2017 (SB-10), as shown in Table 2. [3] [4]

Table 2. Baseline for Energy Recovery Ventilators

Type	Efficiency
ERV	ERV with 55% 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) [5].

Table 3. Efficient Technology for Energy Recovery Ventilators

Type	Efficiency
ERV $\varepsilon_{EE}1$	ERV with Minimum 65% Sensible Heat Recovery Effectiveness and 63% Total Energy Recovery Effectiveness at 32°F at working airflow (CFM)
ERV $\varepsilon_{EE}2$	ERV with Minimum 75% with Sensible Heat Recovery Effectiveness and 73% Total Energy Recovery Effectiveness at 32°F at working airflow (CFM)
ERV $\varepsilon_{EE}3$	ERV with Minimum 85% Sensible Heat Recovery Effectiveness and 83% Total Energy Recovery Effectiveness at 32°F at working airflow (CFM)

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. However, those savings have not been quantified.

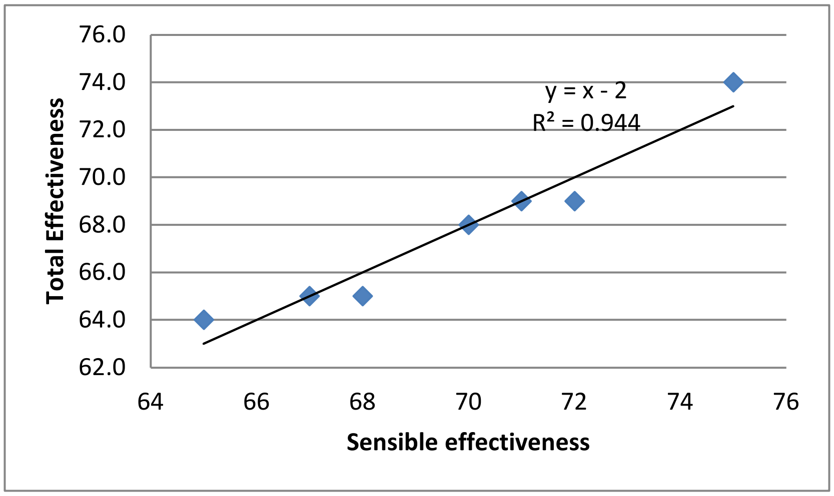
NATURAL GAS SAVINGS ALGORITHMS

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, [6] 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.

$$hrs = hrs_{hs} \times \frac{weeklyhrs}{168\frac{hrs}{week}}$$

and,

$$NG\ Savings = hrs \times \frac{60min}{hr} \times \frac{(\varepsilon_{EE} - 53\%)}{\eta} \times \frac{\rho}{35{,}738\frac{Btu}{m^3}} \times (h_3 - h_1) \times (1 - \frac{DF}{100\%})$$

Where,

hrs	= Annual hours that the ERV is expected to be in use (hours/year)
hrs_{hs}	= 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 efficiency ERV (%)[5]
η	= The efficiency of the building's heating system (%)

ρ = Density of air at 72°F (lb_m/ft^3)

$35{,}738\,\frac{Btu}{m^3}$ = 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 (%)

53% = ERV Baseline Total Effectiveness

ASSUMPTIONS

Table 4 shows the list of assumptions used in the algorithms sections.

Table 4. Assumptions

Variable	Definition	Value	Source
hrs_{hs}	Hours in Heating Season, 55°F Balance Temperature[6]	5,293 hrs	Common assumptions table
$\varepsilon_{EE}1$	Total minimum effectiveness	63%	[6] and analysis in this document
$\varepsilon_{EE}2$	Total minimum effectiveness	73%	[6] and analysis in this document
$\varepsilon_{EE}3$	Total minimum effectiveness	83%	[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
h_1	Average enthalpy of outside (supply) air during the heating season	11.82 Btu/lb	Common assumptions table
h_3	Average enthalpy of inlet exhaust air	22.72 Btu/lb	
RH_1	Average outdoor relative humidity for heating season	76.6%	Common assumptions table
RH_3	Average indoor relative humidity	30%	[9], [2]

Variable	Definition	Value	Source
DF	Defrost control de-rating factor	5%[7]	[1], [2], [9], [10]
T1	Average temperature of outside (supply) air during the heating season (OA temperature heating system enabled)	34.8 °F	Common assumptions table
T3	Average temperature of inlet exhaust air (Space temperature setpoint)	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 [9]

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 an ERV unit working at 500 CFM with a total effectiveness of 73%. In this case the $\varepsilon_{EE}2$ is applicable.

$$hrs = 5{,}293 hrs \times \frac{168\,\frac{hrs}{week}}{168\,\frac{hrs}{week}} = 5{,}293\,\frac{hrs}{year}$$

and,

$$NG\ Savings = 5{,}293\frac{hrs}{year} \times \frac{60\ min}{hr} \times 0.0741\frac{lb_m}{ft^3} \times \frac{(73\% - 53\%)}{80\%} \times \frac{1}{35{,}738\frac{Btu}{m^3}} \times \left(22.72\frac{Btu}{lb_m} - 11.82\frac{Btu}{lb_m}\right) \times \left(1 - \frac{5\%}{100\%}\right) = 1.70\frac{m^3}{CFM \cdot year}$$

Therefore,

$$NG\ Savings = 500CFM \times\ 1.70\frac{m^3}{CFM \cdot year} = 850\ \frac{m^3}{year}$$

USES AND EXCLUSIONS

Note measure is intended for buildings with an existing ERV, or new construction buildings required to have an energy recovery system. For buildings without an existing ERV, or new buildings not required to have an energy 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 [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[8] [12]

References

[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. [Accessed 11 2013].

[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] "Ontario Building Code Act 1992 - Supplementary Standard SB-10," 14 September 2012. [Online].

[4] "Building Code Act 1992 - Potential Changes to Supplementary Standard SB-10," Come into effect January 1, 2017.

[5] ENERGY STAR, "Technical Specifications for Residential Heat Reocovery Ventilators and Energy Recovery Ventilators (H/ERVs) Version 2.0", 2015. [Online]. Available: http://www.nrcan.gc.ca/energy/products/for-participants/specifications/13695. [Accessed Nov 2017].

[6] AHRI, "Directory of Certified Product Performance," [Online]. Available: https://www.ahridirectory.org/ahriDirectory/pages/home.aspx. [Accessed Oct 2014].

[7] W. Jayes, "Psychrometric Calculations," The Sugar Engineers, [Online]. Available: http://www.sugartech.co.za/psychro/index.php. [Accessed Nov 2014].

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[9] Nexant, "Evaluation of Natural Gas DSM Measures: ERVs & HRVs," March 12 2010.

[10] Airxchange, "Frost Control Strategies for Airxchange Enthalpy Wheels," 2005. [Online]. Available: http://www.airxchange.com/Collateral/Documents/English-US/Frost%20Control%20Strategies%20for%20Airxchange%20Wheels.pdf. [Accessed Oct 2014].

[11] CPUC, "Database for Energy Efficient Resources (DEER)," March 2014. [Online]. Available: www.deeresources.com.

[12] ERV/HRV manufacturer, Interviewee, *Incremental costs of installed equipment.* [Interview]. Nov 2015.

COMMERCIAL – ENERGY RECOVERY VENTILATION (ERV) (NO ERV BASELINE) – NEW CONSTRUCTION/RETROFIT

Version Date and Revision History	
Version	2.2 (minor update)
OEB Filing Date	January 8, 2020
OEB Approval Date	January 9, 2020
Commercial→ Space Heating → Energy Recovery Ventilation→ New Construction/Retrofit	

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

Table 1. Measure Key Data

<table>
<tr><th>Parameter</th><th colspan="4">Definitions</th></tr>
<tr><td>Measure Category</td><td colspan="4">New construction (NC), ERV not required by Ontario Building Code
Retrofit (R)</td></tr>
<tr><td>Baseline Technology</td><td colspan="4">No ERV</td></tr>
<tr><td rowspan="4">Efficient Technology</td><td colspan="4">ERV with Minimum 55% Sensible Heat Recovery Effectiveness[1] and 53% Total Energy Recovery Effectiveness at 32°F</td></tr>
<tr><td colspan="4">ERV with Minimum 65% Sensible Heat Recovery Effectiveness and 63% Total Energy Recovery Effectiveness at 32°F</td></tr>
<tr><td colspan="4">ERV with Minimum 75% with Sensible Heat Recovery Effectiveness and 73% Total Energy Recovery Effectiveness at 32°F</td></tr>
<tr><td colspan="4">ERV with Minimum 85% Sensible Heat Recovery Effectiveness and 83% Total Energy Recovery Effectiveness at 32°F</td></tr>
<tr><td>Market Type</td><td colspan="4">Commercial</td></tr>
<tr><td></td><th>Building Type</th><th>Gas Savings Rate (m^3/working CFM), ε_{EE} 1</th><th>Group</th><th>Average Group Gas Savings (m^3/ working CFM), ε_{EE} 1</th></tr>
</table>

[1] This measure is eligible for commercial buildings where Energy Star does not apply (the applicable OBC code is Supplementary Standard SB-10).

Some commercial buildings are required by SB-10 to have Energy Recovery Ventilation or Heat Recovery Ventilation with a minimum of 55% sensible effectiveness. For buildings with no code requirement, systems that bring efficiency up to code level (55% sensible effectiveness) are eligible.

Parameter	Definitions			
Annual Gas Savings Rate with a Minimum ERV Sensible Heat Recovery Effectiveness of 55%, $\varepsilon_{EE}\ 1$ (m³/ working CFM)[1]	Multi-Family, Health Care and Nursing Homes	4.52	High Use	4. 52
	Hotels	3.23	Medium Use	2.51
	Restaurant	2.34		
	Retail	1.96		
	Office	1.72	Low Use	1.60
	Warehouse	1.64		
	School	1.45		
Annual Gas Savings Rate with a Minimum ERV Sensible Heat Recovery Effectiveness of 65%, $\varepsilon_{EE}\ 2$ (m³/ working CFM)[1]	**Building Type**	**Gas Savings Rate (m³/working CFM),** $\varepsilon_{EE}\ 2$	**Group**	**Average Group Gas Savings (m³/working CFM),** $\varepsilon_{EE}\ 2$
	Multi-Family, Health Care and Nursing Homes	5.37	High Use	5.37
	Hotels	3.84	Medium Use	2.98
	Restaurant	2.78		
	Retail	2.33		
	Office	2.05	Low Use	1.91
	Warehouse	1.95		
	School	1.73		
Annual Gas Savings Rate With a Minimum ERV Sensible Heat Recovery Effectiveness of 75%, $\varepsilon_{EE}\ 3$ (m³/ working CFM)[1]	**Building Type**	**Gas Savings Rate (m³/working CFM),** $\varepsilon_{EE}\ 3$	**Group**	**Average Group Gas Savings (m³/working CFM),** $\varepsilon_{EE}\ 3$
	Multi-Family, Health Care and Nursing Homes	6.22	High Use	6.22
	Hotels	4.44	Medium Use	3.45
	Restaurant	3.22		
	Retail	2.70		
	Office	2.37	Low Use	2.21
	Warehouse	2.26		
	School	2.00		

Parameter	Definitions			
Annual Gas Savings Rate with a Minimum ERV Sensible Heat Recovery Effectiveness of 85%, ε_{EE} 4 (m^3/ working CFM)[1]	**Building Type**	**Gas Savings Rate (m^3/working CFM), ε_{EE} 4**	**Group**	**Average Group Gas Savings (m^3/working CFM), ε_{EE} 4**
	Multi-Family, Health Care and Nursing Homes	7.07	High Use	7.07
	Hotels	5.05	Medium Use	3.93
	Restaurant	3.66		
	Retail	3.07		
	Office	2.69	Low Use	2.51
	Warehouse	2.57		
	School	2.27		
Annual Electric Impact[2] (kWh/ working CFM)	**Building Type**	**Electric Impact Rate (kWh/working CFM)**	**Group**	**Average Group Electric Impact (kWh/working CFM)**
	Multi-Family, Health Care and Nursing Homes	-4.39	High Use	-4.39
	Hotels	-3.14	Medium Use	-2.44
	Restaurant	-2.28		
	Retail	-1.91		
	Office	-1.67	Low Use	-1.56
	Warehouse	-1.60		
	School	-1.41		
Measure Life	14 Years			
Incremental First Cost ($ CAD) ε_{EE} 1	Integrated ERV		Standalone or Bolt-On ERV	
	$4.86/CFM		$7.80/CFM	
Incremental Cost ($ CAD)	$4.86 + $1.00 per CFM at $\boldsymbol{\varepsilon_{EE}}$ **2**		$7.80 + $1.00 per CFM at $\boldsymbol{\varepsilon_{EE}}$ **2**	
	$4.86 + $2.00 per CFM at ε_{EE} 3		$7.80 + $2.00 per CFM at ε_{EE} 3	

[2] The electric impact does not apply when the ERV unit is installed as part of an integrated HVAC package.

	\$4.86 + \$3.00 per CFM at $\varepsilon_{EE}4$	\$7.80 + \$3.00 per CFM at $\varepsilon_{EE}4$
Restrictions	This measure is not eligible in areas where: • ERV is required by building code, • 100% of the exhaust air must be evacuated from the building in order to avoid cross contamination, and therefore 100% fresh air is required such as described in OBC section 1.1.1.4. • No recirculation is allowed by codes or standards. For instance, any limitations as per 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• • Systems where DCV or scheduled setbacks are used during operated hours[3]	

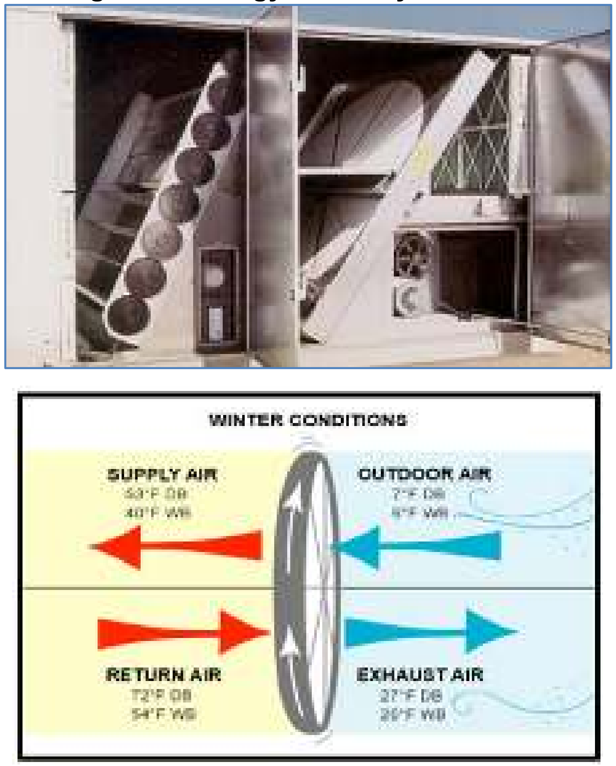
OVERVIEW

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 system installed in new construction because the higher efficiency of the new fans compensates for the additional static pressure. Figure 1 is an illustration of a wheel-type energy recovery ventilator and functionality.

[3] These configurations require that projects be submitted as custom measures.

Figure 1: Energy Recovery Ventilator[4]



[4] 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 55%, 65%, 75%, and 85% 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 $\varepsilon_{EE}1$	Minimum 55% Sensible Heat Recovery Effectiveness and 53% Total Energy Recovery Effectiveness at 32°F at working airflow (CFM)
ERV $\varepsilon_{EE}2$	Minimum 65% Sensible Heat Recovery Effectiveness and 63% Total Energy Recovery Effectiveness at 32°F at working airflow (CFM)

Type	Efficiency
ERV $\varepsilon_{EE}3$	Minimum 75% with Sensible Heat Recovery Effectiveness and 73% Total Energy Recovery Effectiveness at 32°F at working airflow (CFM)
ERV $\varepsilon_{EE}4$	Minimum 85% Sensible Heat Recovery Effectiveness and 83% Total Energy Recovery Effectiveness at 32°F at working airflow (CFM)

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.

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. However, those savings have not been quantified.

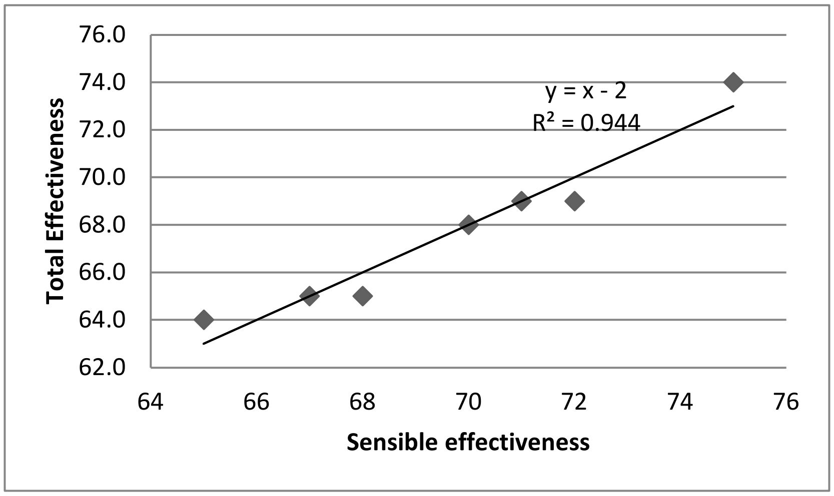
NATURAL GAS SAVINGS ALGORITHMS

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.

The natural gas savings[1] rates in Table 1 are calculated using the following formulae.

$$hrs = hrs_{hs} \times \frac{weeklyhrs}{168\frac{hrs}{week}}$$

and,

$$NG\ Savings = hrs \times \frac{60min}{hr} \times \frac{\varepsilon\varepsilon_{EE}}{\eta} \times \frac{\rho}{35{,}738\frac{Btu}{m^3}} \times (h_3 - h_1) \times (1 - \frac{DF}{100\%})$$

Where,

hrs	= Annual hours that the ERV is expected to be in use (hours/year)
hrs_{hs}	= 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 efficiency ERV (%)[5]
η	= The efficiency of the building's heating system (%)
ρ	= Density of air at 72°F (lb_m/ft^3)

[5] 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 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/CFM/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)

Assumptions

Table 4 shows the list of assumptions used in the algorithms sections.

Table 4. Assumptions

Variable	Definition	Value	Source
hrs_{hs}	Hours in Heating Season, 55°F Balance Temperature[6]	5,293 hrs	Common assumptions table

[6] 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
$\varepsilon_{EE}1$	Total minimum effectiveness	53%	[4] and analysis in this document
$\varepsilon_{EE}2$	Total minimum effectiveness	63%	[4] and analysis in this document
$\varepsilon_{EE}3$	Total minimum effectiveness	73%	[4] and analysis in this document
$\varepsilon_{EE}4$	Total minimum effectiveness	83%	[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	11.82 Btu/lb	Common assumptions table
h_3	Average enthalpy of inlet exhaust air	22.72 Btu/lb	
Fan Efficiency	Assumed fan efficiency	0.83 W/CFM	[3]
RH_1	Average outdoor relative humidity	76.6%	Common assumptions table
RH_3	Average indoor relative humidity	30%	[7], [2]
DF	Defrost control de-rating factor	5%[7]	[1] [2] [8] [7]
T_1	Average temperature of outside (supply) air during the heating season (OA temperature heating system enabled)	34.8°F	Common assumptions table
T_3	Average temperature of inlet exhaust air (space temperature setpoint)	72°F	Common assumptions table

The assumed weekly hours of operation for different building types are given in Table 5.

[7] 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.

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 is assumed that a new health care facility installs an ERV unit working at 500 CFM with a total effectiveness of 63%. In this case the $\varepsilon_{EE}2$ is applicable.

$$hrs = 5{,}293 hrs \times \frac{168\frac{hrs}{week}}{168\frac{hrs}{week}} = 5{,}293\frac{hrs}{year}$$

and,

$$NG\ Savings = 5{,}293\frac{hrs}{year} \times \frac{60min}{hr} \times 0.0741\frac{lb_m}{ft^3} \times \frac{63\%}{80\%} \times \frac{1}{35{,}738\frac{Btu}{m^3}}$$
$$\times \left(22.72\frac{Btu}{lb_m} - 11.82\frac{Btu}{lb_m}\right) \times \left(1 - \frac{5\%}{100\%}\right) = 5.37\frac{m^3}{CFM \cdot year}$$

Therefore,

$$NG\ Savings = 500CFM \times 5.37\frac{m^3}{CFM \cdot year} = 2{,}685\ \frac{m^3}{year}$$

The electrical penalty can be calculated as the following.

$$kWh\ penalty = 500\ CFM \times -0.83\frac{W}{CFM} \times 5{,}293\ \frac{hrs}{year} \times \frac{1kW}{1000W} = -2{,}197\ \frac{kWh}{year}$$

USES AND EXCLUSIONS

- Restriction for New Building Construction: This measure is not applicable to buildings in which an ERV is required by Ontario Building Code. [9] 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 and 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 [10].

INCREMENTAL COST

Table 6 demonstrates the first incremental cost of energy recovery ventilators. The first incremental costs were developed by ERS using RSMeans and were corroborated with manufacturer data. The costs for integrated systems were found to be $4.86/CFM for ERVs integrated into HVAC systems and $7.80/CFM for standalone systems [11]. 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.

The first costs represent the incremental costs between no ERV and 55% efficient units. Additional incremental costs between high efficiency units are $1.00 per CFM at 65%, $2.00 at 75%, and $3.00 at 85% efficiency[8] [12].

Table 6. Incremental Cost[9] [11]

Measure Type	Cost
First Cost Integrated units	$4.86/CFM
First Cost Bolted-on systems	$7.80/CFM

[8] 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.

