NATURAL GAS DEMAND SIDE MANAGEMENT TECHNICAL RESOURCE MANUAL

Version 10.0

Date: March 19, 2026

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.

Date	Version	Reasons for Update
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

Date	Version	Reasons for Update
December 15, 2021	6.0	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

November 30, 2022	7.0	The OEB's Evaluation Contractor (DNV and Dunsky), with input from the Evaluation Advisory Committee (EAC), updated or added the following measures:
		• Commercial ENERGY STAR Griddles
		• Commercial ENERGY STAR Conveyor Oven
		• Commercial – Energy Star Fryer – New Construction/Time of Natural Replacement
		• Commercial – Energy Star Steam Cooker – New Construction/Time of Natural Replacement
		• Commercial – High Efficiency Under-Fired Broiler – New Construction/Time of Natural Replacement
		• Commercial – Energy Efficient Conveyor Broiler
		• Commercial Energy Star Dishwashers – New Construction / Time of Natural Replacement
		• Commercial ENERGY STAR Griddles
		• Common Assumptions Table, including
		  o Average City or Inlet Water Temperature
		  o Recovery Efficiency Residential Storage-Type Water Heater
		  o Thermal Efficiency Commercial Storage-Type Water Heater
		  o Affected substantiation documents.

Date	Version	Reasons for Update

April 30, 2024	8.0	The OEB's Evaluation Contractor (DNV and Dunsky), with input from the Evaluation Advisory Committee (EAC), updated or added the following measures:
		• Commercial Condensing Storage Water Heater (targeted review)
		• Commercial Condensing Unit Heater
		• Commercial Tankless Water Heater
		• Commercial Demand Controlled Kitchen Ventilation (DCKV) – New Construction/Retrofit
		• Common Assumptions Table, including:
		  o Effective full load heating hours commercial New Construction
		  o Effective full load heating hours commercial Retrofit
		  o Affected substantiation documents.

May 23, 2025	9.0	The OEB's Evaluation Contractor (DNV and Dunsky Energy + Climate Advisors), with input from the Evaluation Advisory Committee (EAC), updated or added the following measures:
		• Commercial Small and Medium Business Adaptive Thermostat – Retrofit
		• Residential – Cathedral/Flat Roof Insulation – Retrofit
		• Residential – Attic Insulation - Retrofit
		• Common Assumptions Table, including:
		  o Heating balance point (heating system enabled) residential
		  o Heating setpoint temperature residential
		  o Cooling balance point (OA temperature cooling system enabled) residential
		  o Cooling setpoint temperature residential

March 18, 2026	10.0	The OEB's Evaluation Contractor (DNV and Dunsky Energy + Climate Advisors), with input from the Evaluation Advisory Committee (EAC), updated or added the following measures: • Commercial – Demand Control Ventilation – Retrofit/Time of Natural Replacement/New Construction • Commercial – Air Curtains for Shipping and Receiving doors – "Dock-in" – New Construction/Retrofit • Commercial – Air Curtains for Shipping and Receiving doors – "Drive-in" – New Construction/Retrofit • Commercial – Air Curtains for Pedestrian doors – New Construction/Retrofit • Commercial – HVLS (High Volume Low Speed) Destratification Fans – New Construction/Retrofit • Commercial – Hybrid Heat Pump Roof Top Unit – Time of Natural Replacement/New Construction • Residential – Adaptive Thermostats – Retrofit

Date	Version	Reasons for Update

		• Residential – Cold Climate Air Source Heat pump and Air Source Heat Pump for Central systems – Time of Natural Replacement
		• Common Assumption Table, including:
		  ○ Commercial heating system efficiency (Air Systems)
		  ○ Heating hours per year
		  ○ Heating days per year
		  ○ Rooftop unit cooling system efficiency
		  ○ Space temperature setpoint commercial

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.

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 is indexed 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
Conversion of liter/gallons of water	3.7854	liter/gallons	https://www.unitconverters.net/volume/liters-to-gallons.htm	Commercial Energy Star Dishwashers
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.	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
	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.	Residential Showerheads (Single) 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 (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 (2018).	Commercial Cooking Measures (Underfired Broilers, Steamers, Fryers, Convection Ovens, Combi Ovens, Rack Ovens, Griddles, Conveyor Ovens, Conveyor Broilers) Commercial ENERGY STAR Dishwasher

Weather/Water Assumptions				
Input Variable	**Assumption**	**Units**	**Source / Comments**	Affected Subdocs
Average city or inlet water temperature	8.53 C (47.35 F)	deg C (deg F)	Canada Weather Year for Energy Calculation (CWEC 2016) for London, ON http://climate.weather.gc.ca/prods_servs/engineering_e.html Aligns with National Building Code of Canada guidance that identifies that ground temperatures in the climatic data file can be used to determine the service water temperature. This is the average ground temperature below 6 ft from Canada Weather Year for Energy calculation (CWEC 2016) for London, ON.	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)	77.10%		Average recovery efficiency of all gas residential storage-type water heater. https://www.ahridirectory.org/NewSearch?programId=24&searchTypeId=1 (2022) Used AHRI, which is publicly available, includes all water heaters (not just ENERGY STAR) and aligns with approach for commercial assumption.	Residential Faucet Aerators (Kitchen and Bathroom) Residential Pipe Wrap
	Thermal Efficiency (Commercial)	83.6%		Average thermal efficiency of all gas commercial storage-type water heater. https://www.ahridirectory.org/NewSearch?programId=27&searchTypeId=1 (2022) EGI calculated the value.	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 90.1-2022, for units below 225 MBH (Table 6.8.1-5 "Warm-Air Furnaces and Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces, and Unit Heaters—Minimum Efficiency Requirements")	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, commercial	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*	Commercial	6,019	hours	Relative to 56°F balance point temperature and based on CWEC data for London, ON (2020). 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.	Commercial Destratification Fans Commercial HRV Commercial ERV Commerical Air Curtains
	Residential	6,253	hours	Relative to 59°F balance point temperature and based on CWEC data for London, ON (2020). 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
Heating days per year	Commercial	251	days	Relative to a 56˚F balance point. Based on CWEC data for London, ON (2020).	Commercial Air Curtains
Heating days per year	Residential	261	days	Relative to 59°F balance point temperature and based on CWEC data for London, ON (2020).	
Effective full load heating hours commercial New Construction		1,172	hrs	The median EFLH value of all new construction building segments in Zone 2 (Chicago) in the 2023 IL TRM is calculated and adjusted to London, ON using researched weather data (HDD, balance point, and design temperature) from ASHRAE for Chicago, IL and London, ON. 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 High Efficiency Condensing Furnace
Effective full load heating hours commercial Retrofit		1,651	hrs	The median EFLH value of all existing building segments in Zone 2 (Chicago) in the 2023 IL TRM is calculated and adjusted to London, ON using a) researched weather data (HDD, balance point, and design temperature) from ASHRAE for Chicago, IL and London, ON and b) an adjustment to convert the ASHRAE balance point of 50°F to a balance point of 55°F for existing buildings, to ensure consistency with the rest of the TRM. 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 High Efficiency Condensing Furnace
Rooftop Unit Cooling System Efficiency		3.8	COP	-Cooling capacity of less than 19 kW (65,000 Btu/h) from Energy Efficiency Regulations, Canada. Source: https://natural-resources.canada.ca/energy-efficiency/energy-efficiency-regulations/single-package-central-air-conditioners-heat-pumps, and -Cooling capacity of at least 19 kW (65,000 Btu/h) but less than 223 kW (760,000 Btu/h) from Energy Efficiency Regulations, Canada. Source: https://natural-resources.canada.ca/energy-efficiency/energy-efficiency-regulations/large-air-conditioners-heat-pumps-condensing-units	Commercial Air Curtains for Pedestrian door Commercial Air Curtains for Shipping & Receiving door Commercial Condensing Make-Up Air Unit Commercial Dock Door Seals Commercial ERV Commercial HRV Commercial Kitchen DCV
Space Temperature Setpoint, commercial		68.0	°F	Calculated average from NECB 2020 Table A-8.4.3.2.(2)-A. Table A temperature schedules by building type. Source: https://nrc-publications.canada.ca/eng/view/ft/?id=af36747e-3eee-4024-a1b4-73833555c7fa&dp=2&dsl=en	Commercial Condensing Make-Up Air Unit Commercial DCV Commercial Air Curtains for Pedestrian door Commercial ERV Commercial HRV
		20.0	°C		
		527.7	R		
		293.2	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, commercial		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		
Heating balance point (heating system enabled), residential		60.0	°F	Based on industry best-practice in Illinois, Maine, and Mid-Atlantic in the US (Efficiency Maine, "Efficiency Maine TRM (2024): Retail/Residential," 2024). The Mid-Atlantic 60°F balance point is based on a PRISM evaluation of approximately 600,000 Ohio residential single-family customers showing this is the point below which heating is generally used (Northeast Energy Efficiency Partnerships, "Mid-Atlantic Technical Resource Manual," 2019). For Illinois, residential heating is based on 60°F, in accordance with regression analysis of heating fuel use and weather by state by the Pacific Northwest National Laboratory (Illinois Commerce Commission, "Illinois Statewide Technical Reference Manual for Energy Efficiency Version 12.0, VOLUME 3: RESIDENTIAL MEASURES," 1 Jan 2024)	Residential Attic Roof Insulation Residential Cathedral/Flat Roof Insulation
		15.6	°C		
		519.7	R		
		288.7	K		
Heating setpoint temperature, residential		68.0	°F	The Posterity Group Report for Attic Insulation, assumptions table (Exhibit 10 - Section 3.3.6) with reference to ASHRAE Fundamentals 2021, Chapters 17 and 19 ("2021 ASHRAE Handbook - Fundamentals (I-P Edition)").	Residential Attic Roof Insulation Residential Cathedral/Flat Roof Insulation
		20.0	°C		
		527.7	R		
		293.2	K		
Cooling balance point (OA temperature cooling system enabled), residential		70.0	°F	Based on Efficiency Maine TRM (2024) for new and existing residential buildings (Efficiency Maine, "Efficiency Maine TRM (2024): Retail/Residential," 2024. [Online]. Available: https://www.efficiencymaine.com/docs/EMT-TRM_Retail_Residential_v2024_3.pdf)	Residential Attic Roof Insulation Residential Cathedral/Flat Roof Insulation
		21.1	°C		
		529.7	R		
		294.3	K		
Cooling setpoint temperature, residential		75.0	°F	In residential buildings, the cooling setpoint temperature is assumed to be 75oF (23.9oC), with a maximum relative humidity of 65%, which corresponds to typical design practice for cooling; this cooling setpoint temperature applies to existing buildings and to new constructions. (ASHRAE Handbook - Fundamentals (I-P Edition) Chapter 17. Residential Cooling and Heating Load Calculations. 6. Common Data and Procedures. Sub-section. Design Conditions. Indoor Conditions, 2021)	Residential Attic Roof Insulation Residential Cathedral/Flat Roof Insulation
		23.9	°C		
		534.7	R		
		297.0	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 (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 (Retrofit)
11. Residential – Cathedral/Flat Roof Insulation (Retrofit)
12. Residential – Attic Insulation (Retrofit)
13. Residential – Cold Climate Air Source Heat Pump and Air Source Heat Pump for Central Systems (Time of Natural Replacement)
14. Commercial – Air Curtains for Shipping and Receiving Doors “Dock-In”(New Construction/Retrofit)
15. Commercial – Air Curtains for Shipping and Receiving Doors “Drive-In” (New Construction/Retrofit)
16. Commercial – Air Curtains for Pedestrian Doors (New Construction/Retrofit)
17. Commercial – Condensing Make Up Air Unit (New Construction/Time of Natural Replacement)
18. Commercial – Condensing Storage Gas Water Heater (New Construction/Time of Natural Replacement)
19. Commercial – Condensing Unit Heater (New Construction/Time of Natural Replacement)
20. Commercial – Demand Controlled Ventilation (New Construction/ Retrofit/Time of Natural Replacement)
21. Commercial – High Volume Low Speed (HVLS) Destratification Fans (New Construction/Retrofit)
22. Commercial – Dock Door Seals (Retrofit)
23. Commercial – Incremental Energy Recovery Ventilation (ERV) (55% effectiveness baseline) (New Construction/Time of Natural Replacement)
24. Commercial – Energy Recovery Ventilation (ERV) (No ERV baseline) (New Construction/Retrofit)
25. Commercial – ENERGY STAR Convection Oven (New Construction/Time of Natural Replacement)
26. Commercial – ENERGY STAR Dishwasher (New Construction/Time of Natural Replacement)
27. Commercial – ENERGY STAR Fryer (New Construction/Time of Natural Replacement)

28. Commercial – ENERGY STAR Steam Cooker (New Construction/Time of Natural Replacement)
29. Commercial – Incremental Heat Recovery Ventilation (HRV) (55% effectiveness baseline) (New Construction/Time of Natural Replacement)
30. Commercial – Heat Recovery Ventilation (HRV) (No HRV baseline) (New Construction/Retrofit)
31. Commercial – High Efficiency Condensing Furnace (New Construction/ Time of Natural Replacement)
32. Commercial – Energy-Efficient Under-Fired Broiler (New Construction/Time of Natural Replacement)
33. Commercial – Multi-Residential Low-Flow Showerhead (New Construction)
34. Commercial – Multi-Residential Low-Flow Showerhead (Retrofit)
35. Commercial – Ozone Laundry Treatment (New Construction/Retrofit)
36. Commercial – Condensing Tankless Gas Water Heater (New Construction/ Time of Natural Replacement)
37. Commercial – Kitchen Demand Controlled Ventilation (New Construction/Time of Natural Replacement)
38. Commercial – Kitchen Demand Controlled Ventilation (Retrofit)
39. Commercial – ENERGY STAR Rack Ovens (New Construction/Time of Natural Replacement)
40. Commercial – ENERGY STAR Combi Oven (New Construction/Time of Natural Replacement)
41. Commercial – ENERGY STAR Griddles (New Construction/Time of Natural Replacement)
42. Commercial – Efficient Conveyor Oven (New Construction/Time of Natural Replacement)
43. Commercial – Energy Efficient Conveyor Broiler (New Construction/Time of Natural Replacement)
44. Commercial – Small and Medium Business Adaptive Thermostat (Retrofit)
45. Commercial – Hybrid Heat Pump Roof Top Unit (Time of Natural Replacement/New Construction)

RESIDENTIAL – ADAPTIVE THERMOSTATS – RETROFIT

Version Date and Revision History	
Version	
OEB Filing Date	
OEB Approval Date	
Residential → Space Heating → Adaptive 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	Non-Programmable Thermostat (NPT) or Programmable Thermostat (PT)		
Efficient Technology	Adaptive Thermostat		
Market Type	Residential, Residential - Other Use[1]		
Annual Natural Gas Savings (m^3/yr per building)	**Retrofit - Retail Purchase, mixed baseline**	**Retrofit - Direct Install, non-programmable thermostat baseline**	**Retrofit - Direct Install, programmable thermostat baseline**
	130	181	145
Annual Electrical Cooling Impacts (kWh/ yr per building)	182	217	
Measure Life	10 years		
Incremental Cost ($ CAD)	**Retrofit - Retail Purchase**	**Retrofit - Direct Install, Low-Income**	**Retrofit - Direct Install, Non-Low-Income**
	$270	$330	$305
Restrictions	This measure requires that an adaptive thermostat would replace a conventional programmable or non-programmable thermostat serving a gas-fired space heating system in a residential building. Restricted to all buildings of three or fewer stories in building height, having a building area not exceeding 600 m^2(6,460 ft^2), and used for		

[1] Refers to residential buildings used for major occupancies classified as business and personal services occupancies, or mercantile occupancies. Medium hazard industrial occupancies and low hazard industrial occupancies are not included.

Parameter	Definition
	major occupancies classified as: residential occupancies other than buildings used for retirement homes, business and personal services occupancies, or mercantile occupancies. Applicable where the space heating load is satisfied by a natural gas heating system. This sub-doc does not apply to buildings that have or are in the process of installing a hybrid (dual-fuel) space heating system (e.g., an electric air-source heat pump with natural gas furnace backup, a ground-source heat pump with a natural gas furnace backup, etc.).

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 $130 for basic models to $535 for more sophisticated models and packages.

APPLICATION

Applicable to all buildings- that have either a programmable or non-programmable thermostat- of three or fewer stories in building height, having a building area not exceeding 600 m^2 (6,460 ft^2), and used for major occupancies classified as: residential occupancies other than buildings used for retirement homes, business and personal services occupancies, or mercantile occupancies. Applicable where the space heating load is satisfied by a natural gas-fired heating system.

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

A 2015 study conducted a survey on the misuse of programmable thermostats and found that many of the key barriers/issues previously identified with older style programmable thermostats continue to be relevant for programmable thermostats in general [2]. Some key issues include:

- Confusing or cumbersome set up.
- Effectiveness can be significantly limited by household routines and schedules.
- Unfamiliarity with terminology and device capabilities.
- Lack of understanding of how home thermostat and HVAC system operate.

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 and 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. [3]

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. Adaptive thermostats use geofencing and

occupancy sensors to detect occupancy in the building and automatically implement temperature setback during unoccupied periods.

System Performance Optimization

System performance optimization capabilities use analytics to run a household's HVAC equipment more efficiently. 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. [3]

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. [3]

ENERGY IMPACTS

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

NATURAL GAS SAVINGS ALGORITHMS

Enbridge performed a billing data analysis to examine savings for participants who installed adaptive thermostats during the 2021 program year. Data from over 17,500 participants was used to determine the retrofit natural gas savings for the program. This includes a breakdown of savings that were achieved in retail purchase and direct install applications. For direct install scenarios, it was also possible to produce differentiated savings estimates for customers who had programmable thermostats and non-programmable thermostats.

An estimate of the retrofit natural gas savings was developed using one-year baseline and monitoring periods with 2020 selected as the baseline year for adaptive thermostats that were installed in 2021. Despite the impacts of the COVID pandemic, which started in mid-March 2020, the 2020 baseline was chosen as it represented the most complete data available for

program participants. Similarly, 2022 was chosen as the monitoring period for savings since it represented the first full year following program participation.

Data on the proportion of Ontarians working most of their hours from home during 2020 and 2022 was combined with heating degree day data for these periods to investigate differences in occupancy patterns during the baseline and monitoring periods [4]. The results of this analysis indicate that a higher proportion of Ontario workers were working most of their hours from home during 2022 (28.3%) compared to 2020 (23.7%). This likely reduces the potential natural gas savings due to a higher level of occupancy being directly proportional to fewer temperature setback opportunities. As such, this suggests that the selection of baseline and monitoring periods likely leads to a reasonable and conservative estimate of natural gas savings.

Retrofit Natural gas savings - Retail Purchase, mixed baseline.

The natural gas savings for this scenario were based on average difference in the baseline and monitoring period annual natural gas consumptions for 17,142 program participants who purchased adaptive thermostats directly from retailers. The average annual natural gas savings is 130 m^3, which represents 5.2% savings over the baseline year average annual total natural gas consumption and 7.5% savings over the baseline year average annual space heating natural gas consumption (estimating that space heating accounts for 70% of the baseline year average annual natural gas consumption [5]). The results of the literature review suggest that this savings value is within a reasonable range.

Retrofit Natural gas savings - Direct Install, non-programable thermostat baseline.

The natural gas savings for this scenario were based on the average difference in the baseline and monitoring period annual natural gas consumptions for 87 program participants who were 2021 participants of Enbridge's direct install program. The average annual natural gas savings is 181 m^3, which represents a 7.0% savings compared to the baseline year average annual total natural gas consumption and 9.9% savings over the baseline year average annual space heating natural gas consumption (estimating that space heating accounts for 70% of the baseline year average annual natural gas consumption [5]).

It is reasonable that the typical savings in direct install scenarios are higher than the retail scenario, since a direct install ensures proper installation and setup of adaptive thermostats.

Retrofit Natural gas savings - Direct Install, programable thermostat baseline.

The natural gas savings for this scenario were based on the average difference in the baseline and monitoring period annual natural gas consumptions for 462 program participants who were 2021 participants of Enbridge's direct install program. The average annual natural gas savings is 145 m^3, which represents a 5.5% savings compared to the baseline year average annual total natural gas consumption and 7.8% savings over the baseline year average annual

space heating natural gas consumption (estimating that space heating accounts for 70% of annual natural gas consumption [5]).

It is reasonable that the typical savings in this direct install scenarios are higher than the retail scenario since a direct install ensures proper installation and setup of adaptive thermostats.

ELECTRIC COOLING IMPACTS ALGORITHMS

Cooling impacts were estimated based on the typical space cooling energy intensity, average home conditioned area, and typical cooling savings percentage for adaptive thermostats. The space cooling energy intensity was based on data from NRCan's Comprehensive Energy Use Database (CEUD), which estimated an energy intensity of 29.6 MJ/m^2 (0.76 kWh/ft^2) for Ontario homes across the past 3 years (2020-2022) [6]. The average conditioned floor area of 2,593 ft^2 was based on Enbridge HER program participants from 2019-2020. This data is based on EnerGuide audits of Ontario homes. This data suggests that the average cooling load for a typical customer is 1,971 kWh/year.

A review of TRMs and relevant literature from jurisdictions with similar climates suggests that cooling savings are estimated at 6-16%. As shown in the formula below, applying an average of 11% savings results in an estimated electric savings of 217 kWh/year. This value only applies for participants with central air conditioning (AC) who are participating in a direct install program where the presence of a central AC system can be verified.

$$Retrofit\ Cooling\ Savings = 0.76\frac{kWh}{ft^2} \times 2{,}593\ ft^2 \times 11\% = 217\frac{kWh}{yr}$$

For the retail purchase market, it is not known if the adaptive thermostat also controls central air conditioning. According to the Enbridge 2020 Residential Single Family Natural Gas End Use Study (REUS), approximately 84% of single-family households in Ontario have central air conditioning. Employing this value as an estimate of the penetration of central air conditioning, the retail purchase impact is 182 kWh/yr. Calculating cooling savings as 84% of the 11% savings results in a total cooling savings of 9.24% for mixed retail scenarios.

$$Retrofit\ Cooling\ Savings_{Mixed\ Retail} = 0.76\frac{kWh}{ft^2} \times 2{,}593\ ft^2 \times 11\% \times 84\% = 182\frac{kWh}{yr}$$

ASSUMPTIONS

Table 2 provides a list of assumptions utilized in the measure savings algorithms to derive the savings values listed in Table 1 above.

Table 2. Assumptions

Definition	Inputs	Source/Comments
Average conditioned floor area – existing homes	2,593 ft^2	Enbridge HER Program data
Cooling savings percentage	11%	ICF Benchmark analysis
Penetration of central air conditioning – single family	84%	2020 Enbridge REUS
Annual electrical cooling consumption – existing homes	0.76 kWh/ft^2	NRCan CEUD Data for Ontario [6]

SAVINGS CALCULATION EXAMPLE

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

USES AND EXCLUSIONS

Not applicable to buildings that have or are in the process of installing a hybrid (dual-fuel) space heating systems (e.g., an electric air-source heat pump with natural gas furnace backup, a ground-source heat pump with a natural gas furnace backup, etc.).

MEASURE LIFE

The proposed measure life of an adaptive thermostat is 10 years. This is based on a literature review that compared measure life values being used for adaptive thermostats across various jurisdictions in the Unites States. This literature review determined that a 10-year measure life is a reasonable middle-ground between the relevant and widely used evaluated sources.

INCREMENTAL COST

Enbridge conducted a cost analysis that reviewed all currently eligible adaptive thermostat models according to the program criteria as described in the Efficient Technology section above. The analysis considered typical retail costs, as well as sale periods and discounts during 2024 to determine an average retail cost for each eligible thermostat.

The average adaptive thermostat cost in a retail purchase incorporates the weighted average cost based on Enbridge participant data, resulting in an average cost of $270, indicating that market purchases tend to lean towards higher-end, more expensive models [8]. In retail purchase scenarios, it is assumed that customers complete the installation of thermostats on their own.

For typical direct install applications, the costs were found to range from $140 to $380, with an average cost of $225 for adaptive thermostats [8]. Based on Enbridge data, an installation cost of $80 applies to non-low-income direct install applications.

In direct install scenarios with low-income customers, Enbridge assessed the typical wholesale prices that they are able to secure for adaptive thermostats and came to an average cost of $135. Based on Enbridge data, an installation and professional service cost of $145 and $50 administration fee applies to low-income customer installations.

The incremental cost of an adaptive thermostat is outlined in Table 3 below for each scenario. These costs apply to both programmable and non-programmable thermostat baselines.

Table 3. Incremental Cost

Measure Category	Incremental Cost
Retrofit – Retail Purchase	$270
Retrofit – Direct Install, Low-Income	$330
Retrofit – Direct Install, Non-Low-Income	$305

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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 m³/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	1.1 (minor changes)
OEB Filing Date	November 14, 2022
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)	44.1 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.

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

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_{Tank} = 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 (Btu/hr ˚F)

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 Btu/hr ˚F		[4]
T_{Amb}	Ambient air temperature	67.5°F (19.7˚C)		[7]
T_{In}	Average city or inlet water temperature	47.35°F (8.53˚C)		Common assumptions table

Variable	Definition	Inputs		Source/Comments
		Base Efficiency	High Efficiency	
T_{Tank}	Domestic hot water factory set tank temperature	120°F (48.9˚C)		Common assumptions table
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 Btu/ m^3		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:

$$Q_{Out} = 8.29 \times 42 \times 1.00 \times (120°F - 47.35°F) = 25{,}298\ Btu$$

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:

$$Q_{In\ base} = \frac{365}{1000} \times \left(\frac{25{,}298}{0.784} + 5.78 \times (120°F - 67.5°F) \times \left(24 - \frac{25{,}298}{0.784 \cdot 44{,}894} \right) \right)$$

$$= 14{,}415\ kBtu$$

Similarly,

$$Q_{In\ HE} = 12{,}839\ kBtu$$

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

$$Annual\ NG\ savings = 14{,}415 - 12{,}839 = 1{,}576\ kBtu$$

$$Annual\ NG\ savings = 1{,}576\ kBtu \times \frac{1{,}000}{35{,}738} = 44.1\ m^3$$

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:

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

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.