[9] Converted to CAD based on Daily Currency Converted for Bank of Canada, as of 11/30/2016. (http://www.bankofcanada.ca/rates/exchange/daily-converter/)

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COMMERCIAL– ENERGY STAR CONVECTION OVEN– NEW CONSTRUCTION/TIME OF NATURAL REPLACEMENT

Version Date and Revision History	
Version	1.3 (minor changes)
OEB Filing Date	December 16, 2021
OEB Approval Date	December 16, 2021
Commercial →Food Service → ENERGY STAR Convection Oven – Full Size →New Construction/Time of Natural Replacement	

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

Table 1. Measure Key Data

Parameter	Definitions
Measure Category	New Construction (NC) Time of Natural Replacement (TNR)
Baseline Technology	A conventional, full-size single, standard depth convection oven
Efficient Technology	A full-size ENERGY STAR rated convection oven
Market type	Commercial
Annual Natural Gas Savings (m^3)	954 m^3
Annual Electric Savings (kWh)	44.2 kWh
Measure Life	12 years
Incremental Cost ($ CAD)	$1,200
Restrictions	Restricted to full sized, single, standard depth convection ovens using natural gas.

OVERVIEW

Convection ovens are used in commercial and institutional food service preparation as an alternative to conventional ovens. As food cooks in a conventional oven, it is surrounded by a layer of cooler air due to the lower temperature of the food item(s) being cooked. Convection ovens differ from conventional ovens in that a motorized fan (or blower) pulls in air from the oven cavity, heats it, and distributes it back into the oven cavity, resulting in a faster and more even cooking process. Convection ovens are thermostatically controlled appliances. The oven is left on during operations and cycles on and off to maintain the desired temperature setting. [1] This measure focuses on full size commercial convection ovens. Convection ovens consume natural gas when they are pre-heating, idling and cooking. "Standard gas convection ovens have a 30% cooking energy efficiency and an idle energy rate of 19,000 Btu/h, whereas ENERGY STAR certified gas convection ovens must meet the specification requirements of 46% cooking energy efficiency and idle energy rate of 12,000 Btu/h." [2]

APPLICATION

This measure applies to the installation of a full size ENERGY STAR qualifying convection oven in commercial and industrial food processing settings. Convection ovens are designed to cook food within a heated enclosed space, with the food being manually placed into the oven and removed when the cooking process is complete.

BASELINE TECHNOLOGY

The baseline technology is a full size single, standard depth convection oven that is not ENERGY STAR rated.

EFFICIENT TECHNOLOGY

The efficient technology is a full size, single, standard depth convection oven that is ENERGY STAR rated. Table 2 shows the requirements for this measure.

Table 2. Efficient Technology [2]

Type	ENERGY STAR Requirements
ENERGY STAR Convection Oven – Full Size, single, standard depth	Idle rate ≤ 12,000 Btu/hr and cooking energy efficiency of ≥ 46%

ENERGY IMPACTS

The primary energy impact associated with the installation of a full-size single, standard depth ENERGY STAR convection oven is a reduction in natural gas required during pre-heating, idling, and cooking. ENERGY STAR qualified gas convection ovens must meet the specification requirements of 46% cooking energy efficiency and idle energy rate of 12,000 Btu/h. The savings are achieved through reduced cooking time and lower idle energy rate.

There are electric savings resulting from decreased operating hours of the convection fan due to the reduced cooking time.

NATURAL GAS SAVINGS ALGORITHM

The energy savings algorithm compares the annual energy usage of the standard convection equipment and ENERGY STAR qualifying convection ovens. To determine total energy usage, the calculation must determine the energy consumed in the pre-heating, cooking, and idling modes.

The algorithm is based upon the methodology utilized by the Food Service Technology Center. The calculation to determine the energy usage of baseline and ENERGY STAR ovens is as follows:

$$NG\ Usage = Days \times (Daily\ Preheat + Daily\ Idle + Daily\ Cooking)$$

where,

NG Usage	= the amount of natural gas used by the oven annually in Btu/year
Days	= the number of days per year the oven is in use
Daily Preheat	= the amount of natural gas used to preheat the oven daily in Btu/day
Daily Idle	= the amount of natural gas used when the oven is in idle mode in Btu/day
Daily Cooking	= the amount of natural gas used when the oven is cooking in Btu/day

The *"Daily Idle"* usage is calculated by the following equation:

$$Daily\ Idle = Idle\ Time \times Idle\ Rate$$

where,

Idle Time	= length of time the unit is idle per day in hours.
Idle Rate	= energy consumed during idling in Btu/hr

The idle time is calculated by subtracting the preheat time and the times the ovens are in heavy load cooking mode from the number of hours the equipment is on per day. This is shown in the following expression:

$$Idle\ Time = Total\ Operating\ Hours - Preheat\ Time - Daily\ Cooking\ Time$$

where,

Total Operating Hours	= length of time in hours where unit is turned on
Preheat Time	= length of time in hours when unit is in preheat mode
Daily Cooking Time	= length of time in hours where unit is cooking

The daily cooking time is calculated with the following equation:

$$Daily\ Cooking\ Time = \frac{Food\ Weight}{Production\ Capacity}$$

where,

Food Weight	= average quantity of food cooked in unit per day in lbs/day
Production capacity	= the maximum production rate of the appliance while cooking in accordance with the heavy-load cooking test in lbs/hr

Finally, the daily energy consumed during cooking is calculated as follows:

$$Daily\ Cooking\ Time = \frac{Food\ Weight \times ASTM\ Energy\ to\ Food\ Rate}{Efficiency}$$

where,

Food Weight	= average quantity of food cooked in unit per day in lbs
ASTM Energy to Food Rate	= rate at which energy is transferred to food in Btu/lb
Efficiency	= efficiency of the unit

The savings is then calculated from the difference between the baseline and efficient cases.

$$NG_{savings} = (NG\ Usage_{baseline} - NG\ Usage_{ENERGY\ STAR}) \times \frac{1m^3}{35{,}738\ Btu}$$

where,

$NG_{savings}$	= annual reduction in natural gas consumption in m^3/year
$NG\ Usage_{baseline}$	= annual energy usage of a conventional oven in Btu/year
$NG\ Usage_{ENERGY\ STAR}$	= annual energy usage for an ENERGY STAR oven in Btu/year

Electric Savings Algorithms

The electric savings result from the reduction in fan energy from the reduced cooking time. The electric savings are calculated as follows:

$$Elec_{Savings} = (Daily\ Cooking\ Time_{Conventional} - Daily\ Cooking\ Time_{ENERGY\ STAR}) \times HP_{fan} \times 0.7457 \frac{kW}{hp} \times Days$$

Where,

$Elec_{Savings}$ = annual reduction in electric consumptions in kWh/year

$Daily\ Cooking\ Time_{Conventional}$ = Cooking time for a conventional convection oven in hours

$Daily\ Cooking\ Time_{ENERGY\ STAR}$ = Cooking time for an ENERGY STAR convection oven in hours

HP_{fan} = Horsepower of convection fan

Days = the number of days per year the oven is in use

ASSUMPTIONS

The assumptions used to calculate natural gas savings are shown in Table 3.

Table 3. Assumptions

Parameter	Baseline	High Efficiency	Source
Food service days per year	344		Common assumptions table
Preheat Time (hrs)	0.20		[3]
Total Operating Hours (hrs)	12		[4]
Preheat Energy (Btu/day)	19,000	11,000	[5]
Idle Time (hrs/day)	10.4	10.6	Calculated
Idle Rate (Btu/hr)	18,000	11,758	[5]
Food Weight (lbs/day)	100		[5]
ASTM Energy to Food Rate (Btu/lb)	250		[5], [6], [7]
Production Capacity (lbs/hr)	70	83	[5]
Efficiency	30%	46%	[2]

Parameter	Baseline	High Efficiency	Source
Convection oven fan power[1]	0.75 hp		
Energy density of natural gas	35,738 Btu/m³		Common assumptions table

SAVINGS CALCULATION EXAMPLE

The example below illustrates how the savings value is determined for an ENERGY STAR convection oven – full size, single, standard depth, with typical hours of usage.

Daily Conventional Convection Oven Usage:

$$Daily\ Preheat = 19{,}000 \frac{Btu}{day}$$

$$Daily\ Cooking\ Time = \frac{100 \frac{lbs}{day}}{70 \frac{lbs}{hr}} = 1.43 \frac{hrs}{day}$$

$$Idle\ Time = 12 \frac{hrs}{day} - 0.2 \frac{hrs}{day} - 1.43 \frac{hrs}{day} = 10.4 \frac{hrs}{day}$$

$$Daily\ Idle = 10.4 \frac{hrs}{day} \times 18{,}000 \frac{Btu}{hr} = 186{,}686 \frac{Btu}{day}$$

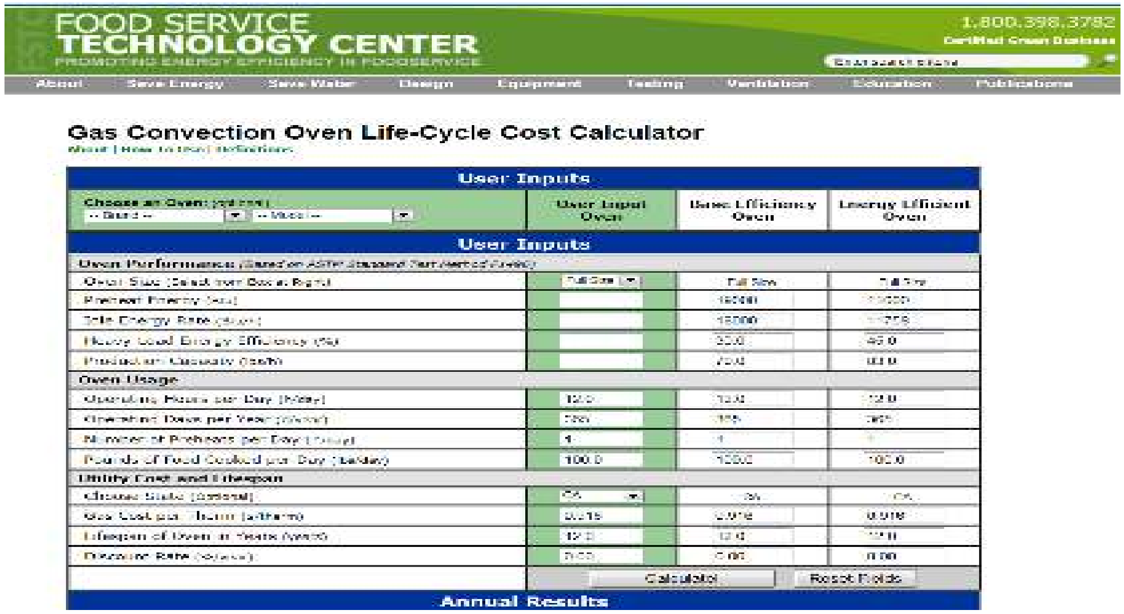
$$Daily\ Cooking = \frac{100 \frac{lbs}{day} \times 250 \frac{Btu}{lb}}{30\%} = 83{,}333 \frac{Btu}{day}$$

$$NG\ Usage = \left(19{,}000 \frac{Btu}{day} + 186{,}686 \frac{Btu}{day} + 83{,}333 \frac{Btu}{day}\right) \times 344 \frac{days}{year} = 99{,}422{,}536 \frac{Btu}{year}$$

Daily ENERGY STAR Convection Oven Usage:

$$Daily\ Preheat = 11{,}000 \frac{Btu}{day}$$

[1] Looking at several manufacturers' websites, the convection fan range in size from 0.5 hp to 0.75 horsepower. (http://montaguecompany.com/uploads/documents/Vectaire-Full-Size-Gas-Convection-Double-Oven-Models-2-70-and-2-115-Spec-Sheet.pdf, http://www.centralrestaurant.com/Gas-Convection-Oven---Double-Stack-120000-BTU-Snorkel-Gas-c105p29049.html, http://www.garland-group.com/docs/uploaded/gar/products/G_GO_SS_CONVECTION_MC0G10SD.pdf, http://www.blodgett.com/blodgett_products/dfg-100-es/)



$$Daily\ Cooking\ Time = \frac{100\,\frac{lbs}{day}}{83\,\frac{lbs}{hr}} = 1.20\,\frac{hrs}{day}$$

$$Idle\ Time = 12\,\frac{hrs}{day} - 0.2\,\frac{hrs}{day} - 1.20\,\frac{hrs}{day} = 10.6\,\frac{hrs}{day}$$

$$Daily\ Idle = 10.6\,\frac{hrs}{day} \times 11{,}758\,\frac{Btu}{hr} = 124{,}578\,\frac{Btu}{day}$$

$$Daily\ Cooking = \frac{100\,\frac{lbs}{day} \times 250\,\frac{Btu}{lb}}{46\%} = 54{,}348\,\frac{Btu}{day}$$

$$NG\ Usage = \left(11{,}000\,\frac{Btu}{day} + 124{,}578\,\frac{Btu}{day} + 54{,}348\,\frac{Btu}{day}\right) \times 344\,\frac{days}{year} = 64{,}334{,}544\,\frac{Btu}{year}$$

Natural Gas Savings:

$$NG_{savings} = (99{,}422{,}536 - 64{,}334{,}544) \times \frac{1\,Btu}{35{,}738\,m^3} = 954\,\frac{m^3}{year}$$

Electric Savings:

$$Elec_{Savings} = (Daily\ Cooking\ Time_{Conventional} - Daily\ Cooking\ Time_{ENERGY\ STAR}) \times HP_{fan} \times 0.7457\,\frac{kW}{HP} \times \frac{Days}{Year}$$

$$Elec_{Savings} = \left(1.43\,\frac{hours}{day} - 1.20\,\frac{hours}{day}\right) \times 0.75\,HP \times 0.7457\,\frac{kW}{hp} \times 344\,\frac{days}{year} = 44.2\,kWh$$

Uses and Exclusions

To qualify for this measure the full size, single, standard depth convection oven must be utilized for food preparation or processing with natural gas as its energy source and must be ENERGY STAR rated.

Measure Life

The measure life attributed to this measure is 12 years. [5]

Incremental Cost

The incremental cost is summarized in the table below. [8]

Description	Cost CAD ($)
Baseline cost	$ 4,279
Energy Efficient cost	$ 5,479
Incremental cost	$ 1,200

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COMMERCIAL ENERGY STAR DISHWASHERS – NEW CONSTRUCTION /TIME OF NATURAL REPLACEMENT

Version Date and Revision History	
Version	1.2 (minor update)
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Commercial → Water Heating → ENERGY STAR Dishwasher→ New Construction/ Time of Natural Replacement	

Table 1Table 1 shows the key measure parameters including the savings for each type of dishwasher.

Table 1. Measure Key Data

Parameter	Definitions			
Measure Category	New Construction Time of Natural Replacement			
Baseline Technology	Table 2			
Efficient Technology	Table 3			
Market Type	Commercial			
Annual Natural Gas Savings (m^3) Annual Electric Savings (kWh) Annual Water Savings (liters)	**Dishwasher Type**	**Savings**		
		Natural Gas (m^3)	**Electric (kWh)**	**Water (liters)**
	High Temperature Dishwashers			
	Under Counter	151	1,975	22,460
	Stationary Single Tank Door	981	4,601	145,828
	Single Tank Conveyor	596	4,686	88,539
	Multi Tank Conveyor	2,260	10,673	335,926
	Low Temperature Dishwashers			
	Under Counter	355	0	52,733
	Stationary Single Tank Door	2,256	0	335,406
	Single Tank Conveyor	1,822	0	270,824
	Multi Tank Conveyor	2,628	0	390,612
Measure Life	**Dishwasher Type**	**High and Low Temperature (years)**		
	Under Counter	10		
	Stationary Single-Tank Door	15		
	Single-Tank Conveyor	20		
	Multi-Tank Conveyor	20		

Parameter	Definitions		
	Dishwasher Type	High Temperature	Low Temperature
Incremental cost ($ CAD)	Under Counter	$171	$71
	Stationary Single-Tank Door	$1,100	$0
	Single-Tank Conveyor	$2,929	$0
	Multi-Tank Conveyor	$1,386	$1,386
Restrictions	Commercial facilities with natural gas hot water heating.		

OVERVIEW

Dishwasher types are broken into two primary categories: high temperature and low temperature. High temperature dishwashers use a booster water heater to heat the already hot tap water to a minimum of 180°F [1] as required by the National Sanitation Foundation (NSF) Standard No. 3 [2]. At these temperatures, hard-to-remove residues like lipstick and grease are dissolved without the need for additional sanitizing chemicals. These dishwashers have the additional benefits of shorter wash cycles and less water use per cycle. Low temperature dishwashers require chemical sanitizers and may require multiple cycles to clean hard to remove residues. Low temperature dishwashers are less expensive than high temperature models. For this measure, booster heaters are assumed to be electric, as they are most prevalent, although natural gas booster heaters are available.

Besides high and low temperature categories, dishwashers can be further categorized by the volume of dishes or the number of racks they handle. Types of dishwashers in order of increasing capacity are under-counter, stationary rack, and rack conveyer. Under-counter types are like residential dishwashers and can handle up to 35 racks per hour. Stationary rack or pull-down-hood dishwashers are suitable for small commercial settings and can handle up to 80 racks an hour. Conveyer dishwashers pull racks through on a conveyer system and can handle up to 400 racks per hour [3].

Conveyer-type dishwashers are configured with either one tank for circulation water or several; one for each stage of the wash cycle (wash, rinse, and sanitize). Multiple-tank dishwashers can handle up to 600 racks per hour and have different ENERGY STAR requirements from their single-tank counterparts.

ENERGY STAR-qualified dishwashers are performance rated for water use per rack and idle power draw. Each type of dishwasher has its own product qualification criteria as outlined in Table 3. The water consumption values are a key component used in the calculation of energy consumption for dishwashers.

New Construction/Time of Natural Replacement Projects

Installing ENERGY STAR-rated dishwashers in new construction projects or at the end of the existing equipment's useful life will result in natural gas savings from the increased washing efficiency. The washing efficiency and energy savings are primarily derived from the reduced use of hot water.

APPLICATION

This measure provides incentives for installing ENERGY STAR-rated dishwashers in a commercial setting.

BASELINE TECHNOLOGY

Non-ENERGY STAR-rated dishwashers are assumed to have the parameters shown in Table 2. The baseline value is derived from the ENERGY STAR commercial kitchen equipment calculator, which cites EPA/Food Service Technology Center's equipment specification research, 2013, as their source.

Table 2. Baseline Technology [4]

Machine Type	High Temperature Efficiency		Low Temperature Efficiency	
	Idle Energy Rate (kW)[1]	Water Consumption (GPR)[2]	Idle Energy Rate (kW)[1]	Water Consumption (GPR)[2]
Under Counter	0.76	1.09	0.50	1.73
Stationary Single Tank Door	0.87	1.29	0.60	2.10
Single Tank Conveyor	1.93	0.87	1.50	1.31
Multiple Tank Conveyor	2.59	0.97	2.00	1.04

[1] Idle results should be measured with the door closed and represent the total idle energy consumed by the machine including all tank heater(s) and controls. Booster heater (internal or external) energy consumption should not be part of this measurement unless it cannot be separately monitored per the ENERGY STAR test method [5].

[2] GPR = gallons per rack

EFFICIENT TECHNOLOGY

ENERGY STAR-rated dishwashers must have idle energy and water consumption rates as defined in Table 3.

Table 3. ENERGY STAR Energy Efficiency Requirements for Commercial Dishwashers [5]

Machine Type	High Temperature Efficiency Requirements		Low Temperature Efficiency Requirements	
	Idle Energy Rate (kW)[1]	Water Consumption (GPR)[2]	Idle Energy Rate (kW)[1]	Water Consumption (GPR)[2]
Under Counter	≤ 0.50 kW	≤ 0.86 GPR	≤ 0.50 kW	≤ 1.19 GPR
Stationary Single Tank Door	≤ 0.70 kW	≤ 0.89 GPR	≤ 0.60 kW	≤ 1.18 GPR
Single Tank Conveyor	≤ 1.50 kW	≤ 0.70 GPR	≤ 1.50 kW	≤ 0.79 GPR
Multiple Tank Conveyor	≤ 2.25 kW	≤ 0.54 GPR	≤ 2.00 kW	≤ 0.54 GPR

[1] Idle results should be measured with the door closed and represent the total idle energy consumed by the machine including all tank heater(s) and controls. Booster heater (internal or external) energy consumption should not be part of this measurement unless it cannot be separately monitored per the ENERGY STAR Test Method [5].

[2] GPR = gallons per rack

ENERGY IMPACTS

Natural gas and electrical savings are achieved due to the fact that the higher efficiency equipment requires less heated water and typically less electricity for each load than its baseline non-ENERGY STAR counterpart.

NATURAL GAS AND ELECTRICAL SAVINGS ALGORITHMS

The following algorithms are referenced from the ENERGY STAR Commercial Kitchen Equipment Calculator for dishwashers.

The natural gas savings are a function of the water saved by the energy efficient technology, and the electrical savings are a result of lower idle energy rates. It is notable that the baseline and ENERGY STAR low temperature dishwashers have the same idle energy rates, which results in zero electricity savings.

First, the heat input required to raise the water to the desired temperature (Q_{in}) is calculated on a per gallon basis. Next, the annual water consumption is calculated for both the baseline and ENERGY STAR-rated dishwashers based on the water use per rack (GPR) and the number of racks washed per day (RPD). Finally the fuel savings are calculated using results from the previous calculations.