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] Barkett, Brent; Cook, Gay, "Resource Savings Values in Selected Residential DSM Prescriptive Programs," Summit Blue, Ontario, 2008.

[5] O. Drolet, "Showerheads/Aerators Flow Rate Validation," Natural Gas Technologies Centre, Ontario, 2007.

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:

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

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

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.

[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] Barkett, Brent; Cook, Gay, "Resource Savings Values in Selected Residential DSM Prescriptive Programs," Summit Blue, Ontario, 2008.

[5] O. Drolet, "Showerheads/Aerators Flow Rate Validation," Natural Gas Technologies Centre, Ontario, 2007.

RESIDENTIAL – LOW FLOW FAUCET AERATORS –RETROFIT

Version Date and Revision History	
Version	1.1 (minor changes)
OEB Filing Date	November 14, 2022
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	6.65 m^3		3.88 m^3
	Kitchen aerator	20.57 m^3		12.00 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:

$$W_{savings} = Fu \times Ppl \times Dr\% \times Fa\% \times \left(\frac{Fl_{base} - Fl_{eff}}{Fl_{base}}\right) \times 3.78541 \frac{liters}{gallon} \times 365 \frac{days}{year}$$

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.

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

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 (%)
C_p	=	Specific heat capacity of water (Btu/lb-°F)

ρ = Density of water at 100°F (lb/gal)

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	8.53°C (47.35°F)	Common assumptions table
T_{out}	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	77.10%	Common assumptions table
C_p	Specific heat capacity of water	1.00 Btu/lb-°F	Common assumptions table
ρ	Density of water at 100°F	8.29 lb/gal (US gallons)	Common assumptions table
	Conversion factor	35,738 Btu/m^3	Common assumptions table
	Conversion factor	365 days/year	

[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.

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:

385.4 gallons / year × 46% heated water × 8.33 BTU / gallon - °F × (120 - 47.35) ^{0}F / 77.10% / 35,738 BTU/m^3 = **3.88 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].

[2] Office of Energy Efficiency and Renewable Energy, "Best Management Practices #7: Faucets and Showerheads," US Department of Energy, 18 August 2014. [Online]. Available: http://energy.gov/eere/femp/best-management-practice-7-faucets-and-showerheads. [Accessed 18 August 2014].

[3] Aquacraft Inc., "Residential End Uses of Water, Page 87," American Water Works Association, Denver, Co., 1999.

[4] Summitt Blue, "Resource Savings Values in Selected Residential DSM Prescriptive Programs, Pages 18-22," Summitt Blue Consulting Services, 2008.

[5] Aquacraft, Inc, "Residential Indoor Water Conservation Study, Page 31," Aquacraft, Iinc., Boulder Co., 2003.

[6] T. Skeel, "Evaluation of Savings from Seattle's "Home Water Saver" Program," American Water Resources Association, Middleburg, VA, 1995.

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

[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	1.3 (minor update)
OEB Filing Date	March 19, 2026
OEB Approval Date	
Residential → Water Heating → Pipe Wrap → Retrofit	

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

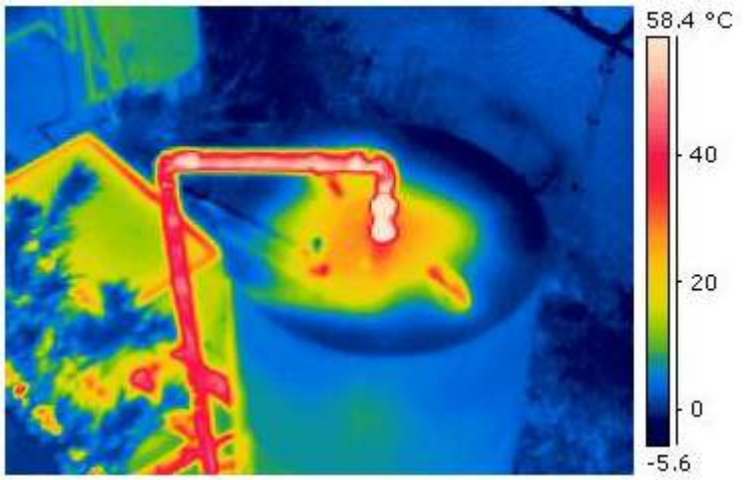
Table 1. Measure Key Data

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)	3.35 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/ft²·°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-ft² -°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·°F·h/Btu)

R_{post} = R-value of efficient equipment (ft^2·°F·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

$$S = \frac{\left[\left(\frac{1}{0.435} - \frac{1}{4.785}\right) \times 0.164 \times (120 - 67.5) \times 8760 \times \left[1 - \left(0.58 \times \frac{6,253}{8,760}\right)\right]\right]}{0.7710 \times 35,738}$$

$$Annual\ NG\ savings = 3.35\ m^3/ft$$

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	77.10%	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	6,253	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.

$$Annual\ NG\ savings = 3.35 \frac{m^3}{ft} \times 6.56\ ft = 22\ m^3$$

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]

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RESIDENTIAL - LOW INCOME – PROGRAMMABLE THERMOSTATS – RETROFIT

Version Date and Revision History	
Version	1.1 (minor change)
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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%.

[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]

[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	1.1 (minor changes)
OEB Filing Date	November 14, 2022
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: 90.7 m^3
	Condensing Tankless: 130.7 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].

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

and,

$$DHWload = dailyDHW \times 365\frac{days}{yr} \times \rho \times C_p \times (T_s - T_c)/1{,}000$$

where,

$Annual\ NG\ Savings$ = Annual natural gas saving (m^3), see Table 1

$DHWload$ = Annual domestic hot water heating load (kBtu), calculated

$EF_{baseline}$ = 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	8.53°C (47.35 °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.

$$DHWload = 54\ \frac{US\ Gal}{day} \times 365 \frac{days}{yr} \times 1 \frac{Btu}{lb°F} \times 8.29 \frac{lb}{US\ gal} \times (120\ °F - 47.35\ °F)/1000$$
$$= 11{,}870\ kBtu/yr$$

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

$$Natural\ Gas\ Savings\ = \frac{11{,}870\ kBtu/yr}{35.738 \frac{kBtu}{m^3}} \times \left(\frac{1}{0.67} - \frac{1}{0.82}\right) = 90.7\ m^3/yr$$

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

$$\boldsymbol{Natural\ Gas\ Savings\ = \frac{11{,}870\ kBtu/yr}{35.738 \frac{kBtu}{m^3}} \times \left(\frac{1}{0.67} - \frac{1}{0.91}\right) = 130.7\ m^3/yr}$$

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)
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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.

$$\begin{aligned} &Annual\ energy\ savings\ (m^3/year) \\ &\quad = Average\ annual\ consumption\ \ (m^3/year) \\ &\quad * \ Average\ change\ in\ consumption\ due\ to\ heat\ reflector\ panels\ (\%) \end{aligned}$$

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.

REFERENCES

[1] Novitherm Heat Reflectors, "Features and Benefits – Residential," 2020. [Online]. Available: http://novitherm.com/?page_id=840.

[2] Enbridge Gas Distribution Inc., "Impact of Radiator Panels on Residential Heating Consumption," Load Research Group, Toronto, 2008.

[3] Novitherm Heat Reflectors, "Installation Guide," Sept 2008. [Online]. Available: http://novitherm.com/wp-content/uploads/2015/04/installationguide.pdf.

[4] Novitherm Heat Reflectors, "Technical Information," Novitherm Heat Reflectors, 2020. [Online]. Available: http://novitherm.com/?page_id=785.

RESIDENTIAL – CATHEDRAL/FLAT ROOF INSULATION – RETROFIT

Version Date and Revision History	
Version	1.1
OEB Filing Date	May 23, 2025
OEB Approval Date	
Residential → Building Envelope→ Cathedral/Flat Roof Insulation → 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	Various insulation levels, please see baseline technology section.							
Efficient Technology	Achieve minimum nominal R-value of R-20 or R-28, please see efficient technology section							
Market Type	Residential, Residential-other use[1]							
Annual Natural Gas Savings	**Existing Nominal R-value**	**Min. Upgrade R-value**	**Manual thermostat**		**Programmable thermostat**		**Adaptive thermostat**	
			Delta R-value savings[2] (m^3/ft^2)	Air leakage reduction savings[3] (m^3/yr)	Delta R-value savings[2] (m^3/ft^2)	Air leakage reduction savings[3] (m^3/yr)	Delta R-value savings[2] (m^3/ft^2)	Air leakage reduction savings[3] (m^3/yr)
	No insulation	R-20	0.882	423	0.864	415	0.794	381
	>R-0 to R-12	R-20	0.105	223	0.103	219	0.095	201

[1] Residential- other use refers to residential buildings, used for major occupancies classified as: business and personal services occupancies, or mercantile occupancies. Medium hazard industrial occupancies and low hazard industrial occupancies is not included.
[2] Natural gas savings due to delta R-value only. It does not include the effect of air leakage reduction inherent from the ceiling insulation activity.
[3] Natural gas savings due to the air leakage reduction from Cathedral/Flat roof insulation activity. It does not include the savings from delta R-value. It is only applicable when the measures completed in the home is either Cathedral/Flat roof insulation or Cathedral/Flat roof + Attic insulation. If customer completes any other measure such as: Basement insulation, space heating equipment upgrade, etc., the air leakage reduction savings will not apply. The savings associated with the reduction of air leakage inherent of the ceiling insulation activity were calculated based on total air volume reductions obtained from HOT2000 simulations using input data extracted from blower door test results in homes that underwent similar attic insulation upgrades as part of the EGI HER+ 2019-2020 program years. The data used to substantiate these assumptions includes homes that completed only ceiling insulation and do not capture interactive effects with other measures mentioned before, hence the restriction in the savings related to the air leakage reduction.

Parameter	Definition							
	No insulation	R-28	0.920	423	0.902	415	0.828	381
	>R-0 to R-12	R-28	0.143	223	0.141	219	0.129	201
	>R-12 to R-25	R-28	0.040	220	0.039	216	0.036	198
Annual Electricity Impact for Residential Buildings Equipped with Central Air Conditioning	**Existing Nominal R-value**	**Min. Upgrade R-value**	**Manual thermostat**		**Programmable thermostat**		**Adaptive thermostat**	
			Delta R-value impacts[4] (kWh/ft^2)	Air leakage reduction impacts[5] (kWh/yr)	Delta R-value impacts[4] (kWh/ft^2)	Air leakage reduction impacts[5] (kWh/yr)	Delta R-value impacts[4] (kWh/ft^2)	Air leakage reduction impacts[5] (kWh/yr)
	No insulation	R-20	0.124	167	0.121	162	0.107	162
	>R-0 to R-12	R-20	0.015	88	0.014	86	0.013	85
	No insulation	R-28	0.130	167	0.126	162	0.112	162
	>R-0 to R-12	R-28	0.020	88	0.020	86	0.017	85

[4] Electricity impacts due to delta R-value only. It does not include the effect of air leakage reduction inherent from the Attic insulation activity.

[5] Electricity impacts due to the air leakage reduction from Cathedral/Flat Roof insulation activity. It does not include the savings from delta R-value. It is only applicable for when the measures completed in the home is either Cathedral/Flat roof insulation or Cathedral/Flat roof + Attic insulation. If customer completes any other measure such as: Basement insulation, space heating equipment upgrade, etc., the air leakage reduction savings will not apply. The savings associated with the reduction of air leakage inherent of the ceiling insulation activity were calculated based on total air volume reductions obtained from HOT2000 simulations using input data extracted from blower door test results in homes that underwent similar attic insulation upgrades as part of the EGI HER+ 2019-2020 program years. The data used to substantiate these assumptions includes homes that completed only ceiling insulation and do not capture interactive effects with other measures mentioned before, hence the restriction in the savings related to the air leakage reduction.

<table>
<tr><th>Parameter</th><th colspan="8">Definition</th></tr>
<tr><td></td><td>>R-12 to R-25</td><td>R-28</td><td>0.006</td><td>87</td><td>0.005</td><td>84</td><td>0.005</td><td>84</td></tr>
<tr><td>Measure Life</td><td colspan="8">30 years</td></tr>
<tr><td rowspan="6">Incremental Cost ($ CAD/ ft^2 of insulated area)</td><td colspan="3">Existing Nominal R-value</td><td colspan="3">Min. Upgrade R-value</td><td colspan="2">$ CAD/ ft^2 of insulated area</td></tr>
<tr><td colspan="3">No insulation</td><td colspan="3">R-20</td><td colspan="2">$6.17</td></tr>
<tr><td colspan="3">>R-0 to R-12</td><td colspan="3">R-20</td><td colspan="2">$3.11</td></tr>
<tr><td colspan="3">No insulation</td><td colspan="3">R-28</td><td colspan="2">$7.96</td></tr>
<tr><td colspan="3">>R-0 to R-12</td><td colspan="3">R-28</td><td colspan="2">$5.17</td></tr>
<tr><td colspan="3">>R-12 to R-25</td><td colspan="3">R-28</td><td colspan="2">$2.94</td></tr>
<tr><td>Restrictions</td><td colspan="8">Restricted to residential buildings[6] of three or fewer storeys in building height, having a building area not exceeding 600 m^2, used for major occupancies classified as: residential occupancies, business and personal services occupancies, or mercantile occupancies. For which the space heating load is satisfied by a natural gas heating system. This sub doc does not apply to hybrid-fuel space heating systems (i.e., an electric heat pump satisfying a portion of the space heating load). In addition, footnotes 3 and 5 on this document.</td></tr>
</table>

OVERVIEW

A cathedral ceiling is an architectural feature in a building, characterized by its steeply sloping or arched design that resembles the interior of a cathedral. These ceilings rise diagonally from the walls to form a peak or ridge at the center. Cathedral ceilings are often constructed with a high, open central space, which can be used for various purposes such as providing a sense of openness and allowing for the installation of large windows, skylights, or decorative elements. This architectural design is popular for its aesthetic appeal and the feeling of openness it imparts to a room.

A flat roof is a type of roof that has a horizontal or flat appearance. Unlike cathedral roofs, which have a noticeable incline to allow rainwater and snow to naturally drain off, flat roofs have a minimal slope that might not be easily noticeable. Flat roofs are used in residential buildings for various reasons, such as modern architectural aesthetics, cost-effectiveness, or to provide outdoor living spaces on the roof.

Structurally, flat roofs and cathedral roofs are alike, and the insulation installation methods are the same for both. Compared to conventional attics, one challenge with cathedral ceiling and flat roof

[6] Medium hazard industrial occupancies and low hazard industrial occupancies is not included.

insulation retrofits is that the interior surface of the ceiling is finished with drywall or paneling, which must be removed prior to installation (blow-in insulation may be used in limited scenarios). Cathedral ceiling and flat roof insulation can be installed in a similar fashion to insulation in an exterior facing wall, fitting batts, spray foam, and/or rigid foam insulation between the joists on the inside of the ceiling. In most cases the existing insulation is removed to make room for the upgrade insulation material.

It is sometimes possible to add additional insulation on top of the existing insulation; rigid foam insulation can be installed above the roof sheathing on the outside of the surface, and a new roof layer created on top of it. This allows the installer to leave the existing insulation inside the ceiling/roof assembly and reduces the amount of additional insulation material required to achieve the desired insulating effect.

Increasing the insulation of a specific building component enhances thermal resistance (R-value) and minimizes heat transfer, thus reducing the energy needed to compensate for heat loss in the heating season, and for heat gains in the cooling season.

Increasing the insulation of the cathedral/flat roofs also reduces air leakage through the roof assembly, thus reducing the energy needed to heat or cool the replacement air.

Energy savings are determined through engineering algorithms. Annual energy savings from enhanced thermal resistance (Delta R-value savings) are expressed in cubic meters per square foot of insulation for natural gas (m^3/ft^2) and kilowatt hours per square foot of insulation for electricity (kWh/ft^2). Annual air leakage reduction savings are expressed in cubic meters per attic for natural gas (m^3) and in kilowatt hours per attic for electricity (kWh).

APPLICATION

This measure applies to:

- The addition or replacement of Cathedral/Flat roof insulation in a residential home in Ontario to achieve a minimum insulation value of nominal R-20 or R-28, Table 2.
- Residential buildings for which the space heating load (full load) is satisfied by a natural gas heating system.
- It is applicable to residential buildings of three or fewer storeys in building height, having a building area not exceeding 600 m^2, used for major occupancies classified as: residential occupancies, business and personal services occupancies, or mercantile occupancies.

This measure does not apply to:

- Hybrid-fuel space heating systems (i.e., an electric heat pump satisfying a portion of the space heating load).
- Residential buildings used for major occupancies classified as: medium hazard industrial occupancies and low hazard industrial occupancies.
- This measure requires a member of the implementation staff to evaluate the pre- and post-project R-values and to measure the retrofitted Cathedral/Flat roof area.

BASELINE TECHNOLOGY

The baseline technology refers to the existing Cathedral/Flat roof insulation conditions, categorized into three levels of nominal insulation:

- No insulation
- >R-0 to R-12
- >R-12 to R-20

These categories represent the varying degrees of insulation present in existing Cathedral/Flat roof before any improvements are made.

EFFICIENT TECHNOLOGY

The energy efficient case is summarized in Table 2.

Table 2. Efficient technology. Cathedral/Flat roof insulation

Baseline	Efficient Technology (minimum R-value)
No Insulation	R-20, or R-28
>R-0 to R-12	R-20, or R-28
>R-12 to R-25	R-28

ENERGY IMPACTS

Energy savings are achieved because of the difference in thermal resistance between the upgraded condition (R-20/R-28 as applicable) and the baseline condition (various) of the cathedral/flat roof. The increased insulation reduces the rate of heat flow between the conditioned space and the outdoor air, reducing the amount of energy needed to heat or cool the conditioned space of the home. In addition, ceiling insulation can contribute to air leakage reduction through the roof, reducing the amount of energy to heat or cool the replacement air.

NATURAL GAS SAVINGS ALGORITHM

The following algorithms were used to determine natural gas savings for the cathedral/flat roof insulation measure. The calculations were performed on an hourly basis using the Canadian Weather Year for Energy Calculation (CWEC 2020). [1]

The analysis is based on three distinct baselines:

- Manual – Baseline building uses a manual (non-programmable) thermostat.

- Programmable – Baseline building uses a programmable thermostat, allowing for programmed variable cooling setpoints.
- Adaptive – Baseline building uses an adaptive thermostat.

The natural gas savings presented in Table 1 for the Manual baseline were obtained by assuming that 45%[7] of manual thermostat users keep the heating setpoint temperature fixed, while 55% of users manually setback the setpoint temperature at night and when leaving their home, following the setpoint schedule presented in Table 3. [2]

The natural gas savings in Table 1 for the Programmable and the Adaptive baselines were derived from the values for the Manual baseline by applying "savings reduction factors" that reflect the space heating energy savings obtained in residential buildings when upgrading from manual thermostats to programmable or adaptive thermostats:

Natural gas savings reduction factors

A billing data analysis of Enbridge Participants in the Adaptive thermostat program for the 2021 program year, presented in a report by ICF, shows average reductions in natural gas consumption for space heating of 8% and 10% in residential buildings where adaptive thermostats replaced programmable thermostats and manual thermostats, respectively. [3] These values imply a reduction in natural gas consumption of 2% when replacing manual thermostats by programmable thermostats. Hence, natural gas savings reduction factors of 2% and 10%, respectively, were applied to the Manual baseline savings of Table 1 to obtain the savings for the Programmable and the Adaptive baselines.

The total natural gas savings from Cathedral/Flat roof insulation have two major components:

- Natural gas savings due to delta R-value only. It does not include the effect of air leakage reduction inherent from the Cathedral/Flat roof insulation activity.
- Natural gas savings due to the air leakage reduction from Cathedral/Flat roof insulation activity. It does not include the savings from delta R-value.

The Natural Gas savings algorithms are presented in two sections:

1. Calculation of the annual natural gas savings per unit of area. This is the annual natural gas savings from enhanced thermal resistance (Delta R-value savings). They are expressed in cubic meters per square foot of insulation for natural gas (m^3/ft^2) as shown in Table 1, and
2. Calculation of the natural gas savings due to air leakage reduction, expressed in cubic meters (m^3) as shown in Table 1.

7 Here, 45% corresponds to (1 - 55%) where 55% is the assumed percentage of manual thermostat users that keep the heating and cooling setpoint temperatures fixed, and 55% is the average of values - 44% and 66% - from two studies referred to in the Residential Retrofit Low Income Programmable Thermostats measure of version 8.0 of the Ontario NG TRM.

Section 1. Calculation of the annual natural gas savings per unit area

$$NG_{\Delta R\ savings} = \left((1 - pct_{setback}) \times NG_{\Delta R\ savings-fixed} + pct_{setback} \times NG_{\Delta R\ savings-setback}\right) \times (1 - SRF)$$

$$NG_{\Delta R\ savings-fixed} = \left(U_{effective-baseline} - U_{effective-eff}\right) \times \frac{\sum_{hr=1}^{8,760}\left(\Delta T_{R-heating-fixed} \times Hr_{heating-fixed}\right)}{35{,}738 \times Eff}$$

$$NG_{\Delta R\ savings-setback} = \left(U_{effective-baseline} - U_{effective-eff}\right) \times \frac{\sum_{hr=1}^{8,760}\left(\Delta T_{R-heating-setback} \times Hr_{heating-setback}\right)}{35{,}738 \times Eff}$$

where,

$NG_{\Delta R\ savings}$ = Annual natural gas savings per square foot of insulated Cathedral/Flat roof area due to increase in ΔR-value (m^3/ft^2)
$NG_{\Delta R\ savings-fixed}$ for fixed setpoint temperature, and

$NG_{\Delta R\ savings-setback}$ for schedule-based temperature setback

$pct_{\ setback}$ = Percentage of manual thermostat users that perform manual schedule-based temperature setback

$U_{effective-baseline}$ = Cathedral/Flat roof assembly overall effective U-value for baseline [Btu/ (°F·ft²·hr)]

$U_{effective-eff}$ = Cathedral/Flat roof assembly overall effective U-value for energy-efficient case [Btu/ (°F·ft²·hr)]

$\Delta T_{R-heating}$ = Space heating temperature difference between indoor and outdoor conditions for Delta R-value savings (^{0}F)

$\Delta T_{R_heating-fixed}$ for fixed setpoint temperature, and

$\Delta T_{R-heating-\text{setback}}$ for scheduled-based temperature setback

$Hr_{heating}$ = Value indicating whether space heating was turned on (=1) or off (=0)

$Hr_{heating} = IF\left(T_{dry-bulb} < T_{balance-heating}\right)$

- If TRUE, → $Hr_{heating} = 1$, heating required.

- If FALSE, → $Hr_{heating} = 0$, no heating required.

$Hr_{heating-fixed}$ for fixed setpoint temperature, and
$Hr_{heating-setback}$ for schedule-based temperature setback

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

Eff = Heating system steady state efficiency (%)

SRF = Savings Reduction Factor for thermostat type

Calculation of the Cathedral/Flat roof assembly-overall effective U-value → $U_{effective}$

$$U_{value-effective} = \frac{1}{RSI_{total} \times C1}$$

$$RSI_{total} = RSI_{roof} + RSI_{cavity} + RSI_{plaster} + RSI_{air}$$

$$RSI_{cavity} = \frac{1}{\frac{\%F}{RSI_{softwood}} + \frac{\%BF}{RSI_{nominal}}}$$

where,

$U_{value-effective}$ = Cathedral/Flat roof assembly overall effective U-value [Btu/ (°F·ft2·hr)]

RSI_{total} = Cathedral/Flat roof assembly overall effective RSI (m^2·K/W)

$C1$ = Conversion factor RSI to R-value $\left[\frac{(°\mathrm{F}\cdot ft^2\cdot \mathrm{hr})/Btu}{(m^2\cdot K)/W}\right]$

RSI_{roof} = Effective RSI value of 1″ roof sheathing wood board (m^2·K/W)

RSI_{cavity} = Effective RSI value of the insulation cavity (m^2·K/W)

$RSI_{plaster}$ = Effective RSI value of 1″ plaster and lathe (m^2·K/W)

RSI_{air} = Effective RSI value of interior air flow (m^2·K/W)

$\%F$ = Percent of total area corresponding to framing

$\%BF$ = Percent of total area corresponding to material[8] between the framing

$RSI_{softwood-RC}$ = Effective RSI value of softwood lumber (Rough Cut) (m^2·K/W)

[8] When no insulation exists, this material is air.

$RSI_{nominal}$ = Nominal insulation RSI value (m²·K/W)

- For nominal R0 → $RSI_{nominal} = \frac{Rvalue_{nominal}}{C1} + RSI_{air-cavity}$
- For nominal bigger than R0 → $RSI_{nominal} = \frac{Rvalue_{nominal}}{C1}$

$Rvalue_{nominal}$ = Nominal insulation R-value (°F·ft²·hr/BTU)

$RSI_{air-cavity}$ = Effective RSI value of air in cavity (m²·K/W)

Calculation of space heating temperature difference between indoor and outdoor conditions → $\Delta T_{R-heating}$

$$\Delta T_{R-heating-fixed} = T_{balance-heating} - T_{dry-bulb}$$

$$\Delta T_{R-heating-setback} = IF\left[T_{balance-heating-setback} = 0,0, Max.\left(0, T_{balance-heating-setback} - T_{dry-bulb}\right)\right]$$

$$T_{balance-heating-setback} = T_{setpoint-setback} \times \frac{T_{balance-heating}}{T_{setpoint-heating}}$$

where,

$\Delta T_{R-heating-fixed}$ = Difference between heating balance point temperature and outdoor temperature – if value is negative set to 0 (°F)

$T_{balance-heating}$ = Heating balance point temperature (°F)

$T_{dry-bulb}$ = Outdoor dry bulb temperature (°F)

$\Delta T_{R-heating-setback}$ = Difference between adjusted heating balance point temperature and outdoor temperature – if value is negative set to 0 (°F)

$T_{balance-heating-setback}$ = Adjusted heating balance point temperature, based on setback schedule (°F)

$T_{setpoint-heating}$ = Indoor heating setpoint temperature (°F) – fixed temperature

$T_{setpoint-setback}$ = Indoor heating setpoint temperature (°F) – schedule-based temperature setback

Section 2. Calculation of the annual natural gas savings due to air leakage reduction

$$NG_{\Delta Q\ savings} = \left((1 - pct_{setback}) \times NG_{\Delta Q\ savings-fixed} + pct_{setback} \times NG_{\Delta Q\ savings-setback}\right) \times (1 - SRF)$$

where :

$$NG_{\Delta Q\ savings-fixed} = \frac{\sum_{hr=1}^{8,760}(60\ \times \rho \times C_p \times \Delta Q\ \times \Delta T_{Q-heating-fixed} \times\ Hr_{heating-fixed})}{35{,}738\ \times Eff}$$

$$NG_{\Delta Q\ savings-setback} = \frac{\sum_{hr=1}^{8,760}(60\ \times \rho \times C_p \times \Delta Q\ \times \Delta T_{Q-heating-setback} \times\ Hr_{heating})}{35{,}738\ \times Eff}$$

where,

$NG_{\Delta Q\ savings}$ = Natural gas savings from the air leakage reduction due to cathedral/flat roof insulation activity (m^3/yr)

$NG_{\Delta R\ savings-fixed}$ for fixed setpoint temperature, and

$NG_{\Delta R\ savings-setback}$ for schedule-based temperature setback

60 = Conversion factor (min/hr)

ρ = Density of dry air, calculated from typical weather data representing each hour in the specific climate zone (lb/ft^3)

C_p = Specific heat of air (Btu/lb.^{0}F)

ΔQ = Reduction in leakage airflow rate between baseline and energy efficient case resulting from attic insulation (cfm)

$\Delta T_{Q-heating}$ = Space heating temperature difference between indoor and outdoor conditions for air leakage reduction savings (^{0}F)

$\Delta T_{Q-heating-fixed}$ for fixed setpoint temperature, and

$\Delta T_{Q-heating-\text{setback}}$ for schedule-based temperature setback

Calculation of space heating temperature difference between indoor and outdoor conditions for air leakage reduction savings → $\Delta T_{Q-heating}$

$$\Delta T_{Q-heating-fixed} = T_{setpoint-heating} - T_{dry-bulb}$$

$$\Delta T_{Q-heating-setback} = IF\left[T_{setpoint-heating-setback} = 0{,}0, Max.\left(0, T_{setpoint-heating-setback} - T_{dry-bulb}\right)\right]$$

where,

$\Delta T_{Q-heating-fixed}$ = Difference between fixed heating setpoint temperature and outdoor temperature – if value is negative set to 0 (°F)

$\Delta T_{Q-heating-setback}$ = Difference between schedule-based heating setpoint temperature and outdoor temperature – if value is negative set to 0 (°F)

$T_{setpoint-heating-setback}$ = Indoor heating setpoint temperature (°F) – schedule-based temperature setback

ELECTRIC SAVINGS ALGORITHM

The following algorithms were used to determine electric impacts for the Cathedral/Flat roof insulation measure. The calculations were performed on an hourly basis using the same insulation baselines assumptions as the natural gas section for Fixed vs Schedule set back base temperature.

The electricity impacts presented in Table 1 for the Manual baseline were obtained by assuming that 45%[7] of manual thermostat users keep the heating and cooling setpoint temperatures fixed, while 55% of users manually setback the setpoint temperatures at night and when leaving their home, following the setpoint schedule presented in Table 3. [2]

The electricity impacts in Table 1**Error! Reference source not found.** for the Programmable and the Adaptive baselines were derived from the values for the Manual baseline by applying "impact reduction factors" that reflect the space cooling energy impact obtained in residential buildings when upgrading from manual thermostats to programmable or adaptive thermostats:

Electricity impact reduction factors

The ICF report shows a space cooling energy consumption lower by 11% in residential buildings with adaptive thermostats than in buildings with programmable thermostats. [3] Electricity "impact reduction factors" of 3% between the Manual and the Programmable baselines, and of 14% between the Manual and Adaptive baselines were derived from the 11% value by assuming similar ratios between the reduction factors of the various thermostat upgrades in cooling than in heating.[9] The electricity impacts for the Programmable and Adaptive baselines in Table 1 were therefore calculated by applying impact reduction factors of 3% and 14%, respectively to the electricity impacts for the Manual baseline.

The total electricity impact from Cathedral/Flat roof insulation has two major components:

- Electricity impact due to delta R-value only. It does not include the effect of air leakage reduction inherent from the Cathedral/Flat roof insulation activity.

[9] For example, the ratio of impact reduction factor for upgrading from Manual to Adaptive to that from Programmable to Adaptive (11%), was assumed equal to the ratio of the savings reduction factor in heating from Manual to Adaptive (10%) to that from Programmable to Adaptive (8%), hence equal to 10%/8%*11% = 14%.

- Electricity impact due to the air leakage reduction from Cathedral/Flat roof insulation activity. It does not include the savings from delta R-value.

The electricity impact algorithms are presented in two sections:

1. Calculation of the annual electricity impact per unit of area. This is the annual electricity cooling impact from enhanced thermal resistance (Delta R-value savings). They are expressed in kilowatt hours per square foot of insulation for electricity (kWh/ft²) as shown in Table 1, and
2. Calculation of the annual electricity impact due to air leakage reduction, expressed in kWh as shown in Table 1.

Section 1. Calculation of the annual electricity impact per unit area

$$Elec_{\Delta R\ impact} = \left((1 - pct_{setback}) \times Elec_{\Delta R\ impact-fixed} + pct_{setback} \times Elec_{\Delta R\ impact-setback}\right) \times (1 - IRF)$$

where:

$$Elec_{\Delta R\ impact-fixed} = \left(U_{effective-baseline} - U_{effective-eff}\right) \times \frac{\sum_{hr=1}^{8,760}(\Delta T_{cooling-fixed} \times Hr_{cooling-fixed})}{COP_{cooling} \times 3{,}412}$$

$$Elec_{\Delta R\ impact-setback} = \left(U_{effective-baseline} - U_{effective-eff}\right) \times \frac{\sum_{hr=1}^{8,760}(\Delta T_{cooling-setback} \times Hr_{cooling-setback})}{COP_{cooling} \times 3{,}412}$$

where,

$Elec_{\Delta R\ impact}$ = Annual electricity impact per square foot of insulated Cathedral/Flat roof area due to increase in ΔR-value (kWh/ft²)

$Elec_{\Delta R\ impact-fixed}$ for fixed setpoint temperature, and

$Elec_{\Delta R\ impact-setback}$ for schedule-based temperature setback

$U_{effective-baseline}$ = Cathedral/Flat roof assembly overall effective U-value for baseline [Btu/ (°F·ft²·hr)]

$U_{effective-eff}$ = Cathedral/Flat roof assembly overall effective U-value for energy-efficient case [Btu/ (°F·ft²·hr)]

$\Delta T_{cooling}$ = Space cooling temperature difference between indoor and outdoor conditions (⁰F) – if value is negative set to 0 (°F)

$\Delta T_{cooling-fixed}$ for fixed setpoint temperature, and

$\Delta T_{cooling-setback}$ for schedule-based temperature setback

$Hr_{cooling}$ = Value indicating whether space cooling was turned on (=1) or off (=0)

$Hr_{cooling} = IF(T_{dry-bulb} > T_{balance-cooling})$

- If TRUE, → $Hr_{cooling} = 1$, cooling required.
- If FALSE, → $Hr_{cooling} = 0$, no cooling required

$Hr_{cooling-fixed}$ for fixed setpoint temperature, and
$Hr_{cooling-setback}$ for schedule-based setback

$COP_{cooling}$ = Cooling system coefficient of performance

3,412 = Conversion factor, Btu per kWh (Btu/kWh)

IRF = Impact Reduction Factor for thermostat type

Calculation of space cooling temperature difference between indoor and outdoor conditions → $\Delta T_{cooling}$

$$\Delta T_{cooling-fixed} = T_{dry-bulb} - T_{setpoint-cooling}$$

$$\Delta T_{cooling-setback} = T_{dry-bulb} - T_{setpoint-cooling-setback}$$

where,

$\Delta T_{cooling-fixed}$ = Difference between fixed cooling setpoint temperature and outdoor temperature – if value is negative set to 0 (°F)

$\Delta T_{cooling-setback}$ = Difference between schedule-based cooling setpoint temperature and outdoor temperature – if value is negative set to 0 (°F)

$T_{setpoint-cooling}$ = Fixed indoor cooling setpoint temperature (°F)

$T_{setpoint-cooling-setback}$ = Indoor cooling setpoint temperature with schedule-based setback (°F)

Section 2. Calculation of the annual electricity impact due to air leakage reduction

$$Elec_{\Delta Q\ impact} = \left((1 - pct_{setback}) \times Elec_{\Delta Q\ impact-fixed} + pct_{setback} \times Elec_{\Delta Q-setback}\right) \times (1 - IRF)$$

where:

$$Elec_{\Delta Q\ impact-fixed} = \frac{\sum_{hr=1}^{8,760}[60 \times \rho \times \Delta Q \times (h_{oc} - h_{ic-fixed}) \times Hr_{cooling-fixed}]}{COP_{cooling} \times 3{,}412}$$

$$Elec_{\Delta Q\ impact-setback} = \frac{\sum_{hr=1}^{8,760}[60 \times \rho \times \Delta Q \times (h_{oc} - h_{ic-setback}) \times Hr_{cooling-setback}]}{COP_{cooling} \times 3{,}412}$$

and,

$Elec_{\Delta Q\ impact}$ = Annual electricity impact from the air leakage reduction due to cathedral/flat roof insulation activity (kWh/yr)

$Elec_{\Delta Q\ impact-fixed}$ for fixed setpoint temperature, and

$Elec_{\Delta Q\ impact-setback}$ for schedule-based temperature setback

60 = Conversion factor (min/hr)

ρ = Density of dry air, calculated from typical weather data representing each hour in the specific climate zone (lb/ft^3)

ΔQ = Reduction in leakage airflow rate between baseline and energy efficient case resulting from Cathedral/ Flat roof insulation (cfm)

h_{oc} = Enthalpy of outdoor air, calculated from typical weather data representing each hour in the specific climate zone (Btu/lb)

h_{ic} = Enthalpy of indoor air, calculated at setpoint (Btu/lb)

$h_{ic-fixed}$ for fixed setpoint temperature, and

$h_{ic-setback}$ for schedule-based temperature setback

ASSUMPTIONS

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

Table 3. Assumptions

Variable	Definition	Value	Unit	Source
$C1$	Conversion factor RSI to R-value	5.678	$\frac{(°\mathrm{F}\cdot ft^2\cdot \mathrm{hr})/Btu}{(m^2\cdot K)/W}$	[4]
	Conversion factor inches to mm	25.4	mm/in	[5]
$C2$	Density conversion factor from metric to imperial	0.062428	$(lb/ft^3)/(kg/m^3)$	[6]
$C3$	Volume flow rate conversion factor	2.118880	cfm/ (L/s)	[7]
RSI_{roof}	Effective RSI value of 1" softwood plywood sheathing	0.221	$m^2\cdot K/W$	[8]
$RSI_{plaster}$	Effective RSI value of 1" plaster and lathe	0.1575	$m^2\cdot K/W$	
RSI_{air}	Effective RSI value of interior air flow (horizontal, heat flow up)	0.11	$m^2\cdot K/W$	
$RSI_{softwood-RC}$	Effective RSI value of softwood lumber, rough cut	1.326	$m^2\cdot K/W$	
$RSI_{air-cavity}$	Effective RSI value of 1" air cavity	0.150	$m^2\cdot K/W$	
$\%F$	Percent of total area corresponding to framing	13.0[10]	%	[9] Table R1-1, note 3
$\%BF$	Percent of total area corresponding to material11 between the framing	87.0[10]	%	
$Rvalue_{nominal}$	Nominal insulation R-value for baseline and upgrade case		$(°\mathrm{F}\cdot ft^2\cdot hr)/Btu$	[10] Section 3.3
		$Rvalue_{nominal-baseline}$	$Rvalue_{nominal-upgrade}$	$(°\mathrm{F}\cdot ft^2\cdot hr)/Btu$
	No Insulation	0	20, 28	$(°\mathrm{F}\cdot ft^2\cdot hr)/Btu$
	>R-0 to R-12	10.6	20, 28	$(°\mathrm{F}\cdot ft^{2\cdot hr})/Btu$
	>R-12 to R-25	19.8	28	$(°\mathrm{F}\cdot ft^2\cdot hr)/Btu$

[10] Assumes an on centre spacing configuration of 16″ with 2″x6″.

[11] When no insulation exists, this material is air.

Variable	Definition	Value	Unit	Source
$pct_{setback}$	Percent of manual thermostat users that perform manual thermostat setback	55%	-	[2]
$T_{setpoint-heating-fixed}$	Fixed Setpoint temperature-heating	68	ºF	[11]
$T_{balance-heating}$	Balance Point temperature-heating	63[12]	ºF	[11], [12]
$T_{setpoint-cooling-fixed}$	Fixed Setpoint temperature-cooling	75	ºF	[11]
$T_{balance-cooling}$	Balance Point temperature-cooling	70	ºF	[11], [12]
$T_{dry-bulb}$	Outdoor dry bulb temperature	Various [13]	ºF	[1]
$T_{setpoint-heating-setback}$	Indoor heating setpoint temperature - schedule based temperature set back	Various 68 – at home 62 – away 62 – nighttime 62 – away on vacation	ºF	[10] Tables 6, 7 and 8
$T_{setpoint-cooling-setback}$	Indoor cooling setpoint temperature – schedule-based temperature setback	Various: 75 – at home 85 – away 75 – nighttime 85 – away on vacation	ºF	[10] Tables 6, 7 and 8
$rh_{cooling}$	Cooling indoor relative humidity	50	%	[11]
	Energy Density of Natural Gas	35,738	Btu/m^3	Common assumption
Eff	Heating System Steady State Efficiency	96.0	%	[10] Section 3.3
ΔQ	Reduction in leakage air flow rate between baseline and energy efficient upgrade (R-50)	Various	cfm	[13]

[12] Assumes that heat gains from the sun and internal processes contribute on average 5°F of "free heat," allowing a setpoint of 68°F with heating required only when the outdoor temperature drops below 63°F as per 2021 ASHRAE Handbook Fundamentals. Better-insulated, more airtight buildings can have lower balance point temperatures.

[13] This is the hourly weather profile for London-ON, used in the Ontario TRM to calculate heating and cooling weather-related common assumptions.

Variable	Definition	Value	Unit	Source
	No Insulation baseline	75	cfm	
	>R-0 to R-12 baseline	39	cfm	
	>R-12 to R-25 baseline	39	cfm	
ρ_{air}	Density of dry air	Hourly calculation	lb/ft^3	
h_{oc}	Enthalpy of outdoor air		Btu/lb	
h_{ic}	Enthalpy of indoor air		Btu/lb	
C_p	Specific heat of dry air	0.240	Btu/(lb·ºF)	Common assumption
COP	Air Conditioner nominal COP	2.79	kW/kW	EGI data[14]
SRF	Savings Reduction Factor	Baseline: Manual: 0% Programmable: 2% Adaptive:10%		[14]
IRF	Impact Reduction Factor	Baseline: Manual: 0% Programmable: 3% Adaptive: 14%		[3]

SAVINGS CALCULATION EXAMPLE

The example below illustrates the annual natural gas and electric impacts for cathedral/flat roof insulation (1000 ft²) of a home with a manual thermostat. The insulation was upgraded from a nominal baseline of R-11 to nominal R-28.

Nominal R-11 corresponds to Existing nominal R-value bucket ">R-0 to R-12" and the upgrade R-value is "R-28" in Table 1, therefore:

If the customer is completing Cathedral/Flat Roof insulation measure only or Cathedral/Flat Roof insulation + Attic insulation,

Annual natural gas savings:

$$1000\ ft^2 \times 0.143\ \frac{m^3}{ft^2} + 223\ m^3 = 367\ m^3$$

[14] Average Air conditioner COP in a residential home from EGI HER+ participants (2019-2020 program years)

Annual electrical impact:

$$1000\ ft^2 \times 0.02\ \frac{kWh}{ft^2} + 88\ kWh = 108\ kWh$$

If the customer is completing Cathedral/Flat Roof insulation, in addition to other measures - other than Attic insulation - (example upgrading the space heating equipment, Basement insulation, etc.),

Annual natural gas savings:

$$1000\ ft^2 \times 0.143\ \frac{m^3}{ft^2} = 143\ m^3$$

Annual electrical impact:

$$1000\ ft^2 \times 0.02\ \frac{kWh}{ft^2} = 20\ kWh$$

USES AND EXCLUSIONS

This measure does not apply to:

- Hybrid-fuel space heating systems (i.e., an electric heat pump satisfying a portion of the space heating load).
- Residential buildings used for major occupancies classified as: medium hazard industrial occupancies and low hazard industrial occupancies.
- This measure requires a member of the implementation staff to evaluate the pre- and post-project R-values and to measure the retrofitted cathedral/flat roof area.

Natural Gas savings and Electricity impact due to the air leakage reduction from Cathedral/Flat roof insulation activity shown in Table 1, does not include the savings from delta R-value. It is only applicable when the only measure(s) completed in the home is (are) Cathedral/Flat roof insulation or Cathedral/Flat roof insulation + Attic insulation. If the customer completes any other measure such as: Basement insulation, space heating equipment upgrade, etc., the air leakage reduction savings will not apply.

Please note that when Attic insulation + Cathedral is completed the following will apply:

1. The R-value natural gas savings/electricity impacts portion of this sub doc will apply, plus.
2. The air sealing natural gas savings/electricity impacts from this sub doc will apply, plus.
3. The R-value natural gas savings/electricity impacts from the Attic Insulation sub doc will apply.

MEASURE LIFE

The measure life attributed to this measure is 30 years. [15]

INCREMENTAL COST

Incremental cost is presented in Table 4 below. [10] It assumes spray foam insulation.

Table 4. Cathedral/Flat Roof Insulation Incremental Cost

Baseline	Efficient nominal R-value	Incremental Cost (CAD $/ft^2)
No Insulation	R-20	$6.17
>R-0 to R-12	R-20	$3.11
No Insulation	R-28	$7.96
>R-0 to R-12	R-28	$5.17
>R-12 to R-25	R-28	$2.94

REFERENCES

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[9] G. o. Canada, "ENERGY STAR for Homes. Tables for Calculating Effective Thermal Resistance of Opaque Assemblies," 23 02 2016. [Online]. Available: https://natural-resources.canada.ca/energy/efficiency/housing/new-homes/energy-starr-new-homes-standard/tables-for-calculating-effective-thermal-resistance-opaque-assemblies/14176#a5. [Accessed 02 04 2024].

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[13] Enbridge Gas Inc., "Attic Insulation savings-Final Report append," EGI, Chatham, 2024.

[14] "Ontario Natural Gas Demand Side Management Technical Reference Manual, Residential Adaptive Thermostat Measure," April 30, 2024.

[15] Guidehouse, "EMV Group A, Deliverable 16 EUL Research – Residential Insulation," California Public Utilities Commission, 2021.

RESIDENTIAL – ATTIC INSULATION – RETROFIT

Version Date and Revision History	
Version	1
OEB Filing Date	March 17, 2025
OEB Approval Date	
Residential → Building Envelope→ Attic Insulation → 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	Various insulation levels, please see baseline technology section.						
Efficient Technology	Achieve minimum nominal R-value of R-50						
Market Type	Residential, Residential-other use[1]						
Annual Natural Gas Savings	Existing Nominal R-value	Manual thermostat		Programmable thermostat		Adaptive thermostat	
		Delta R-value savings[2] (m^3/ft^2)	Air leakage reduction savings[3] (m^3/yr)	Delta R-value savings[2] (m^3/ft^2)	Air leakage reduction savings[3] (m^3/yr)	Delta R-value savings[2] (m^3/ft^2)	Air leakage reduction savings[3] (m^3/yr)
	No insulation	1.697	257	1.663	252	1.527	231
	>R-0 to R-12	0.212	208	0.208	204	0.191	187

[1] Residential-other use refers to residential buildings, used for major occupancies classified as: business and personal services occupancies, or mercantile occupancies. Medium hazard industrial occupancies and low hazard industrial occupancies is not included.
[2] Natural gas savings due to delta R-value only. It does not include the effect of air leakage reduction inherent from the Attic insulation activity.
[3] Natural gas savings due to the air leakage reduction from Attic insulation activity. It does not include the savings from delta R-value. It is only applicable when the only measure completed in the home is Attic insulation. If customer completes any other measure such as: Cathedral/Flat roof Insulation, Basement insulation, space heating equipment upgrade, water heating equipment upgrade, etc. air leakage reduction savings will not apply. The savings associated with the reduction of air leakage inherent of the Attic insulation activity were calculated based on total air volume reductions obtained from HOT2000 simulations using input data extracted from blower door test results in homes that underwent similar attic insulation upgrades as part of the EGI HER+ 2019-2020 program years. The data used to substantiate these assumptions includes homes that completed only Attic insulation and do not capture interactive effects with other measures mentioned before, hence the restriction in the savings related to the air leakage reduction.

<table>
<tr><th>Parameter</th><th colspan="7">Definition</th></tr>
<tr><td></td><td>>R-12 to R-25</td><td>0.088</td><td>203</td><td>0.086</td><td>199</td><td>0.079</td><td>183</td></tr>
<tr><td></td><td>>R-25 to R-35</td><td>0.045</td><td>194</td><td>0.044</td><td>190</td><td>0.040</td><td>175</td></tr>
<tr><td rowspan="6">Annual Electricity Impact for Residential Buildings Equipped with Central Air Conditioning</td><td rowspan="2">Existing Nominal R-value</td><td colspan="2">Manual thermostat</td><td colspan="2">Programmable thermostat</td><td colspan="2">Adaptive thermostat</td></tr>
<tr><td>Delta R-value impact[4] (kWh/ft^2)</td><td>Air leakage reduction impact[5] (kWh/yr)</td><td>Delta R-value impacts[4] (kWh/ft^2)</td><td>Air leakage reduction impact[5] (kWh/yr)</td><td>Delta R-value impact[4] (kWh/ft^2)</td><td>Air leakage reduction impact[5] (kWh/yr)</td></tr>
<tr><td>No insulation</td><td>0.239</td><td>102</td><td>0.232</td><td>98</td><td>0.206</td><td>87</td></tr>
<tr><td>>R-0 to R-12</td><td>0.030</td><td>82</td><td>0.029</td><td>80</td><td>0.026</td><td>71</td></tr>
<tr><td>>R-12 to R-25</td><td>0.012</td><td>80</td><td>0.012</td><td>78</td><td>0.011</td><td>69</td></tr>
<tr><td>>R-25 to R-35</td><td>0.006</td><td>77</td><td>0.006</td><td>74</td><td>0.005</td><td>66</td></tr>
<tr><td>Measure Life</td><td colspan="7">30 years</td></tr>
<tr><td rowspan="2">Incremental Cost ($ CAD/ ft^2 of insulated area)</td><td>No insulation</td><td colspan="2">>R-0 to R-12</td><td colspan="2">>R-12 to R-25</td><td colspan="2">>R-25 to R-35</td></tr>
<tr><td>$1.84</td><td colspan="2">$1.84</td><td colspan="2">$1.84</td><td colspan="2">$1.84</td></tr>
<tr><td>Restrictions</td><td colspan="7">Restricted to residential buildings[6] of three or fewer stories in building height, having a building area not exceeding 600 m^2, used for major occupancies classified as: residential occupancies, business and personal services occupancies, or mercantile occupancies. For which the space heating load is satisfied by a natural gas heating system. This sub doc does not apply to hybrid-fuel space heating systems (i.e., an electric heat pump satisfying a portion of the space heating load). In addition, footnotes 3 and 5 on this document.</td></tr>
</table>

[4] Electricity impact due to delta R-value only. It does not include the effect of air leakage reduction inherent from the Attic insulation activity.

[5] Electricity impact due to the air leakage reduction from Attic insulation activity. It does not include the savings from delta R-value. It is only applicable for when the only measure completed in the home is Attic insulation. If customer completes any other measure such as: Cathedral/Flat roof Insulation, Basement insulation, space heating equipment upgrade, water heating equipment upgrade, this savings will not apply. The savings associated with the reduction of air leakage inherent of the Attic insulation activity were calculated based on total air volume reductions obtained from HOT2000 simulations using input data extracted from blower door test results in homes that underwent similar attic insulation upgrades as part of the EGI HER+ 2019-2020 program years. The data used to substantiate these assumptions includes homes that completed only Attic insulation and do not capture interactive effects with other measures mentioned before, hence the restriction in the savings related to the air leakage reduction.

[6] Medium hazard industrial occupancies and low hazard industrial occupancies is not included.

OVERVIEW

The attic is found in the space located directly underneath the roof of a home. In many homes, the attic may only be reached through a loft hatch using a ladder and is not accessible by stairs. The attics referred to in this measure are unconditioned, meaning the attic is not livable.

Because attics sit above the conditioned spaces of a home, the floor of the attic is often insulated to prevent heat loss. In unfinished attics, the air cavity above the insulated attic floor is vented, allowing moisture and other contaminants to escape the space.

Attics are relatively straightforward to insulate compared to other building features because of their ease of accessibility. There are several types of attic insulation available including batt, blown-in, and spray foam insulation. A combination of these options may also be appropriate, depending on the application.

It may be possible to add additional insulation on top of the existing insulation, such as adding a layer of batt or rigid foam insulation on top of an existing layer of insulation. In some cases, the existing insulation should be removed first, such as when the existing insulation is damaged or poses a potential health risk.

Increasing the insulation of the attic enhances its thermal resistance (R-value) and minimizes heat transfer, thus reducing the energy needed to compensate for heat loss in the heating season, and for heat gains in the cooling season.

Increasing the insulation of the attic assembly also reduces air leakage, thus reducing the energy needed to heat or cool the replacement air.