Starting with the calculation for the water heater specific energy consumption:

$$Q_{In} = T_{Inc} \times C_P \times \frac{\rho}{Eff_{Gas}}$$

where,

Q_{In} = Water heater specific energy consumption (Btu/gal)

T_{Inc} = Temperature increase required by building heating system for supply water (see Table 4, °F)

C_P = Specific heat of water (Btu/lb °F)

ρ = Density of water (lb/gal)

Eff_{Gas} = Building water heating system efficiency (%)

The annual water consumption can be calculated as:

$$Annual\ water\ consumption = GPR \times RPD \times Days$$

where,

$Annual\ water\ consumption$ = Annual water consumption of the dishwasher (gallons/year)

GPR = Gallons per rack water consumption of dishwasher (gal/rack)

RPD = Racks washed per day (racks/day)

$Days$ = Annual days of operation (days/year)

The annual fuel consumption can be calculated as:

$$Annual\ fuel\ consumption = Annual\ water\ consumption \times Q_{In}$$

where,

$Annual\ fuel\ consumption$ – Annual fuel consumption to heat water for the dishwasher (MMBtu)

The fuel savings can be calculated as the difference between the baseline and energy efficiency calculated annual fuel consumptions.

$$Fuel\ savings = Annual\ fuel\ consumption_{Base} - Annual\ fuel\ consumption_{EE}$$

where,

Base refers to the annual fuel consumption for the baseline technology.

EE refers to the annual fuel consumption for the energy efficient technology.

Dishwashers use electricity while idle, called the idle energy rate (IER), and are performance rated for this parameter by ENERGY STAR. The electricity consumption of a dishwasher can be calculated from the idle energy rate and by calculating the amount of time that the machine spends idle.

$$Elec = IER \times (Hrs \times Days - Days \times RPD \times \frac{TWT}{60})$$

where,

$Elec$ = Annual electricity consumption (kWh)

IER = Idle energy rate (kW)

Hrs = Average daily operation (hours)

$Days$ = Annual days of operation (days/year)

RPD = Racks washed per day (racks/day)

TWT = Typical wash time (minutes)

For high temperature models there is also an electric component that is attributable to the booster heater, which is responsible for heating the supply water from 140°F to 180°F. The energy required to heat the water the additional 40°F is calculated in a way similar to that for the primary natural gas water heater by first calculating the kWh per gallon required to raise the temperature of the water the desired amount.

$$Q_{Boost} = \frac{T_{Boost} \times C_P \times \rho}{Eff_{Elec} \times 3{,}412\ Btu/kWh}$$

where,

Q_{Boost} = Energy required to raise the temperature of the water from the primary water heater set point to the high temperature set point of the booster heater (kWh/gallon)

T_{Boost} = Temperature difference between the primary water heater setpoint and the booster heater high temperature setpoint (°F)

C_P = Specific heat of water (Btu/lb °F)

ρ = Density of water (lb/gal)

Eff_{Elec} = Efficiency of the electrical booster heater (%)

$3{,}412\,\frac{Btu}{kWh}$ = Conversion factor for kilowatt hours (kWh) British thermal units (Btus)

The electrical energy attributable to the booster heater can be calculated by multiplying the kWh per gallon required to raise the temperature of the water to 180°F by the annual water consumption.

$$Elec_{Boost} = Q_{Boost} \times Annual\ water\ consumption$$

The electrical savings can be calculated by tabulating electrical consumption for both the base and energy efficient models from the idle energy equation and the booster heater of a high temperature model.

$$Elec\ savings = Elec_{Base} - Elec_{EE}$$

where,

Elec savings = Annual electricity savings for the measure (kWh)

$Elec_{Base}$ = Annual electricity consumption for the baseline dishwasher, including the booster heater contribution if a high temperature model (kWh)

$Elec_{EE}$ = Annual electricity consumption for the ENERGY STAR dishwasher, including the booster heater contribution of a high temperature model (kWh)

ASSUMPTIONS

Table 4 shows the list of conversions utilized in the measure savings algorithm.

Table 4. Assumptions

Variable	Definition	Inputs for Baseline and Energy Efficient Options	Source/Comments
C_P	Specific heat capacity of water	1.00 Btu/lb ˚F	Common assumptions table
ρ	Density of water	8.29 lb/gal (US)	Common assumptions table
	City supply water temperature	48.9°F (9.39°C)	Common assumptions table
	Commercial hot water tank temperature	140°F (60°C)	Common assumptions table
T_{Inc}	Temperature delta that building heating system will need to heat city supply water to feed hot water tank	ΔT = 91.1˚F (ΔT = 50.61°C)	T_{inc}=140°F – 48.9°F
	Energy density of natural gas	35,738 Btu/m^3	Common assumptions table
T_{Boost}	Temperature difference that needs to be met by booster heater	ΔT = 40˚F (ΔT = 22.2°C)	[5]
Eff_{Gas}	Commercial water heating efficiency	83%	Common assumptions table
Eff_{Elec}	Electric booster heater efficiency	98%	[6]
Hrs	Average daily operation	18 hrs	[6]
Days	Food service days per year	344 days	Common assumptions table

ENERGY STAR uses the assumptions in Table 5 for racks washed per day.

Table 5. Assumptions for Racks Washed Per Day [6]

Dishwasher Type	High and Low Temperature
Under counter	75

Dishwasher Type	High and Low Temperature
Stationary single-tank door	280
Single-tank conveyor	400
Multi-tank conveyor	600

ENERGY STAR uses the assumptions in Table 6 for typical wash times.

Table 6. Assumptions for Typical Wash Time Minutes [6]

Dishwasher Type	High Temperature	Low Temperature
Under counter	2.0	2.0
Stationary single-tank door	1.0	1.5
Single-tank conveyor	0.3	0.3
Multi-tank conveyor	0.2	0.3

There are two considerations that should be considered before making the savings calculations:

1. All high temperature boosters are assumed to be electric.
2. Primary water heating systems are assumed to be natural gas.

Savings Calculation Example

The example below shows how the savings would be calculated for the measure. For the example, it will be assumed that an ENERGY STAR-rated low temperature single-tank conveyor dishwasher will be installed.

The heat required to raise the temperature of the water to the desired point (constant for all dishwasher types):

$$Q_{In} = \frac{91.1^{\circ}\ F \times 1 \frac{Btu}{lb}{}^{\circ}\ F \times 8.29 \frac{lb}{gal} \div}{0.83 \times 35{,}738\ Btu/m^3} = 0.02546\ m^3/US\ gal$$

Then the annual water consumption can be calculated for the ENERGY STAR-rated dishwasher as:

$$\begin{aligned} Annual\ water\ consumption_{EE} &= 0.79\ gal/rack \times 400\ racks/day \times 344\ days/year \\ &= 108{,}704\ gallons\ per\ year \end{aligned}$$

The conventional water consumption can be calculated similarly as:

$$Annual\ water\ consumption_{Base} = 180{,}256 \text{gallons per year}$$

Energy efficient fuel consumption can be calculated as follows:

$$Annual\ fuel\ consumption_{EE} = 108{,}704 \frac{gal}{year} \times 0.02546 \frac{m^3}{gal} = 2767.6 \frac{m^3}{yr}$$

$$Annual\ fuel\ consumption_{Base} = 180{,}256 \frac{\text{gal}}{\text{year}} \times 0.02546 \frac{\text{m}^3}{gal} = 4{,}589.3 \frac{m^3}{yr}$$

Annual fuel savings:

$$Fuel\ savings = 4{,}589.3 \frac{m^3}{yr} - 2767.6 \frac{m^3}{yr} = 1{,}821.7 \frac{m^3}{yr}$$

The low temperature dishwashers do not have any electricity savings.

USES AND EXCLUSIONS

The installed dishwasher must be ENERGY STAR-qualified and installed in a commercial setting.

MEASURE LIFE

Table 7 shows the measure lifetimes for each type of dishwasher

Table 7. Equipment Lifetime (Years) [5] [7]

Dishwasher Type	High and Low Temperature
Under counter	10
Stationary single-tank door	15
Single-tank conveyor	20
Multi-tank conveyor	20

The equipment lifetimes were derived from the Food Service Technology Center (FSTC), which contributed to the development of the ENERGY STAR U.S. calculator. No lifetime distinction was identified relative to the sanitation method (high or low temperature) or to the efficiency (ENERGY STAR-qualified or not) of the dishwashers.

INCREMENTAL COST

Table 8 shows the equipment incremental costs for each type of dishwasher.

Table 8. Incremental Costs[1] [8]

Dishwasher Type	High Temperature	Low Temperature
Under counter	$171	$71
Stationary single-tank door	$1,100	$0
Single-tank conveyor	$2,929	$0

[1] Converted to CAD based on Daily Currency Converted for Bank of Canada, as of 1/22/2016. (http://www.bankofcanada.ca/rates/exchange/daily-converter/)

Dishwasher Type	High Temperature	Low Temperature
Multi-tank conveyor	$1,386	$1,386

Incremental costs were obtained from the ENERGY STAR commercial kitchen equipment energy savings calculator.

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COMMERCIAL – ENERGY STAR FRYER – NEW CONSTRUCTION/TIME OF NATURAL REPLACEMENT

Version Date and Revision History	
Version	1
OEB Filing Date	Dec 21, 2016
OEB Approval Date	
Commercial → Food Service → ENERGY STAR Fryer →New Construction/Time of Natural Replacement	

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

Table 1. Measure Key Data

Parameter	Definitions
Measure Category	New Construction (NC) Time of Natural Replacement (TNR)
Baseline Technology	A non-ENERGY STAR rated fryer
Efficient Technology	An ENERGY STAR rated fryer
Market Type	Commercial
Annual Natural Gas Savings (m^3 per vat)	1,408 m^3
Measure Life	12 years
Incremental Cost ($CAD)	$2,476
Restrictions	Restricted to commercial facilities with standard or large-vat natural gas fryers for food service.

OVERVIEW

Fryers are used in commercial and institutional food service preparation for frying food in heated oil. Though fryers are available in a range of configurations, with the exception of specialized fryers for specific food items, they share a common design. The food is immersed in a kettle that holds the oil, which is typically heated by atmospheric or infrared gas burners underneath the kettle, or via “fire tubes” running through the kettle wall. The heating elements are controlled by a thermostat. The kettle holds enough oil so that the food is supported by displacement of the oil, rather than by the bottom of the vessel. There are three primary types of fryers: open deep-fat fryers, pressure fryers, and specialty fryers. Open fryers are the most common. [1]

During food service operations the fryers are turned on at the beginning of the day and turned off at the end of the shift; the fryer cycles on and off to maintain the desired temperature setting. Fryers are estimated to be idle 75% of the time. [1]

ENERGY STAR fryers are up to 30% more efficient than non-ENERGY STAR rated fryers. [2]

Application

This measure applies to ENERGY STAR qualifying open-vat fryers in commercial and institutional food processing settings. A fryer is designed to cook food in heated oil. The fryer consumes natural gas during three modes: preheat – at the beginning of the shift when the fryer is turned on and the oil is raised from room temperature to cooking temperature, idling - maintaining the temperature of the cooking oil between cooking, and cooking – restoring heat to the oil when cold foods are dropped in the fryer.

ENERGY STAR fryers save energy by offering shorter cook times and higher production rates through advanced burner and heat exchanger designs. Fry pot insulation reduces standby losses resulting in a lower idle energy rate.

Baseline Technology

The baseline technology is a single or multiple, standard and large open-vat commercial fryer.

Efficient Technology

The efficient technology is a single, or multiple, open-vat fryer that is ENERGY STAR rated. Vats may be standard size (12 inches to 18 inches wide) or large size (18 to 24 inches wide)[1] [3]

Table 2. Efficient Requirements [2] [4]

Type	ENERGY STAR Requirements
ENERGY STAR Open-Vat Fryer	Single or multiple gas-fired open deep-fat fryers with cooking efficiency of >=50%, and maximum idling rates of: • Standard vat size; <=9,000 Btu/hr idling rate • Large vat fryers (larger than 18" wide);<=12,000 Btu/hr idling rate.

[1] The ENERGY STAR cooking efficiency requirements are the same for standard, large, and multiple vat fryers. The idling rate requirement varies with vat size.

ENERGY IMPACTS

The primary energy impact associated with the installation of an ENERGY STAR fryer is natural gas savings associated with a reduction in natural gas required during pre-heat, idling and cooking times. ENERGY STAR qualified fryers must meet a minimum cooking efficiency of 50%, and maximum idling rates. This savings is achieved through shorter cook times and higher production rates through advanced burner and heat exchanger designs. Fry pot insulation also reduces standby losses resulting in lower idle energy rates. There are no electric savings for this measure.

NATURAL GAS SAVINGS ALGORITHM

The energy savings algorithm is calculated by determining and comparing the annual energy usage in baseline and ENERGY STAR qualifying fryers. To determine total energy usage the calculation must determine the energy consumed during pre-heating, cooking, and idling modes.

The algorithm is based upon the methodology utilized by the Food Service Technology Center and ENERGY STAR for each vat. For both the baseline and the efficient case, the following calculation is used to determine the energy usage.

$$NG\ Usage = Days\ \times\ (Daily\ Preheat + Daily\ Idle\ + Daily\ Cooking\ )$$

where,

NG Usage	= the amount of natural gas used by the fryer annually in Btu/year
Days	= the number of days per year the fryer is in use
Daily Preheat	= the amount of natural gas used to preheat the fryer daily in Btu/day
Daily Idle	= the amount of natural gas used when the fryer is in idle mode in Btu/day
Daily Cooking	= the amount of natural gas used when the fryer is cooking in Btu/day

The daily idle energy is calculated using the following equation:

$$Daily\ Idle = Idle\ Time \times Idle\ Rate$$

where,

Idle Time	= length of time the unit is idle per day in hours
Idle Rate	= energy consumed during idling in Btu/hr

The idle time is calculated using the following equation:

$$Idle\ Time = Total\ Operating\ Hours - Preheat\ Time - Cooking\ Time$$

where,

Idle Time = length of time the unit is idle per day in hours

Total Operating Hours =amount of time fryers operate a day in hours

Preheat Time = length of time unit is in preheat mode in hours

Cooking Time =amount of time fryers are cooking food in hours

$$Daily\ Cooking = \frac{Food\ Weight \times ASTM\ Energy\ to\ Food\ Rate}{Efficiency}$$

where,

Food Weight = average quantity of food cooked in unit per day in pounds

ASTM Energy to Food Rate = rate at which energy is transferred to food in Btu/lb

Efficiency = efficiency of the unit

The savings is then calculated from the difference between the baseline and efficient cases.

$$NG_{savings} = (NG\ Usage_{baseline} - NG\ Usage_{ENERGY\ STAR}) \times \frac{1\ m^3}{35{,}738\ Btu}$$

where,

$NG_{savings}$ = annual reduction in natural gas consumption in m^3/year

$NG\ Usage_{baseline}$ = annual energy usage of a conventional fryer in Btu/year

$NG\ Usage_{ENERGY\ STAR}$ = annual energy usage for an ENERGY STAR fryer in Btu/year

ASSUMPTIONS

The assumptions used to calculate natural gas savings are shown in Table 3.

Table 3. Assumptions

Parameter	Baseline	High Efficiency	Source
Food Service Days	312		Common assumptions table
Preheat Time (hours)	0.175		[5]
Preheat Energy (Btu)	18,500	16,000	[5]

Parameter	Baseline	High Efficiency	Source
Cooking Time (hours)	2		[6]
Operating hours per day	14		[5]
Idle Time (hours)	11.83		Calculated
Idle Rate (Btu/h)	17,000	9,841	[5]
Food Weight (lbs/day)	150		[5]
Heavy Load Energy to Food (Btu/pound)	577		[7] [8]
Efficiency	35%	50%	[5] [4]
Energy Density of Natural Gas	35,738 Btu/m³		Common assumptions table

SAVINGS CALCULATION EXAMPLE

The example below illustrates how the deemed savings value is determined for an ENERGY STAR Fryer with typical hours of usage.

$Annual\ Conventional\ Fryer\ Usage$:

$$Daily\ Preheat = 18{,}500\ Btu$$

$$Daily\ Idle = 11.825\ hours\ \times\ 17{,}000 \frac{Btu}{hr} = 201{,}025\ Btu$$

$$Daily\ Cooking = \frac{150\ pounds\ \times\ 577\ Btu/pound}{35\%} = 247{,}286\ Btu$$

To calculate the annual conventional fryer consumption:

$$NG\ Usage = 312 \frac{days}{year} \times \left(18{,}500 \frac{Btu}{day} + 201{,}025 \frac{Btu}{day} + 247{,}286 \frac{Btu}{day}\right) = 145{,}644{,}943 \frac{Btu}{year}$$

$Annual\ ENERGY\ STAR\ Fryer\ Usage$:

$$Daily\ Preheat = 16{,}000\ Btu$$

$$Daily\ Idle = 11.83\ hours\ \times\ 9{,}841 \frac{Btu}{hr} = 116{,}375\ Btu$$

$$Daily\ Cooking = \frac{150\ pounds\ \times\ 577\ Btu/pound}{50\%} = 173{,}100\ Btu$$

To calculate the annual ENERGY STAR fryer consumption:

$$NG\ Usage = 312 \frac{days}{year} \times \left(16{,}000 \frac{Btu}{day} + 116{,}375 \frac{Btu}{day} + 173{,}100 \frac{Btu}{day}\right) = 95{,}308{,}295 \frac{Btu}{year}$$

$Natural\ Gas\ Savings$:

$$NG_{savings} = (145{,}644{,}943\ Btu - 95{,}308{,}295\ Btu) \times \frac{1}{35{,}738\ \frac{Btu}{m^3}} = 1{,}408\ m^3$$

Uses and Exclusions

To qualify for this measure the fryer must be utilized for food preparation or processing with natural gas as its energy source and be ENERGY STAR rated.

Measure Life

The measure life attributed to this measure is 12 years. [5]

Incremental Cost

Table 4 presents the measure incremental cost.

Table 4. Incremental Cost[2] [9]

Measure Category	Incremental Cost ($)
New Construction/Time of Natural Replacement	$2,476

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COMMERCIAL – ENERGY STAR STEAM COOKER – NEW CONSTRUCTION/TIME OF NATURAL REPLACEMENT

Version Date and Revision History	
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OEB Approval Date	
Commercial →Food Service → ENERGY STAR Steam Cookers→New Construction/Time of Natural Replacement	

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

Table 1. Measure Key Data

Parameter	Definitions
Measure Category	New Construction (NC) Time of Natural Replacement (TNR)
Baseline Technology	Boiler-Based Steam Cooker
Efficient Technology	ENERGY STAR Rated Steam Cooker
Market Type	Commercial
Annual Natural Gas Savings (m^3)	8,889 m^3
Annual Water Savings (liters)	340,142 liters
Measure Life	12 years
Incremental Cost ($ CAD)	$3,880
Restrictions	Measure is limited to steam cookers that have either a connectionless or steam-generator design.

OVERVIEW

Steam cookers are used in commercial and institutional food service preparation to cook foods that do not need to form a crust. The steamer resembles an oven where food is steamed in a sealed cavity. [1]

The steam can be delivered to the cavity in several different ways. In a pressureless steamer, steam is injected through openings in the sides of the cooking compartment. A variety of foods can be cooked at the same time, and the cooking compartment door can be opened at any time during the cooking procedure. Pressure steamers use steam that has been pressurized to 5 to 15 psi. The cooking compartment needs to be depressurized before it can be opened. [2]

The steam itself may be produced in several ways:

- Boiler steamer: The steamer has an external boiler (relative to the cooking compartment) that generates potable steam.
    - Pressurized steamers: The pressurized steam is delivered as demanded by control settings. Compartment must be depressurized before it is opened.
    - Pressureless steamer: The compartment is openly connected to a condensate drain and the pressure in the compartment is at or slightly above atmospheric pressure.
- Steam generator: The steam generator is located within or connected to the cooking cavity, generating steam at (or slightly above) atmospheric pressure.
- "Connectionless" Steamer: the steam is produced by boiling water delivered directly to a reservoir located within the cooking compartment prior to operation. [1]

There are several steam cooker configurations which include: countertop models, wall-mounted models, and floor models mounted on pedestal or cabinet-style base. Commercial steamers come in different sizes, but steamers holding six or more pans are the most common, based on the ENERGY STAR approved products list. [3] Energy efficient steam cookers that have earned the ENERGY STAR designation offer shorter cook times, higher production rates, and reduced heat loss due to better insulation and more efficient steam delivery system. [4]

This measure is for ENERGY STAR approved steam cookers with either connectionless or steam-generator design. These steamer designs are often termed: "boilerless." Standard boiler steamers are not eligible as they do not meet ENERGY STAR efficiency criteria due to their low efficiencies during idling and cooking. [1]

APPLICATION

This measure applies to the installation of ENERGY STAR qualifying steam cookers in commercial and institutional food preparation. The food is manually placed into the steamer and removed when the cooking is complete. Steam cookers consume natural gas when they are pre-heating, idling and cooking.

BASELINE TECHNOLOGY

The baseline technology is a standard boiler-based steam cooker. No boiler-based steam cookers are ENERGY STAR-listed as their efficiency levels fall below the ENERGY STAR requirements. Boiler-based steamers are connected to a potable water line and continually supply steam to the cooking compartment, leading to high idle energy consumption [1]

EFFICIENT TECHNOLOGY

The efficient technology is an ENERGY STAR rated steam cooker meeting the criteria presented in Table 2.

Table 2. Efficient Technology [5]

Type	ENERGY STAR Requirements
6-pan ENERGY STAR Steam Cooker	ENERGY STAR rated Steam Cooker used in a commercial or institutional environment, with a minimum efficiency of 38% and a maximum idle-rate of 12,500 Btu/hr

The majority of ENERGY STAR steamers on the qualifying products list are "connectionless." "Connectionless steamers" do not require potable water feed, or condensate drain connections. Water is poured into a compartment at the bottom that is refilled during the day and any remaining water at the end of operation is drained from the cavity into a pan or bucket. [1] ENERGY STAR steam generation cookers require a water connection and a condensate drain, but offers improved efficiency over standard boiler-based cookers.

ENERGY IMPACTS

The primary energy impact associated with the installation of an ENERGY STAR steam cooker is a reduction in natural gas required during pre-heat, idle and cooking modes.