Energy savings are determined through engineering algorithms. Annual energy savings from enhanced thermal resistance (Delta R-value savings) are expressed in cubic meters per square foot of insulation for natural gas (m^3/ft^2) and kilowatt hours per square foot of insulation for electricity (kWh/ft^2). Annual air leakage reduction savings are expressed in cubic meters for natural gas (m^3) and in kilowatt hours for electricity (kWh).

APPLICATION

This measure applies to:

- The addition or replacement of attic insulation in a residential home in Ontario to achieve a minimum insulation value of nominal R-50.
- Residential buildings for which the space heating load (full load) is satisfied by a natural gas heating system.
- It is applicable to residential buildings of three or fewer stories in building height, having a building area not exceeding 600 m^2, used for major occupancies classified as: residential occupancies, business and personal services occupancies, or mercantile occupancies.

This measure does not apply to:

- Hybrid-fuel space heating systems (i.e., an electric heat pump satisfying a portion of the space heating load).
- Residential buildings used for major occupancies classified as: medium hazard industrial occupancies and low hazard industrial occupancies.

- This measure requires a member of the implementation staff to evaluate the pre- and post-project R-values and to measure the retrofitted attic area.

BASELINE TECHNOLOGY

The baseline technology refers to the existing attic insulation conditions, categorized into four levels of nominal insulation:

- No insulation
- >R-0 to R-12
- >R-12 to R-25
- >R-25 to R-35

These categories represent the varying degrees of insulation present in existing attics before any improvements are made.

EFFICIENT TECHNOLOGY

The energy efficient case is an attic with -at minimum -nominal R-50 insulation.

ENERGY IMPACTS

Energy savings are achieved because of the difference in thermal resistance between the upgraded condition (R-50) and the baseline condition (various) of the attic. The increased insulation reduces the rate of heat flow between the conditioned space and the outdoor air, reducing the amount of energy needed to heat or cool the conditioned space of the home. In addition, insulation can contribute to air leakage reduction.

NATURAL GAS SAVINGS ALGORITHM

The following algorithms were used to determine natural gas savings for the attic insulation measure. The calculations were performed on an hourly basis using the Canadian Weather Year for Energy Calculation (CWEC 2020). [1]

The analysis is based on three distinct baselines:

- Manual – Baseline building uses a manual (non-programmable) thermostat.
- Programmable – Baseline building uses a programmable thermostat, allowing for programmed variable heating setpoints.
- Adaptive – Baseline building uses an adaptive thermostat.

The natural gas savings presented in Table 1 for the Manual baseline were obtained by assuming that 45%[7] of manual thermostat users keep the heating setpoint temperature fixed, while 55% of users manually setback the setpoint temperature at night and when leaving their home, following the setpoint schedule presented in Table 2. [2]

The natural gas savings in Table 1 for the Programmable and the Adaptive baselines were derived from the values for the Manual baseline by applying "savings reduction factors" that reflect the space heating energy savings obtained in residential buildings when upgrading from manual thermostats to programmable or adaptive thermostats:

Natural gas savings reduction factors

A billing data analysis of Enbridge Participants in the Adaptive thermostat program for the 2021 program year, presented in a report by ICF, shows average reductions in natural gas consumption for space heating of 8% and 10% in residential buildings where adaptive thermostats replaced programmable thermostats and manual thermostats, respectively. [3] These values imply a reduction in natural gas consumption of 2% when replacing manual thermostats by programmable thermostats. Hence, natural gas savings reduction factors of 2% and 10%, respectively, were applied to the Manual baseline savings of Table 1 to obtain the savings for the Programmable and the Adaptive baselines.

The total natural gas savings from Attic insulation have two major components:

- Natural gas savings due to delta R-value. It does not include the effect of air leakage reduction inherent from the Attic insulation activity.
- Natural gas savings due to the air leakage reduction from Attic insulation activity. It does not include the savings from delta R-value.

The Natural Gas savings algorithms are presented in two sections:

1. Calculation of the annual natural gas savings per unit of area. This is the annual natural gas savings from enhanced thermal resistance (Delta R-value savings). They are expressed in cubic meters per square foot of insulation for natural gas (m^3/ft^2) as shown in Table 1, and
2. Calculation of the natural gas savings due to air leakage reduction, expressed in cubic meters (m^3) as shown in Table 1.

Section 1. Calculation of the annual natural gas savings per unit area

$$NG_{\Delta R\ savings} = \left((1 - pct_{setback}) \times NG_{\Delta R\ savings-fixed} + pct_{setback} \times NG_{\Delta R\ savings-setback}\right) \times (1 - SRF)$$

7 Here, 45% corresponds to (1 - 55%) where 55% is the assumed percentage of manual thermostat users that keep the heating and cooling setpoint temperatures fixed, and 55% is the average of values - 44% and 66% - from two studies referred to in the Residential Retrofit Low Income Programmable Thermostats measure of version 8.0 of the Ontario NG TRM.

$$NG_{\Delta R\ savings-fixed} = \left(U_{effective-baseline} - U_{effective-eff}\right) \times \frac{\sum_{hr=1}^{8,760}\left(\Delta T_{R-heating-fixed} \times Hr_{heating-fixed}\right)}{35{,}738 \times Eff}$$

$$NG_{\Delta R\ savings-setback} = \left(U_{effective-baseline} - U_{effective-eff}\right) \times \frac{\sum_{hr=1}^{8,760}\left(\Delta T_{R-heating-setback} \times Hr_{heating-setback}\right)}{35{,}738 \times Eff}$$

where,

$NG_{\Delta R\ savings}$ = Annual natural gas savings per square foot of insulated attic area due to increase in ΔR-value (m^3/ft^2)
$NG_{\Delta R\ savings-fixed}$ for fixed setpoint temperature, and

$NG_{\Delta R\ savings-setback}$ for schedule-based temperature setback

$pct_{\ setback}$ = Percentage of manual thermostat users that perform manual schedule-based temperature setback

$U_{effective-baseline}$ = Attic assembly overall effective U-value for baseline [Btu/ (°F·ft²·hr)]

$U_{effective-eff}$ = Attic assembly overall effective U-value for energy-efficient case [Btu/ (°F·ft²·hr)]

$\Delta T_{R-heating}$ = Space heating temperature difference between indoor and outdoor conditions for Delta R-value savings (^{0}F)

$\Delta T_{R-heating-fixed}$ for fixed setpoint temperature, and

$\Delta T_{R-heating-\text{setback}}$ for schedule-based temperature setback

$Hr_{heating}$ = Value indicating whether space heating was turned on (=1) or off (=0)

$Hr_{heating} = IF\left(T_{dry-bulb} < T_{balance-heating}\right)$

- If TRUE, → $Hr_{heating} = 1$, heating required.

If FALSE, → $Hr_{heating} = 0$, no heating required.
$Hr_{heating-fixed}$ for fixed setpoint temperature, and
$Hr_{heating-setback}$ for schedule-based setback

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

Eff = Heating system steady state efficiency (%)

SRF = Savings Reduction Factor for thermostat type

Calculation of the attic assembly-overall effective U-value → $U_{effective}$

$$U_{value-effective} = \frac{1}{RSI_{total} \times C1}$$

$$RSI_{total} = RSI_{roof} + RSI_{cavity} + RSI_{drywall} + RSI_{air}$$

$$RSI_{cavity} = \frac{1}{\frac{\%F}{RSI_{softwood}} + \frac{\%BF}{RSI_{nominal}}}$$

where,

$U_{value-effective}$ = Attic assembly overall effective U-value [Btu/ (°F·ft²·hr)]

RSI_{total} = Attic assembly overall effective RSI (m²·K/W)

$C1$ = Conversion factor RSI to R-value $\left[\frac{(°\text{F}\cdot ft^2\cdot \text{hr})/Btu}{(m^2\cdot K)/W}\right]$

RSI_{roof} = Effective RSI value of vented roof air space (m²·K/W)

RSI_{cavity} = Effective RSI value of the insulation cavity (m²·K/W)

$RSI_{drywall}$ = Effective RSI value of ½" drywall (m²·K/W)

RSI_{air} = Effective RSI value of interior air flow (m²·K/W)

$\%F$ = Percent of total area corresponding to framing

$\%BF$ = Percent of total area corresponding to material[8] between the framing

$RSI_{softwood}$ = Effective RSI value of softwood lumber (m²·K/W)

$RSI_{nominal}$ = Nominal insulation RSI value (m²·K/W)

- For nominal R0 → $RSI_{nominal} = \frac{Rvalue_{nominal}}{C1} + RSI_{air-cavity}$
- For nominal R bigger than R0 → $RSI_{nominal} = \frac{Rvalue_{nominal}}{C1}$

[8] When no insulation exists, this material is air.

$Rvalue_{nominal}$ = Nominal insulation R-value (°F·ft²·hr/BTU)

$RSI_{air-cavity}$ = Effective RSI value of air in cavity (m²·K/W)

Calculation of space heating temperature difference between indoor and outdoor conditions for Delta R-value savings → $\Delta T_{R-heating}$

$$\Delta T_{R-heating-fixed} = T_{balance-heating} - T_{dry-bulb}$$

$$\Delta T_{R-heating-setback} = IF\left[T_{balance-heating-setback} = 0{,}0, Max.\left(0, T_{balance-heating-setback} - T_{dry-bulb}\right)\right]$$

$$T_{balance-heating-setback} = T_{setpoint-setback} \times \frac{T_{balance-heating}}{T_{setpoint-heating}}$$

where,

$\Delta T_{R-heating-fixed}$ = Difference between heating balance point temperature and outdoor temperature – if value is negative set to 0 (°F)

$T_{balance-heating}$ = Heating balance point temperature (°F)

$T_{dry-bulb}$ = Outdoor dry bulb temperature (°F)

$\Delta T_{R-heating-setback}$ = Difference between adjusted heating balance point temperature and outdoor temperature – if value is negative set to 0 (°F)

$T_{balance-heating-setback}$ = Adjusted heating balance point temperature, based on setback schedule (°F)

$T_{setpoint-heating}$ = Indoor heating setpoint temperature (°F) – fixed temperature

$T_{setpoint-setback}$ = Indoor heating setpoint temperature (°F) – schedule-based temperature setback

Section 2. Calculation of the annual natural gas savings due to air leakage reduction

$$NG_{\Delta Q\ savings} = \left((1 - pct_{setback}) \times NG_{\Delta Q\ savings-fixed} + pct_{setback} \times NG_{\Delta Q\ savings-setback}\right) \times (1 - SRF)$$

where :

$$NG_{\Delta Q\ savings-fixed} = \frac{\sum_{hr=1}^{8,760}(60\ \times \rho \times C_p \times \Delta Q\ \times \Delta T_{Q-heating-fixed} \times\ Hr_{heating-fixed})}{35{,}738\ \times Eff}$$

$$NG_{\Delta Q\ savings-setback} = \frac{\sum_{hr=1}^{8,760}(60\ \times \rho \times C_p \times \Delta Q\ \times \Delta T_{Q-heating-setback} \times\ Hr_{heating})}{35{,}738\ \times Eff}$$

where,

$NG_{\Delta Q\ savings}$ = Natural gas savings from the air leakage reduction due to attic insulation activity (m^3/yr)

$NG_{\Delta R\ savings-fixed}$ for fixed setpoint temperature, and

$NG_{\Delta R\ savings-setback}$ for schedule-based temperature setback

60 = Conversion factor (min/hr)

ρ = Density of dry air, calculated from typical weather data representing each hour in the specific climate zone (lb/ft^3)

C_p = Specific heat of air (Btu/lb.^{0}F)

ΔQ = Reduction in leakage airflow rate between baseline and energy efficient case resulting from attic insulation (cfm)

$\Delta T_{Q-heating}$ = Space heating temperature difference between indoor and outdoor conditions for air leakage reduction savings (^{0}F)

$\Delta T_{Q-heating-fixed}$ for fixed setpoint temperature, and

$\Delta T_{Q-heating-}$setback for schedule-based temperature setback

Calculation of space heating temperature difference between indoor and outdoor conditions for air leakage reduction savings → $\Delta T_{Q-heating}$

$$\Delta T_{Q-heating-fixed} = T_{setpoint-heating} - T_{dry-bulb}$$

$$\Delta T_{Q-heating-setback} = IF\left[T_{setpoint-heating-setback}\right.$$
$$\left. = 0{,}0, Max.\left(0, T_{setpoint-heating-setback} - T_{dry-bulb}\right)\right]$$

where,

$\Delta T_{Q-heating-fixed}$ = Difference between fixed heating setpoint temperature and outdoor temperature – if value is negative set to 0 (°F)

$\Delta T_{Q-heating-setback}$ = Difference between schedule-based heating setpoint temperature and outdoor temperature – if value is negative set to 0 (°F)

$T_{setpoint-heating-setback}$ = Indoor heating setpoint temperature (°F) – schedule-based temperature setback

ELECTRIC SAVINGS ALGORITHM

The following algorithms were used to determine electric impacts for the attic insulation measure. The calculations were performed on an hourly basis using the same insulation and thermostat baselines assumptions as the natural gas section.

The electricity impacts presented in Table 1 for the Manual baseline were obtained by assuming that 45%[7] of manual thermostat users keep the heating and cooling setpoint temperatures fixed, while 55% of users manually setback the setpoint temperatures at night and when leaving their home, following the setpoint schedule presented in Table 2. [2]

The electricity impacts in Table 1 for the Programmable and the Adaptive baselines were derived from the values for the Manual baseline by applying "impact reduction factors" that reflect the space cooling energy impact obtained in residential buildings when upgrading from manual thermostats to programmable or adaptive thermostats:

Electricity impact reduction factors

The ICF report shows a space cooling energy consumption lower by 11% in residential buildings with adaptive thermostats than in buildings with programmable thermostats. [3] Electricity "impact reduction factors" of 3% between the Manual and the Programmable baselines, and of 14% between the Manual and Adaptive baselines were derived from this 11% value by assuming similar ratios between the reduction factors of the various thermostat upgrades in cooling than in heating.[9] The electricity impacts for the Programmable and Adaptive baselines in Table 1 were therefore calculated by applying impact reduction factors of 3% and 14%, respectively to the electricity impacts for the Manual baseline.

The total electricity impact from Attic insulation has two major components:

- Electricity impact due to delta R-value only. It does not include the effect of air leakage reduction inherent from the Attic insulation activity.

[9] For example, the ratio of impact reduction factor for upgrading from Manual to Adaptive to that from Programmable to Adaptive (11%), was assumed equal to the ratio of the savings reduction factor in heating from Manual to Adaptive (10%) to that from Programmable to Adaptive (8%), hence equal to 10%/8%*11% = 14%.

- Electricity impact due to the air leakage reduction from Attic insulation activity. It does not include the savings from delta R-value.

The electricity impact algorithms are presented in two sections:

1. Calculation of the annual electricity impact per unit area. This is the annual electricity cooling impact from enhanced thermal resistance (Delta R-value savings). They are expressed in kilowatt hours per square foot of insulation for electricity (kWh/ft²) as shown in Table 1, and
2. Calculation of the annual electricity impact due to air leakage reduction, expressed in kWh as shown in Table 1.

Section 1. Calculation of the annual electricity impact per unit area

$$Elec_{\Delta R\ impact} = \left((1 - pct_{setback}) \times Elec_{\Delta R\ impact-fixed} + pct_{setback} \times Elec_{\Delta R\ impact-setback}\right) \times (1 - IRF)$$

where:

$$Elec_{\Delta R\ impact-fixed} = \left(U_{effective-baseline} - U_{effective-eff}\right) \times \frac{\sum_{hr=1}^{8,760}(\Delta T_{cooling-fixed} \times Hr_{cooling-fixed})}{COP_{cooling} \times 3{,}412}$$

$$Elec_{\Delta R\ impact-setback} = \left(U_{effective-baseline} - U_{effective-eff}\right) \times \frac{\sum_{hr=1}^{8,760}(\Delta T_{cooling-setback} \times Hr_{cooling-setback})}{COP_{cooling} \times 3{,}412}$$

where,

$Elec_{\Delta R\ impact}$ = Annual electricity impact per square foot of insulated attic area due to increase in ΔR-value (kWh/ft²)

$Elec_{\Delta R\ impact-fixed}$ for fixed setpoint temperature, and

$Elec_{\Delta R\ impact-setback}$ for schedule-based temperature setback

$U_{effective-baseline}$ = Attic assembly overall effective U-value for baseline [Btu/ (°F·ft²·hr)]

$U_{effective-eff}$ = Attic assembly overall effective U-value for energy-efficient case [Btu/ (°F·ft²·hr)]

$\Delta T_{cooling}$ = Space cooling temperature difference between indoor and outdoor conditions (⁰F) – if value is negative set to 0 (°F)

$\Delta T_{cooling-fixed}$ for fixed setpoint temperature, and

$\Delta T_{cooling-setback}$ for schedule-based temperature setback

$Hr_{cooling}$ = Value indicating whether space cooling was turned on (=1) or off (=0)

$Hr_{cooling} = IF(T_{dry-bulb} > T_{balance-cooling})$

- If TRUE, $\rightarrow Hr_{cooling} = 1$, cooling required.
- If FALSE, $\rightarrow Hr_{cooling} = 0$, no cooling required.

$Hr_{cooling-fixed}$ for fixed setpoint temperature, and
$Hr_{cooling-setback}$ for schedule-based setback

$COP_{cooling}$ = Cooling system coefficient of performance

3,412 = Conversion factor, Btu per kWh (Btu/kWh)

IRF = Impact Reduction Factor for thermostat type

Calculation of space cooling temperature difference between indoor and outdoor conditions → $\Delta T_{cooling}$

$$\Delta T_{cooling-fixed} = T_{dry-bulb} - T_{setpoint-cooling}$$

$$\Delta T_{cooling-setback} = T_{dry-bulb} - T_{setpoint-cooling-setback}$$

where,

$\Delta T_{cooling-fixed}$ = Difference between fixed cooling setpoint temperature and outdoor temperature – if value is negative set to 0 (°F)

$\Delta T_{cooling-setback}$ = Difference between schedule-based cooling setpoint temperature and outdoor temperature – if value is negative set to 0 (°F)

$T_{setpoint-cooling}$ = Fixed indoor cooling setpoint temperature (°F)

$T_{setpoint-cooling-setback}$ = Indoor cooling setpoint temperature with schedule-based setback (°F)

Section 2. Calculation of the annual electricity impact due to air leakage reduction

$$Elec_{\Delta Q\ impact} = \left((1 - pct_{setback}) \times Elec_{\Delta Q\ impact-fixed} + pct_{setback} \times Elec_{\Delta Q-setback}\right) \times (1 - IRF)$$

where:

$$Elec_{\Delta Q\ impact-fixed} = \frac{\sum_{hr=1}^{8,760}[60\ \times \rho \times \Delta Q \times (h_{oc} - h_{ic-fixed})\ \times\ Hr_{cooling-fixed}]}{COP_{cooling} \times 3{,}412}$$

$$Elec_{\Delta Q\ impact-setback} = \frac{\sum_{hr=1}^{8,760}[60\ \times \rho \times \Delta Q \times (h_{oc} - h_{ic-setback})\ \times\ Hr_{cooling-setback}]}{COP_{cooling} \times 3{,}412}$$

and,

$Elec_{\Delta Q\ impact}$ = Annual electricity impact from the air leakage reduction due to attic insulation activity (kWh/yr)

$Elec_{\Delta Q\ impact-fixed}$ for fixed setpoint temperature, and

$Elec_{\Delta Q\ impact-setback}$ for schedule-based temperature setback

60 = Conversion factor (min/hr)

ρ = Density of dry air, calculated from typical weather data representing each hour in the specific climate zone (lb/ft^3)

ΔQ = Reduction in leakage airflow rate between baseline and energy efficient case resulting from attic insulation (cfm)

h_{oc} = Enthalpy of outdoor air, calculated from typical weather data representing each hour in the specific climate zone (Btu/lb)

h_{ic} = Enthalpy of indoor air, calculated at setpoint temperature (Btu/lb)

$h_{ic-fixed}$ for fixed setpoint temperature, and

$h_{ic-setback}$ for schedule-based temperature setback

ASSUMPTIONS

Table 2 provides a list of assumptions utilized in the measure savings algorithm to derive the stipulated savings values listed in Table 1 above.

Table 2. Assumptions

Variable	Definition	Value	Unit	Source
$C1$	Conversion factor RSI to R-value: $R = RSI \times C1$	5.678	$\frac{(°\mathrm{F} \cdot ft^2 \cdot \mathrm{hr})/Btu}{(m^2 \cdot K)/W}$	[4]
	Conversion factor inches to mm	25.4	mm/in	[5]
$C2$	Density conversion factor from metric to imperial	0.062428	(lb/ft^3)/(kg/m^3)	[6]
$C3$	Volume flow rate conversion factor	2.118880	cfm/ (L/s)	[7]
RSI_{roof}	Effective RSI value of vented roof air space	0.03	m^2·K/W	[8]
$RSI_{drywall}$	Effective RSI value of ½" drywall	0.0775	m^2·K/W	
RSI_{air}	Effective RSI value of interior air flow (horizontal, heat flow up)	0.11	m^2·K/W	
$RSI_{softwood}$	Effective RSI value of 3 ½" softwood lumber	0.773	m^2·K/W	
$RSI_{air-cavity}$	Effective RSI value of 1" air cavity	0.150	m^2·K/W	
$\%F$	Percent of total area corresponding to framing	12.5[10]	%	[9] Table R1-1, note 3
$\%BF$	Percent of total area corresponding to material[11] between the framing	87.5[11]	%	
$Rvalue_{nominal}$	Nominal insulation R-value for baseline and upgrade case	Various	$(hr \cdot °\mathrm{F} \cdot ft^2)/Btu$	[10] Section 3.3
$Rvalue_{nominal-baseline}$	No Insulation	0	$(hr \cdot °\mathrm{F} \cdot ft^2)/Btu$	
	>R-0 to R-12	11.0	$(hr \cdot °\mathrm{F} \cdot ft^2)/Btu$	
	>R-12 to R-25	20.7	$(hr \cdot °\mathrm{F} \cdot ft^2)/Btu$	
	>R-25 to R-35	29.2	$(hr \cdot °\mathrm{F} \cdot ft^2)/Btu$	
$Rvalue_{nominal-upgrade}$	R-50	50	$(hr \cdot °\mathrm{F} \cdot ft^2)/Btu$	
$pct_{setback}$	Percent of manual thermostat users that perform manual thermostat setback	55%	-	[2]
$T_{setpoint-heating-fixed}$	Fixed Setpoint temperature-heating	68	ºF	[11]

[10] Assumes an on centre spacing configuration of 19.2″ with 2″x4″.

[11] When no insulation exists, this material is air.

Variable	Definition	Value	Unit	Source
$T_{balance-heating}$	Balance Point temperature-heating	63[12]	ºF	[11], [12]
$T_{setpoint-cooling-fixed}$	Fixed Setpoint temperature-cooling	75	ºF	[11]
$T_{balance-cooling}$	Balance Point temperature-cooling	70	ºF	[11], [12]
$T_{dry-bulb}$	Outdoor dry bulb temperature	Various [13]	ºF	[1]
$T_{setpoint-heating-setback}$	Indoor heating setpoint temperature - schedule based temperature setback	Various : 68 – at home 62 – away 62 – nighttime 62 – away on vacation	ºF	[10] Tables 6, 7 and 8
$T_{setpoint-cooling-setback}$	Indoor cooling setpoint temperature – schedule-based temperature setback	Various: 75 – at home 85 – away 75 – nighttime 85 – away on vacation	ºF	[10] Tables 6, 7 and 8
$rh_{cooling}$	Cooling indoor relative humidity	50	%	[11]
	Energy Density of Natural Gas	35,738	Btu/m^3	Common assumption
Eff	Heating System Steady State Efficiency	96.0	%	[10] Section 3.3
ΔQ	Reduction in leakage air flow rate between baseline and energy efficient upgrade (R-50)	Various	cfm	[13]
	No insulation baseline	46	cfm	
	>R-0 to R-12 baseline	37	cfm	
	>R-12 to R-25 baseline	36	cfm	
	>R-25 to R-35 baseline	34	cfm	
ρ_{air}	Density of dry air	Hourly calculation	lb/ft^3	

[12] Assumes that heat gains from the sun and internal processes contribute on average 5°F of "free heat," allowing a setpoint of 68°F with heating required only when the outdoor temperature drops below 63°F as per 2021 ASHRAE Handbook Fundamentals. Better-insulated, more airtight buildings can have lower balance point temperatures.

[13] From the CWEC 2020 hourly weather profile for London-ON, used in the Ontario TRM to calculate heating and cooling weather-related common assumptions.

Variable	Definition	Value	Unit	Source
h_{oc}	Enthalpy of outdoor air		Btu/lb	
h_{ic}	Enthalpy of indoor air		Btu/lb	
C_p	Specific heat of dry air	0.240	Btu/(lb·ºF)	Common assumption
COP	Air Conditioner nominal COP	2.79	kW/kW	EGI data[14]
SRF	Savings Reduction Factor	Baseline: Manual: 0% Programmable: 2% Adaptive:10%		[14]
IRF	Impact Reduction Factor	Baseline: Manual: 0% Programmable: 3% Adaptive: 14%		[3][15]

SAVINGS CALCULATION EXAMPLE

The example below illustrates the annual natural gas and electric savings for attic insulation (1,000 ft² attic,) of a home with a manual thermostat. The insulation was upgraded from a nominal baseline of R-11 to nominal R-50.