Connectionless steamers are inherently more energy efficient than boiler-based or conventional steam generation systems since any steam that does not condense on the food remains in the cooking compartment, rather than being condensed and drained. [1]

ENERGY STAR qualified steam cookers must meet the specification requirements of 38% natural gas minimum cooking efficiency, and a maximum idle rate. The idle rate requirement varies with the size of the steamer. The savings are achieved through shorter cook times, higher production rates, through improved steam delivery, and reduced heat loss due to better insulation. Water savings are also achieved through reduced consumption of steam during shorter cooking times and reduced condensate draining. [4] [6] There are no electric impacts for this measure.

NATURAL GAS SAVINGS ALGORITHM

The energy savings algorithm is calculated by determining and comparing the annual energy usage in baseline and ENERGY STAR steam cookers. To determine total energy usage, the calculation must determine the energy consumed during pre-heating, cooking, and idling modes.

The algorithm is based upon the methodology utilized by the Food Service Technology Center and ENERGY STAR. For both the baseline and the efficient case, the following calculation is used to determine the energy usage.

$$NG\ Usage = Days\ \times\ (Daily\ Preheat + Daily\ Idle\ + Daily\ Cooking\ )$$

where,

NG Usage	= the amount of natural gas used by the steam cooker annually in Btu/year
Days	= the number of days per year the steam cooker is in use
Daily Preheat	= the amount of natural gas used to preheat the steam cooker daily in Btu/day
Daily Idle	= the amount of natural gas used daily when the steam cooker is in idle mode in Btu/day
Daily Cooking	= the amount of natural gas used daily when the steam cooker is cooking in Btu/day

The *"Daily Idle"* energy is calculated using the following equation:

$$Daily\ Idle = Actual\ Idling + Residual\ Idling$$

where,

Actual Idling	= energy consumed when unit is actually idling in Btu/day
Residual Idling	= energy consumed in manual mode during idling in Btu/day

The baseline steamers operate in manual mode 90% of the time. That means that the operator has control of the unit, and the steamer will typically be maintained at a constant steam mode, using energy equivalent to when cooking. During that time, "idle" energy rate is equal to full-load energy rate. ENERGY STAR units are typically controlled by an integral timer.

The *"Actual Idling"* energy is calculated using the following equation:

$$Actual\ Idling = (1 - \%Manual\ Mode) \times Idle\ Rate \times Idling\ Time$$

where,

%Manual Mode	=Percentage of time unit is injecting steam in the cavity but is not actually cooking
Idle Rate	= Idling energy rate in Btu/hr
Idling Time	= Time unit is in idle mode in hours

The *"Idling Time"* is determined using the following equation:

$$Idling\ Time = Total\ Hours\ of\ Operation - Preheat\ time - \frac{Food\ Cooked\ per\ Day}{Production\ Capacity}$$

where,

Total Hours of Operation	= Total hours unit is operation in hours
Preheat time	= time it takes to preheat the unit to operating temperature in hours
Food cooked per day	= amount of food cooked by unit per day in lbs/day
Production capacity	= the average load capacity of unit to cook food in lbs/hr.

The expression "$\frac{Food\ Cooked\ per\ Day}{Production\ Capacity}$" calculates the actual cooking time.

The other portion of the *Daily Idling* use is the *Residual Idling*. This is the amount of energy the unit is on manual mode and continually providing steam without the need for cooking. The expression to calculate this is as follows:

$$Residual\ Idling = \%Manual\ Mode \times \frac{Production\ Capacity \times ASTM\ Energy\ to\ Food\ Rate}{Efficiency} \times\ Idling\ Time$$

where,

ASTM Energy to Food Rate	= rate at which energy is transferred to food in Btu/lb
Efficiency	= efficiency of the unit

The expression, "$\frac{Production\ Capacity \times ASTM\ Energy\ to\ Food\ Rate}{Efficiency}$," in the "*Residual Idling"* equation calculates the cooking rate in Btu/hr. During manual mode, the unit will provide steam at the cooking rate.

The daily cooking energy is calculated as follows:

$$Daily\ Cooking = \frac{Food\ Cooked\ per\ Day \times ASTM\ Energy\ to\ Food\ Rate}{Efficiency}$$

where,

Daily Cooking= the amount of natural gas used when the unit is cooking in Btu/day. The savings is then calculated from the difference between the baseline and efficient cases.

$$NG_{savings} = (NG\ Usage_{baseline}\ - NG\ Usage_{ENERGY\ STAR}) \times \frac{1m^3}{35{,}738Btu}$$

where,

$NG_{savings}$	= annual reduction in natural gas consumption in m³/year
$NG\ Usage_{baseline}$	= annual energy usage of a conventional steamer in Btu/year
$NG\ Usage_{ENERGY\ STAR}$	= annual energy usage for an ENERGY STAR steamer in Btu/year

WATER SAVINGS ALGORITHM

There are also water savings associated with this measure. They are calculated according to this formula:

$$Water\ Saved = Days\ \times Total\ Hours\ of\ Operation \times (Water\ Use_{baseline} - Water\ Use_{ENERGY\ STAR})$$

where,

Total Hours of Operation = the total hours unit is operating per day

Water Use = the water use of the unit in liters per hour

ASSUMPTIONS

The assumptions used to calculate natural gas savings are shown in Table 3.

Table 3. Assumptions

Parameter	Baseline	High Efficiency	Source
Food Service Days per Year	312		Common assumptions table
Operation Time (hours)	12		[7] [8]
Preheat Time (hours)	0.17		[9]
Preheat Energy (Btu/h)	20,000	9,000	[7]
Idle Rate (Btu/hr)	15,000	2,921	[7]
Production Capacity (lbs/hr)	140	125	[7]
Food Cooked per Day (lbs/day)	100	100	[7]
Percent of Time in Manual Mode	0.9	0	[7]
ASTM Energy to Food Rate (Btu/pound)	105		[7], [10], [11]
Efficiency	15% [7]	38% [5]	[7], [5]
Water Use(liters/hr)	136 liters/hr (36 gals/hr)	45.4 liters/hr (12 gals/hr)	[7]

SAVINGS CALCULATION EXAMPLE

The example below illustrates how the savings values are determined for an ENERGY STAR Steam Cooker with typical hours of usage.

Daily Baseline Steamer Usage:

$$Daily\ Preheat = 20{,}000\frac{Btu}{day}$$

Daily Idle:

$$Daily\ Idle = Actual\ Idling + Residual\ Idling$$

First we need to determine actual idling time to determine actual and residual idling energy.

$$Idling\ Time = 12\ hrs - 0.17\ hrs - \frac{100\frac{lbs}{day}}{140\ \frac{lbs}{hr}} = 11.1\ \frac{hrs}{day}$$

Actual Idling:

$$Actual\ Idling = (1 - 90\%) \times 15{,}000\frac{Btu}{hr} \times 11.1\frac{hrs}{day} = 16{,}674\frac{Btu}{day}$$

Residual Idling:

$$Residual\ Idling = 90\% \times \frac{140\frac{lbs}{hr} \times 105\frac{Btu}{lb}}{15\%} \times 11.1\frac{hrs}{day} = 980{,}406\frac{Btu}{day}$$

Daily Idle Energy:

$$Daily\ Idle = 16{,}674\frac{Btu}{day} + 980{,}406\frac{Btu}{day} = 997{,}080\frac{Btu}{day}$$

Daily Cooking:

$$Daily\ Cooking = \frac{100\frac{lb}{day}\ \times\ 105\frac{Btu}{lb}}{15\%} = 70{,}000\frac{Btu}{day}$$

Total Daily Usage:

$$NG\ Usage = \left(20{,}000\frac{Btu}{day} + 997{,}080\frac{Btu}{day} + 70{,}000\frac{Btu}{day}\right) = 1{,}087{,}080\frac{Btu}{day}$$

Total Annual Usage:

$$NG\ Usage_{Baseline} = 1{,}087{,}080\frac{Btu}{day} \times 312\frac{days}{year} = 339{,}168{,}826\frac{Btu}{year}$$

Daily ENGERY STAR Usage:

$$Daily\ Preheat = 9{,}000\frac{Btu}{day}$$

Daily Idle:

$$Daily\ Idle = Actual\ Idling + Residual\ Idling$$

First we need to determine actual idling time to determine actual and residual idling energy.

$$Idling\ Time = 12\ hrs - 0.17\ hrs - \frac{100\,\frac{lbs}{day}}{125\,\frac{lbs}{hr}} = 11.03\,\frac{hrs}{day}$$

Actual Idling:

$$Actual\ Idling = (1 - 0\%) \times 2{,}921\,\frac{Btu}{hr} \times 11.03\,\frac{hrs}{day} = 32{,}219\,\frac{Btu}{day}$$

Residual Idling:

$$Residual\ Idling = 0\% \times \frac{125\,\frac{lbs}{hr} \times 105\,\frac{Btu}{lb}}{38\%} \times 11.03\,\frac{hrs}{day} = 0\,\frac{Btu}{day}$$

Daily idle energy:

$$Daily\ Idle = 32{,}219\,\frac{Btu}{day} + 0\,\frac{Btu}{day} = 32{,}219\,\frac{Btu}{day}$$

Daily cooking:

$$Daily\ Cooking = \frac{100\,\frac{lb}{day}\ \times\ 105\,\frac{Btu}{lb}}{38\%} = 27{,}632\,\frac{Btu}{day}$$

Total Daily Usage:

$$NG\ Daily\ Usage = \left(9{,}000\,\frac{Btu}{day} + 32{,}219\,\frac{Btu}{day} + 27{,}632\,\frac{Btu}{day}\right) = 68{,}850\,\frac{Btu}{day}$$

Total Annual Usage:

$$NG\ Usage_{ENERGY\ STAR} = 68{,}850\,\frac{Btu}{day} \times 312\,\frac{days}{year} = 21{,}481{,}265\,\frac{Btu}{year}$$

Natural Gas Savings:

$$NG_{savings} = \left(339{,}168{,}826\,\frac{Btu}{year} - 21{,}481{,}265\,\frac{Btu}{year}\right) \times \frac{1}{35{,}738\,\frac{Btu}{m^3}} = 8{,}889\ m^3$$

Water Savings:

$$Water\ Saved = 312\,\frac{days}{year}\ \times\ 12\,\frac{hours}{day}\ \times\ \left(136.3\,\frac{liters}{hour} - 45.4\,\frac{liters}{hour}\right) = 340{,}142\,\frac{liters}{year}$$

Uses and Exclusions

To qualify for this measure the steam cooker must be utilized for food preparation or processing with natural gas as its energy source and be ENERGY STAR rated. The measure is limited to steam cookers that have either a connectionless or steam-generator design.

MEASURE LIFE

The measure life attributed to steam cookers is 12 years. [7]

INCREMENTAL COST

Table 4 presents the measure incremental cost. The average incremental cost for ENERGY STAR rated 6-pan, floor standing steam cookers, compared with standard efficiency steam cookers of the same type and capacity is listed.

Table 4. Incremental Cost [12]

Measure Category	Incremental Cost ($)
New Construction/Time of Natural Replacement	$3,880

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Commercial – Incremental Heat Recovery Ventilation (HRV) (55% Effectiveness Baseline) – New Construction/Time of Natural Replacement

<table>
<tr><th colspan="2">Version Date and Revision History</th></tr>
<tr><td>Version</td><td>2.2 (minor update)</td></tr>
<tr><td>OEB Filing Date</td><td>December 20, 2019</td></tr>
<tr><td>OEB Approval Date</td><td>January 9, 2020</td></tr>
<tr><td colspan="2">Commercial → Space Heating → Incremental Heat Recovery Ventilation → New Construction/Time of Natural Replacement</td></tr>
</table>

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

Table 1. Measure Key Data

<table>
<tr><th>Parameter</th><th colspan="4">Definition</th></tr>
<tr><td>Measure Category</td><td colspan="4">New construction (NC) where HRV is required by Ontario Building Code
Time of Natural Replacement (TNR)</td></tr>
<tr><td>Baseline Technology</td><td colspan="4">HRV with Minimum 55% Sensible Heat Recovery Effectiveness as per Ontario Building Code 2017, Supplement SB-10 January 1, 2017</td></tr>
<tr><td rowspan="3">Efficient Technology</td><td colspan="4">HRV with Minimum 65% Sensible Heat Recovery Effectiveness[1] at 32°F</td></tr>
<tr><td colspan="4">HRV with Minimum 75% Sensible Heat Recovery Effectiveness at 32°F</td></tr>
<tr><td colspan="4">HRV with Minimum 85% Sensible Heat Recovery Effectiveness at 32°F</td></tr>
<tr><td>Market Type</td><td colspan="4">Commercial</td></tr>
<tr><th>Measure Efficiency</th><th>Building Type</th><th>Gas Savings Rate (m^3/working CFM), ε_{EE} 1</th><th>Group</th><th>Average Group Gas Savings (m^3/working CFM)</th></tr>
<tr><td rowspan="2">Annual Natural Gas Savings Rate with a HRV with Minimum 65% Sensible Heat Recovery</td><td>Multi-Family, Health Care and Nursing Homes</td><td>0.70</td><td>High Use</td><td>0.70</td></tr>
<tr><td>Hotels</td><td>0.50</td><td></td><td></td></tr>
</table>

[1] This measure is eligible for commercial buildings where Energy Star does not apply (the applicable OBC code is Supplementary Standard SB-10).

Parameter	Definition			
Effectiveness at 32°F, ε_{EE} 1 (m³/ working CFM)	Restaurant	0.36	Medium Use	0.39
	Retail	0.30		
	Office	0.27	Low Use	0.25
	Warehouse	0.25		
	School	0.22		
Measure Efficiency	**Building Type**	**Gas Savings Rate (m³/CFM), ε_{EE} 2**	**Group**	**Average Group Gas Savings (m³/working CFM)**
Annual Natural Gas Savings Rate with a HRV with Minimum 75% Sensible Heat Recovery Effectiveness at 32°F, ε_{EE} 2 (m³/ working CFM)	Multi-Family, Health Care and Nursing Homes	1.39	High Use	1.39
	Hotels	1.00	Medium Use	0.78
	Restaurant	0.72		
	Retail	0.61		
	Office	0.53	Low Use	0.50
	Warehouse	0.51		
	School	0.45		
Measure Efficiency	**Building Type**	**Gas Savings Rate (m³/working CFM), ε_{EE} 3**	**Group**	**Average Group Gas Savings (m³/working CFM)**
Annual Natural Gas Savings Rate with a HRV with Minimum 85% Sensible Heat Recovery Effectiveness at 32°F, ε_{EE} 3 (m³/working CFM)	Multi-Family, Health Care and Nursing Homes	2.09	High Use	2.09
	Hotels	1.49	Medium Use	1.16
	Restaurant	1.08		
	Retail	0.91		
	Office	0.80	Low Use	0.74
	Warehouse	0.76		
	School	0.67		
Measure Life	14 Years			
	$1.00 per CFM at ε_{EE} 1			

Parameter	Definition
Incremental Cost ($ CAD)	$2.00 per CFM at ε_{EE} 2
	$3.00 per CFM at ε_{EE}3
Restrictions	This measure is not eligible in areas where: • The HRV unit has an effectiveness of less than 65%, • 100% of the exhaust air must be evacuated from the building in order to avoid cross contamination, and therefore 100% fresh air is required such as described in OBC section 1.1.1.4. • No recirculation is allowed by codes or standards. For instance, any limitations as per 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 DCV or scheduled setbacks are used during operated hours[2]

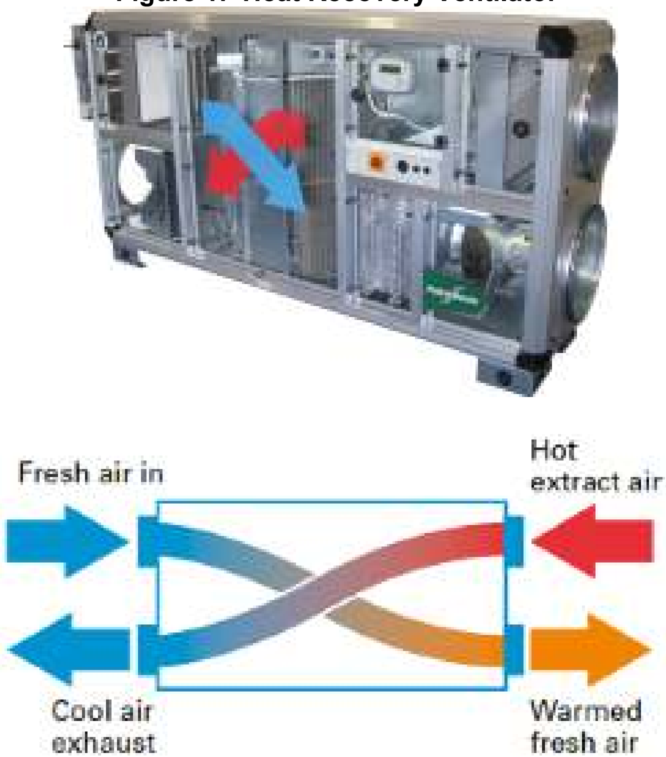
OVERVIEW

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.

[2] These configurations require that projects be submitted as custom measures.

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 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 2017 (SB-10) and as shown in Table 2. [3] [4]

[3] 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 55% 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) [5].

Table 3. Efficient Technology for Heat Recovery Ventilators

Type	Efficiency
HRV $\varepsilon_{EE}1$	HRV with Minimum 65% Sensible Heat Recovery Effectiveness at 32°F at working airflow (CFM)
HRV $\varepsilon_{EE}2$	HRV with Minimum 75% Sensible Heat Recovery Effectiveness at 32°F at working airflow (CFM)
HRV $\varepsilon_{EE}3$	HRV with Minimum 85% Sensible Heat Recovery Effectiveness at 32°F at working airflow (CFM)

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.

$$hrs = hrs_{hs} \times \frac{weeklyhrs}{168\frac{hrs}{week}}$$

and,

$$NG\ Savings = hrs \times \frac{60min}{hr} \times \rho \times \frac{(\varepsilon_{EE} - 55\%)}{\eta} \times \frac{C_p}{35{,}738\frac{Btu}{m^3}} \times (T_3 - T_1) \times (1 - \frac{DF}{100\%})$$

Where,

hrs	= Annual hours that the HRV is expected to be in use (hours/year)
hrs_{hs}	= 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 efficiency 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)
$35{,}738\frac{Btu}{m^3}$	= 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 (%)

ASSUMPTIONS

Table 4 shows the list of assumptions used in the algorithms sections.

Table 4. Assumptions

Variable	Definition	Value	Source
hrs_{hs}	Hours in Heating Season, 55°F Balance Temperature[4]	5,293 hrs	Common assumptions table
$\varepsilon_{EE}1$	Minimum sensible effectiveness	65%	
$\varepsilon_{EE}2$	Minimum sensible effectiveness	75%	
$\varepsilon_{EE}3$	Minimum sensible effectiveness	85%	
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	5%[5]	[7] [8] [9] [10]
T1	Average temperature of outside (supply) air during the heating season (OA temperature heating system enabled)	34.8°F	Common assumptions table
T3	Average temperature of inlet exhaust air (Space Temperature Setpoint)	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 [10]

Building Type	Hours of Operation per Week
Multi-Family	168
Health Care	168
Nursing Home	168

[4] 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.

[5] 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
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 an HRV unit working at 500 CFM with a sensible effectiveness of 75%. In this case the $\varepsilon_{EE}2$ is applicable.

$$hrs = 5{,}293\frac{hrs}{year} \times \frac{168\,\frac{hrs}{week}}{168\,\frac{hrs}{week}} = 5{,}293\frac{hrs}{year}$$

and,

$$NG\ Savings = 5{,}293\frac{hrs}{year} \times \frac{60min}{hr} \times 0.0741\frac{lb_m}{ft^3} \times \frac{75\% - 55\%}{80\%} \times \frac{0.240\,\frac{Btu}{lb_m - °F}}{35{,}738\,\frac{Btu}{m^3}}$$

$$\times\,(72°F - 34.8°F) \times \left(1 - \frac{5\%}{100\%}\right) = 1.39\frac{m^3}{CFM \cdot year}$$

Therefore,

$$NG\ Savings = 500CFM \times 1.39\frac{m^3}{CFM \cdot year} = 695\ \frac{m^3}{year}$$

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[6] [12].

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COMMERCIAL – HEAT RECOVERY VENTILATION (HRV) (NO HRV BASELINE) – NEW CONSTRUCTION/RETROFIT

Version Date and Revision History	
Version	2.2 (minor update)
OEB Filing Date	January 8, 2020
OEB Approval Date	January 9, 2020
Commercial→ Space Heating → Heat Recovery Ventilation→ New Construction/Retrofit	

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

Table 1. Measure Key Data

Parameter	Definition			
Measure Category	New construction (NC) where no HRV is required by Ontario Building Code Retrofit (R)			
Baseline Technology	No HRV			
Efficient Technology	HRV with minimum 55% Sensible Heat Recovery Effectiveness[1] at 32°F			
	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			
	Building Type	**Gas Savings Rate (m^3/working CFM), ε_{EE} 1**	**Group**	**Average Group Gas Savings (m^3/working CFM) ε_{EE} 1**

[1] This measure is eligible for commercial buildings where Energy Star does not apply (the applicable OBC code is Supplementary Standard SB-10).

Some commercial buildings are required by SB-10 to have Energy Recovery Ventilation or Heat Recovery Ventilation with a minimum of 55% sensible effectiveness. For buildings with no code requirement, systems that bring efficiency up to code level (55% sensible effectiveness) are eligible.