Nominal R-11 corresponds to Existing nominal R-value bucket ">R-0 to R-12" in Table 1, therefore:

If the customer is completing the Attic insulation measure only,

Annual natural gas savings:

$$1000\ ft^2 \times\ 0.212\ \frac{m^3}{ft^2} +\ 208\ m^3\ =\ 420\ m^3$$

Annual electrical impact:

$$1000\ ft^2 \times\ 0.030\ \frac{kWh}{ft^2} + 82\ kWh = 112\ \ kWh$$

If the customer is completing Attic insulation, in addition to other measures (for example upgrading the space heating equipment, Cathedral/Flat roof Insulation, Basement insulation, etc.),

Annual natural gas savings:

[14] Average Air conditioner COP in a residential home from EGI HER+ participants (2019-2020 program years)

[15] The ICF study reports 11% electricity impact in cooling when upgrading from programmable to adaptive thermostats. The electricity impact reduction factor of 14% between the Manual and the Adaptive baselines was obtained by assuming that the ratio of the savings/impact reduction from Manual to Adaptive to the savings from Programmable to Adaptive is the same in heating and in cooling, hence 0.1/0.08*0.11 = 0.14. The electricity impact reduction factor of 3% between the Manual and the Programmable baselines was derived from these values.

$$1000\ ft^2 \times\ 0.212\ \frac{m^3}{ft^2} =\ 212m^3$$

Annual electrical impact:

$$1000\ ft^2 \times 0.003\ \frac{kWh}{ft^2} = 30\ kWh$$

USES AND EXCLUSIONS

This measure does not apply to:

- Hybrid-fuel space heating systems (i.e., an electric heat pump satisfying a portion of the space heating load).
- Residential buildings used for major occupancies classified as: medium hazard industrial occupancies and low hazard industrial occupancies.
- This measure requires a member of the implementation staff to evaluate the pre- and post-project R-values and to measure the retrofitted attic area.

Natural Gas savings, and Electricity impact due to the air leakage reduction from Attic insulation activity shown in Table 1, do not include the savings from delta R-value. It is only applicable when the only measure completed in the home is Attic insulation. If the customer completes any other measure such as: Cathedral/Flat roof Insulation, Basement insulation, space heating equipment upgrade, water heating equipment upgrade, etc., the air leakage reduction savings will not apply.

Please note that when Attic insulation + Cathedral is completed the following will apply:

1. The R-value natural gas savings/electricity impacts portion of this sub doc will apply, plus;
2. The R-value natural gas savings/electricity impacts from the Cathedral/Flat Roof Insulation sub doc will apply, plus;
3. The air sealing natural gas savings/electricity impacts from only the Cathedral/Flat Roof Insulation sub doc will apply.

MEASURE LIFE

The measure life attributed to this measure is 30 years. [15]

INCREMENTAL COST

Incremental costs do not vary significantly across the various baselines. They can be estimated using an average value of $ CAD 1.84/ft^2 across all baselines[16].

[16] Results from an analysis based on data from [16].

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RESIDENTIAL – COLD CLIMATE AIR SOURCE HEAT PUMP AND AIR SOURCE HEAT PUMP FOR CENTRAL SYSTEMS – TIME OF NATURAL REPLACEMENT

Version Date and Revision History	
Version	1.0
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OEB Approval Date	
Residential → Space Heating → Cold Climate Air Source Heat Pump and Air Source Heat Pump for Central Systems → 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	For heat pump sizing option 4A, Time of Natural Replacement (TNR) of the A/C unit. For heat pump sizing option 4B, Time of Natural Replacement (TNR) of the A/C unit, or Time of Natural Replacement (TNR) of the A/C unit and the space heating system. For heat pump sizing options 4C and 4D, Time of Natural Replacement (TNR) of the A/C unit, the space heating system, or both.
Baseline Technology	For heat pump sizing option 4A, the baseline technology is a new A/C unit and the existing Natural Gas Furnace. For heat pump sizing option 4B, the baseline is a new A/C unit and the existing Natural Gas Furnace, or a new A/C unit and a new Natural Gas Furnace. For heat pump sizing options 4C and 4D, the baseline is a new A/C unit and a new Natural Gas Furnace, or the existing A/C or no A/C (for residential buildings with no cooling in place) and a new Natural Gas Furnace, or a new A/C unit and a new Natural Gas Furnace.
Efficient Technology	Cold Climate Air Source Heat Pump (ccASHP) or Air Source Heat Pump (ASHP) central systems as described in the Efficient Technology section.
Market Type	Residential, Residential-other use[1]
Annual Natural Gas Savings (m3/yr)	Parameter details can be found below: Table 2 ccASHP and Table 3 ASHP
Annual Electric Impact (kWh/yr)	Parameter details can be found below: Table 2 for ccASHP and Table 3 for ASHP
Winter Peak Electric Impact (kW)	Parameter details can be found below: Table 2 for ccASHP and Table 3 for ASHP
Summer Peak Electric Impact (kW)	Parameter details can be found below: Table 2 for ccASHP and Table 3 for ASHP
Measure Life	16 years.

[1] Residential-other use refers to residential buildings, used for major occupancies classified as: business and personal services occupancies, or mercantile occupancies. Medium hazard industrial occupancies and low hazard industrial occupancies is not included.

Restrictions	Restricted to residential buildings[2] of three or fewer stories in building height, having a building area not exceeding 600 m^2, used for major occupancies classified as: residential occupancies, business and personal services occupancies, or mercantile occupancies. For which the space heating load is satisfied by a natural gas heating system. This sub doc does not apply to residential buildings that currently have a hybrid-fuel space heating systems (i.e., an electric heat pump satisfying a portion of the space heating load). This sub doc only applies to the addition of a new ccASHP or ASHP central systems, this is not applicable to the replacement of an existing heat pump nor the addition of ductless systems.								
	System	**No electrical panel upgrade**				**Electrical panel upgrade required**			
		4A	**4B**	**4C**	**4D**	**4A**	**4B**	**4C**	**4D**
Incremental Cost ($ CAD/ton)[3]	**ccASHP**	$1,136	$1,136	$1,888	$2,782	$2,378	$2,378	$3,129	$4,024
	ASHP	$1,088	$1,088	$1,928	$2,939	$2,492	$2,492	$3,332	$4,344

[2] Medium hazard industrial occupancies and low hazard industrial occupancies is not included.

[3] ton calculated as follows and rounded to 1 decimal place, $ton = (Rated\ heating\ capacity\ at\ 8.3℃\ (47℉)\ in\ Btu/hr)/12{,}000$

Table 2. Natural Gas savings and Electricity Impacts for ccASHP

Parameter	HP Switchover Temperature		North				South			
	(ºF)	(ºC)	Option 4A[4]	Option 4B[5]	Option 4C[6]	Option 4D[7]	Option 4A	Option 4B	Option 4C	Option 4D
Annual Natural Gas savings (m3/yr) for ccASHP	Automatic Switchover		547	717	907	1,834	1,077	1,409	1,594	1,717
	17	-8.3	536	672	747	1,834	1,072	1,397	1,531	1,717
	19.4	-7	519	629	653	1,834	1,070	1,380	1,487	1,717
	21.2	-6	502	584	588	1,834	1,061	1,349	1,430	1,717
	23.0	-5	478	537	537	1,834	1,043	1,284	1,328	1,717
	24.8	-4	437	475	472	1,834	1,011	1,192	1,220	1,717
	26.6	-3	400	415	412	1,834	959	1,090	1,111	1,717
	28.4	-2	354	358	354	1,834	894	985	1,002	1,717
	30.2	-1	297	296	293	1,834	813	864	869	1,717
	32	0	231	228	226	1,834	719	742	739	1,717
	33.8	1	176	173	172	1,834	633	645	642	1,717
	35.6	2	141	139	138	1,834	536	536	531	1,717
	37.4	3	111	110	109	1,834	428	420	417	1,717
	39.2	4	82	80	80	1,834	328	322	319	1,717
	41.0	5	60	59	59	1,834	252	247	245	1,717
	42.8	6	40	40	39	1,834	184	181	179	1,717
	44.6	7	30	29	29	1,834	130	128	127	1,717
	46.4	8	19	19	19	1,834	75	73	73	1,717
	48.2	9	12	12	12	1,834	42	41	40	1,717
	50.0	10	8	8	7	1,834	24	24	23	1,717
Annual Electricity Impacts for Residential Buildings Equipped with Central Air Conditioning (kWh/yr) and for ccASHP	Automatic Switchover		-1,898	-2,595	-3,473	-11,620	-3,530	-4,872	-5,727	-6,685
	17	-8.3	-1,853	-2,399	-2,745	-13,567	-3,511	-4,819	-5,452	-7,450
	19.4	-7	-1,781	-2,220	-2,358	-14,160	-3,503	-4,752	-5,271	-7,791
	21.2	-6	-1,711	-2,042	-2,100	-14,558	-3,466	-4,628	-5,044	-8,170
	23.0	-5	-1,617	-1,863	-1,903	-14,878	-3,392	-4,376	-4,645	-8,827
	24.8	-4	-1,460	-1,626	-1,654	-15,297	-3,272	-4,026	-4,233	-9,519
	26.6	-3	-1,323	-1,405	-1,431	-15,686	-3,073	-3,643	-3,822	-10,264
	28.4	-2	-1,151	-1,195	-1,221	-16,066	-2,832	-3,260	-3,422	-10,996
	30.2	-1	-945	-972	-998	-16,479	-2,539	-2,823	-2,939	-11,897
	32	0	-711	-733	-758	-16,927	-2,202	-2,389	-2,473	-12,795
	33.8	1	-520	-542	-567	-17,300	-1,900	-2,050	-2,129	-13,485
	35.6	2	-398	-422	-446	-17,541	-1,566	-1,672	-1,740	-14,249
	37.4	3	-296	-320	-343	-17,752	-1,199	-1,276	-1,341	-15,059
	39.2	4	-194	-218	-239	-17,966	-863	-941	-1,001	-15,743
	41.0	5	-121	-145	-163	-18,129	-610	-685	-741	-16,285
	42.8	6	-56	-78	-94	-18,279	-385	-456	-506	-16,782
	44.6	7	-19	-40	-55	-18,368	-208	-273	-317	-17,186
	46.4	8	15	-5	-18	-18,455	-26	-85	-122	-17,600
	48.2	9	39	20	9	-18,520	82	28	-3	-17,858
	50.0	10	55	38	27	-18,566	142	91	63	-18,008

Table 2 continues on the following page.

[4] Hybrid heating Option 4A is sized to match the cooling load of the building

[5] Hybrid heating Option 4B is sized to match 125% of the cooling load. The customer is interested in both cooling and heating

[6] Hybrid heating Option 4C is sized to displace 75% of the heating load

[7] All Electric Option 4D the heat pump is sized to displace 100% of the heating load

Parameter	HP Switchover Temperature		North				South			
	(ºF)	(ºC)	Option 4A[4]	Option 4B[5]	Option 4C[6]	Option 4D[7]	Option 4A	Option 4B	Option 4C	Option 4D
Annual Electricity Impacts for Residential Buildings **not** Equipped with Central Air Conditioning (kWh/yr) and for ccASHP	Automatic Switchover		-1,898	-2,595	-3,633	-12,073	-3,530	-4,872	-6,608	-7,864
	17	-8.3	-1,853	-2,399	-3,044	-14,020	-3,511	-4,819	-6,367	-8,629
	19.4	-7	-1,781	-2,220	-2,678	-14,613	-3,503	-4,752	-6,192	-8,970
	21.2	-6	-1,711	-2,042	-2,437	-15,011	-3,466	-4,628	-5,979	-9,349
	23.0	-5	-1,617	-1,863	-2,251	-15,331	-3,392	-4,376	-5,604	-10,006
	24.8	-4	-1,460	-1,626	-2,019	-15,750	-3,272	-4,026	-5,219	-10,697
	26.6	-3	-1,323	-1,405	-1,810	-16,139	-3,073	-3,643	-4,829	-11,443
	28.4	-2	-1,151	-1,195	-1,613	-16,519	-2,832	-3,260	-4,454	-12,175
	30.2	-1	-945	-972	-1,403	-16,932	-2,539	-2,823	-3,997	-13,076
	32	0	-711	-733	-1,178	-17,380	-2,202	-2,389	-3,557	-13,974
	33.8	1	-520	-542	-996	-17,753	-1,900	-2,050	-3,231	-14,664
	35.6	2	-398	-422	-881	-17,994	-1,566	-1,672	-2,861	-15,428
	37.4	3	-296	-320	-782	-18,205	-1,199	-1,276	-2,479	-16,238
	39.2	4	-194	-218	-682	-18,419	-863	-941	-2,151	-16,922
	41.0	5	-121	-145	-608	-18,582	-610	-685	-1,897	-17,464
	42.8	6	-56	-78	-540	-18,732	-385	-456	-1,667	-17,961
	44.6	7	-19	-40	-502	-18,821	-208	-273	-1,480	-18,365
	46.4	8	15	-5	-465	-18,908	-26	-85	-1,286	-18,779
	48.2	9	39	20	-438	-18,973	82	28	-1,166	-19,037
	50.0	10	55	38	-419	-19,019	142	91	-1,100	-19,187
Winter Peak Demand Impacts for Residential Buildings Equipped with Central Air Conditioning (kW) for ccASHP	Automatic Switchover		-1.420	-1.669	-2.068	-5.441	-1.904	-2.153	-2.561	-2.859
	17	-8.3	-1.354	-1.541	-1.529	-5.706	-1.904	-2.153	-2.456	-5.239
	19.4	-7	-1.354	-1.409	-1.402	-5.706	-1.903	-2.153	-2.376	-5.969
	21.2	-6	-1.354	-1.409	-1.402	-5.706	-1.903	-2.122	-2.288	-5.969
	23.0	-5	-1.352	-1.403	-1.395	-5.706	-1.852	-2.045	-2.080	-5.969
	24.8	-4	-1.201	-1.168	-1.163	-5.756	-1.852	-2.045	-2.080	-5.969
	26.6	-3	-1.116	-1.086	-1.082	-5.756	-1.848	-2.026	-2.065	-5.969
	28.4	-2	-0.726	-0.707	-0.705	-5.756	-1.778	-1.933	-1.973	-5.969
	30.2	-1	-0.440	-0.430	-0.430	-5.756	-1.757	-1.769	-1.775	-6.007
	32	0	-0.413	-0.404	-0.404	-5.756	-1.491	-1.513	-1.523	-6.007
	33.8	1	-0.156	-0.155	-0.158	-5.756	-1.352	-1.406	-1.416	-6.007
	35.6	2	-0.142	-0.142	-0.145	-5.756	-1.275	-1.339	-1.354	-6.067
	37.4	3	-0.089	-0.090	-0.093	-5.756	-0.759	-0.767	-0.783	-7.085
	39.2	4	-0.053	-0.054	-0.057	-5.756	-0.581	-0.592	-0.609	-7.085
	41.0	5	0.000	0.000	0.000	-5.756	-0.446	-0.459	-0.474	-7.085
	42.8	6	0.000	0.000	0.000	-5.756	-0.397	-0.410	-0.425	-7.085
	44.6	7	0.000	0.000	0.000	-5.756	-0.161	-0.169	-0.177	-7.085
	46.4	8	0.000	0.000	0.000	-5.756	-0.109	-0.115	-0.120	-7.085
	48.2	9	0.000	0.000	0.000	-5.756	-0.037	-0.041	-0.046	-7.085
	50.0	10	0.000	0.000	0.000	-5.756	-0.032	-0.036	-0.040	-7.085

Table 2 continues on the following page.

Parameter	HP Switchover Temperature		North				South			
	(ºF)	(ºC)	Option 4A[4]	Option 4B[5]	Option 4C[6]	Option 4D[7]	Option 4A	Option 4B	Option 4C	Option 4D
Winter Peak Demand Impacts for Residential Buildings **not** Equipped with Central Air Conditioning (kW) for ccASHP	Automatic Switchover		-1.420	-1.669	-1.967	-5.441	-1.904	-2.153	-2.415	-2.859
	17	-8.3	-1.354	-1.541	-1.432	-5.706	-1.904	-2.153	-2.313	-5.239
	19.4	-7	-1.354	-1.409	-1.310	-5.706	-1.903	-2.153	-2.235	-5.969
	21.2	-6	-1.354	-1.409	-1.310	-5.706	-1.903	-2.122	-2.153	-5.969
	23.0	-5	-1.352	-1.403	-1.303	-5.706	-1.852	-2.045	-1.958	-5.969
	24.8	-4	-1.201	-1.168	-1.090	-5.756	-1.852	-2.045	-1.958	-5.969
	26.6	-3	-1.116	-1.086	-1.014	-5.756	-1.848	-2.026	-1.952	-5.969
	28.4	-2	-0.726	-0.707	-0.662	-5.756	-1.778	-1.933	-1.869	-5.969
	30.2	-1	-0.440	-0.430	-0.405	-5.756	-1.757	-1.769	-1.689	-6.007
	32	0	-0.413	-0.404	-0.381	-5.756	-1.491	-1.513	-1.456	-6.007
	33.8	1	-0.156	-0.155	-0.151	-5.756	-1.352	-1.406	-1.356	-6.007
	35.6	2	-0.142	-0.142	-0.139	-5.756	-1.275	-1.339	-1.304	-6.067
	37.4	3	-0.089	-0.090	-0.090	-5.756	-0.759	-0.767	-0.760	-7.085
	39.2	4	-0.053	-0.054	-0.056	-5.756	-0.581	-0.592	-0.595	-7.085
	41.0	5	0.000	0.000	0.000	-5.756	-0.446	-0.459	-0.466	-7.085
	42.8	6	0.000	0.000	0.000	-5.756	-0.397	-0.410	-0.420	-7.085
	44.6	7	0.000	0.000	0.000	-5.756	-0.161	-0.169	-0.177	-7.085
	46.4	8	0.000	0.000	0.000	-5.756	-0.109	-0.115	-0.121	-7.085
	48.2	9	0.000	0.000	0.000	-5.756	-0.037	-0.041	-0.046	-7.085
	50.0	10	0.000	0.000	0.000	-5.756	-0.032	-0.036	-0.040	-7.085
Summer Peak Demand Impacts for Residential Buildings Equipped with Central Air Conditioning (kW) and for ccASHP	All	All	0.203	0.172	0.156	0.220	0.306	0.251	0.223	0.308
Summer Peak Demand Impacts for Residential Buildings **not** Equipped with Central Air Conditioning (kW) and for ccASHP	All	All	0.203	0.172	-1.072	-1.029	0.306	0.251	-1.431	-1.372

Table 3. Natural Gas savings and Electricity Impacts for ASHP

Parameter	HP Switchover Temperature		North				South			
	(ºF)	(ºC)	Option 4A[8]	Option 4B[9]	Option 4C[10]	Option 4D[11]	Option 4A	Option 4B	Option 4C	Option 4D
Annual Natural Gas savings (m3/yr) for ASHP	Automatic Switchover		433	591	747	1,834	859	1,231	1,464	1,717
	17	-8.3	431	579	696	1,834	858	1,227	1,448	1,717
	19.4	-7	426	558	639	1,834	858	1,222	1,428	1,717
	21.2	-6	419	534	585	1,834	853	1,210	1,387	1,717
	23.0	-5	409	501	537	1,834	848	1,179	1,305	1,717
	24.8	-4	391	451	472	1,834	837	1,125	1,204	1,717
	26.6	-3	369	407	412	1,834	811	1,042	1,100	1,717
	28.4	-2	332	355	354	1,834	774	953	992	1,717
	30.2	-1	282	295	293	1,834	719	847	866	1,717
	32	0	224	228	226	1,834	652	736	738	1,717
	33.8	1	175	173	172	1,834	592	641	642	1,717
	35.6	2	141	139	138	1,834	519	535	531	1,717
	37.4	3	111	110	109	1,834	424	420	417	1,717
	39.2	4	82	80	80	1,834	328	322	319	1,717
	41.0	5	60	59	59	1,834	252	247	245	1,717
	42.8	6	40	40	39	1,834	184	181	179	1,717
	44.6	7	30	29	29	1,834	130	128	127	1,717
	46.4	8	19	19	19	1,834	75	73	73	1,717
	48.2	9	12	12	12	1,834	42	41	40	1,717
	50.0	10	8	8	7	1,834	24	24	23	1,717
Annual Electricity Impacts for Residential Buildings Equipped with Central Air Conditioning (kWh/yr) for ASHP	Automatic Switchover		-1,444	-2,065	-2,732	-12,288	-2,741	-4,183	-5,175	-6,936
	17	-8.3	-1,436	-2,013	-2,510	-13,618	-2,735	-4,163	-5,106	-7,669
	19.4	-7	-1,417	-1,932	-2,282	-14,207	-2,735	-4,144	-5,025	-7,948
	21.2	-6	-1,388	-1,838	-2,072	-14,604	-2,717	-4,099	-4,866	-8,314
	23.0	-5	-1,353	-1,714	-1,890	-14,924	-2,696	-3,981	-4,556	-8,965
	24.8	-4	-1,286	-1,533	-1,650	-15,343	-2,659	-3,785	-4,180	-9,657
	26.6	-3	-1,206	-1,374	-1,432	-15,733	-2,564	-3,483	-3,799	-10,402
	28.4	-2	-1,072	-1,189	-1,227	-16,113	-2,429	-3,165	-3,415	-11,135
	30.2	-1	-896	-979	-1,009	-16,525	-2,237	-2,794	-2,965	-12,036
	32	0	-699	-747	-775	-16,973	-2,002	-2,408	-2,515	-12,931
	33.8	1	-529	-561	-587	-17,344	-1,798	-2,084	-2,182	-13,619
	35.6	2	-415	-443	-468	-17,584	-1,552	-1,723	-1,801	-14,378
	37.4	3	-317	-343	-366	-17,793	-1,239	-1,338	-1,407	-15,182
	39.2	4	-217	-243	-263	-18,005	-923	-1,007	-1,070	-15,858
	41.0	5	-146	-170	-188	-18,165	-674	-754	-811	-16,393
	42.8	6	-81	-103	-119	-18,313	-454	-526	-576	-16,882
	44.6	7	-45	-66	-80	-18,400	-279	-343	-386	-17,277
	46.4	8	-12	-30	-43	-18,485	-100	-155	-189	-17,680
	48.2	9	12	-5	-15	-18,548	9	-40	-69	-17,930
	50.0	10	28	13	3	-18,592	68	24	-1	-18,075

Table 3 continues on the following page.

[8] Hybrid heating Option 4A is sized to match the cooling load of the building

[9] Hybrid heating Option 4B is sized to match 125% of the cooling load. The customer is interested in both cooling and heating

[10] Hybrid heating Option 4C is sized to displace 75% of the heating load

[11] All Electric Option 4D the heat pump is sized to displace 100% of the heating load

Parameter	HP Switchover Temperature		North				South			
	(ºF)	(ºC)	Option 4A[8]	Option 4B[9]	Option 4C[10]	Option 4D[11]	Option 4A	Option 4B	Option 4C	Option 4D
Annual Electricity Impacts for Residential Buildings **not** Equipped with Central Air Conditioning (kWh/yr) for ASHP	Automatic Switchover		-1,444	-2,065	-3,143	-12,741	-2,741	-4,183	-6,299	-8,115
	17	-8.3	-1,436	-2,013	-2,904	-14,071	-2,735	-4,163	-6,209	-8,848
	19.4	-7	-1,417	-1,932	-2,643	-14,660	-2,735	-4,144	-6,116	-9,127
	21.2	-6	-1,388	-1,838	-2,428	-15,058	-2,717	-4,099	-5,932	-9,493
	23.0	-5	-1,353	-1,714	-2,254	-15,377	-2,696	-3,981	-5,597	-10,144
	24.8	-4	-1,286	-1,533	-2,028	-15,796	-2,659	-3,785	-5,225	-10,836
	26.6	-3	-1,206	-1,374	-1,823	-16,186	-2,564	-3,483	-4,863	-11,581
	28.4	-2	-1,072	-1,189	-1,629	-16,566	-2,429	-3,165	-4,495	-12,314
	30.2	-1	-896	-979	-1,423	-16,978	-2,237	-2,794	-4,057	-13,215
	32	0	-699	-747	-1,201	-17,426	-2,002	-2,408	-3,626	-14,110
	33.8	1	-529	-561	-1,022	-17,797	-1,798	-2,084	-3,307	-14,798
	35.6	2	-415	-443	-907	-18,037	-1,552	-1,723	-2,940	-15,557
	37.4	3	-317	-343	-808	-18,246	-1,239	-1,338	-2,558	-16,361
	39.2	4	-217	-243	-708	-18,458	-923	-1,007	-2,229	-17,037
	41.0	5	-146	-170	-633	-18,619	-674	-754	-1,973	-17,572
	42.8	6	-81	-103	-565	-18,766	-454	-526	-1,739	-18,061
	44.6	7	-45	-66	-525	-18,854	-279	-343	-1,548	-18,456
	46.4	8	-12	-30	-487	-18,938	-100	-155	-1,347	-18,859
	48.2	9	12	-5	-459	-19,001	9	-40	-1,223	-19,109
	50.0	10	28	13	-440	-19,045	68	24	-1,155	-19,254
Winter Peak Demand impacts for Residential Buildings Equipped with Central Air (kW) for ASHP	Automatic Switchover		-1.120	-1.374	-1.680	-6.261	-1.629	-1.901	-2.282	-2.896
	17	-8.3	-1.120	-1.368	-1.492	-5.706	-1.629	-1.901	-2.270	-5.250
	19.4	-7	-1.120	-1.357	-1.366	-5.706	-1.629	-1.901	-2.270	-5.979
	21.2	-6	-1.120	-1.357	-1.366	-5.706	-1.629	-1.890	-2.219	-5.979
	23.0	-5	-1.080	-1.350	-1.359	-5.706	-1.629	-1.834	-2.035	-5.979
	24.8	-4	-1.072	-1.136	-1.134	-5.756	-1.626	-1.834	-2.035	-5.979
	26.6	-3	-1.072	-1.057	-1.055	-5.756	-1.626	-1.822	-2.023	-5.979
	28.4	-2	-0.704	-0.689	-0.688	-5.756	-1.626	-1.733	-1.935	-5.979
	30.2	-1	-0.428	-0.420	-0.421	-5.756	-1.626	-1.733	-1.745	-6.017
	32	0	-0.402	-0.394	-0.395	-5.756	-1.399	-1.485	-1.501	-6.017
	33.8	1	-0.152	-0.152	-0.156	-5.756	-1.319	-1.382	-1.397	-6.017
	35.6	2	-0.139	-0.139	-0.143	-5.756	-1.247	-1.319	-1.340	-6.067
	37.4	3	-0.087	-0.089	-0.092	-5.756	-0.744	-0.759	-0.778	-7.085
	39.2	4	-0.052	-0.054	-0.057	-5.756	-0.571	-0.588	-0.607	-7.085
	41.0	5	0.000	0.000	0.000	-5.756	-0.439	-0.457	-0.475	-7.085
	42.8	6	0.000	0.000	0.000	-5.756	-0.391	-0.409	-0.426	-7.085
	44.6	7	0.000	0.000	0.000	-5.756	-0.159	-0.170	-0.179	-7.085
	46.4	8	0.000	0.000	0.000	-5.756	-0.108	-0.116	-0.122	-7.085
	48.2	9	0.000	0.000	0.000	-5.756	-0.037	-0.042	-0.046	-7.085
	50.0	10	0.000	0.000	0.000	-5.756	-0.032	-0.037	-0.041	-7.085

Table 3 continues on the following page.