Parameter	Definition			
Annual Gas Savings Rate with a Minimum HRV Sensible Heat Recovery Effectiveness of 55%, ε_{EE} 1 (m³/ working CFM)	Multi-Family, Health Care and Nursing Homes	3.84	High Use	3.84
	Hotels	2.74	Medium Use	2.13
	Restaurant	1.99		
	Retail	1.67		
	Office	1.46	Low Use	1.36
	Warehouse	1.39		
	School	1.23		
Annual Gas Savings Rate with a Minimum HRV Sensible Heat Recovery Effectiveness of 65%, ε_{EE} 2 (m³/ working CFM)	**Building Type**	**Gas Savings Rate (m³/working CFM),** ε_{EE} 2	**Group**	**Average Group Gas Savings (m³/working CFM)** ε_{EE} 2
	Multi-Family, Health Care and Nursing Homes	4.54	High Use	4. 54
	Hotels	3.24	Medium Use	2.52
	Restaurant	2.35		
	Retail	1.97		
	Office	1.73	Low Use	1.61
	Warehouse	1.65		
	School	1.46		
Annual Gas Savings Rate with a Minimum HRV Sensible Heat Recovery Effectiveness of 75%, ε_{EE} 3 (m³/ working CFM)	**Building Type**	**Gas Savings Rate (m³/working CFM),** ε_{EE} 3	**Group**	**Average Group Gas Savings (m³/working CFM)** ε_{EE} 3
	Multi-Family, Health Care and Nursing Homes	5.24	High Use	5.24
	Hotels	3.74	Medium Use	2.91
	Restaurant	2.71		
	Retail	2.28		
	Office	1.99	Low Use	1.86

Parameter	Definition			
	Warehouse	1.90		
	School	1.68		
Annual Gas Savings Rate with a Minimum HRV Sensible Heat Recovery Effectiveness of 85%, ε_{EE} 4 (m³/ working CFM)	**Building Type**	**Gas Savings Rate (m³/working CFM),** ε_{EE} 4	**Group**	**Average Group Gas Savings (m³/working CFM)** ε_{EE} 4
	Multi-Family, Health Care and Nursing Homes	5.93	High Use	5.93
	Hotels	4.24	Medium Use	3.30
	Restaurant	3.07		
	Retail	2.58		
	Office	2.26	Low Use	2.11
	Warehouse	2.15		
	School	1.91		
Annual Electric Impact[2] (kWh/ working CFM)	**Building Type**	**Electric Impact Rate (kWh/working CFM)**	**Group**	**Average Group Electric Impact (kWh/working CFM)**
	Multi-Family, Health Care and Nursing Homes	-4.39	High Use	-4.39
	Hotels	-3.14	Medium Use	-2.44
	Restaurant	-2.28		
	Retail	-1.91		
	Office	-1.67	Low Use	-1.56
	Warehouse	-1.60		
	School	-1.41		
Measure Life	14 Years			
First Incremental Cost ($ CAD) ε_{EE} 1	Integrated HRV		Standalone or Bolt-On HRV	
	$5.35/CFM		$8.28/CFM	

[2] The electric impact does not apply when the HRV unit is installed as part of an integrated HVAC package.

Parameter	Definition	
Incremental Cost ($ CAD)	$5.35 + $1.00 per CFM at $\boldsymbol{\varepsilon_{EE}}$ **2**	$8.28 +$1.00 per CFM at $\boldsymbol{\varepsilon_{EE}}$ **2**
	$5.35 + $2.00 per CFM at ε_{EE} 3	$8.28 +$2.00 per CFM atε_{EE} 3
	$5.35 + $3.00 per CFM at ε_{EE}4	$8.28 +$3.00 per CFM atε_{EE}4

Restrictions	This measure is not eligible in areas where: • HRV is required by building code, • 100% of the exhaust air must be evacuated from the building in order to avoid cross contamination, and therefore 100% fresh air is required such as described in OBC section 1.1.1.4. • No recirculation is allowed by codes or standards. For instance, any limitations as per 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 DCV or scheduled setbacks are used during operated hours[3]

OVERVIEW

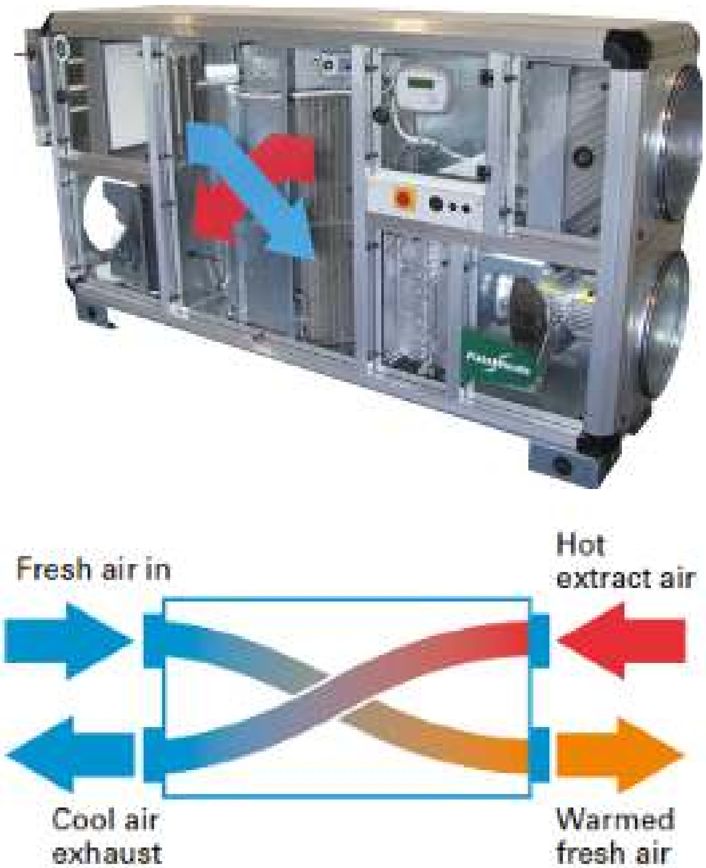
A heat recovery ventilator (HRV) refers to heat exchanger equipment that is designed to transfer sensible heat from the building exhaust air to the outside supply air. The temperature of the outside supply air is raised by the heat transferred from the exhaust air stream within the heat exchanger. By 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].

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 compensates for the additional static pressure.

[3] These configurations require that projects be submitted as custom measures.

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[4]



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].

[4] From http://www.nfan.co.uk/what_are_heat_recovery_systems, 12/15/2014

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 a sensible effectiveness of 55%, 65%, 75%, and 85% 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	Efficiency
HRV $\varepsilon_{EE}1$	Minimum 55% Sensible Heat Recovery Effectiveness at 32°F at working airflow (CFM)
HRV $\varepsilon_{EE}2$	Minimum 65% Sensible Heat Recovery Effectiveness at 32°F at working airflow (CFM)
HRV $\varepsilon_{EE}3$	Minimum 75% with Sensible Heat Recovery Effectiveness at 32°F at working airflow (CFM)
HRV $\varepsilon_{EE}4$	Minimum 85% Sensible Heat Recovery Effectiveness at 32°F at working airflow (CFM)

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.

$$hrs = hrs_{hs} \times \frac{weeklyhrs}{168\frac{hrs}{week}}$$

and,

$$NG\ Savings = hrs \times \frac{60min}{hr} \times \rho \times \frac{\varepsilon_{EE}}{\eta} \times \frac{C_p}{35{,}738\frac{Btu}{m^3}} \times (T_3 - T_1) \times (1 - \frac{DF}{100\%})$$

Where,

hrs	= Annual hours that the HRV is expected to be in use (hours/year)
hrs_{hs}	= 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)
ε_{EE}	= Sensible effectiveness of the high efficiency HRV (%)[5]
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)
T_1	= Average outside temperature during heating hours (°F)
DF	= Defrost control de-rating factor (%)

[5] Note, for this analysis the rated effectiveness is being used as an average effectiveness.

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)

Assumptions

Table 4 shows the list of assumptions used in the algorithms sections.

Table 4. Assumptions

Variable	Definition	Value	Source
hrs_{hs}	Hours in Heating Season, 55°F Balance Temperature[6]	5,293 hrs	Common assumptions table
$\varepsilon_{EE}1$	Sensible effectiveness	55%	
$\varepsilon_{EE}2$	Sensible effectiveness	65%	
$\varepsilon_{EE}3$	Sensible effectiveness	75%	
$\varepsilon_{EE}4$	Sensible effectiveness	85%	
ρ	Density of the exhaust air	0.0741 lb_m/ft^3	Common assumptions table

[6] 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
η	Commercial Heating System Efficiency	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 (OA temperature heating system enabled)	34.8°F	Common assumptions table
T_3	Average temperature of inlet exhaust air (Space temperature setpoint)	72°F	Common assumptions table
Fan Efficiency	Assumed fan efficiency	0.83 W/CFM	[3]
DF	Defrost control de-rating factor	5%[7]	[1], [2], [6] , [7]

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
School	54

[7] 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%.

EXAMPLE

For this example, it is assumed that a new health care facility installs an HRV unit working at 500 CFM with a total effectiveness of 65%. In this case the $\varepsilon_{EE}2$ is applicable.

$$hrs = 5{,}293 hrs \times \frac{168\frac{hrs}{week}}{168\frac{hrs}{week}} = 5{,}293\frac{hrs}{year}$$

and,

$$NG\ Savings = 5{,}293\frac{hrs}{year} \times \frac{60min}{hr} \times 0.0741\frac{lb_m}{ft^3} \times \frac{65\%}{80\%} \times \frac{0.240\frac{Btu}{lb_m - °R}}{35{,}738\frac{Btu}{m^3}}$$
$$\times (72°F - 34.8°F) \times \left(1 - \frac{5\%}{100\%}\right) = 4.54\frac{m^3}{CFM \cdot year}$$

Therefore,

$$NG\ Savings = 500CFM \times 4.54\frac{m^3}{CFM \cdot year} = 2{,}270\frac{m^3}{year}$$

The electrical penalty can be calculated as the following.

$$kWh\ penalty = 500\ CFM \times -0.83\frac{W}{CFM} \times 5{,}293\ \frac{hrs}{year} \times \frac{1kW}{1000W} = -2{,}197\ \frac{kWh}{year}$$

USES AND EXCLUSIONS

- 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 and 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 [9].

Incremental Cost

Table 6 demonstrates the incremental cost of heat recovery ventilators. ERS used RSMeans corroborated with manufacturer data to determine the first costs for integrated systems at $5.66/CFM and for standalone or bolt-on units at $8.76/CFM. These costs values are also supported by the 2010 Nexant review of the measure. 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 [10].

The first costs represent the incremental costs between no HRV and 55% efficient units. Additional incremental costs between high efficiency units are $1.00 per CFM at 65%, $2.00 at 75%, and $3.00 at 85% efficiency[8] [11].

Table 6. Incremental Cost[9] [6] [10]

Measure Type	Cost
First Cost Integrated units	$5.35/CFM
First Cost Bolted-on systems	$8.28/CFM

References

[1] Natural Resources Canada, "Heat Recovery Ventilators," 2 2012. [Online]. Available: http://oee.nrcan.gc.ca/sites/oee.nrcan.gc.ca/files/files/pdf/publications/HRV_EN.pdf . [Accessed 11 2013].

[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] ENERGY STAR, "Technical Specifications for Residential Heat Reocovery Ventilators and Energy Recovery Ventilators (H/ERVs) Version 2.0", 2015 [Online].

8 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.

9 Converted to CAD based on Daily Currency Converted for Bank of Canada, as of 11/30/2016. (http://www.bankofcanada.ca/rates/exchange/daily-converter/)

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[11] Manufacturer, Interviewee, *ERV/HRV Incremental costs of installed equipment..* [Interview]. Nov 2015.

Commercial – High Efficiency Condensing Furnace – New Construction/Time of Natural Replacement

Version Date and Revision History	
Version	2
OEB Filing Date	December 20, 2019
OEB Approval Date	January 9, 2020
Commercial → Space Heating → High Efficiency Condensing Furnace → New Construction /Time of Natural Replacement	

Table 1 below provides a summary of the key measure parameters and savings coefficient.

Table 1. Measure Key Data

Parameter	Definitions	
Measure Category	New Construction (NC) Time of Natural Replacement (TNR)	
Baseline Technology	95% AFUE	
Efficient Technology	97% AFUE	
Market Type	Commercial, Multiresidential	
Annual Natural Gas Savings Rate (m^3/kBtu/hr)	New Construction	0.884 m^3 per kBtu/hr input capacity
	Time of Natural Replacement	1.178 m^3 per kBTU input capacity
Measure Life	18 years	
Incremental Cost ($ CAD)	$188	
Restriction	Must have a rated efficiency of at least 97% 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 97% 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 gases. 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 and using single phase electric current to have at least a 95% AFUE [2]. The baseline technology is the minimum efficiency required by the regulations established December 12, 2019.

Table 2. Baseline Technology AFUE

Type	AFUE
Gas Condensing Furnace	95%

EFFICIENT TECHNOLOGY

The efficient technology is a condensing furnace with an AFUE rating equal to, or higher than 97%.

Table 3. Efficient Technology AFUE

Type	AFUE
Gas Condensing Furnace	97%

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.

Canada's Energy Efficiency Regulations now require that new residential furnace fans have a Fan Efficiency Rating (FER), rated in Watts/cfm [3]. In order to comply with the regulation, it will, in most cases, require a change from a permanent split capacitor (PSC) motor to an electronically commutated motor (ECM). 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].

No water consumption or electric impacts are associated with this measure.

NATURAL GAS SAVINGS ALGORITHMS

The measure gas savings are calculated using a common assumption for the equivalent full load hours (EFLH) 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 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 (m³/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 m³/hr, common assumptions table
$AFUE_{base}$	= Baseline equipment thermal efficiency (%), see Table 2

[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 savings by 5% if output capacity is the basis.

$AFUE_{EE}$ = Efficient equipment thermal efficiency (%), see Table 3

ASSUMPTIONS

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

Table 4. Assumptions

Variable	Definition	Inputs		Source
$EFLH$	Equivalent full load hours	NC	1,500 hours	Common assumptions table
		TNR	2,000 hours	

*

SAVINGS CALCULATION EXAMPLE

The example below shows how to calculate gas savings achieved from installing one condensing furnace in a newly constructed building with a rated input of 110 kBtu/h from the savings factor in Table 1.

$$NG\ Savings\ Factor = \frac{1{,}500 hrs}{35.738 \frac{kBtu}{m^3}} \times \left(\frac{97\%}{95\%} - 1\right) = \frac{0.884\ (m^3/yr)}{\frac{kBtu}{hr}}$$

And,

$$Annual\ NG\ savings = \frac{0.884 \left(\frac{m^3}{yr}\right)}{\frac{kBtu}{hr}} \times 110 \frac{kBtu}{hr} = 97\ m^3$$

USES AND EXCLUSIONS

To qualify for this measure the condensing furnaces must be gas-fired, have an AFUE of at least 97% 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 $188[2] based on the average difference in incremental cost between 95 AFUE and 97 AFUE residential furnaces. [9]

References

[1] ASHRAE, "AHRI Directory of Certified Product Performance for Furnaces," [Online]. Available: (http://www.ahridirectory.org/ahridirectory/pages/rwh/defaultSearch.aspx).

[2] Government of Canada, "Regulations Amending the Energy Efficiency Regulations, 2016 (Amendment 15)," [Online]. Available: http://www.gazette.gc.ca/rp-pr/p2/2019/2019-06-12/html/sor-dors164-eng.html. [Accessed October 2019].

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[8] ASHRAE, ASHRAE Handbook - HVAC Applications I-P Edition, Atlanta: ASHRAE, 2008, p. 32.8.

[9] U.S. Department of Energy, "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces," 2015.

[2] Converted from 2013 USD to 2019 USD using the consumer price index (CPI) and then to 2019 CAD based on a 12 month (November 2018 to October to 2019) weighted average of monthly exchange rates from the Bank of Canada (https://www.bankofcanada.ca/rates/exchange/monthly-exchange-rates)

COMMERCIAL – HIGH EFFICIENCY UNDER-FIRED BROILER – NEW CONSTRUCTION/TIME OF NATURAL REPLACEMENT

Version Date and Revision History	
Version	1
OEB Filing Date	Dec 21, 2016
OEB Approval Date	
Commercial →Food Service → High Efficiency Underfired Broilers →New Construction/Time of Natural Replacement	

Table 1 provides a summary of the key measure parameters.

Table 1. Measure Key Data

Parameter	Definitions			
Measure Category	New Construction (NC) Time of Natural Replacement (TNR)			
Baseline Technology	A conventional under-fired broiler, see table 2			
Efficient Technology	A high-efficiency under-fired broiler, see table 3			
Market type	Commercial			
Annual Natural Gas Savings[1] (m^3)	Three-foot 2,511 m^3	Four-foot 3,347 m^3	Five-foot 4,184 m^3	Six-foot 5,021 m^3
Measure Life	12 years			
Incremental Cost [1] ($ CAD)	$1,900			
Restrictions	Restricted to commercial/institutional food service broiler using natural gas, 3-feet or larger			

OVERVIEW

Under-fired broilers (often referred to as "charbroilers") are used in commercial and institutional food service to do a range of tasks that range from melting cheese to cooking large cuts of meat. Under-fired broilers come in different sizes ranging from three-foot to six-foot. High efficiency broilers utilize improved radiant design and burner control to allow lower firing and gas input levels during both preheat and cooking modes.

The basic design of an under-fired broiler is a suspended metal grill with heat applied from below. Due to their preheat times (up to 30 minutes), broilers are allowed to idle

[1] Broiler sizes are nominal and may vary ½-foot +/- within each category.

during the day. They usually idle at full input so that they are ready to cook when they are needed. It is possible for operators to manually turn down the input, when not actively cooking, but our research revealed no automatic controls that modulate the broilers.

APPLICATION

Under-fired broilers consume natural gas when they are pre-heating and cooking. This measure provides incentives for installing a high efficiency under-fired broilers in commercial or institutional cooking settings. An under fired broiler is designed to cook food on a metal grill with the heat source below the food. The broiler is typically left on during all operating hours so that the broiler is instantly available for cooking. [1]

BASELINE TECHNOLOGY

The baseline technology is a conventional under-fired broiler.

Table 2. Baseline Technology [2]

Type	Inputs
Conventional under-fired broiler	Under-fired broiler, with pre-heat energy and a cooking energy rate at or below the following standard. • Three foot broiler: pre-heat of 48,000 Btu or less and a cooking energy rate of 96,000 Btu/hr or less • Four foot broiler: pre-heat between 48,001 and 64,000 Btu and a cooking energy rate between 96,001 and 128,000 Btu/hr • Five foot broiler: pre-heat between 64,001 and 80,000 Btu and a cooking energy rate between 128,001 and 160,000 Btu/hr • Six foot broiler: pre-heat between 80,001 and 96,000 Btu and a cooking energy rate between 160,001 and 192,000 Btu/hr

EFFICIENT TECHNOLOGY

The efficient technology is a high-efficiency under-fired broiler designed to operate at lower firing and input levels.

Table 3. Efficient Technology [2]

Type	Requirement
High Efficiency Under-Fired broiler	Under-fired broiler, with pre-heat energy and a cooking energy rate at or below the following standard. • Three foot broiler: pre-heat of 40,500 Btu or less and a cooking energy rate of 72,000 Btu/hr or less

Type	Requirement
	• Four foot broiler: pre-heat between 40,501and 54,000 Btu and a cooking energy rate between 72,001 and 96,000 Btu/hr • Five foot broiler: pre-heat between 54,001 and 67,500 Btu and a cooking energy rate between 96,001 and 120,000 Btu/hr • Six foot broiler: pre-heat between 67,501 and 81,000 Btu and a cooking energy rate between 120,001 and 144,000 Btu/hr

ENERGY IMPACTS

The primary energy impact associated with the installation of a high efficiency under-fired broiler is a reduction in natural gas required during the pre-heat and cook/idle modes. According to the Food Service Technology Center, broilers typically operate continuously with operators leaving the equipment at full burner output, regardless of cooking status. The energy savings is achieved through better radiant design and better burner control which allow lower gas input rates during preheating and idling/cooking activities. There are no electric impacts for this measure.

NATURAL GAS SAVINGS ALGORITHM

The algorithm to determine energy savings is calculated determining and comparing the annual energy usage for a conventional and a high efficiency under-fired broiler. To determine total energy usage, the calculation uses the energy used to pre-heat the broiler and the energy used when cooking.

The savings algorithm is based upon the methodology developed by the Food Service Technology Center. The following calculation determines the energy usage of a conventional and high efficiency under-fired broiler:

$$NG\ Usage = Days\ \times\ (Daily\ Preheat + Full\ Burn\ Load\ \times\ Cook\ Time)$$

where,

NG Usage	= the amount of natural gas used by the broiler annually in Btu/year
Days	= the number of days per year the broiler is in use
Daily Preheat	= the amount of natural gas used to preheat the broiler daily in Btu/day
Full Burn Load	= the rate of natural gas used when the unit is in cooking mode in Btu/hr
Cook Time	= the number of hours per day that the unit is cooking

The savings is then calculated from the difference between the baseline and efficient cases.

$$NG_{savings} = (NG\ Usage_{baseline} - NG\ Usage_{high\ efficiency}) \times \frac{1m^3}{35{,}738Btu}$$

where,

$NG_{savings}$ = annual reduction in natural gas consumption in m^3/year

$NG\ Usage_{baseline}$ = annual energy usage of a conventional broiler in Btu/year

$NG\ Usage_{high\ efficiency}$ = annual energy usage for a high efficiency broiler in Btu/year

ASSUMPTIONS

The assumptions used to calculate natural gas savings are shown in Table 4.

Table 4. Assumptions

Parameter	Baseline	High Efficiency	Source
Food Service Days per Year	312		Common assumptions table
Cook Time (hours)	12		[3]
Preheat time (hours)	0.33		[3]
Three foot broiler			
Daily Preheat (Btu)	48,000	40,500	[2]
Full Burn Load (Btu/hr)	96,000	72,000	[2]
Four foot broiler			
Daily Preheat (Btu)	64,000	54,000	[2]
Cooking (Btu/hr)	128,000	96,000	[2]
Five foot broiler			
Daily Preheat (Btu)	80,000	67,500	[2]
Cooking (Btu/hr)	160,000	120,000	[2]
Six foot broiler			
Daily Preheat (Btu)	96,000	81,000	[2]
Cooking (Btu/hr)	192,000	144,000	[2]

Savings Calculation Example

The example below illustrates how the deemed savings value is determined for a three foot high efficiency under-fired broiler with typical hours of usage.

$Annual\ Conventional\ Broiler\ Usage$:

$$NG\ Usage = 312\ \times\ \left(48{,}000\ Btu + 96{,}000\ Btuh\ \times\ (12\ hours - 0.33\ hours)\right)$$
$$= 364{,}515{,}840\ Btu$$

$Annual\ High\ Efficiency\ Broiler\ Usage$:

$$NG\ Usage = 312\ \times\ \left(40{,}500\ Btu + 72{,}000\ Btuh\ \times\ (12\ hours - 0.33\ hours)\right)$$
$$= 274{,}790{,}880\ Btu$$

$Natural\ Gas\ Savings$:

$$NG_{savings} = (364{,}515{,}840\ Btu - 274{,}790{,}880\ Btu) \times \frac{1}{35{,}738} = 2{,}511\ m^3$$

Uses and Exclusions

To qualify for this measure, the under-fired broiler must use natural gas as its energy source and meet the following standards:

Table 5. Assumptions [2]

Broiler Size	Criteria
Three foot	• Preheat energy less than 40,500 Btu • Cooking energy rate less than 72,000 Btu/hr
Four foot	• Preheat energy less than 54,000 Btu • Cooking energy rate less than 96,000 Btu/hr
Five foot	• Preheat energy less than 67,500 Btu • Cooking energy rate less than 120,000 Btu/hr
Six foot	• Preheat energy less than 81,000 Btu • Cooking energy rate less than 144,000 Btu/hr

Measure Life

The measure life attributed to high efficiency under-fired broilers is 12 years. [2]

Incremental Cost

Table 6 presents the measure incremental cost.

Table 6. Incremental Cost [4]

Measure Category	Incremental Cost ($)
All categories of broilers	$1,900

The incremental cost is very similar for the broilers regardless of their size. This is likely due to the burner technology being similar for high efficiency models. Cost variability between models is related to additional features.

REFERENCES

[1] Food Service Technology Center, "Commercial Cooking Appliance Technology Assesment," Fisher-Nickel, 2002, p.4-9. [Online]. Available: http://www.fishnick.com/equipment/techassessment/Appliance_Tech_Assessment.pdf. [Accessed July 2014].

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MULTI-RESIDENTIAL – LOW-FLOW SHOWERHEADS – NEW CONSTRUCTION

Version Date and Revision History	
Version	2.2 (minor update)
OEB Filing Date	December 16, 2021
OEB Approval Date	December 16, 2021
Multi-residential/Low-Income → Water Heating →Low-flow showerheads→ New Construction	

Table 1 provides a summary of the key measure parameters and savings values based on the efficient technology.

Table 1. Measure Key Data

Parameter	Definitions	
Measure category	New Construction (NC)	
Baseline technology	2.0 gpm	
Efficient technology	1.5 gpm	
	1.25 gpm	
Market type	Multi-residential	
Annual natural gas savings per showerhead (m^3/yr)	***Efficient Technology***	***Savings***
	1.25 gpm	23.2
	1.5 gpm	15.5
Annual water impact per showerhead (liters/yr)	1.25 gpm	7,775
	1.5 gpm	4,107
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 base case is equal to or less efficient than 2.0 gpm.	

OVERVIEW

In multi-residential households, one of the ways to reduce domestic hot water heating costs is by reducing 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 2.0 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. There is an additional reduction in water consumption associated with this measure.

Natural Gas Savings Algorithm

This algorithm outlines a methodology to determine the energy consumption as a function of a showerhead's rated flowrate. 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 in each household was 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.

$$Single\ family\ savings\ \left(\frac{m^3}{yr.showerhead}\right) = \frac{44\ \frac{\frac{m^3}{yr}}{gpm\ .household} \times\ (baseline\ rated\ gpm - high\ efficiency\ gpm)}{2.06\frac{showerheads}{household}}$$

This results in a savings calculation of:

$$Single\ family\ savings\ \left(\frac{m^3}{yr.showerhead}\right) = 21.4\ \frac{\frac{m^3}{yr}}{gpm\cdot showerhead} \times\ (baseline\ rated\ gpm - high\ efficiency\ gpm)$$

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 for buildings of five stories or less) is 1.9 people.

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.

[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.

$$Multifamily\ Savings \times \frac{MF\ People}{} = Single\ family\ savings \times \frac{SF\ People}{}$$

Based on these factors, the adjustment can be made as follows:

$$Multifamily\ Savings = Single\ family\ savings \times \frac{SF\ People}{} \times \frac{1}{MF\ People}$$

We know the savings per showerhead for single family homes as determined above, thus the relationship reduces to:

$$\begin{aligned} &Multifamily\ Savings \\ &\quad = 21.4\ \frac{\frac{m^3}{yr}}{gpm \cdot showerhead} \times (baseline\ rated\ gpm \\ &\quad - high\ efficiency\ gpm) \times SF\ People \times \frac{}{MF\ People} \end{aligned}$$

The relationship (natural gas savings approach described in sub doc above) should be expressed as follow:

$$\begin{aligned} &Multifamily\ Savings \\ &\quad = 21.4\ \frac{\frac{m^3}{yr}}{gpm\ \cdot\ showerhead} \times (baseline\ rated\ gpm \\ &\quad - high\ efficiency\ gpm) \times \frac{SF\ People}{MF\ People} \end{aligned}$$

Unit of measurement analysis for proposal

$$Multifamily\ Savings \rightarrow \frac{\frac{m^3}{yr}}{\cancel{gpm} \cdot showerhead} \times (\cancel{gpm} - \cancel{gpm}) \times \frac{\cancel{people}}{\cancel{people}} \rightarrow \frac{m^3}{yr}\ per\ showerhead$$

Applying all the factors above: the resulting savings per showerhead for multi-residential is:

$$\begin{aligned} &Multifamily\ Savings \\ &\quad = 21.4\ \frac{\frac{m^3}{yr}}{gpm \cdot showerhead} \times (baseline\ rated\ gpm - high\ efficiency\ gpm) \\ &\quad \times 2.75\ people \times \frac{1}{1.9\ people} \end{aligned}$$

$$Multifamily\ Savings = 21.4\ \frac{\frac{m^3}{yr}}{gpm\ \cdot\ showerhead} \times\ (baseline\ rated\ gpm - high\ efficiency\ gpm) \times \frac{2.75\ People}{1.9\ People}$$

Where:

$$\frac{44.0\frac{m^3}{yr \cdot gpm}}{2.06\frac{showerhead}{household}} \times \frac{SF_{people}}{MF_{people}} \rightarrow \left(\frac{m^3}{yr \cdot gpm \cdot showerhead}\right)$$

21.4 = This is the ratio of the average reduction in annual natural gas rate (consumption per rated showerhead flow rate) use in each household from the single-family residential study, over the average number of showers per household from the single-family residential study.

Resulting in:

$$Multifamily\ Savings\left(\frac{m^3}{yr}\ per\ showerhead\right) = \frac{31.0\frac{m^3}{yr}}{gpm} \times\ (baseline\ rated\ gpm - high\ efficiency\ gpm)$$

Where:

$$\left(\frac{m^3}{yr \cdot gpm \cdot showerhead}\right)$$

31.0 = This is the adjustment ratio of the average reduction in annual natural gas rate (consumption per rated showerhead flow rate) use in each household from the single-family residential study to the multi-family household natural gas savings rate per showerhead.

WATER SAVINGS ALGORITHM

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:

$$Savings = \frac{Ppl \times Sh \times 365\frac{days}{year} \times T \times \left(Fl_{base} - Fl_{eff}\right) \times 3.785\frac{L}{gal}}{Number\ of\ Showerheads}$$

Where,

$Savings$ = Annual water savings per showerhead (L/yr per showerhead)

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 flowrate 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:

$$As - Used\ Flow\ Rate^{4} = 0.542 \times Nominal\ Flow\ Rate + 0.691 \text{ [5]}$$

Where,

$As - Used\ Flow\ Rate$	= Actual flow of installed showerhead
$Nominal\ Flow\ Rate$	= Rated flow listed on the showerhead

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 residence (2016)	1.9	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]

[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 flowrate. [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 provides a list of constants and assumption used in the derivation of the water savings values.

Table 4. Constants and Assumptions for Water Savings Calculation

Assumption	Value	Source
Average persons per multi family residnce (2016)	1.9	Common assumptions table
Number of showerheads per residence	1.02	Enbridge Gas 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 2.0 gpm showerhead with a 1.5 gpm showerhead,

$$Annual\ natural\ gas\ savings\ (\frac{m^3}{yr}\ per\ showerhead) = 31.0\ \frac{m^3/yr}{gpm \cdot showerhead} \times\ (baseline\ rated\ gpm - high\ efficiency\ gpm)$$

$$Annual\ natural\ gas\ savings\ (\frac{m^3}{yr}\ per\ showerhead)\ = 31.0 \times\ (2.0 - 1.5)$$

$$Annual\ energy\ savings = 15.3\,\frac{m^3}{yr}$$

Water Savings

$$Water\ Savings = 1.9\,\frac{people}{MF\ household} \times 0.75\,\frac{\frac{showers}{person}}{day} \times 7.6\,\frac{mins}{shower} \times 365\,\frac{days}{year} \times \left(1.78\ \frac{gallons}{min}\ -\ 1.5\ \frac{gallons}{min}\right) \times 3.785\,\frac{liters}{gal} \div 1.02\,\frac{showerhead}{MF\ household} = 4{,}107\,\frac{liters}{year}\ per\ showerhead$$

USES AND EXCLUSIONS

To qualify for this measure, low-flow showerheads must be installed in multi-residential households where sampling confirms the base case is equal to or less efficient than 2.0 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 5 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

[1] "Ontario Building Code Act, 1992; O.Reg. 332/12," Service Ontario, e-Law.

[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,* 2014.

[4] 2012-0441 Joint Submission from Enbridge Gas Distribution and Union Gas Ltd., "Low-Flow Showerheads (Various gpm, Enbridge TAPS, ESK and Multifamily) - Navigant Proposed Method of Occupancy Load Adjustment for Multi-Family," 2012.

[5] Barkett, Brent; Cook, Gay, "Resource Savings Values in Selected Residential DSM Prescriptive Programs," Summit Blue, Ontario, 2008.

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MULTI-RESIDENTIAL – LOW-FLOW SHOWERHEADS – RETROFIT

Version Date and Revision History	
Version	1.2 (minor update)
OEB Filing Date	December 16, 2021
OEB Approval Date	December 16, 2021
Multi-residential/Low-Income → Water Heating →Low-flow showerheads→ Retrofit	

Table 1 provides a summary of the key measure parameters and savings values based on the efficient technology.

Table 1. Measure Key Data

Parameter	Definitions	
Measure category	Retrofit (R)	
Baseline technology	2.5 gpm	
Efficient technology	1.5 gpm	
	1.25 gpm	
Market type	Multi-residential	
Annual natural gas savings per showerhead (m^3/yr)	***Efficient Technology***	***Savings***
	1.25 gpm	38.7
	1.5 gpm	31.0
Annual water impact per showerhead (liters/yr)	1.25 gpm	11,734
	1.5 gpm	8,068
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 base case 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 by reducing 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. There is an additional reduction in water consumption associated with this measure.

NATURAL GAS SAVINGS ALGORITHM

This algorithm outlines a methodology to determine the energy consumption as a function of a showerhead's rated flowrate. 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 in each household was 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.

$$Single\ family\ savings\ \left(\frac{m^3}{yr}\right) = \frac{44\ \frac{\frac{m^3}{yr}}{gpm} \times\ (baseline\ rated\ gpm - high\ efficiency\ gpm)}{2.06\,\frac{showerheads}{household}}$$

This results in a savings calculation of:

$$Single\ family\ savings\ \left(\frac{m^3}{yr}\right) = 21.4\ \frac{\frac{m^3}{yr}}{gpm \cdot showerhead} \times\ (baseline\ rated\ gpm - high\ efficiency\ gpm)$$

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 for buildings of five stories or less) is 1.9 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.

$$Multifamily\ Savings \times \frac{MF\ People}{} = Single\ family\ savings \times \frac{SF\ People}{}$$

Based on these factors, the adjustment can be made as follows:

$$Multifamily\ Savings = Single\ family\ savings \times \frac{SF\ People}{} \times \frac{1}{MF\ People}$$

We know the savings per showerhead for single family homes as determined above, thus the relationship reduces to:

$$Multifamily\ Savings = 21.4\ \frac{\frac{m^3}{yr}}{gpm \cdot showerhead} \times (baseline\ rated\ gpm - high\ efficiency\ gpm) \times SF\ People \times \frac{1}{MF\ People}$$

The relationship (natural gas savings approach described in sub doc above) should be expressed as follow:

$$Multifamily\ Savings = 21.4\ \frac{\frac{m^3}{yr}}{gpm \cdot showerhead} \times (baseline\ rated\ gpm - high\ efficiency\ gpm) \times \frac{SF\ People}{MF\ People}$$

Unit of measurement analysis for proposal

$$Multifamily\ Savings \rightarrow \frac{\frac{m^3}{yr}}{\cancel{gpm} \cdot showerhead} \times (\cancel{gpm} - \cancel{gpm}) \times \frac{\cancel{people}}{\cancel{People}} \rightarrow \frac{m^3}{yr}\ per\ showerhead$$

Applying all the factors above: the resulting savings per showerhead for multi-residential is:

$$Multifamily\ Savings = 21.4\ \frac{\frac{m^3}{yr}}{gpm \cdot showerhead} \times (baseline\ rated\ gpm - high\ efficiency\ gpm) \times 2.75\ people \times \frac{1}{1.9\ People}$$

$$Multifamily\ Savings = 21.4\ \frac{\frac{m^3}{yr}}{gpm\ \cdot\ showerhead} \times\ (baseline\ rated\ gpm - high\ efficiency\ gpm) \times \frac{2.75\ People}{1.9\ People}$$

Where:

$$\frac{44.0\,\frac{m^3}{yr \cdot gpm}}{2.06\,\frac{showerhead}{household}} \times \frac{SF_{people}}{MF_{people}} \rightarrow \left(\frac{m^3}{yr \cdot gpm \cdot showerhead}\right)$$

21.4 = This is the ratio of the average reduction in annual natural gas rate (consumption per rated showerhead flow rate) use in each household from the single-family residential study, over the average number of showers per household from the single-family residential study.

Resulting in:

$$Multifamily\ Savings\left(\frac{m^3}{yr}\ per\ showerhead\right) = 31.0 \times\ (baseline\ rated\ gpm - high\ efficiency\ gpm)$$

Where:

$$\left(\frac{m^3}{yr \cdot gpm \cdot showerhead}\right)$$

31.0 = This is the adjustment ratio of the average reduction in annual natural gas rate (consumption per rated showerhead flow rate) use in each household from the single-family residential study to the multi-family household natural gas savings rate per showerhead.

WATER SAVINGS ALGORITHM

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:

$$Savings = \frac{Ppl \times Sh \times 365\,\frac{days}{year} \times T \times \left(Fl_{base} - Fl_{eff}\right) \times 3.785\,\frac{L}{gal}}{Number\ of\ Showerheads}$$

Where,

$Savings$ = Annual water savings per showerhead (L/yr per showerhead)

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 flowrate 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

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 residence (2016)	1.9	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]

[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 provides a list of constants and assumption used in the derivation of the water savings values.

Table 4. Constants and Assumptions for Water Savings Calculation

Assumption	Value	Source
Average persons per multi family residnce (2016)	1.9	Common assumptions table
Number of showerheads per residence	1.02	Enbridge Gas 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,

$$Annual\ natural\ gas\ savings\ (\frac{m^3}{yr} per\ showerhead) = 31.0\ \frac{m^3/yr}{gpm \cdot showerhead}\ x\ (baseline\ rated\ gpm - high\ efficiency\ gpm)$$

$$Annual\ natural\ gas\ savings\ (\frac{m^3}{yr} per\ showerhead\ ) = 31.0 \times\ (2.5 - 1.5)$$

$$Annual\ natural\ savings = 31.0 \frac{m^3}{yr}\ per\ showerhead$$

Water Savings

$$Water\ Savings = 1.9 \frac{people}{MFhousehold} \times 0.75 \frac{\frac{showers}{person}}{day} \times 7.6 \frac{mins}{shower} \times 365 \frac{days}{year} \times \left(2.05\ \frac{gallons}{min}\ -\ 1.5\ \frac{gallons}{min}\right) \times 3.785 \frac{liters}{gal} \div 1.02 \frac{showerheads}{MF\ household} = 8{,}068 \frac{liters}{year}\ per\ showerhead$$

Uses and Exclusions

To qualify for this measure, low-flow showerheads must be installed in multi-residential households where sampling confirms the base case 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 5 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

[1] "Ontario Building Code Act, 1992; Regulation 350/06," Service Ontario, e-Law, Ontario, 1992.

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COMMERCIAL — OZONE LAUNDRY TREATMENT — NEW CONSTRUCTION/ RETROFIT

Version Date and Revision History	
Version	2
OEB Filing Date	December 16, 2021
OEB Approval Date	December 16, 2021
Commercial → Water Heating → Ozone Laundry Treatment → New Construction/Retrofit	

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

Table 1. Measure Key Data

Parameter	Definitions			
Measure Category	New Construction (NC) Retrofit (R)			
Baseline Technology	Commercial laundry with no ozone treatment system			
Efficient Technology	Ozone treatment system for commercial laundry			
Market Type	Commercial, Multi-residential[1]			
Annual Natural Gas Savings[2] Annual Electric Savings Annual Water Savings	**Washer Type**	**Natural Gas Savings Factor - NGSF (m^3/lb)**	**Electric Savings Factor - ESF (kWh/lb)**	**Water Savings Factor - WSF (L/lb)**
	Extractor Washers	0.0373	0.00211	2.10
	Tunnel Washers	0.0294	0.00150	1.29
Measure Life	15 years			
Incremental Cost ($ CAD)	**Washer Type**	**Incremental Cost**		
	Washer extractor – ≤ 60 lbs	$15,714		
	Washer extractor – > 60 lbs and < 500 lbs	$35,714		
	Washer extractor – ≥ 500 lbs	$44,286		
	Tunnel washer – ≤ 120 lbs	$71,429		
	Tunnel washer – > 120 lbs and < 500 lbs	$150,000		
	Tunnel washer – ≥500 lbs	$228,571		

[1] Multi-residential building must have commercial extraction or tunnel washers.
[2] To derive Annual Savings (for natural gas, electric, and water), the savings factor must be multiplied by washer capacity and annual loads. See Natural Gas Savings Algorithms section for further details.

Parameter	Definitions
Restrictions	This measure is restricted to commercial clothes washers using water heated by natural gas. Washers dedicated to cleaning heavily soiled laundry are not eligible.

OVERVIEW

In the commercial laundry industry, ozone is generated via a corona discharge or an ultraviolet light. The ozone dissolves in water temperatures ranging from cold to ambient, and activates the detergents, improving their activity and leading to stronger cleaning capabilities. The improved cleaning action results in hot water savings, and as a result, natural gas savings. However, since the solubility of ozone is low and its decomposition is faster at higher temperatures (38°C/100°F), the use of ozone is not recommended for heavily soiled laundry, which requires hotter water.

An important consideration with the use of ozone systems is laundry worker safety. Ozone exposure is regulated worldwide. The exposure limits for workers in Canadian facilities is limited to 0.12 parts per million over a time-weighted average of a one-hour period. The installation of an ozone system usually includes the installation of an ozone sensor to ensure that unsafe levels are not reached [1]. Figure 1 shows the schematics of a laundry system equipped with an ozone treatment system.

Figure 1. Washer Extractors – Example Schematic

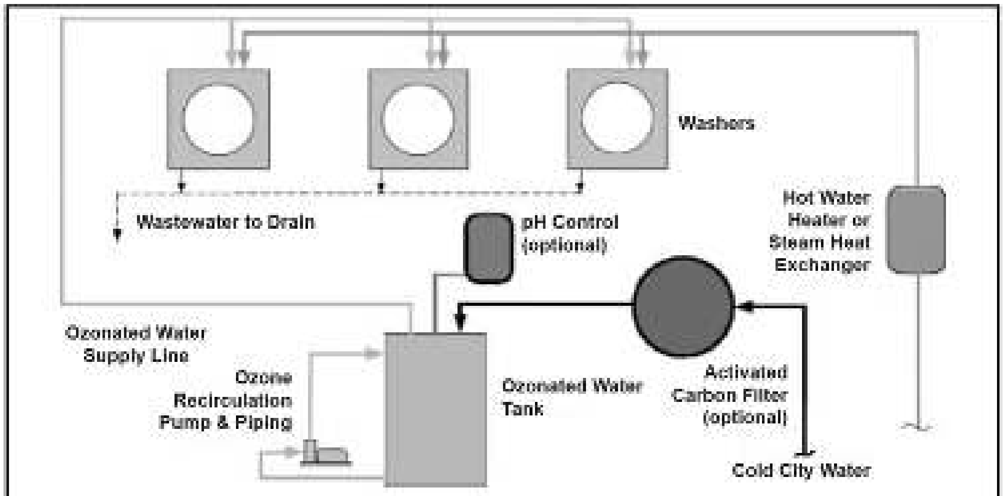

FIGURE 1. Ozone laundry systems (California Urban Water Conservation Council, 2006).

APPLICATION

This measure is for installing an ozone system on a commercial clothes washer. There is no distinction between the retrofit and new construction project types for this measure, as the applicable assumptions are the same.

BASELINE TECHNOLOGY

The baseline for this measure is standard commercial laundry equipment that does not utilize ozone laundry treatment and uses natural gas for water heating.

EFFICIENT TECHNOLOGY

The efficient case for this measure is ozone laundry treatment equipment installed on commercial laundry equipment using natural gas for water heating.

ENERGY IMPACTS

The primary savings produced by installing an ozone treatment system are hot water savings from reduced cycles and more efficient cleaning. Natural gas is saved from the reduced hot water demand, in addition to water savings. Although the ozone system consumes additional electricity, electric savings are also realized due to the reduced cycles required per load.