Parameter	HP Switchover Temperature		North				South			
	(ºF)	(ºC)	Option 4A[8]	Option 4B[9]	Option 4C[10]	Option 4D[11]	Option 4A	Option 4B	Option 4C	Option 4D
Winter Peak Demand impacts for Residential Buildings **not** Equipped with Central Air (kW) for ASHP	Automatic Switchover		-1.120	-1.374	-1.717	-6.261	-1.629	-1.901	-2.229	-2.896
	17	-8.3	-1.120	-1.368	-1.409	-5.706	-1.629	-1.901	-2.205	-5.250
	19.4	-7	-1.120	-1.357	-1.285	-5.706	-1.629	-1.901	-2.205	-5.979
	21.2	-6	-1.120	-1.357	-1.285	-5.706	-1.629	-1.890	-2.124	-5.979
	23.0	-5	-1.080	-1.350	-1.278	-5.706	-1.629	-1.834	-1.932	-5.979
	24.8	-4	-1.072	-1.136	-1.070	-5.756	-1.626	-1.834	-1.932	-5.979
	26.6	-3	-1.072	-1.057	-0.996	-5.756	-1.626	-1.822	-1.928	-5.979
	28.4	-2	-0.704	-0.689	-0.651	-5.756	-1.626	-1.733	-1.850	-5.979
	30.2	-1	-0.428	-0.420	-0.400	-5.756	-1.626	-1.733	-1.676	-6.017
	32	0	-0.402	-0.394	-0.376	-5.756	-1.399	-1.485	-1.450	-6.017
	33.8	1	-0.152	-0.152	-0.150	-5.756	-1.319	-1.382	-1.351	-6.017
	35.6	2	-0.139	-0.139	-0.138	-5.756	-1.247	-1.319	-1.306	-6.067
	37.4	3	-0.087	-0.089	-0.091	-5.756	-0.744	-0.759	-0.766	-7.085
	39.2	4	-0.052	-0.054	-0.056	-5.756	-0.571	-0.588	-0.603	-7.085
	41.0	5	0.000	0.000	0.000	-5.756	-0.439	-0.457	-0.475	-7.085
	42.8	6	0.000	0.000	0.000	-5.756	-0.391	-0.409	-0.428	-7.085
	44.6	7	0.000	0.000	0.000	-5.756	-0.159	-0.170	-0.182	-7.085
	46.4	8	0.000	0.000	0.000	-5.756	-0.108	-0.116	-0.125	-7.085
	48.2	9	0.000	0.000	0.000	-5.756	-0.037	-0.042	-0.047	-7.085
	50.0	10	0.000	0.000	0.000	-5.756	-0.032	-0.037	-0.041	-7.085
Summer Peak Demand Impacts for Residential Buildings Equipped with Central Air Conditioning (kW) and for ASHP	All	All	0.138	0.111	0.098	0.150	0.210	0.164	0.140	0.222
Summer Peak Demand Impacts for Residential Buildings **not** Equipped with Central Air Conditioning (kW) and for ASHP	All	All	0.138	0.111	-1.124	-1.104	0.210	0.164	-1.504	-1.462

OVERVIEW

A heat pump is an electrically driven device that extracts heat from a low temperature place (a **source**) and delivers it to a higher temperature place (a **sink**).

Heat naturally flows from places with higher temperatures to locations with lower temperatures (e.g., in the winter, heat from inside the building is lost to the outside). A heat pump uses additional electrical energy to counter the natural flow of heat and pumps the energy available in a colder place to a warmer one.

Heating and cooling with a heat pump. As energy is extracted from a **source**, the temperature of the source is reduced. If the home is used as the source, thermal energy will be removed, cooling this space. This is how a heat pump operates in cooling mode, and it is the same principle used by air conditioners and refrigerators. Similarly, as energy is added to a **sink**, its temperature increases. If the home is used as a sink, thermal energy will be added, heating the space. A heat pump is fully reversible, meaning that it can both heat and cool the space. [1]

Sources and Sinks for Heat Pumps in heating mode [1]

Sources: Two sources of thermal energy are commonly used for heating homes with heat pumps in Canada:

- **Air-Source**: The heat pump draws heat from the outside air during the heating season and rejects heat outside during the summer cooling season.
- **Ground-Source**: A ground-source heat pump uses the earth, ground water, or both as the source of heat in the winter, and as a reservoir to reject heat removed from the home in the summer.

Sinks: Two sinks for thermal energy are commonly used for heating homes with heat pumps in Canada:

- Indoor air: indoor air is heated by the heat pump. This can be done through:
  - A centrally ducted system or
  - A ductless indoor unit, such as a wall mounted unit.
- Water: water inside the building is heated. This water can then be used to serve terminal systems like radiators, a radiant floor, or fan coil units via a hydronic system.

Air-source heat pumps (ASHPs) including cold climate air-source heat pumps (ccASHP) are high-efficiency electric heating and cooling systems that use the outdoor air as a source of thermal energy in heating mode, and as a sink to reject energy when in cooling mode.
These types of systems can generally be classified into two categories: [1]

- **Air-Air Heat Pumps**. These units heat or cool the air inside a building and represent the vast majority of air-source heat pump integrations in Canada. They can be further classified according to the type of installation:

    - Ducted: The indoor coil of the heat pump is located in a duct. Air is heated or cooled by passing over the coil, before being distributed via the ductwork to different locations in the home.
    - Ductless: The indoor coil of the heat pump is located in an indoor unit. These indoor units are generally located on the floor or wall of an occupied space, and heat or cool the air in that space directly. Further classification of these units:
        - Mini-Split: A single indoor unit is located inside the home, served by a single outdoor unit.
        - Multi-Split: Multiple indoor units are located in the building and are served by a single outdoor unit.

- **Air-Water Heat Pumps:** Less common in Canada, air-water heat pumps heat or cool water, and are used in homes with hydronic (water-based) distribution systems such as low temperature radiators, radiant floors, or fan coil units. In heating mode, the heat pump provides thermal energy to the hydronic system. This process is reversed in cooling mode, and thermal energy is extracted from the hydronic system and rejected to the outdoor air.

Supplementary Heat Sources. [1]
Since air-source heat pumps have a minimum outdoor operating temperature (between -15°C to -25°C) and reduced heating capacity at very cold temperatures, it is important to consider a supplemental heating source for air-source heat pump operations. Supplementary heating may also be required when the heat pump is defrosting. Different options are available:

- **All Electric**: In this configuration, heat pump operations are supplemented with electric resistance elements located in the ductwork or with electric baseboards. These resistance elements are less efficient than the heat pump, but their ability to provide heating is independent of outdoor temperature.
- **Hybrid System**: In a hybrid system, the air-source heat pump uses a supplemental system such as a furnace or boiler.

This measure is focused on air-source heat pumps (**source**) centrally ducted system (**sink**), specifically air-air heat pumps and covers both types of supplemental heating: Hybrid systems and All Electric.

In heating mode, air-source heat pumps save energy by displacing fossil fuel consumption with electricity (a portion or all of it, depending on the supplemental heat configuration).

In cooling mode, ASHPs function like standard air conditioners but are typically more efficient due to advanced compressor and control technologies, providing additional energy savings and reductions in peak demand during the summer months.

APPLICATION

This measure applies to:

- The addition of a new ccASHP or ASHP centrally ducted systems in a residential building in Ontario. Specifically, air-air heat pump and cover both types of supplemental heating: Hybrid systems and All Electric
- Residential buildings for which the space heating load (full load) is satisfied by a natural gas heating system prior to the installation of the heat pump.
- It is applicable to residential buildings of three or fewer stories in building height, having a building area not exceeding 600 m^2, used for major occupancies classified as: residential occupancies, business and personal services occupancies, or mercantile occupancies.

This measure does not apply to:

- Residential buildings that currently have a hybrid-fuel space heating system (i.e., an electric heat pump satisfying a portion of the space heating load).
- Residential buildings used for major occupancies are classified as: medium hazard industrial occupancies and low hazard industrial occupancies.
- The addition of ductless systems.
- The replacement of an existing heat pump.

BASELINE TECHNOLOGY

There is a specific baseline definition for each of the heat pump sizing options, they are summarized below and details presented in Table 4:

- For heat pump sizing option 4A, the baseline technology is a new A/C unit and the existing Natural Gas Furnace.
- For heat pump sizing option 4B, the baseline is:
    - A new A/C unit and the existing Natural Gas Furnace, or
    - A new A/C unit and a new Natural Gas Furnace.
- For heat pump sizing options 4C and 4D, the baseline is:
    - A new A/C unit and the existing Natural Gas Furnace, or
    - The existing A/C or no A/C (for residential buildings with no cooling in place) and a new Natural Gas Furnace, or
    - A new A/C unit and a new Natural Gas Furnace.

Table 4 Baseline Technology

HP Sizing Option	The customer is interested in	Baseline definition	Baseline Equipment		Baseline Efficiency	
			A/C unit	Furnace	A/C unit COP	Furnace AFUE
4A	Cooling	1. Replace existing A/C unit with new one	New A/C	Existing	2.72	90%
		2. Add cooling (new A/C)	New A/C	Existing	2.72	90%
4B	Cooling	1. Replace existing A/C unit with new one	New A/C	Existing	2.72	90%
		2. Add cooling (new A/C)	New A/C	Existing	2.72	90%
	Heating and cooling	5. If customer is looking to replace heating and cooling	New A/C	New Furnace	2.72	95%
4C and 4D	Cooling	1. Replace existing A/C unit with new one	New A/C	Existing	2.72	90%
		2. Add cooling (new A/C)	New A/C	Existing	2.72	90%
	Heating	3. Replace heating and it had cooling in place	Existing	New Furnace	2.72	95%
		4. Replace heating and it didn't have cooling in place (add cooling)	Didn't have cooling	New Furnace	N/A	95%
	Heating and cooling	5. If customer is looking to replace heating and cooling	New A/C	New Furnace	2.72	95%

EFFICIENT TECHNOLOGY

The efficient technology is defined by three elements:

1. Heat pump performance efficiency requirements. The heat pump must meet the minimum requirements in this section.
2. Heat Pump Sizing. A sizing option must be specified, and
3. Control methodology in heating mode. A control methodology must be properly specified.

Heat pump performance efficiency requirements

The efficient technology is the addition of a new ASHP or ccASHP centrally ducted systems in a residential building in Ontario that meets the performance efficiency/criteria specified in the table below. Specifically, air-air heat pumps with supplemental heating: Hybrid systems and All Electric.

Table 5 Efficient Technology for Residential ASHP and ccASHP centrally ducted systems

System configuration	Min. HSPF2 Region V	Min. SEER2	Min. Heating Rated Capacity at 8.3°C (47°F) Btu/hr	Min. COP @ Max capacity[12] 5°F (-15 °C)	Min Capacity maintenance[13] (max -15°C (5°F))/Rated 8.3°C (47°F)), %
ASHP	6.6	15.2	12,000	N/A	N/A
ccASHP	6.6	15.2	12,000	1.8	70

Heat Pump Sizing. Four sizing options are assessed based on the NRCan toolkit for air source heat pump sizing and selection. [2]

Hybrid heating

- Option 4A is sized to match the cooling load of the building. The customer is primarily interested in cooling. The heat pump is seen as an alternative for a new or existing A/C unit; The backup / existing heating system is seen as the primary heating source for most of the heating season.
- Option 4B is sized to match 125% of the cooling load. The customer is interested in both cooling and heating. The backup heating system is used primarily during colder weather.
- Option 4C is sized to displace 75% of the heating load. Option 4C differs from the NRCan sizing which targets a heating capacity at 17°F (Fahrenheit) and is thus different for each installation location – instead a fixed percentage was chosen so that the sizes can scaled up or down with the heating load of the building. The customer is interested in heating. The backup heating system is used during the coldest periods. Cooling performance is of secondary interest to the client.

All Electric

- Option 4D is sized to displace 100% of the heating load. Option 4D is considered only when full electrification (heat pump + installation of an electric resistance backup heater) is planned.

Control methodology in heating mode

- **Switchover Temperature**. The switchover temperature is the temperature at which the heating system in use transitions from the heat pump (at warmer temperatures) to the back-up system at colder temperatures: either natural gas (sizing options 4A, 4B and 4C) or electric resistance (sizing option 4D).
- **Automatic Switchover Temperature**. This is an 'integrated controller' built into a smart thermostat that controls both systems (heat pump and back-up) that enables the switchover temperature automatically. This option ensures the optimal performance of the heat pump, meaning the heat pump can perform to its maximum potential without compromising comfort.

[12] at maximum capacity operation.

[13] Capacity maintenance is the ratio of the capacity at -15°C vs the capacity at 8.3°C – the higher the number the more heat the ccASHP is able to output at low temperatures.

ENERGY IMPACTS

Natural gas savings are achieved from the installation of ccASHP/ASHP by displacing heat production in the building from a natural gas-fired furnace with electric heating, either in part or in full. The amount of natural gas displaced is a function of the location, the ccASHP/ASHP size, and the control methodology in heating mode.

Heat Pump Sizing. The larger the heat pump installed, the more natural gas can be saved by displacing natural gas heating with electricity. In contrast, the larger the heat pump, the more electricity is consumed in heating mode. In addition, the larger the heat pump can also impact the cooling efficiency.

Control methodology in heating mode. Switchover Temperature: The lower the switchover temperature, the more natural gas is saved in general. This trend is not perfectly linear due to the variance in the number of hours at each temperature, and the reduction in efficiency and capacity of the heat pump as temperatures decrease. In contrast, the lower the switchover temperature is set, the more electricity is consumed by the heat pump operating in heating mode. **Automatic Switchover Temperature:** Rather than using a fixed outdoor air temperature to switch between the ccASHP or ASHP and the back-up heating system, the automatic switchover temperature controller automatically determines what is the best temperature to switch from heat pump to back-up depending on the heating demand of the building and outdoor temperature. If the heat pump is sized correctly, this option maximizes the natural gas savings, but it also has the largest electricity consumption in heating mode.

For residential buildings equipped with central air conditioning. Options 4A, B and C summer electricity impacts are positive as ccASHP and ASHPs will be more efficient than the base case A/C unit, and winter electricity impacts will be progressively more negative as switchover temperature decreases, as more of the heat load will be met by electricity. For option 4D, the ASHP is a more efficient electrical heat source than the back-up electric resistance heat source; therefore, increasing the switchover temperature means that more electricity is used, reversing the trend from the other three options. Therefore, it is recommended for option 4D to use only Automatic switchover temperature as preferred control strategy.

For residential buildings not equipped with central air conditioning, the annual electricity impact is always negative as there will be a large electricity load added all year round (heating and cooling).

NATURAL GAS SAVINGS ALGORITHM

The natural gas savings were calculated using the Heat Pump Analysis Tool (HPAT). [3] The HPAT is an Excel-based model used to calculate the natural gas savings relative to the baseline for all system configurations on an hourly basis (8760 model), using specific system sizing and input parameters. The six system configurations covered are:

1. ccASHP with existing Gas furnace,
2. ccASHP with new Gas furnace,
3. ccASHP with Elec back-up,
4. ASHP with existing Gas furnace,
5. ASHP with new Gas furnace, and
6. ASHP with Elec back-up

The algorithms used in the tool to determine the natural gas savings are as follows:

Natural gas savings equations.

$$NG_{savings} = NG_{baseline} - NG_{EE} \quad (1)$$

System configuration:
ccASHP with existing Gas furnace,
ccASHP with new Gas furnace,
ASHP with existing Gas furnace, and
ASHP with new Gas furnace,

$$NG_{savings} = NG_{baseline} \quad (1a)$$

System configuration:
ccASHP with Elec back-up, and
ASHP with Elec back-up

where:

$NG_{savings}$	=	Annual natural gas savings (m^3/yr)
$NG_{baseline}$	=	Baseline natural gas consumption (m^3/yr)
NG_{EE}	=	Energy efficient case natural gas consumption (m^3/yr)

Natural gas baseline consumption equations.

$$NG_{baseline} = \sum_{1}^{8760} NG_{hourly} \times HHV_{NG} \quad (2)$$

$$NG_{hourly} = \frac{D_{heating}}{Eff} \quad (3)$$

$$D_{heating} = LF_{heating-base} \times Q_{heating} \quad (4)$$

$$HHV_{NG} = \frac{35{,}738 \times 1.055056}{1{,}000{,}000} \quad (5)$$

where:

NG_{hourly}	=	Hourly natural gas consumption- baseline (Btu/h)
HHV_{NG}	=	Natural gas heating value (GJ/m^3)
$D_{heating}$	=	Space heating demand-baseline (Btu/h)
Eff	=	Natural gas furnace efficiency (%)
$LF_{heating-base}$	=	Baseline Furnace heating load factor (dimensionless). Determined for each hour of the year through energy modelling- Energy Plus. It is the space heating load of the house for a specific hour divided by the maximum space heating load of the house.
$Q_{heating}$	=	Design space heating load (Btu/hr). Maximum space heating demand
35,738	=	Energy Density of Natural Gas (Btu/m^3)
1.055056	=	Conversion factor (GJ/MMBtu)

Natural gas efficient case consumption equations

$$NG_{EE} = \sum_{1}^{8760} NG_{hourly-EE} \times HHV_{NG} \quad (6)$$

$$NG_{hourly-EE} = IF\ (H_{mode} = "Backup") \quad (7)$$
$$If\ True = \frac{D_{heating}}{Eff}, If\ False = 0$$

$H_{mode} = "Backup"\ when$: (8)

- $if\ Intergrated\ Controles = "Yes"$
  - $T_{db} < T_{lockout}$, OR
  - $HP_{MHC} < D_{heating-EE}$, *OR*
  - $HP_{RHC} < D_{heating-EE}$
- $if\ Intergrated\ Controles = "No"$
  - $T_{db} < T_{switchover}$, OR
  - $HP_{MHC} < D_{heating-EE}$, *OR*
  - $HP_{RHC} < D_{heating-EE}$

where:

$NG_{hourly-EE}$	=	Hourly natural gas consumption- efficient case (Btu/hr)

H_{mode}	=	Space heating mode[14] (Heat Pump, Backup, or OFF)
T_{db}	=	Dry bulb temperature- outdoor (°F)
$T_{lockout}$	=	Heat pump lock-out temperature (°F). Is the temperature that causes the heat pump to cease operation. It is used to specify that it is in place to prevent over-pressure damage to a dual fuel system or to override an integrated controller in an all-electric system. For electric resistance back-up systems, simultaneous operation with the heat pump is allowed when the heat pump capacity is below the heating demand but maintains a COP above one. If the capacity is insufficient and COP falls below one, 100% of the heating demand is met by the back-up system.
$T_{switchover}$	=	Heat pump switchover temperature (°F). The switchover temperature is the temperature at which the heating system in use transitions from the heat pump to the back-up.
HP_{MHC}	=	Heat pump maximum heating capacity at a specific outdoor temperature (Btu/hr)
HP_{RHC}	=	Heat pump rated heating capacity at a specific outdoor temperature (Btu/hr)

Heat pump Maximum and Rated heating capacity hourly equations

$$HP_{MHC} = HC_{Max} \times HCap_{Max-system} \quad (10)$$

$$HP_{RHC} = HC_{Rate} \times TCap_{heating} \quad (11)$$

$$HC_{Max} = \quad (12)$$
$$If\ T_{db} \geq 47°\text{F} \rightarrow HC_{Max} = 1$$
$$If\ -5°\text{F} < T_{db} < 47°\text{F} \rightarrow HC_{Max} = a \times T_{db}^2 + b \times T_{db} + c$$
$$If\ T_{db} \leq -5°\text{F} \rightarrow HC_{Max} = minimun\ value$$

$$HC_{Rated} = \quad (13)$$
$$If\ T_{db} \geq 47°\text{F} \rightarrow HC_{Rated} = 1$$
$$If\ -5°\text{F} < T_{db} < 47°\text{F} \rightarrow HC_{Rated} = a \times T_{db}^2 + b \times T_{db} + c$$
$$If\ T_{db} \leq -5°\text{F} \rightarrow HC_{Rated} = minimun\ value$$

$$HCap_{Max-system} = TCap_{heating} \times RH_{Max-to-Rated} \quad (14)$$

where:

[14] The equations for "Backup" mode are located in the Natural Gas algorithms section (Equation 8). The equations for "Heat pump" mode can be found in the Electricity Impact algorithms section (Equation 31). "OFF" mode refers to when the system is neither operating in heat pump mode nor in backup mode.

HC_{Max}	=	Heat pump Maximum Capacity heating performance curve (polynomial)
$HCap_{Max-system}$	=	Heat pump heating maximum system capacity (Btu/hr)
HC_{Rated}	=	Heat pump Rated Capacity heating performance curve (polynomial)
$TCap_{heating}$	=	Target heat pump rated heating capacity (Btu/hr)
a, b, c	=	Heat pump Maximum and Rated Capacity heating performance curve polynomial coefficients.
$RH_{Max-to-Rated}$	=	Heat pump Maximum capacity curve fraction (dimensionless)

Heat pump target heating and cooling capacity hourly equations

	HP sizing option	
$TCap_{heating} = TCap_{cooling} \times 1.05$	4A & 4B	(15)
$TCap_{cooling} = Q_{cooling}$	4A[15]	(16)
$TCap_{cooling} = Q_{cooling} \times 1.25$	4B[16]	(17)
$TCap_{cooling} = TCap_{heating} \times 0.95$	4C & 4D	(18)
$TCap_{heating} = Q_{heating} \times 0.75$	4C[17]	(19)
$TCap_{heating} = Q_{heating}$	4D[18]	(20)

where:

$TCap_{heating}$	=	Target heat pump rated heating capacity (Btu/hr)
$TCap_{cooling}$	=	Target heat pump rated cooling capacity (Btu/hr)
$Q_{cooling}$	=	Design space cooling load (Btu/hr). Maximum space cooling demand

The tool was setup for the scenarios described in tables 6 and 7. A total of 1,200 scenarios were run (600 scenarios for the North and 600 for the South) and the outputs are presented in table 1. The specific assumptions used in the calculations are captured in the Assumptions section.

[15] HP sizing Option 4A is sized to match the cooling load of the building.
[16] HP sizing Option 4B is sized to match 125% of the cooling load.
[17] HP sizing Option 4C is sized to displace 75% of the heating load.
[18] HP sizing Option 4D is sized to displace 100% of the heating load.