NATURAL GAS SAVINGS ALGORITHMS

The savings for this measure are determined utilizing a savings calculator developed by NGTC (Natural Gas Technology Center). The factors are determined by calculating the water saved from installing an ozone generating system on a washer.

The following algorithm is used to calculate the actual gas impact in cubic meters from the natural gas savings factor.

$$\Delta(m^3) = NGSF \times WC \times Load$$

Where,

NGSF	= Natural gas savings factor; see Table 1 (m^3/lbs)
WC	= Washer capacity; see application (lbs/load)
Load	= Annual loads processed by the washer; see application (loads/yr)

ELECTRIC SAVINGS ALGORITHMS

The following algorithm is used to calculate the electric impact in kilowatt-hours from the electric energy savings factor.

$$\Delta(kWh) = ESF \times WC \times Load$$

Where,

ESF	= Electric savings factor, (kWh/(lbs))

WC = Washer capacity; see application (lbs/load)

Load = Annual loads processed by the washer; see application (loads/yr)

WATER SAVINGS ALGORITHMS

The following algorithm is used to calculate the water impact from the water savings factor.

$$\Delta(L) = WSF \times WC \times Load$$

Where,

WSF = Water savings factor; see Table 1 (L/lbs)

WC = Washer capacity; see application (lbs/load)

Load = Annual loads processed by the washer; see application (loads/yr)

ASSUMPTIONS

Table 2 shows the list of assumptions utilized in the calculations spreadsheet to derive the savings factors in Table 1. Ozone laundry systems cannot use high temperature water since ozone breaks down above 35°C [2]. It is also notable that there is broad range of water recycling capability from commercial machines depending on the rigor of the recycling purification methods. About 30% to 50% of the water can be reused. For this analysis, a recycling rate of 30% is assumed at that will result in a conservative estimate [3] . For this analysis, operating conditions used to calculate the energy consumption per pound of laundry were evaluated using input data from representatives of an ozone laundry products manufacturer and a large linen services company. These operating conditions are assumed to be typical for industrial laundry facilities. The difference in water savings between facilities that have a 30% rate of recycling and a facility that does not have recycling at all is negligible – about 0.1 L/lb. Therefore, water savings calculated here can be applied to facilities without recycling systems as well.

Table 2. Assumptions

Variable	Value	Sources
Average city or inlet water temperature	48.9 F (9.39 C)	Common assumptions table
Commercial water heating efficiency	83%	Common assumptions table
Ratio of water recycled	30.0%	[5]
Water temperature for medium soil (ozone)	20.0°C	[3] [2]

SAVINGS CALCULATION EXAMPLE

The natural gas savings for a 120 pound per load tunnel washer where the estimated annual loads are estimated to be 30 loads per hour for 8 hours a day for 350 days a year can be calculated in the following fashion.

The annual number of loads is:

$$Annual\ Loads = 30\frac{loads}{hr} \times 8\frac{hr}{day} \times 350\frac{days}{yr} = 84{,}000\frac{loads}{yr}$$

The annual natural gas savings are:

$$\Delta(m^3) = 0.0294\frac{(m^3)}{lb} \times 120\frac{lb}{load} \times 84{,}000\frac{loads}{yr} = 296{,}352\ \frac{m^3}{yr}$$

The annual electric and water savings can be calculated similarly to be:

$$Electric\ savings = 15{,}120\ kWh/yr$$

$$Water\ savings = 13{,}003{,}200\ L/yr$$

USES AND EXCLUSIONS

Residential-style clothes washers do not qualify for this measure. Commercial washers that process heavily soiled laundry do not qualify for this measure because of the higher water temperatures utilized.

MEASURE LIFE

The measure life is 15 years [3].

INCREMENTAL COST

Table 4 shows the incremental costs associated with the two different types of washers and grouped into two different sized bins each.

Table 4: Incremental Costs [3] [6] [7] [8][3]

Washer Type	Incremental Cost
Washer extractor – ≤ 60 lbs	$15,714
Washer extractor – > 60 lbs and < 500 lbs	$35,714

[3] Converted to CAD based on Daily Currency Converted for Bank of Canada, as of 1/22/2016. (http://www.bankofcanada.ca/rates/exchange/daily-converter/)

Washer Type	Incremental Cost
Washer extractor – ≥ 500 lbs	$44,286
Tunnel washer – ≤ 120 lbs	$71,429
Tunnel washer – > 120 lbs and < 500 lbs	$150,000
Tunnel washer – ≥ 500 lbs	$228,571

Capital and installation incremental costs were obtained from interviews with manufacturer sales representatives. Please note that installed system costs can be highly variable, especially for the tunnel washer systems which tend to be custom installations. The size and cost of the ozone system are primarily determined by the amount of water being used and the level of soil in the laundry but can also be affected by the type and arrangement of the washers.

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[9] J. R. G. Riopelle, *Redacted - Final Report DSM Ozone Laundry Calculator,* 2009, updated 2014.

[10] Excalibur Water Systems, "Series SFLC Sureflo Lite Commercial Reverse Osmosis System,"

Excalibur Water Systems, [Online]. Available: https://www.excaliburwater.com/commercial-products/series-sflc-sureflo-lite-commercial-reverse-osmosis-system. [Accessed September 2021].

Commercial – Condensing Tankless Gas Water Heaters – New Construction/Time of Natural Replacement

Version Date and Revision History	
Version	1
OEB Filing Date	Dec 21, 2016
OEB Approval Date	
Commercial → Water Heating → Condensing Tankless Water Heater → New Construction/Time of Natural Replacement	

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

Table 1. Measure Key Data

<table>
<tr><th>Parameter</th><th colspan="4">Definition</th></tr>
<tr><td>Measure Category</td><td colspan="4">New Construction (NC)
Time of Natural Replacement (TNR)</td></tr>
<tr><td>Baseline Technology</td><td colspan="4">Non-Condensing Storage Water Heater 75 kBtu/hr. and greater
Thermal efficiency of units shipped = 80.1%
Stand-by Loss $Q/0.8 + 110\sqrt{V_0}$</td></tr>
<tr><td>Efficient Technology</td><td colspan="4">Condensing Tankless Water Heater 75 kBtu/hr. and greater
Thermal efficiency of units shipped = 92.9%
Stand-by Loss = negligible</td></tr>
<tr><td>Market Type</td><td colspan="4">Commercial</td></tr>
<tr><td rowspan="7">Annual Natural Gas Savings Rate (m^3/ kBtu/hr + m^3)</td><th>Utilization Category</th><th>Combustion Efficiency Savings</th><th>Input Rating</th><th>Storage Savings</th></tr>
<tr><td rowspan="2">Low</td><td rowspan="2">0.790 m^3/ kBtu/hr. input</td><td><200 kBtu/hr.</td><td>212 m^3</td></tr>
<tr><td>≥ 200 kBtu/hr.</td><td>326 m^3</td></tr>
<tr><td rowspan="2">Medium</td><td rowspan="2">1.290 m^3/ kBtu/hr. input</td><td><200 kBtu/hr.</td><td>212 m^3</td></tr>
<tr><td>≥ 200 kBtu/hr.</td><td>326 m^3</td></tr>
<tr><td rowspan="2">High</td><td rowspan="2">1.79 m^3/ kBtu/hr. input</td><td><200 kBtu/hr.</td><td>212 m^3</td></tr>
<tr><td>≥ 200 kBtu/hr.</td><td>326 m^3</td></tr>
<tr><td>Measure Life</td><td colspan="4">20 years</td></tr>
<tr><td>Incremental Cost ($ CAD)</td><td colspan="4">$2,227</td></tr>
<tr><td>Restrictions</td><td colspan="4">This measure applies to the installation of natural gas condensing tankless water heaters in commercial facilities.</td></tr>
</table>

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 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. The 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 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 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, rated 75 kBtu/hr. and greater [2] [3], 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. [2] [3] or greater are eligible for this measure. Units must be certified according to the appropriate CSA standard such as: CAN/CSA P.7-10, CSA 4.3/ANSI Z21.10.3, or DOE 10 CFR Part 431.

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. [4] A 2012 Enbridge Gas funded study [5] 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) [4]

$Demand_{peak\ 15\ minute}$ = The peak 15-minute hot water demand for a specific building type (US gallon/occupant-hour) [4] [5]

OS_{factor} = Typical tankless water heater oversizing factor relative to 15-minute peak demand (200%)[1] [5]

$Days\ per\ year$ = 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, multi-residential

These average efficiency and EFLH values are used to derive 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)
η_{proposed}	=The weighted shipment average efficiency for tankless water heaters (see Table 2)
η_{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;

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

[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.

ASSUMPTIONS

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

Table 6. 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 [4] 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 [5]
$V_{0\ baseline}$	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 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. [7]

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 7.

Table 7. Incremental Cost[4]

Material	Installation	Total
$1,327	$900	$2,227

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[1] Caneta Research Inc., "Refinement to DSM Asessment of Commercial Water Heater Applications, Page 8-10," Caneta Research Inc, Mississauga, ON, 2009.

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[5] M. Armstrong, "Enbridge Prescriptive Commercial Bolier Program - Prescriptive Savings Analysis, pages 14-15," AMEC, Cambridge, Ontario, 2012.

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[9] Schoenbauer, "Tankless Water Heaters: Do They Really Save Money?," Minnesota Center for Energy and Enviornment, Minneapolis, MN, 2012.

COMMERCIAL – KITCHEN – DEMAND CONTROLLED VENTILATION – NEW CONSTRUCTION/TIME OF NATURAL REPLACEMENT

Version Date and Revision History	
Version	1
OEB Filing Date	Dec 21, 2016
OEB Approval Date	
Commercial → Space Heating → Kitchen – Demand Controlled Ventilation → New Construction / Time of Natural Replacement	

Table 1 provides a summary of the key measure parameters and 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 (m^3)	**Hood Capacity**	**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 (kWh)	**Hood Capacity**	**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 ($ CAD)	**Hood Capacity**	**Incremental Cost**
	Up to 5,000 CFM	$2,383
	5,001 – 10,000 CFM	$5,958
	10,001 – 15,000 CFM	$9,929
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 Controlled 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 controlled 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 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, saving values are provided for three ranges of size, with the 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%.

[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 22.2^{0}C (72^{0}F), 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 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,

$NG\ Savings$	= 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)	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 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 fan power savings are shown in Table 4 below.

Table 4. Fan Power Savings

Hood Capacity (CFM)	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.

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

Where,

$Cooling\ Savings$	= 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 from 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 (3,412 Btu/kWh)

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

Table 5. Fan Power Savings

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

ASSUMPTIONS

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

Table 6. 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]
$Eff_{Heating}$	Commercial heating system efficiency	80%		Common assumptions table
$Eff_{Cooling}$	Commercial cooling system efficiency	13 SEER		[7]

Variable	Definition	Value	Inputs	Source
		3.81 COP		
EC_{NG}	Energy Density of Natural Gas	35,738 Btu/m³		Common assumptions table
EC_{Elec}	Conversion of Btu/kWh	3,412 Btu/kWh		Common assumptions table
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 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/m³)

= 10,517 m³ 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 × 3,412 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 $1.70 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 [4]

Category	Incremental Cost
Up to 5,000 CFM	$2,383
5,001 – 10,000 CFM	$5,958
10,001 – 15,000 CFM	$9,929

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.

[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.

[4] Converted to CAD based on Daily Currency Converted for Bank of Canada, as of 1/22/2016. (http://www.bankofcanada.ca/rates/exchange/daily-converter/)

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COMMERCIAL – KITCHEN – DEMAND CONTROLLED VENTILATION – RETROFIT

Version Date and Revision History	
Version	1
OEB Filing Date	Dec 21, 2016
OEB Approval Date	
Commercial → Space Heating → Kitchen – Demand Controlled Ventilation → Retrofit	

Table 1 provides a summary of the key measure parameters and 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 (m^3)	**Hood Capacity**	**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 (kWh)	**Hood Capacity**	**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 ($CAD)	**Hood Capacity**	**Incremental Cost**
	Up to 5,000 CFM	$4,766
	5,001 – 10,000 CFM	$11,915
	10,001 – 15,000 CFM	$19,859
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 Controlled 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 controlled 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 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, saving values are provided for three ranges of size, with the 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%.

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[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 22.2^{0}C (72^{0}F), 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 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,

$NG\ Savings$	= 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)	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 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 fan power savings are shown in Table 4 below.

Table 4. Fan Power Savings

Hood Capacity (CFM)	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,

$Cooling\ Savings$ = 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 (3,412 Btu/kWh)

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

Table 5. Fan Power Savings

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

ASSUMPTIONS

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

Table 6. 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]
$Eff_{Heating}$	Commercial heating system efficiency	80%		Common assumptions table

Variable	Definition	Value	Inputs	Source
$Eff_{Cooling}$	Commercial cooling system efficiency	13 SEER 3.81 COP		[7]
EC_{NG}	Energy Density of Natural Gas	35,738 Btu/m^3		Common assumptions table
EC_{Elec}	Conversion of Btu/kWh	3,412 Btu/kWh		Common assumptions table
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 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 × 3,412 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 $1.70 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 [4]

Category	Incremental Cost
Up to 5,000 CFM	$4,766
5,001 – 10,000 CFM	$11,915
10,001 – 15,000 CFM	$19,859

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COMMERCIAL – ENERGY STAR RACK OVEN– NEW CONSTRUCTION/TIME OF NATURAL REPLACEMENT

Version Date and Revision History	
Version History	1.2 (minor update)
OEB Filing Date	December 16, 2021
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Commercial → Food Service → ENERGY STAR Rack Oven –Single & Double Rack → New Construction/Time of Natural Replacement	

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

Table 1. Measure Key Data

Parameter	Definition	
Measure Category	New Construction (NC) Time of Natural Replacement (TNR)	
Baseline Technology	A conventional single or double rack oven	
Efficient Technology	An ENERGY STAR rated single or double rack oven	
Market Type	Commercial	
	Single	**Double**
Annual Natural Gas Savings (m^3/yr per oven)	915	1,187
Annual Electric Impact (kWh/yr per oven)	826	1,858
Measure Life	12 years	
	Single	**Double**
Incremental Cost (CAD $)	$1,544	$2,591
Restriction	Restricted to rack ovens using natural gas.	

OVERVIEW

Rack ovens are used in commercial sectors like institutional, and retail food service operations for high-volume production of bakery food items. Rack ovens consist of a thermally insulated chamber inside which hot air, heated by either natural gas or electricity, is circulated at high volumes throughout the cavity. Convection is the primary mode of baking; however, certain rack oven models offer limited steam injection capabilities. The characteristic feature of rack ovens is a mechanism to rotate the pans inside the oven cavity during baking. This helps the oven to provide more control and consistency during the baking process.

Most rack ovens (single rack and double rack) have a removable, or roll-in, rack trolley to facilitate loading and unloading large volumes of product. Each roll-in rack can accommodate up to 15 full-size sheet pans of product at a time. Rack ovens are generally used to cook breads, cakes, pies, cookies, and other bakery items. These ovens are commonly found in grocery retail, K-12 commissary kitchens, and hotel kitchens with some present in quick-service and full-service restaurants.

Based on full size sheet pans, single and double rack oven can be grouped in the following size categories: Single (15 pans, 1 per level, roll-in rack) and Double (30 pans, 2 per level, roll-in rack). Single and double rack ovens are the most common types of rack oven on the market. Single rack ovens accommodate one rack trolley that can hold up to 15 pans (at 102 mm spacing). Double rack ovens accommodate two 15-pan single rack trolleys, or a 30-pan double rack trolley. Double rack ovens have a slightly wider footprint than single rack ovens but offer significantly greater production capacity.

Natural gas rack ovens must be ventilated for flue combustion products and cooking cavity effluent during door openings. Single and double rack ovens are usually equipped with a hood for capturing door-opening effluent. Rack ovens utilize a fan motor for exhaust which is included in the oven's energy usage. For indirect-fired ovens, flue combustion products are exhausted separately using a direct vent with an external fan motor, which is not included in the oven's energy consumption. Flue exhaust rates vary from 300 to 500 cfm and are adjusted using dampers during oven installation since they may have a significant effect on burner performance.

APPLICATION

This measure applies to the installation of single and double rack ENERGY STAR® qualifying ovens in the commercial sector like institutional and retail food service operations and the fuel source is natural gas. [1]

BASELINE TECHNOLOGY

The baseline technology is a conventional single or double rack oven that does not meet the ENERGY STAR Commercial Oven Key Product Criteria. [1]

EFFICIENT TECHNOLOGY

Energy-efficient single and double rack ovens must comply with ENERGY STAR Commercial Oven Key Product Criteria v2.2. [1]

ENERGY IMPACTS

The primary energy impact associated with the installation of a single or double rack ENERGY STAR rack oven is a reduction in natural gas required during preheating, idling, and cooking. Savings are achieved through reduced cooking energy consumption and a lower idle energy rate.

There are associated electric savings resulting from a lower average input rate of electrical components including the blower fan and rack rotation motors.

NATURAL GAS SAVINGS ALGORITHM

The industry standard for rack oven energy use and cooking performance is ASTM F2093, *Standard Test Method for the Performance of Rack Ovens* [2]. The results of this testing procedure form the basis for the energy savings calculation of rack ovens. Annual energy consumption is also greatly affected by the hours of operation per day, days operating per year, number of preheats per day, and pounds of food cooked per day.

The algorithm is based upon the methodology used by the Food Service Technology Center.

1. **Calculation of the daily natural gas consumed by the rack oven**

$$E_{day} = \frac{\left(Lb_{food} \times E_{food}\right)}{Eff} + Idle \times \left(T_{on} - \frac{Lb_{food}}{PC} - nP \times \frac{TP}{60}\right) + nP \times EP$$

where,

E_{day} = Daily energy Consumption- Natural Gas (Btu/day)

Lb_{food} = Pounds of Food Cooked per Day (lb/day)

E_{food} = ASTM Energy to Food Rate, this is the energy absorbed by food product during cooking (Btu/lb)

Eff = Heavy-Load Cooking Energy Efficiency (%)

$Idle$ = Natural Gas Idle Energy Rate (Btu/hr)

T_{on} = Operating hours per day (hr/day)

PC = Production Capacity (lb/hr)

TP = Preheat Time (min/preheat)

nP = Number of preheats per day (preheats/day)

60 = 60 min/hr

EP = Preheat Energy (Btu/preheat)

2. **Calculation of the annual natural gas consumption for baseline and ENERGY STAR rack ovens**

$$NG_{usage} = E_{day} \times days$$

where,

NG_{usage} = Annual natural gas consumption by the rack oven (Btu/year)

$days$ = The number of days per year the rack oven is in use (day/yr)

3. **Calculation of the natural gas savings**

$$NG_{savings} = \frac{\left(NG_{usage\_b} - NG_{usage\_E}\right)}{35{,}738}$$

where,

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

NG_{usage_b} = Annual natural gas consumption of the baseline oven (Btu/year)

NG_{usage_E} = Annual natural gas consumption of the ENERGY STAR rack oven (Btu/year)

35,738 = Energy density of natural gas (Btu/m^3)

ELECTRIC SAVINGS ALGORITHM

1. **Calculation of the daily electricity consumed by the rack oven**

$$E_{day-elec} = Idle_{elec} \times T_{on}$$

where,

$E_{day-elec}$ = Daily energy Consumption- Electricity (kWh/day)

$Idle_{elec}$ = Electricity Idle Rate (kW)

2. **Calculation of the annual electricity consumption for baseline and ENERGY STAR rack ovens**

$$Elec_{usage} = E_{day-elec} \times days$$

where,

$Elec_{usage}$ = Electricity consumed by the rack oven annually (kWh/year)

$days$ = The number of days per year the rack oven is in use (day/yr)

3. **Calculation of the electricity impact.**

$$Elec_{savings} = Elec_{usage_b} - Elec_{usage_E}$$

where,

$Elec_{savings}$ = Annual electrical impact (kWh/yr)

$Elec_{usage_b}$ = Annual electricity consumption of the baseline oven (kWh/year)

$Elec_{usage_E}$ = Annual electricity consumption of the ENERGY STAR rack oven (kWh/year)

ASSUMPTIONS

The assumptions used to calculate energy savings are shown in Tables 1 and 2.

Table 1. Single Rack Oven Assumptions

Performance	Baseline Model	Energy Efficient Model	Source
Preheat Time (min/preheat)	22.9	17.2	[3]
Preheat Energy (Btu/preheat)	54,674	42,584	[3]
Idle Energy Rate- Natural Gas (Btu/hr)	25,610	19,567	[3]
Idle Energy Rate- Electricity (kW)	0.95	0.75	[3]
Heavy Load Cooking Energy Efficiency (%)	44%	51%	[3]
Production Capacity (lb/hr)	138		[3]
Operating hours per day (hr/day)	12		[4]
Food service days per year (day/yr)	344		Common assumption
Number of preheats per day (preheats/day)	1		[4]
Pounds of food cooked per day (lb/day)	474		[4]
ASTM Energy to Food (Btu/lb)	239		[2]
Energy density of natural gas (Btu/m^3)	35,738		Common assumption

Table 2 Double Rack Oven Assumptions

Performance	Baseline Model	Energy Efficient Model	Source
Preheat Time (min/preheat)	25.1	16	[3]
Preheat Energy (Btu/preheat)	85,361	64,707	[3]
Idle Energy Rate- Natural Gas (Btu/hr)	32,749	22,632	[3]
Idle Energy Rate- Electricity (kW)	1.49	1.04	[3]
Heavy Load Cooking Energy Efficiency (%)	53%	56%	[3]
Production Capacity (lb/hr)	282		[3]
Operating hours per day (hr/day)	12		[4]
Food service days per year (day/yr)	344		Common assumption
Number of preheats per day (preheats/day)	1		[4]
Pounds of food cooked per day (lb/day)	948		[4]
ASTM Energy to Food (Btu/lb)	239		[2]
Energy density of natural gas (Btu/m^3)	35,738		Common assumption

SAVINGS CALCULATION EXAMPLE

The example below illustrates the annual natural gas savings and electrical impact due to the replacement of a conventional rack oven with an ENERGY STAR- rated rack oven – single rack size.