Table 6 Natural Gas savings for ccASHP centrally ducted systems

HP Sizing Option	Baseline description	Baseline technology		Efficient technology		Heating Natural gas savings calculation	
		A/C unit	Furnace	Type of system	Control methodology, heating mode	Baseline consumption	Eff. Case consumption
4A	Replace existing A/C unit with New one or Add cooling (new A/C)	New A/C	Existing	ccASHP with existing Gas furnace back-up	Switchover Temperature	Existing Gas Furnace, full load	Existing Gas Furnace, reduced load
					Automatic Switchover Temperature		
4B	Replace existing A/C unit with New one or Add cooling (new A/C)	New A/C	Existing	ccASHP with existing Gas furnace back-up	Switchover Temperature	Existing Gas Furnace, full load	Existing Gas Furnace, reduced load
					Automatic Switchover Temperature		
	Replace heating and cooling	New A/C	New Furnace	ccASHP with New Gas furnace back-up	Switchover Temperature	New Gas Furnace, full load	New Gas Furnace, reduced load
					Automatic Switchover Temperature		
4C	Replace existing A/C unit with New one or Add cooling (new A/C)	New A/C	Existing	ccASHP with existing Gas furnace back-up	Switchover Temperature	Existing Gas Furnace, full load	Existing Gas Furnace, reduced load
					Automatic Switchover Temperature		
	Replace heating and it had cooling in place	Existing	New Furnace	ccASHP with New Gas furnace back-up	Switchover Temperature	New Gas Furnace, full load	New Gas Furnace, reduced load
					Automatic Switchover Temperature		
	Replace heating and it didn't have cooling in place (add cooling)	No cooling	New Furnace	ccASHP with New Gas furnace back-up	Switchover Temperature	New Gas Furnace, full load	New Gas Furnace, reduced load
					Automatic Switchover Temperature		
	Replace heating and cooling	New A/C	New Furnace	ccASHP with New Gas furnace back-up	Switchover Temperature	New Gas Furnace, full load	New Gas Furnace, reduced load
					Automatic Switchover Temperature		
4D	Replace existing A/C unit with New one or Add cooling (new A/C)	New A/C	Existing	ccASHP with electric back-up	Switchover Temperature	New Gas Furnace, full load	Furnace load fully displaced by electricity
					Automatic Switchover Temperature		
	Replace heating and it had cooling in place	Existing	New Furnace	ccASHP with electric back-up	Switchover Temperature	New Gas Furnace, full load	Furnace load fully displaced by electricity
					Automatic Switchover Temperature		
	Replace heating and it didn't have cooling in place (add cooling)	No cooling	New Furnace	ccASHP with electric back-up	Switchover Temperature		
					Automatic Switchover Temperature		
	Replace heating and cooling	New A/C	New Furnace	ccASHP with electric back-up	Switchover Temperature	New Gas Furnace, full load	Furnace load fully displaced by electricity
					Automatic Switchover Temperature		

Table 7 Natural Gas savings for ASHP centrally ducted systems

HP Sizing Option	Baseline description	Baseline technology		Efficient technology		Heating Natural gas savings calculation	
		A/C unit	Furnace	Type of system	Control methodology, heating mode	Baseline consumption	Eff. Case consumption
4A	Replace existing A/C unit with New one or Add cooling (new A/C)	New A/C	Existing	ASHP with existing Gas furnace back-up	Switchover Temperature Automatic Switchover Temperature	Existing Gas Furnace, full load	Existing Gas Furnace, reduced load
4B	Replace existing A/C unit with New one or Add cooling (new A/C)	New A/C	Existing	ASHP with existing Gas furnace back-up	Switchover Temperature Automatic Switchover Temperature	Existing Gas Furnace, full load	Existing Gas Furnace, reduced load
	Replace heating and cooling	New A/C	New Furnace	ASHP with New Gas furnace back-up	Switchover Temperature Automatic Switchover Temperature	New Gas Furnace, full load	New Gas Furnace, reduced load
4C	Replace existing A/C unit with New one or Add cooling (new A/C)	New A/C	Existing	ASHP with existing Gas furnace back-up	Switchover Temperature Automatic Switchover Temperature	Existing Gas Furnace, full load	Existing Gas Furnace, reduced load
	Replace heating and it had cooling in place	Existing	New Furnace	ASHP with New Gas furnace back-up	Switchover Temperature Automatic Switchover Temperature	New Gas Furnace, full load	New Gas Furnace, reduced load
	Replace heating and it didn't have cooling in place (add cooling)	No cooling	New Furnace	ASHP with New Gas furnace back-up	Switchover Temperature Automatic Switchover Temperature	New Gas Furnace, full load	New Gas Furnace, reduced load
	Replace heating and cooling	New A/C	New Furnace	ASHP with New Gas furnace back-up	Switchover Temperature Automatic Switchover Temperature	Existing Gas Furnace, full load	Existing Gas Furnace, reduced load
4D	Replace existing A/C unit with New one or Add cooling (new A/C)	New A/C	Existing	ASHP with electric back-up	Switchover Temperature Automatic Switchover Temperature	New Gas Furnace, full load	Furnace load fully displaced by electricity
	Replace heating and it had cooling in place	Existing	New Furnace	ASHP with electric back-up	Switchover Temperature Automatic Switchover Temperature	New Gas Furnace, full load	Furnace load fully displaced by electricity
	Replace heating and it didn't have cooling in place (add cooling)	No cooling	New Furnace	ASHP with electric back-up	Switchover Temperature Automatic Switchover Temperature	New Gas Furnace, full load	Furnace load fully displaced by electricity
	Replace heating and cooling	New A/C	New Furnace	ASHP with electric back-up	Switchover Temperature Automatic Switchover Temperature	New Gas Furnace, full load	Furnace load fully displaced by electricity

ELECTRICITY IMPACTS ALGORITHM

The electricity impacts were calculated using the Heat Pump Analysis Tool (HPAT). [3] HPAT is an Excel-base model used to calculate the electricity impacts relative to the baseline for all system configurations on an hourly basis, using specific system sizing and input parameters. The six system configurations covered are:

1. ccASHP with existing Gas furnace,
2. ccASHP with new Gas furnace,
3. ccASHP with Elec back-up,
4. ASHP with existing Gas furnace,
5. ASHP with new Gas furnace, and
6. ASHP with Elec back-up

The algorithms used in the tool to determine the electricity impacts are as follows:

Electricity impact equations.

$$Elec_{impacts} = Elec_{baseline} - Elec_{EE} \quad (21)$$

where:

$Elec_{impacts}$ = Annual total electricity impacts (m^3/yr)

$Elec_{baseline}$ = Baseline electricity consumption (m^3/yr)

$Elec_{EE}$ = Energy efficient case electricity consumption (m^3/yr)

Baseline Electricity consumption equations.

$$Elec_{baseline} = \sum_{1}^{8760} Elec_{hourly-cooling} + \sum_{1}^{8760} Elec_{hourly-fan} \quad (22)$$

$$Elec_{hourly-cooling} = \frac{D_{cooling}}{COP_{cooling-base} \times 3412} \quad (23)$$

$$D_{cooling} = LF_{cooling-base} \times Q_{cooling} \quad (24)$$

$$Elec_{hourly-fan} = Elec_{hourly-fan-heat} + Elec_{hourly-fan-cool} \quad (25)$$

$$Elec_{hourly-fan-heat} = Run_{Fur} \times P_{fan-Fur} \quad (26)$$

$$Elec_{hourly-fan-cool} = Run_{cool} \times P_{fan-cool} \quad (27)$$

$$Run_{Fur} = LF_{heating-base} \quad (28)$$

$$Run_{cool} = LF_{cooling-base} \quad (29)$$

$$P_{fan-Fur} = \frac{TCap_{heating}}{12{,}000} \times CFM_{Fur} \times \frac{Eff_{fan-motor}}{1{,}000} \quad (30)$$

$$P_{fan-cool} = \frac{TCap_{heating}}{\times 12{,}000} \times CFM_{cool} \times \frac{Eff_{fan-motor}}{1{,}000} \quad (31)$$

where:

$Elec_{baseline}$	=	Hourly total electricity consumption- baseline (kWh)
$Elec_{hourly-cooling}$	=	Hourly space cooling electricity consumption- baseline (kWh)
$Elec_{hourly-fan}$	=	Hourly fan electricity consumption- baseline (kWh)
$D_{cooling}$	=	Space cooling demand-baseline (Btu/hr)
$COP_{cooling-base}$	=	Coefficient of performance curve of the A/C unit-baseline (dimensionless)
3412	=	Conversion factor Btu/hr to kWh
$LF_{heating-base}$	=	Baseline Furnace heating load factor (dimensionless). Determined for each hour of the year through energy modelling- Energy Plus. It is the space heating load of the house satisfied by the baseline space heating equipment (Furnace) for a specific hour divided by the maximum space heating load of the house.
$LF_{cooling-base}$	=	Baseline A/C unit cooling load factor (dimensionless). Determined for each hour of the year through energy modelling- Energy Plus. It is the space cooling load of the house satisfied by the baseline equipment (AC unit) for a specific hour divided by the maximum cooling load of the house.
$Q_{cooling}$	=	Design space cooling load (Btu/hr).
$Elec_{hourly-fan-heat}$	=	Hourly furnace fan electricity consumption-baseline (kWh)
$Elec_{hourly-fan-cool}$	=	Hourly Ac unit fan electricity consumption-baseline (kWh)
Run_{Fur}	=	Furnace run time- baseline (dimensionless)
Run_{cool}	=	Ac unit run time-baseline (dimensionless)
$P_{fan-Fur}$	=	Furnace fan power (kW)
$P_{fan-cool}$	=	Ac unit fan power (kW)
CFM_{Fur}	=	Conditioned airflow rate produced by a typical condensing furnace (CFM/ton)
CFM_{cool}	=	Conditioned airflow rate produced by a typical AC unit or heat pump (CFM/ton)
$Eff_{fan-motor}$	=	Efficiency of the fan motor (Watt/CFM)

Efficient case Electricity consumption equations

$$Elec_{EE} = \sum_{1}^{8760} Elec_{hp-heat} + \sum_{1}^{8760} Elec_{hp-cool} + \sum_{1}^{8760} Elec_{backup-heat} + \sum_{1}^{8760} Elec_{fan-hp} \quad (32)$$

where:

$Elec_{EE}$	=	Hourly total electricity consumption- efficient case (kWh)
$Elec_{hp-heat}$	=	Hourly heat pump electricity consumption in space heating mode (kWh)
$Elec_{hp-cool}$	=	Hourly heat pump electricity consumption in space cooling mode (kWh)
$Elec_{backup-heat}$	=	Hourly backup equipment electricity consumption in space heating mode (kWh)
$Elec_{fan-hp}$	=	Hourly heat pump total fan electricity consumption (kWh)

Heat pump electricity consumption in space heating mode equations

System configuration

$Elec_{hp-heat} = IF\ (H_{mode} = "Heat\ Pump"),$
$If\ True = Eq.35, \quad If\ False = 0$

ccASHP with Existing and New Gas furnace, ASHP with Existing and New Gas furnace, And sizing options 4A, 4B, and 4C (33)

$Elec_{hp-heat} = IF\ (H_{mode4D} = "Heat\ Pump"\ or\ "Dual"),$
$If\ True = Eq.35, \quad If\ False = 0$

ccASHP with Elec back-up, ASHP with Elec back-up, And sizing option 4D (34)

$= IF\ (HP_{heat,mode} = "Rated")$
$If\ True = \frac{D_{heating}}{COP_{hp-AdjRated} \times 3412}$

$= IF\ (HP_{heat,mode} = "Max")$
$If\ False = \frac{D_{heating}}{COP_{hp-AdjMax} \times 3412}$ (35)

$H_{mode} = "Heat\ Pump"\ or\ H_{mode4D} = "Heat\ Pump"\ when$: (36)

- $if\ Intergrated\ Controles = "Yes"$
  - $T_{db} \geq T_{lockout}$, AND
  - $HP_{MHC} \geq D_{heating}$, *OR*
  - $HP_{RHC} \geq D_{heating}$
- $if\ Intergrated\ Controles = "No"$
  - $T_{db} \geq T_{switchover}$, AND
  - $HP_{MHC} \geq D_{heating}$, *OR*
  - $HP_{RHC} \geq D_{heating}$

$H_{mode4D} = "Dual"\ when$: (37)

- $if\ Intergrated\ Controles = "Yes", AND$

- $T_{db} \geq T_{lockout}$, AND
- $D_{heating} > HP_{MHC}$, *AND*
- $COP_{hp-AdjMax} > 1$

$$HP_{heat,mode} = "Rated" \text{ or } "Max" \text{ when:} \quad (38)$$
$$IF\left(HP_{MHC} > D_{heating}\right), If\ True = Eq39, If\ False = 0$$

$$HP_{heat,mode} = IF\left(D_{heating} < HP_{RHC}\right), If\ True = "Rated", If\ False = "Max" \quad (39)$$

where:

H_{mode}	=	Space heating mode[19] (Heat Pump, Backup, or OFF)
H_{mode4D}	=	Space heating mode for sizing option 4D[20] (Heat Pump, Backup, Dual or OFF)
$HP_{heat,mode}$	=	Heat pump capacity mode (Rated or Max)
$COP_{hp-AdjRated}$	=	Heat Pump Defrost Performance Adjusted COP at Rated Capacity for a specific outdoor temperature (dimensionless)
$COP_{hp-AdjMax}$	=	Heat Pump Defrost Performance Adjusted COP at Maximum Capacity for a specific outdoor temperature (dimensionless)

Heat pump COP performance curve equations adjusted to defrost at Maximum and Rated heating capacity equations

$$COP_{hp-AdjRated} = If(T_{db} > 40°\text{F}) \quad (40)$$
$$If\ True = COP_{hp-Rated}, \qquad If\ False = COP_{hp-Rated} \times \left(1 - COP_{defrost}\right)$$

$$COP_{hp-Rated} = HP_{COP-Rated} \times HP_{COP-Rated@47°\text{F}} \quad (41)$$

$$HP_{COP-Rated} = \quad (42)$$
$$If\ T_{db} \geq 47°\text{F} \rightarrow HP_{COP-Rated} = 1$$
$$If\ -5°\text{F} < T_{db} < 47°\text{F} \rightarrow\ HP_{COP-Rated} = a_1 \times T_{db}^2 + b_2 \times T_{db} + c_1$$
$$If\ T_{db} \leq -5°\text{F} \rightarrow\ \ HP_{COP-Rated} = minimun\ value$$

$$COP_{defrost} = c_3 \times T_{db}^3 + c_2 \times T_{db}^2 + c_1 \times T_{db} + c_0 \quad (43)$$

[19] The equations for "Backup" mode are located in the Natural Gas algorithms section (Equation 8). The equations for "Heat pump" mode can be found in the Electricity Impact algorithms section (Equation 33). "OFF" mode refers to when the system is neither operating in heat pump mode nor in backup mode.

[20] The equations for "Backup" mode are located in the Natural Gas algorithms section (Equation 8). The equations for "Heat pump" or "Dual" mode can be found in the Electricity Impact algorithms section (Equation 34). "OFF" mode refers to when the system is neither operating in heat pump mode nor in backup mode.

$$COP_{hp-AdjMax} = If(T_{db} > 40°\text{F}) \quad (44)$$

$$If\ True = COP_{hp-Max}, \qquad If\ False = COP_{hp-Max} \times \left(1 - COP_{defrost}\right)$$

$$COP_{hp-Max} = HP_{COP-Max} \times HP_{COP-Max@47°\text{F}} \quad (45)$$

$$HP_{COP-Max} = \quad (46)$$

$$If\ T_{db} \geq 47°\text{F} \rightarrow HP_{COP-Max} = 1$$

$$If\ -5°\text{F} < T_{db} < 47°\text{F} \rightarrow\ HP_{COP-Max} = a_1 \times T_{db}^2 + b_2 \times T_{db} + c_1$$

$$If\ T_{db} \leq -5°\text{F} \rightarrow\ \ HP_{COP-Max} = minimun\ value$$

where:

$COP_{hp-Rated}$	=	Heat Pump COP at Rated Capacity for a specific outdoor temperature (dimensionless)
$HP_{COP-Rated}$	=	Heat pump COP heating performance curve at Rated Capacity (dimensionless)
$HP_{COP-Rated@47°\text{F}}$	=	Heat pump COP heating performance curve at Rated Capacity, and at 47°F (dimensionless)
$COP_{defrost}$	=	Heat pump Defrost efficiency polynomial, steady-state heating performance.
COP_{hp-Max}	=	Heat Pump COP at Maximum Capacity for a specific outdoor temperature (dimensionless)
$HP_{COP-Max}$	=	Heat pump COP heating performance curve at Maximum Capacity (dimensionless)
$HP_{COP-Max@47°\text{F}}$	=	Heat pump COP heating performance curve at Maximum Capacity, and at 47°F (dimensionless)
a_1, b_1, c_1	=	Heat pump Maximum and Rated Capacity heating performance curve polynomial coefficients.

Heat pump electricity consumption in space cooling mode equations

$$Elec_{hp-cool} = \quad (47)$$

$$= IF\left(HP_{cool,mode} = "Rated"\right) \qquad = IF\left(HP_{cool,mode} = "Max"\right)$$

$$Elec_{hp-cool} = \frac{D_{cooling-EE}}{COP_{hp-Rated-cool} \times 3412} \qquad Elec_{hp-cool} = \frac{D_{cooling-EE}}{COP_{hp-Max-cool} \times 3412}$$

$$HP_{cool,mode} = "Rated"\ or\ "Max"\ when: \quad (48)$$

$$IF(T_{db} > 60°\text{F}), If\ True = Eq49, \qquad If\ False = 0$$

$$HP_{cool,mode} = IF\left(D_{cooling-EE} < HP_{RCC}\right) \quad (49)$$

$$If\ True = "Rated", \qquad If\ False = "Max"$$

$$HP_{RCC} = CC_{Rated} \times TCap_{cooling} \quad (50)$$

$$CC_{Rated} = \quad (51)$$

- $If\ T_{db} \geq 60°\text{F} \rightarrow CC_{Rated} = a_2 \times T_{db} + b_2$

$$D_{cooling-EE} = LF_{cooling} \times Q_{cooling} \quad (52)$$

$$COP_{hp-Rated-cool} = HP_{COP-Rated-cool} \times COP_{hp-Rated@95°\text{F}} \quad (53)$$

$$COP_{hp-Max-cool} = HP_{COP-Max-cool} \times COP_{hp-Max@95°\text{F}} \quad (54)$$

$$HP_{COP-Rated-cool} = If\ T_{db} \geq 60°\text{F} \rightarrow HP_{COP-Rated-cool} = a_3 \times T_{db} + b_3 \quad (55)$$

$$HP_{COP-Max-cool} = If\ T_{db} \geq 60°\text{F} \rightarrow HP_{COP-Max-cool} = a_3 \times T_{db} + b_3 \quad (56)$$

where:

$HP_{cool,mode}$	=	Heat pump cooling capacity mode (Rated or Max)
$D_{cooling-EE}$	=	Heat pump space cooling demand (Btu/hr)
$COP_{hp-Rated-cool}$	=	Heat Pump COP cooling performance curve at Rated Capacity for a specific outdoor temperature (dimensionless)
$COP_{hp-Max-cool}$	=	Heat Pump COP cooling performance curve at Maximum Capacity for a specific outdoor temperature (dimensionless)
HP_{RCC}	=	Heat pump cooling rated capacity at a specific outdoor temperature (Btu/hr)
CC_{Rated}	=	Heat Pump cooling Rated Capacity performance curve (dimensionless)
$TCap_{cooling}$	=	Target heat pump rated cooling capacity (Btu/hr)
a_2, b_2	=	Heat pump Maximum and Rated Capacity cooling performance curve polynomial coefficients.
$HP_{COP-Rated-cool}$	=	Heat pump COP cooling performance curve at Rated Capacity (dimensionless)
$HP_{COP-Max-cool}$	=	Heat pump COP cooling performance curve at Maximum Capacity (dimensionless)
$HP_{COP-Rated@95°\text{F}}$	=	Heat pump COP cooling performance at Rated Capacity, and at 95°F (dimensionless)
$HP_{COP-Max@95°\text{F}}$	=	Heat pump COP cooling performance at Maximum Capacity, and at 95°F (dimensionless)

a_3, b_3 = Heat pump COP cooling performance curve at Maximum and Rated Capacity polynomial coefficients.

Backup equipment electricity consumption in space heating mode equations

	HP sizing option	
$Elec_{backup-heat} = 0$	4A, 4B, and 4C	(57)
$Elec_{backup-heat} =$	4D	(58)

$if\ H_{mode4D} = "Backup"$[21] $if\ H_{mode4D} = "Dual"$

$Elec_{backup-heat} = \frac{D_{heating-EE}}{3412}$ $Elec_{backup-heat} = \frac{\left(D_{heating-EE} - HP_{MHC}\right)}{3412}$

where:

$Elec_{backup-heat}$ = Hourly backup equipment electricity consumption in space heating mode (kWh)

Efficient case total fan electricity consumption equations

	System configuration	
$Elec_{fan-hp} = Elec_{fan-hp-heat} + Elec_{fan-hp-cool} + Elec_{fan-backup-heat}$	ccASHP with Existing and New Gas furnace, ASHP with Existing and New Gas furnace, And sizing options 4A, 4B, and 4C	(59)
$Elec_{fan-hp} = Elec_{fan-heat} + Elec_{fan-hp-cool}$	ccASHP with Elec back-up, ASHP with Elec back-up, And sizing option 4D	(60)

$Elec_{fan-hp-heat} = Run_{hp-heat} \times P_{fan-hp}$ (61)

$Elec_{fan-hp-cool} = Run_{hp-cool} \times P_{fan-hp}$ (62)

$Elec_{fan-backup-heat} = Run_{Fur} \times P_{fan-Fur}$ (63)

$Run_{hp-heat} = if H_{mode} = "Heat\ Pump", if\ True \rightarrow Run_{hp-heat} = LF_{heating-hp}$ 64)

$Run_{hp-cool} = if Elec_{hp-cool} > 0, if\ True \rightarrow Run_{hp-cool} = LF_{cooling}$ (65)

[21] Same as equation 8 in the Natural Gas savings algorithms

$$Run_{Fur} = if\, H_{mode} = "Backup", if\ True \rightarrow Run_{Fur} = LF_{heating-backup} \quad (66)$$

$$P_{fan-backup} = \frac{TCap_{heating}}{12{,}000} \times CFM_{Fur} \times \frac{Eff_{fan-motor}}{1{,}000} \quad (67)$$

$$P_{fan-hp} = \frac{TCap_{heating}}{12{,}000} \times CFM_{cool} \times \frac{Eff_{fan-motor}}{1{,}000} \quad (68)$$

$$Elec_{fan-heat} = if\ H_{mode4D} = "Dual", \quad (69)$$
$$if\ True \rightarrow Elec_{fan-heat} = \left(Run_{hp-heat} + Run_{backup}\right) \times P_{fan-hp}, If\ False\ Eq.70$$

$$Elec_{fan-heat} = if\ H_{mode4D} = "Heat\ pump", \quad (70)$$
$$if\ True \rightarrow Elec_{fan-heat} = Run_{hp-heat} \times P_{fan-hp}, \qquad If\ False\ Eq.71$$

$$Elec_{fan-heat} = if\ H_{mode4D} = "Backup", \quad (71)$$
$$if\ True \rightarrow Elec_{fan-heat} = Run_{backup} \times P_{fan-backup}, \qquad If\ False\ 0$$

where:

$Elec_{fan-hp}$	=	Heat pump total fan electricity hurly consumption (kWh)
$Elec_{fan-hp-heat}$	=	Heat pump fan electricity hourly consumption, heat mode (kWh)
$Elec_{fan-hp-cool}$	=	Heat pump fan electricity hourly consumption, cooling mode (kWh)
$Elec_{fan-backup-heat}$	=	Backup heating system fan hourly consumption (kWh) Backup system for sizing options 4A, 4B, and 4C is a natural gas furnace, and back up system for sizing option 4D is electric resistance.
$Elec_{fan-heat}$	=	Total fan electricity hourly consumption, heat mode (kWh)
$Run_{hp-heat}$	=	Heat pump run time, heating mode (dimensionless)
$Run_{hp-cool}$	=	Heat pump run time, cooling mode (dimensionless)
Run_{Fur}	=	Furnace run time (dimensionless)
P_{fan-hp}	=	Heat pump fan power (kW)
$P_{fan-backup}$	=	heating backup system fan power (kW)
CFM_{Fur}	=	Conditioned airflow rate produced by a typical condensing furnace (CFM/ton)
CFM_{cool}	=	Conditioned airflow rate produced by a typical AC unit or heat pump (CFM/ton)
$Eff_{fan-motor}$	=	Efficiency of the fan motor (Watt/CFM)

The tool was setup for the scenarios described in tables 8 and 9. A total of 1,200 scenarios were run (600 scenarios for the North and 600 for the South) and the outputs are presented in table 1. The total electricity impacts are equal to the heating electric impact + cooling electricity impact. The specific assumptions used in the calculations are captured in the Assumptions section.

Table 8 Electricity impacts for ccASHP centrally ducted systems

HP Sizing Option	Baseline description	Baseline technology		Efficient technology		Heating Electricity impact calculation		Cooling Electricity impact calculation	
		A/C unit	Furnace	Type of system	Control methodology, heating mode	Baseline	Eff. Case	Baseline	Eff. Case
4A	Replace existing A/C unit with New one or Add cooling (new A/C)	New A/C	Existing	ccASHP with existing Gas furnace back-up	Switchover Temperature Automatic Switchover Temperature	none	ccASHP	New A/C	ccASHP
4B	Replace existing A/C unit with New one or Add cooling (new A/C)	New A/C	Existing	ccASHP with existing Gas furnace back-up	Switchover Temperature Automatic Switchover Temperature	None	ccASHP	New A/C	ccASHP
	Replace heating and cooling	New A/C	New Furnace	ccASHP with New Gas furnace back-up	Switchover Temperature Automatic Switchover Temperature	None	ccASHP	New A/C	ccASHP
4C	Replace existing A/C unit with New one or Add cooling (new A/C)	New A/C	Existing	ccASHP with existing Gas furnace back-up	Switchover Temperature Automatic Switchover Temperature	None	ccASHP	New A/C	ccASHP
	Replace heating and it had cooling in place	Existing	New Furnace	ccASHP with New Gas furnace back-up	Switchover Temperature Automatic Switchover Temperature	None	ccASHP	Existing A/C	ccASHP
	Replace heating and it didn't have cooling in place (add cooling)	No cooling	New Furnace	ccASHP with New Gas furnace back-up	Switchover Temperature Automatic Switchover Temperature	None	ccASHP	None	ccASHP
	Replace heating and cooling	New A/C	New Furnace	ccASHP with New Gas furnace back-up	Switchover Temperature Automatic Switchover Temperature	None	ccASHP	New A/C	ccASHP
4D	Replace existing A/C unit with New one or Add cooling (new A/C)	New A/C	Existing	ccASHP with electric back-up	Switchover Temperature Automatic Switchover Temperature	None	ccASHP + Electric resistance back-up	New A/C	ccASHP
	Replace heating and it had cooling in place	Existing	New Furnace	ccASHP with electric back-up	Switchover Temperature Automatic Switchover Temperature	None	ccASHP + Electric resistance back-up	Existing A/C	ccASHP
	Replace heating and it didn't have cooling in place (add cooling)	No cooling	New Furnace	ccASHP with electric back-up	Switchover Temperature Automatic Switchover Temperature	None	ccASHP + Electric resistance back-up	None	ccASHP
	Replace heating and cooling	New A/C	New Furnace	ccASHP with electric back-up	Switchover Temperature Automatic Switchover Temperature	None	ccASHP + Electric resistance back-up	New A/C	ccASHP

Table 9 Electricity impacts for ASHP centrally ducted systems

HP Sizing Option	Baseline description	Baseline technology		Efficient technology		Heating Electricity impact calculation		Cooling Electricity impact calculation	
		A/C unit	Furnace	Type of system	Control methodology, heating mode	Baseline	Eff. case	Baseline	Eff. case
4A	Replace existing A/C unit with New one or Add cooling (new A/C)	New A/C	Existing	ASHP with existing Gas furnace back-up	Switchover Temperature Automatic Switchover Temperature	None	ASHP	New A/C	ASHP
4B	Replace existing A/C unit with New one or Add cooling (new A/C)	New A/C	Existing	ASHP with existing Gas furnace back-up	Switchover Temperature Automatic Switchover Temperature	None	ASHP	New A/C	ASHP
	Replace heating and cooling	New A/C	New Furnace	ASHP with New Gas furnace back-up	Switchover Temperature Automatic Switchover Temperature	None	ASHP	New A/C	ASHP
4C	Replace existing A/C unit with New one or Add cooling (new A/C)	New A/C	Existing	ASHP with existing Gas furnace back-up	Switchover Temperature Automatic Switchover Temperature	None	ASHP	New A/C	ASHP
	Replace heating and it had cooling in place	Existing	New Furnace	ASHP with New Gas furnace back-up	Switchover Temperature Automatic Switchover Temperature	None	ASHP	Existing A/C	ASHP
	Replace heating and it didn't have cooling in place (add cooling)	No cooling	New Furnace	ASHP with New Gas furnace back-up	Switchover Temperature Automatic Switchover Temperature	None	ASHP	None	ASPH
	Replace heating and cooling	New A/C	New Furnace	ASHP with New Gas furnace back-up	Switchover Temperature Automatic Switchover Temperature	None	ASHP	New A/C	ASHP
4D	Replace existing A/C unit with New one or Add cooling (new A/C)	New A/C	Existing	ASHP with electric back-up	Switchover Temperature Automatic Switchover Temperature	None	ASHP + Electric resistance back-up	New A/C	ASHP
	Replace heating and it had cooling in place	Existing	New Furnace	ASHP with electric back-up	Switchover Temperature Automatic Switchover Temperature	None	ASHP + Electric resistance back-up	Existing A/C	ASHP
	Replace heating and it didn't have cooling in place (add cooling)	No cooling	New Furnace	ASHP with electric back-up	Switchover Temperature Automatic Switchover Temperature	None	ASHP + Electric resistance back-up	None	ASHP
	Replace heating and cooling	New A/C	New Furnace	ASHP with electric back-up	Switchover Temperature Automatic Switchover Temperature	None	ASHP + Electric resistance back-up	New A/C	ASHP

WINTER AND SUMMER PEAK ELECTRICITY IMPACTS ALGORITHM

The approach for quantifying the electricity summer and winter peak impacts from the installation of a ccASHP/ASHP centrally ducted in Ontario uses the analysis approach described in the IESO-CDM-CE-Tool-V9-7-January-28-2025 tool, modified to account for negative impacts in the summer and/or winter. [4]

Step 1. Calculate hourly summer and winter peak electricity impact. The following equations were applied to the hourly profile for each of the scenarios described in the electricity impact section.