Annual natural gas savings:

$$1\ oven \times 914\ \frac{m^3/yr}{oven} = 915\ m^3/yr$$

Annual Electrical Impact:

$$1\ oven \times 826\ \frac{kWh/yr}{oven} = 826\ kWh/yr$$

USES AND EXCLUSIONS

To qualify for this measure, the single or double rack oven must be utilized for food preparation or processing with natural gas as its energy source and must be ENERGY STAR rated v2.2. [1]

MEASURE LIFE

The measure life attributed to this measure is 12 years. [5]

INCREMENTAL COST

The incremental cost is summarized in the table below. [6]

Table 3 Rack Oven Incremental cost

Description	Single Rack Oven	Double Rack Oven
Baseline cost	$30,036	$36,890
Energy Efficient cost	$31,580	$39,481
Incremental cost	$1,544	$2,591

REFERENCES

[1] E. S. C. a. partners, "Commercial Ovens Key Product Criteria, Version 2.2," [Online]. Available: https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ovens/partners.

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COMMERCIAL – ENERGY STAR COMBI OVEN– NEW CONSTRUCTION/TIME OF NATURAL REPLACEMENT

Version Date and Revision History	
Version History	1.0
OEB Filing Date	December 16, 2021
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Commercial → Food Service → ENERGY STAR Combi Oven→ New Construction/Time of Natural Replacement	

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

Table 1. Measure Key Data

Parameter	Definition		
Measure Category	New Construction (NC), Time of Natural Replacement (TNR)		
Baseline Technology	A conventional combination oven		
Efficient Technology	An ENERGY STAR rated[1] combination oven		
Market Type	Commercial		
	6-14 pan	**15-28 pan**	**29+ pan**
Annual Natural Gas Savings (m^3/yr per oven)	1,104	1,295	1,048
Annual Natural Gas Savings- weighted average[2] (m^3/yr per oven)	1,186		
Annual Electric Impact (kWh/yr per oven)	72	4,747	485
Annual Electric Impact- weighted average (kWh/yr per oven)	2,088		
Annual Water Impact (L/yr per oven)	209,664	51,684	599,459
Annual Water Impact- weighted average (L/yr per oven)	145,120		
Incremental Cost (CAD $ per oven)	$3,941	$5,007	$8,507
Incremental Cost-- weighted average (CAD $ per oven)	$4,440		
Measure Life	12 years		
Restrictions	Restricted to combi ovens using natural gas.		

[1] Based on qualifying products under ENERGY STAR Commercial Oven Key Product Criteria V2.2 [2]
[2] Weighted based on segment and equivalent pan size [3]

OVERVIEW

An oven can be simply described as a fully enclosed, insulated chamber used to heat food. Commercial combination ovens (also known as "combi ovens") offer more options with their ability to add steam to the oven cavity. In addition to baking and roasting, a combination oven is also capable of steaming, proofing, and reheating various food products. Foods can be cooked in a convection dry heat-only mode, a steam-only mode, and a combination of dry heat and steam modes. The programmability of combination ovens also allows food to be cooked partially in one mode at a certain temperature, then finished in another mode at a different temperature. For example, a turkey can be cooked in combination mode at low temperature for several hours, then increased to a higher temperature in dry heat mode to finish. With competition rising amongst equipment manufacturers, new designs that incorporate time-saving features via sophisticated control packages are continually being introduced in the market.

Combination ovens are available in a variety of sizes ranging from 6-pan countertop models to 40-pan roll-in models. Combi oven sizes are based on the capacity to accommodate 30.5 x 50.8 x 6.4-cm (12 x 20 x 2½-inch) hotel pans. Half-size models can accommodate one column of hotel pans and 23 x 33-cm (half-size) sheet pans, while full-size models can accommodate two columns of hotel pans and 46 x 61-cm (full-size) sheet pans.

Combi oven performance is determined by applying ASTM F2861 *Standard Test Method for the Performance of Combination Ovens in Various Modes* [1]. The ASTM standard test method is considered the industry standard for quantifying energy consumption, efficiency, and cooking performance of combination ovens.

APPLICATION

This measure applies to the installation of ENERGY STAR rated combi ovens qualifying under ENERGY STAR Commercial Oven Key Product Criteria V2.2 in commercial food settings. Combi ovens are designed to cook food within a heated, enclosed space by convection with hot air blowing on the product. These ovens are different from convection ovens because they also generate steam via a separate boiler compartment or inside the cavity itself. Food can be cooked in a humid, fully saturated cooking cavity, or a dry air-only cavity, or a combination thereof.

BASELINE TECHNOLOGY

The baseline technology is a combination oven that does not meet the ENERGY STAR Commercial Oven Key Product Criteria, Version 2.2 [2]. Key energy consumption metrics include cooking-energy efficiency and idle rate when tested according to ASTM F2861.

EFFICIENT TECHNOLOGY

Combi ovens are among the most advanced designed appliances in the commercial oven category. Efficient designs employ advanced burners with automatically adjustable airflow that optimizes burner efficiency based on ambient and cooking cavity conditions. Recent advancements in combi oven technology reduced water consumption by controlling moisture inside the cavity. This is achieved through either direct or indirect humidity measurements. A reduction in water consumption is a reduction in energy consumption since all water entering the cavity must be heated either directly using a boiler or indirectly by evaporation from a hot cavity surface.

Key energy consumption criteria include cooking energy efficiency and idle rate in both convection and steam modes according the ASTM F2861 [1]. Energy-efficient models must be at a minimum ENERGY STAR rated combi ovens based on ENERGY STAR Commercial Oven Key Product Criteria V2.2 [2]. Table 2 summarizes the efficient technology threshold.

Table 2 Efficient Technology Threshold *[2]*

Pan Capacity (P)*	Convection Mode Efficiency	Steam Mode Efficiency	Convection Idle Rate (Btu/h)*	Steam Idle Rate (Btu/h)*
6-14 pan	≥ 56%	≥ 41%	≤ 150P+5,425	≤ 200P+6,511
15-28 pan				
29+ pan				

*Idle rate only includes gas energy, P = Pan capacity

ENERGY IMPACTS

The primary energy impact associated with the ENERGY STAR combi oven is a reduction in natural gas required during preheating, idling, and cooking. The savings are achieved through reduced cooking input rate and lower idle energy rate. The biggest driver for energy savings is a reduced steam idle rate. ENERGY STAR combi ovens will also improve electricity consumption from motors distributing heat in the cooking chamber.

NATURAL GAS SAVINGS ALGORITHM

The industry standard for energy use and cooking performance of combi ovens is ASTM F2861, *Standard Test Method for the Performance of Combination Ovens* [1]. The results of this testing procedure form the basis for the energy savings calculation of combination ovens. Annual energy consumption is also greatly affected by the hours of operation per day, days operating per year, number of preheats per day, and pounds of food cooked per day.

The algorithm is based upon methodology used by the Food Service Technology Center ("FSTC"); one of the leading commercial foodservice compliance and certification testing labs and source of energy efficiency information for the foodservice industry. The calculation to determine the daily energy usage of baseline and ENERGY STAR combi ovens is as follows:

1. **Calculation of the daily natural gas consumed by the oven**

$$E_{day} = E_{cooking} + E_{Idle} + E_{pre-heat}$$

where,

E_{day}	=	Daily energy Consumption- Natural Gas (Btu/day)
$E_{cooking}$	=	Daily energy Consumption cooking mode- Natural Gas (Btu/day)
E_{Idle}	=	Daily energy Consumption idle mode- Natural Gas (Btu/day)
$E_{pre-heat}$	=	Daily energy Consumption pre-heat mode- Natural Gas (Btu/day)

1a. Calculation of the daily natural gas consumed by the oven- cooking mode

$$E_{cooking} = \frac{Lb_{food} \times \%conv \times E_{food\_conv}}{Eff_{conv}} + \frac{Lb_{food} \times \%steam \times E_{food\_steam}}{Eff_{steam}}$$

where,

Lb_{food}	=	Pounds of Food Cooked per Day (lb/day)
$\%conv$	=	Percentage operating time in convection mode (%)
E_{food_conv}	=	ASTM Energy to Food Rate, this is the energy absorbed by food product during cooking – convection (Btu/lb)
$\%steam$	=	Percentage operating time in steam mode (%)
E_{food_steam}	=	ASTM Energy to Food Rate, this is the energy absorbed by food product during cooking – steam (Btu/lb)
Eff_{conv}	=	Heavy-Load Cooking Energy Efficiency- convection mode (%)
Eff_{steam}	=	Heavy-Load Cooking Energy Efficiency- steam mode (%)

1b. Calculation of the daily natural gas consumed by the oven- idle mode

$$E_{Idle} = Idle_{conv} \times \%conv \times T_{Idle} + Idle_{steam} \times \%steam \times T_{Idle}$$

Expanded, that is

$$E_{Idle} = (Idle_{conv} \times \%conv + Idle_{steam} \times \%steam) \times \left(T_{on} - \frac{Lb_{food}}{PC_{conv}} - \frac{Lb_{food}}{PC_{steam}} - nP \times \frac{TP}{60}\right)$$

where,

$Idle_{conv}$ = Natural Gas Idle Energy Rate- convection mode (Btu/hr)

$\%conv$ = Percentage operating time in convection mode (%)

$Idle_{steam}$ = Natural Gas Idle Energy Rate- steam mode (Btu/hr)

$\%steam$ = Percentage operating time in steam mode (%)

T_{Idle} = Idle time (hr/day)

T_{on} = Operating hours per day- oven (hr/day)

Lb_{food} = Pounds of Food Cooked per Day (lb/day)

PC_{conv} = Production Capacity- convection mode (lb/hr)

PC_{steam} = Production Capacity- steam model (lb/hr)

nP = Number of preheats per day (preheats/day)

TP = Preheat Time (min/preheat)

1c. Calculation of the daily natural gas consumed by the oven- preheat mode

$$E_{pre-heat} = nP \times (\%conv \times EP_{conv} + \%steam \times EP_{steam})$$

where,

nP = Number of preheats per day (preheats/day)

$\%conv$ = Percentage operating time in convection mode (%)

EP_{conv} = Preheat Energy- convection mode (Btu/preheat)

$\%steam$ = Percentage operating time in steam mode (%)

EP_{steam} = Preheat Energy- steam mode (Btu/preheat)

2. Calculation of the annual natural gas consumption for baseline and ENERGY STAR combi ovens

$$NG_{usage} = E_{day} \times days$$

where,

NG_{usage}	=	Annual natural gas consumption by the combi oven (Btu/year)
E_{day}	=	Daily energy Consumption- Natural Gas (Btu/day)
$days$	=	The number of days per year the combi oven is in use (day/yr)

3. **Calculation of the natural gas savings**

$$NG_{savings} = \frac{\left(NG_{usage\_b} - NG_{usage\_E}\right)}{35{,}738}$$

where,

$NG_{savings}$	=	Annual natural gas savings (m^3/year)
NG_{usage_b}	=	Annual natural gas consumption of the baseline oven (Btu/year)
NG_{usage_E}	=	Annual natural gas consumption of the ENERGY STAR combi oven (Btu/year)
35,738	=	Energy density of natural gas (Btu/m^3)

ELECTRIC SAVINGS ALGORITHM

1. **Calculation of the daily electricity consumed by the oven**

$$E_{day-elec} = T_{on} \times \left(\%conv \times Idle_{elec\_conv} + \%steam \times Idle_{elec\_steam}\right)$$

where,

$E_{day-elec}$	=	Daily Electricity consumption by the oven- (kWh/day)
T_{on}	=	Operating hours per day- oven (hr/day)
$\%conv$	=	Percentage operating time in convection mode (%)
$Idle_{elec\_conv}$	=	Idle Energy Rate- convection mode (kW)
$\%steam$	=	Percentage operating time in steam mode (%)
$Idle_{elec\_steam}$	=	Idle Energy Rate- steam mode (kW)

2. **Calculation of the annual electricity consumption for baseline and ENERGY STAR combi ovens**

$$Elec_{usage} = E_{day-elec} \times days$$

where,

$Elec_{usage}$ = Electricity consumed by the combi oven annually (kWh/year)

$days$ = The number of days per year the combi oven is in use (day/yr)

3. **Calculation of the electricity impact**

$$Elec_{savings} = Elec_{usage_b} - Elec_{usage_E}$$

where,

$Elec_{savings}$ = Annual electrical impact (kWh/yr)

$Elec_{usage_b}$ = Annual electricity consumption of the baseline oven (kWh/year)

$Elec_{usage_E}$= Annual electricity consumption of the ENERGY STAR combi oven (kWh/year)

WATER SAVINGS ALGORITHM

1. **Calculation of the annual water consumption for baseline and ENERGY STAR combination ovens:**

$W_{use} = W_{Idle} + W_{cooking}$

$Water\ Usage = 3.78541 \times \%_{steam} \times W_{use} \times T_{on} \times days$

where,

W_{use}	=	Average Water Consumption Rate (gal/h)
W_{Idle}	=	Idle Average Water Consumption Rate (gal/h)
$W_{cooking}$	=	Cooking Average Water Consumption Rate (gal/h)
$Water\ Usage$	=	The amount of water used by the combi oven annually (L/year)
3.78541	=	Conversion factor (L/gal)
$\%steam$	=	Percentage operating time in steam mode (%)
T_{on}	=	Operating hours per day (hr/day)
$days$	=	The number of days per year the combination oven is in use

2. **Calculation of the water consumption impact**

$Water_{savings} = Water\ Usage_{baseline} - Water\ Usage_{ENERGYSTAR}$

where,

$Water_{savings}$	=	Annual water impact (L/year)
$Water\ Usage_{baseline}$	=	Annual water consumption for the baseline combi oven (L/year)
$Water\ Usage_{ENERGYSTAR}$	=	Annual water consumption ENERGY STAR combi oven (L/year)

ASSUMPTIONS

Combi ovens are split into three categories based on pan capacity: 6-14 pans, 15-28 pans, and 29+ pans. A representative size combi oven was chosen for each category based on the most popular combi ovens sold for each category. All pan sizing is based on 30.5 x 50.8 x 6.4-cm full-size steam pan (also known as Gastronome GN1/1). Combi ovens come in two sizes based on width and depth: full-size (accommodating two steam pans front-to-back per level) and half-size (accommodating one steam pan per level). Combi ovens come in three sizes by height: 6-pan, 12-pan, and 20-pan (roll-in). The matrix below shows the most popular combi oven sizes.

Table 3 Most Common Combi Oven Sizes

Levels	Half width	Full width
6 levels	6 pans	12 pans
10 levels	10 pans	20 pans
20 levels (roll in)	20 pans	40 pans

Ovens for different manufacturers may differ in each category ±1 pan per level based on cavity dimensions and rack spacing. An oven may be marketed based on sheet pan capacity that may differ from steam pan capacity due to narrower depth.

Table 4 Representative Size Combi Ovens

Size Category	Representative Size	Popular Description	Also, Could Be
6-14 pan	12-pan	Six-Pan Full-Size	Twelve-Pan Half-Size
15-28 pan	20-pan	Ten-Pan Full-Size	Twenty-Pan Half-Size, Roll-In
29+ pan	40-pan	Twenty-Pan Full-Size, Roll-In	N/A

The assumptions used to calculate energy savings are shown in Tables 5 to 7.

Table 5 Combi oven assumptions size 6-14 pan

Performance	Baseline Model	Energy-Efficient Model	Unit	Source
Preheat Time	8.92	6.04	min/preheat	[3]
Preheat Energy- convection mode	9,844	6,022	Btu/preheat	[3]
Preheat Energy- steam mode	9,310	4,889	Btu/preheat	[3]
Convection Idle Energy Rate	8,585	4,965	Btu/h	[3]
Convection Idle Energy Rate	0.39	0.38	kW	[3]
Convection Cooking Energy Efficiency	50	59	%	[3]
Convection Production Capacity	129	120	lb/hr	[3]
Steam Idle Energy Rate	21,530	6,869	Btu/h	[3]
Steam Idle Energy Rate	0.38	0.36	kW	[3]
Steam Cooking Energy Efficiency	38	50	%	[3]
Steam Production Capacity	201	194	lb/hr	[3]
Idle Water Consumption Rate	14.32	3.56	gal/h	[3]
Cooking Water Consumption Rate	13.96	6.83	gal/h	[3]
Operating Hours/Day	12		hr/day	[3]
Food Service Days/Year	344		day/yr	common assumption
Number of Preheats per Day	1		preheat/day	[3]
Pounds of Food Cooked per Day	389		lb/day	[3]
Percentage Time in Steam Mode	75		%	[3]
Percentage Time in Convection Mode	25		%	[3]
ASTM Convection Mode Energy to Food	250		Btu/lb	[1]
ASTM Steam Mode Energy to Food	105		Btu/lb	[1]
Conversion factor (min to hr)	60		min/hr	
Conversion factor (Btu to m^3)	35,738		Btu/m^3	common assumption
Conversion factor (US gallons to L)	3.78541		L/gal	[4]

Table 6 Combi oven assumptions size 15-28 pan

Performance	Baseline Model	Energy-Efficient Model	Unit	Source
Preheat Time	10.59	3.84	min/preheat	[3]
Preheat Energy- convection mode	5,417	8,538	Btu/preheat	[3]
Preheat Energy- steam mode	11,403	6,219	Btu/preheat	[3]
Convection Idle Energy Rate	8,600	6,591	Btu/h	[3]
Convection Idle Energy Rate	1.83	0.65	kW	[3]
Convection Cooking Energy Efficiency	69	61	%	[3]
Convection Production Capacity	163	201	lb/hr	[3]
Steam Idle Energy Rate	44,454	6,152	Btu/h	[3]
Steam Idle Energy Rate	1.81	0.67	kW	[3]
Steam Cooking Energy Efficiency	38	51	%	[3]
Steam Production Capacity	205	257	lb/hr	[3]
Idle Water Consumption Rate	6.75	2.10	gal/h	[3]
Cooking Water Consumption Rate	8.20	8.44	gal/h	[3]
Operating Hours/Day	12		hr/day	[3]
Food Service Days/Year	344		day/yr	common assumption
Number of Preheats per Day	1		preheat/day	[3]
Pounds of Food Cooked per Day	725		lb/day	[3]
Percentage Time in Steam Mode	75		%	[3]
Percentage Time in Convection Mode	25		%	[3]
ASTM Convection Mode Energy to Food	250		Btu/lb	[1]
ASTM Steam Mode Energy to Food	105		Btu/lb	[1]
Conversion factor	60		min/hr	
Conversion factor (Btu to m^3)	35,738		m^3/Btu	common assumption
Conversion factor (US gallons to L)	3.78541		L/gal	[4]

Table 7 Combi oven assumptions size 29+ pan

Performance	Baseline Model	Energy-Efficient Model	Unit	Source
Preheat Time	6.61	6.62	min/preheat	[3]
Preheat Energy- convection mode	18,286	14,829	Btu/preheat	[3]
Preheat Energy- steam mode	15,667	13,864	Btu/preheat	[3]
Convection Idle Energy Rate	15,845	9,704	Btu/h	[3]
Convection Idle Energy Rate	1.33	1.04	kW	[3]
Convection Cooking Energy Efficiency	56	61	%	[3]
Convection Production Capacity	374	403	lb/hr	[3]
Steam Idle Energy Rate	29,334	10,736	Btu/h	[3]

Performance	Baseline Model	Energy-Efficient Model	Unit	Source
Steam Idle Energy Rate	1.08	1.02	kW	[3]
Steam Cooking Energy Efficiency	53	54	%	[3]
Steam Production Capacity	598	487	lb/hr	[3]
Idle Water Consumption Rate	26.90	4.30	gal/h	[3]
Cooking Water Consumption Rate	38.50	9.95	gal/h	[3]
Operating Hours/Day	12		hr/day	[3]
Food Service Days/Year	344		day/yr	common assumption
Number of Preheats per Day	1		preheat/day	[3]
Pounds of Food Cooked per Day	1,450		lb/day	[3]
Percentage Time in Steam Mode	75		%	[3]
Percentage Time in Convection Mode	25		%	[3]
ASTM Convection Mode Energy to Food	250		Btu/lb	[1]
ASTM Steam Mode Energy to Food	105		Btu/lb	[1]
Conversion factor (min to hr)	60		min/hr	
Conversion factor (Btu to m^3)	35,738		m^3/Btu	common assumption
Conversion factor (US gallons to L)	3.78541		L/gal	[4]

SAVINGS CALCULATION EXAMPLE

The example below illustrates the annual natural gas savings, electrical and water impact due to the replacement of a conventional combi oven with an ENERGY STAR combi oven – 40 pan size.

Annual natural gas savings:

$$1\ oven \times 1{,}048\ \frac{m^3/yr}{oven} = 1{,}048\ m^3/yr$$

Annual Electrical Impact:

$$1\ oven \times 485\ \frac{kWh/yr}{oven} = 485\ kWh/yr$$

Annual Water Impact:

$$1\ oven \times 599{,}459\ \frac{L/yr}{oven} = 599{,}459\ L/yr$$

USES AND EXCLUSIONS

To qualify for this measure, the combi oven must be used for food preparation or processing with natural gas as its fuel source and must, at a minimum, be ENERGY STAR rated based on ENERGY STAR Commercial Oven Key Product Criteria V2.2. [2]

MEASURE LIFE

The measure life attributed to this measure is 12 years. [5]

INCREMENTAL COST

The incremental cost is summarized in the table below.

Table 8 Combi Oven Incremental cost [6]

Description	6-14 pan	15-28 pan	29+ pan
Energy Efficient cost	$24,132	$34,489	$51,415
Baseline cost	$20,191	$29,482	$42,908
Incremental cost	$3,941	$5,007	$8,507

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