Eq.1) $$S_{Peak} = IF\ (S_{APeak-Min} < 0)$$
$$if\ True\ S_{Peak} = S_{APeak-Min}$$
$$if\ False\ S_{Peak} = S_{APeak-Max}$$

Eq.2) $$S_{APeak-Min} = [Min(AP_{Summer}), If\ (S_{Peak-h} = 0.04)\ ] + [Min(AP_{Summer}), If\ (S_{Peak-h} = 0.05)\ ] + [Min(AP_{Summer}), If\ (S_{Peak-h} = 0.42)\ ] + [Min(AP_{Summer}), If\ (S_{Peak-h} = 0.49)\ ]$$

Eq.3) $$S_{APeak-Max} = [Max(AP_{Summer}), If\ (S_{Peak-h} = 0.04)\ ] + [Max(AP_{Summer}), If\ (S_{Peak-h} = 0.05)\ ] + [Max(AP_{Summer}), If\ (S_{Peak-h} = 0.42)\ ] + [Max(AP_{Summer}), If\ (S_{Peak-h} = 0.49)\ ]$$

Eq.4) $$AP_{Summer} = S_{Peak-h} \times Elec_h \times Hr_{cooling}$$

Eq.5) $$W_{Peak} = IF\ (W_{APeak-Min} < 0)$$
$$if\ True\ W_{Peak} = W_{APeak-Min}$$
$$if\ False\ W_{Peak} = W_{APeak-Max}$$

Eq.6) $$W_{APeak-Min} = [Min(AP_{Winter}), If(W_{Peak-h} = 0.13)\ ] + [Min(AP_{Winter}), If(W_{Peak-h} = 0.24)\ ] + [Min(AP_{Winter}), If(W_{Peak-h} = 0.30)\ ] + [Min(AP_{Winter}), If(W_{Peak-h} = 0.33)]$$

Eq.7) $$W_{APeak-Max} = [Max(AP_{Winter}) If(W_{Peak-h} = 0.13)\ ] + [Max(AP_{Winter}), If(W_{Peak-h} = 0.24)\ ] + [Max(AP_{Winter}), If(W_{Peak-h} = 0.30)\ ] + [Max(AP_{Winter}), If(W_{Peak-h} = 0.33)\ ]$$

Eq.8) $$AP_{Winter} = W_{Peak-h} \times Elec_h$$

where

S_{Peak} = Summer peak electricity impact (kW)

W_{Peak} = Winter peak electricity impact (kW)

$S_{APeak-Min}$ = Minimum alternative summer peak demand (kW)

$S_{APeak-Max}$ = Maximum alternative summer peak demand (kW)

$W_{APeak-Min}$ = Minimum alternative winter peak demand (kW)

$W_{APeak-Max}$ = Maximum alternative winter peak demand (kW)

AP_{Summer} = Hourly alternative summer peak demand in a typical year[22] (kW)

$Hr_{cooling}$ = Cooling hour

$$Hr_{cooling} = IF\left(T_{dry-bulb} > T_{balance-cooling}\right)$$
$$If\ TRUE \rightarrow\ Hr_{cooling} = 1, \text{ cooling required.}$$

S_{Peak-h} = Alternative summer peak hour fraction

AP_{Winter} = Hourly alternative winter peak demand in a typical year (kW)

W_{Peak-h} = Alternative winter peak hour fraction

$Elec_h$ = Hourly electricity impact in a typical year (kW)

ASSUMPTIONS

The efficient case technology efficiency is sourced from the Northeast Energy Efficiency Partnerships (NEEP) database of ASHPs. Efficiencies are averaged from the database for each combination of ASHP/ccASHP with existing gas furnace, new gas furnace and electric backup.

The AHRI codes and NEEP data fields used to differentiate between the combinations are:

Existing furnace: HRCU-A-C and no entry in the Furnace Model Number field. These are units that have an indoor coil that can be placed in an existing furnace.

New Furnace: HRCU-A-CB and an entry in the Furnace Model Number field. These are units that have both a coil and blower and are tied to a specific new furnace.

Electric Backup: Any model without an entry in the Furnace Model Number field. All of these units can be combined with any electric resistance heating type.

The capacities input to the calculations are assumed to be rated capacities, so the ratio of max to rated capacity for heating at 47°F and cooling at 95°F are used to determine the maximum system capacity.

Rated and max capacities and COPs are provided in the source data at 47, 17, 5 and -5 degree Fahrenheit for heating, and at 95 and 82 degree Fahrenheit for cooling. The ratios of capacities and COPs at each temperature are used to derate the values and create curves that provide the capacity and COP at each degree Fahrenheit from 95 to -45.

Table 10 provides a list of assumptions used in the calculations of the: natural gas savings, electricity impacts and electricity peak impacts.

[22] Assumed 8,760 hours in a typical year.

Table 10. Assumptions

Variable	Definition	Value	Source/Comment
35,738	Energy Density of Natural Gas	35, 738 Btu/m3	Common assumption table
1.055056	Conversion factor	1.055056 GJ/MMBtu	Online conversion calculator
Eff	Natural gas furnace efficiency-Existing	90%	[5]
	Natural gas furnace efficiency-New	95%	[6]
$LF_{heating-base}$	Baseline Furnace heating load factor.	Determined for each hour of the year through energy modelling. It is the heating load of the house for a specific hour divided by the maximum heating load of the house. (dimensionless)[23]	EnergyPlus energy modeling was used to determine the hourly heating load fraction and cooling load fraction, which is the percent of maximum heating or cooling demand associated with each hour of the year.
$LF_{heating-hp}$	Heating load factor for the Efficient technology primary space heating equipment (ASHP/ccASHP).		
$LF_{heating-backup}$	Heating load factor for the Efficient technology back-up space heating equipment (Furnace). This is for hybrid heating (Sizing options 4A, 4B, and 4C)		
$LF_{heating-Elec}$	Heating load factor for the Efficient technology back-up space heating equipment (Electric Resistance). This is for full electric (Sizing option D)		
$LF_{cooling-base}$	Baseline cooling load factor.	Determined for each hour of the year through energy modelling. It is the cooling load of the house for a specific hour divided by the maximum cooling load of the house. (dimensionless)	
$LF_{cooling-hp}$	Cooling load factor for the Efficient technology: ASHP/ccASHP.		
$Q_{heating}$	Design space heating load for Climate Region: South	37,500 (Btu/hr)	Calculated based on EGI weighed average space heating natural gas consumption of residential buildings in NBC Climate zone 5, and 6. Normalized to CWEC 2020 and baseline furnace efficiency (90% AFUE). [7]
	Design space heating load for Climate Region: North	25,000 (Btu/hr)	Calculated based on EGI weighed average space

[23] The heating load fraction (LF) represents the building's normalized hourly thermal demand and is normally derived from a natural-gas furnace baseline to keep building load separate from equipment performance. This LF is applied consistently across scenarios to convert annual heating load into an hourly profile.
Scenario 4D is the intentional exception because fully electrifying space heating changes how thermal demand appears on the electric grid. Without a combustion backup, all heating demand becomes electrical load, producing a different and more peak-concentrated hourly pattern. Thus, Scenario 4D uses an electricity-based LF to reflect grid-observed demand, while all other modeling steps and the fundamental purpose of LF remain unchanged.

Variable	Definition	Value	Source/Comment
			heating consumption of residential buildings in NBC Climate zone 7A, 7B, and 8. Normalized to CWEC 2020. and baseline furnace efficiency (90% AFUE) [7]
$Q_{cooling}$	Design space cooling load for Climate Region: South	17,000 (Btu/hr)	Design cooling load was set at 45% of the heating load, rounded to the nearest 1000 Btu. This % is the average heating and cooling load ratios generated from EnergyPlus energy modelling (the same models used to define the heat load fractions)
	Design space cooling load for Climate Region: North	11,000 (Btu/hr)	
T_{db}	Dry bulb temperature- outdoor	8760 profile (°F)	CWEC 2020 Timmins and Toronto. [7]
$T_{lockout}$	Heat pump lock-out temperature	-40°F	This is the coldest temperature available in the CWEC[24].
$RH_{Max-to-Rated}$	Ratio of Max to Rated Heating Capacity at 47°F	Table 11	Calculated average ratios based on NEEP database of heat pumps available in Canada. The data was grouped into six distinct system configurations, first by disaggregating between ASHP and ccASHP using minimum requirements described in table 5 and then diving each subsect into three subcategories: • Existing gas furnace.[25] • New gas furnace.[26] • Elec Back-up.[27]
$RC_{Max-to-Rated}$	Ratio of Max to Rated Cooling Capacity at 95°F		
$HP_{COP-Rated@47°F}$	Heat pump COP heating performance curve at Rated Capacity, and at 47°F	Table 12	
$HP_{COP-Max@47°F}$	Heat pump COP heating performance curve at Maximum Capacity, and at 47°F		
$HP_{COP-Rated@95°F}$	Heat pump COP cooling performance curve at Rated Capacity, and at 95°F		
$HP_{COP-Max@95°F}$	Heat pump COP cooling performance curve at Maximum Capacity, and at 95°F		
HC_{Max}	Heat pump Maximum Capacity heating performance curve	Table 13	Calculated based on NEEP database of heat pumps available in Canada. Using as reference Maximum & Rated Capacities, and COP Maximum & Rates Capacity at
HC_{Rated}	Heat pump Rated Capacity heating performance curve	Table 14	
$HP_{COP-Max}$	Heat pump COP heating performance curve at Maximum Capacity	Table 15	

[24] The performance curves were extended to this temperature (coldest temperature in CWEC data).
[25] This category is associated with the AHRI type HRCU-A-C (coil alone). It is for adding to an existing system. These can be cased (its own box for installing in-line with the furnace) or uncased (for inserting into an existing forced air furnace).
[26] This category is associated with the AHRI type HRCU-A-CB (coil and blower). It is a heat pump fan coil unit with associated furnace model number.
[27] This category is associated with the AHRI type HRCU-A-CB and HRCU-A-CB-O. It is a heat pump fan coil unit with no associated furnace model number, indicating that the back-up heat is electric resistance.

<table>
<tr><th>Variable</th><th>Definition</th><th>Value</th><th>Source/Comment</th></tr>
<tr><td>$HP_{COP-Rated}$</td><td>Heat pump COP heating performance curve at Rated Capacity</td><td>Table 16</td><td>47°F. Ratios Maximum & Rated Capacities, and Ratios of COP at maximum at rated capacities at 17°F, 5°F, and –5°F relative to those at 47°F were calculated for each of the six system configurations. A trend formula (polynomial) was derived from plotting each of the four data points, creating the Heating performance curves for the heat pump Maximum & Rated capacity, and COP at Maximum capacity & at Rated capacity.</td></tr>
<tr><td rowspan="3">$COP_{defrost}$</td><td colspan="2">Heat pump Defrost efficiency polynomial, steady-state heating performance</td><td>Various</td><td rowspan="3">Laboratory Test Report was used to develop the Defrost polynomial. [8]</td></tr>
<tr><td>c_3</td><td>c_2</td><td>c_1</td><td>c_0</td></tr>
<tr><td>-0.000003</td><td>0.000256</td><td>-0.007741</td><td>0.088440</td></tr>
<tr><td>CFM_{Fur}</td><td colspan="2">Conditioned airflow rate produced by a typical condensing furnace</td><td>150 CFM per 10,000 Btu (180 CFM/ton)</td><td>General industry rule of thumb for a condensing furnace</td></tr>
<tr><td>CFM_{cool}</td><td colspan="2">Conditioned airflow rate produced by a typical A/C unit or heat pump</td><td>400 CFM/ton</td><td>[9]</td></tr>
<tr><td>$Eff_{fan-motor}$</td><td colspan="2">Efficiency of the ECM fan motor (Watt/CFM)</td><td>0.375 Watts/CFM</td><td>An average Watts per CFM is calculated based on test procedure defaults from the US DOE [10]</td></tr>
<tr><td rowspan="2">$COP_{cooling-base}$</td><td colspan="2">Coefficient of performance of the A/C unit-baseline (%)</td><td>2.7</td><td>Average values from 91,218 EGI customers (past participants into DSM HER/HRS program). This also aligns with the code minimum EER of 9.305 from the 2014 Ontario Building Code – the last time EER was published as a minimum for residential AC</td></tr>
<tr><td colspan="2">Coefficient of performance curve of the A/C unit-baseline (%)</td><td>Hourly calculated value</td><td>In the absence of the AC unit COP performance curve, the minimum value from all system configurations of the heat pump COP curves was used to adjust the 2.7 value to a hourly COP value. The COP of the baseline AC unit is adjusted for outdoor air temperature using the minimum of the COP from the upgrade case cooling curve at each temperature as a</td></tr>
</table>

Variable	Definition	Value	Source/Comment
			conservative assumption that the upgrade case ASHP will always be-at least-as efficient as the baseline.
CC_{Rated}	Heat pump Rated Capacity cooling performance curve	Table 17	Calculated based on NEEP database of heat pumps available in Canada. Using as reference Rated Capacity and COP at Rated & Maximum Capacity at 95°F, Ratios of rated capacities and Ratios of COP at Rated & Maximum capacity at 85°F relative to those at 95°F were calculated for each of the six system configurations. A trend formula (line) was derived from plotting each of the two data points, creating the Cooling performance curves for the heat pump Rated capacity and the COP at Rated & Max capacity.
$HP_{COP-Max-cool}$	Heat pump COP cooling performance curve at Maximum Capacity	Table 1	
$HP_{COP-Rated-cool}$	Heat pump COP cooling performance curve at Rated Capacity	Table 1	

Table 11 Heat Pump Ratios of Max to Rate Heating Capacity

System configuration	$RH_{Max-to-Rated}$	$RC_{Max-to-Rated}$
ccASHP with existing Gas furnace	1.19	1.15
ccASHP with new Gas furnace	1.01	1.07
ccASHP with Elec back-up	1.16	1.17
ASHP with existing Gas furnace	1.09	1.05
ASHP with new Gas furnace	1.00	1.00
ASHP with Elec back-up	1.06	1.05

Table 12 Heat pump heating and cooling Average COP at Maximum and Rated Capacity

System configuration	$HP_{COP-Rated@47°F}$	$HP_{COP-Max@47°F}$	$HP_{COP-Rated@95°F}$	$HP_{COP-Max@95°F}$
ccASHP with existing Gas furnace	3.10	3.20	3.00	2.80
ccASHP with new Gas furnace	3.30	3.17	3.00	3.21
ccASHP with Elec back-up	3.18	3.51	3.40	3.05
ASHP with existing Gas furnace	3.20	3.22	2.94	2.81
ASHP with new Gas furnace	3.11	3.03	2.84	2.96
ASHP with Elec back-up	3.18	3.28	3.08	2.95

Table 13 Heat pump Maximum Capacity heating performance curve coefficients

System configuration	Polynomial coefficients			Minimum value
	a	b	c	
ccASHP with existing Gas furnace	-0.0001	0.0128	0.5871	0.49
ccASHP with new Gas furnace	-0.0005	0.0341	0.4718	0.19
ccASHP with Elec back-up	-0.0004	0.0281	0.4945	0.29
ASHP with existing Gas furnace	0.0000	0.0132	0.4743	0.40
ASHP with new Gas furnace	-0.0003	0.0248	0.4391	0.27
ASHP with Elec back-up	-0.0003	0.0268	0.3925	0.21

Table 14 Heat pump Rated Capacity heating performance curve coefficients

System configuration	Polynomial coefficients			Minimum value
	a	b	c	
ccASHP with existing Gas furnace	-0.0004	0.0279	0.4908	0.26
ccASHP with new Gas furnace	-0.0006	0.0414	0.4058	0.07
ccASHP with Elec back-up	-0.0005	0.0376	0.3934	0.10
ASHP with existing Gas furnace	-0.0003	0.0293	0.3428	0.16
ASHP with new Gas furnace	-0.0005	0.0367	0.3264	0.07
ASHP with Elec back-up	-0.0004	0.0327	0.2744	0.07

Table 15 Heat pump COP heating performance curve coefficients at Maximum Capacity

System configuration	Polynomial coefficients			Minimum value
	a_1	b_1	c_1	
ccASHP with existing Gas furnace	0.0000	0.0119	0.5425	0.47
ccASHP with new Gas furnace	-0.0004	0.0341	0.3824	0.17
ccASHP with Elec back-up	-0.0003	0.0245	0.4418	0.28
ASHP with existing Gas furnace	-0.0001	0.0130	0.5798	0.51
ASHP with new Gas furnace	-0.0004	0.0287	0.4576	0.29
ASHP with Elec back-up	-0.0003	0.0276	0.4273	0.24

Table 16 Heat pump COP heating performance curve coefficients at Rated Capacity

System configuration	Polynomial coefficients			Minimum value
	a_1	b_1	c_1	
ccASHP with existing Gas furnace	0.0000	0.0105	0.5439	0.49
ccASHP with new Gas furnace	-0.0003	0.0260	0.4652	0.30
ccASHP with Elec back-up	-0.0002	0.0205	0.4320	0.33
ASHP with existing Gas furnace	-0.0001	0.0125	0.5394	0.50
ASHP with new Gas furnace	-0.0005	0.0348	0.4090	0.19
ASHP with Elec back-up	-0.0003	0.0297	0.3639	0.21

Table 17 Heat Pump Rated cooling capacity performance curve coefficients

System configuration	Polynomial coefficients	
	a_2	b_2
ccASHP with existing Gas furnace	-0.0067	1.6387
ccASHP with new Gas furnace	-0.0052	1.4905
ccASHP with Elec back-up	-0.0040	1.3831
ASHP with existing Gas furnace	-0.0031	1.2919
ASHP with new Gas furnace	-0.0061	1.5821
ASHP with Elec back-up	-0.0045	1.4259

Table 18 Polynomial coefficients for COP @ Rated and Maximum capacity

System configuration	Polynomial coefficients for COP @ Rated capacity		Polynomial coefficients for COP @ Max capacity	
	a_3	b_3	a_3	b_3
ccASHP with existing Gas furnace	-0.0354	4.3637	-0.0354	4.3637
ccASHP with new Gas furnace	-0.0212	3.0113	-0.0212	3.0113
ccASHP with Elec back-up	-0.0246	3.3411	-0.0246	3.3411
ASHP with existing Gas furnace	-0.0283	3.6900	-0.0283	3.6900
ASHP with new Gas furnace	-0.0205	2.9465	-0.0205	2.9465
ASHP with Elec back-up	-0.0254	3.4093	-0.0254	3.4093

SAVINGS CALCULATION EXAMPLE

This section provides 4 examples of a savings calculation:

1. A customer installs a ASHP centrally ducted in the South, sizing option 4A with Natural Gas Furnace, switchover temperature set at 0°C, and it had an Air conditioner unit in the building.
2. A customer installs a ASHP centrally ducted in the South, sizing option 4B with Natural Gas Furnace, switchover temperature set at -2°C, and it had an Air conditioner unit in the building.
3. A customer installs a ccASHP centrally ducted in the South, sizing option 4C with Natural Gas Furnace as backup, switchover temperature set at -4°C, and it had an Air conditioner unit in the building.
4. A customer installs a ccASHP centrally ducted in the North, sizing option 4D with electricity back-up, and automatic switchover temperature, and it didn't have an Air conditioner unit in the building.

Example 1. From Table 3, select the corresponding savings/impacts: ASHP, 4A South switchover temperature 0°C, and it had an Air conditioner unit in the building.

- Annual Natural Gas savings = 652 m3/yr

- Annual Electricity Impacts for Residential Buildings Equipped with Central Air Conditioning = -2,002 kWh/yr
- Winter Peak Demand = -1.40 kW
- Summer Peak Demand = 0.21 kW

Example 2. From Table 3, select the corresponding savings/impacts: ASHP, 4B South switchover temperature -2°C, and it had an Air conditioner unit in the building.

- Annual Natural Gas savings = 953 m3/yr
- Annual Electricity Impacts for Residential Buildings Equipped with Central Air Conditioning = -3,165 kWh/yr
- Winter Peak Demand = -1.73kW
- Summer Peak Demand = 0.16 kW

Example 3. From Table 2, select the corresponding savings/impacts: ccASHP, 4C South switchover temperature -4°C, and it had an Air conditioner unit in the building.

- Annual Natural Gas savings = 1,220 m3/yr
- Annual Electricity Impacts for Residential Buildings Equipped with Central Air Conditioning = -4,233 kWh/yr
- Winter Peak Demand = -2.08 kW
- Summer Peak Demand = 0.22 kW

Example 4. From Table 2, select the corresponding savings/impacts: ccASHP, 4D North automatic switchover temperature, and it didn't have an Air conditioner unit in the building.

- Annual Natural Gas savings = 1,717 m3/yr
- Annual Electricity Impacts for Residential Buildings Equipped with Central Air Conditioning = -7,864 kWh/yr
- Winter Peak Demand = -2.86 kW
- Summer Peak Demand = -1.37 kW

USES AND EXCLUSIONS

This measure does not apply to:

- Residential buildings that currently have a hybrid-fuel space heating systems (i.e., an electric heat pump satisfying a portion of the space heating load).
- Residential buildings used for major occupancies classified as: medium hazard industrial occupancies and low hazard industrial occupancies.
- The addition of ductless systems.
- The replacement of an existing heat pump.

MEASURE LIFE

The measure life of a ccASHP and ASHP is assumed to be 16 years. [11]

INCREMENTAL COST

The incremental cost -in CAD $/ton- is presented in table 10.

Table 19 ccASHP and ASHP Incremental cost (CAD $/ton[28])

System	No electrical panel upgrade				Electrical panel upgrade required			
	4A	4B	4C	4D	4A	4B	4C	4D
ccASHP	$1,136	$1,136	$1,888	$2,782	$2,378	$2,378	$3,129	$4,024
ASHP	$1,088	$1,088	$1,928	$2,939	$2,492	$2,492	$3,332	$4,344

The incremental cost data was collected via an online survey directed to HVAC contractors across the entire province of Ontario. The data collection includes installation and equipment costs for various heat pump sizes ranging from 1.5 tons to 5 tons. The information provided in Table 20 contains the assumptions used to determine the incremental cost for each heat pump sizing option: 4A, 4B, 4C, and 4D. The incremental cost for each tonnage (1.5 to 5 tons) by sizing option (4A to 4D) was determined, and the average incremental cost per ton was calculated for each of the sizing options 4A to 4D. This is presented in Table 10. The following data points were used to develop the incremental cost: 76 data points for ccASHP, 40 for ASHP, 42 for Furnace, 111 for A/C unit, 27 for Air handler, 60 for controls, and 17 for Panel upgrade.

Table 20 Incremental cost scenario analysis for ccASHP and ASHP centrally ducted systems

HP Sizing Option	Baseline Description	Baseline Equipment		Efficient Equipment	Baseline cost	Efficient cost	Incremental cost
		A/C unit	Furnace				
4A	Replace existing A/C unit with New one Add cooling (new A/C)	New A/C	Existing Furnace	ccASHP[29]	New A/C + Control	ccASHP + Control + Panel Upgrade[30]	ccASHP (+ Panel Upgrade) - New A/C
4B	Replace existing A/C unit with New one Add cooling (new A/C)	New A/C	Existing Furnace	ccASHP	New A/C + Control	ccASHP + Control + Panel Upgrade	(ccASHP (+ Panel Upgrade) - New A/C
	Customer is looking to replace heating and cooling	New A/C	New Furnace	ccASHP + New Furnace	New A/C + New Furnace + Control	ccASHP + New Furnace + Control + Panel Upgrade	ccASHP (+ Panel Upgrade) - New A/C
4C	Replace existing A/C unit with New one Add cooling (new A/C)	New A/C	Existing Furnace	ccASHP	New A/C + Control	ccASHP + Control + Panel Upgrade	ccASHP (+ Panel Upgrade) - New A/C

[28] ton calculated as follows and rounded to 1 decimal place, $ton = (Rated\ heating\ capacity\ at\ 8.3℃\ (47°F)\ in\ Btu/hr)/12{,}000$

[29] For the purposes of Table 20(entire content), when referring to ccASHP, the same is applicable to ASHP

[30] Since not all applications require Electrical Pannel upgrades and this is a significant cost to the customer, the incremental cost presented in table 1 was provided with 2 options: applications requiring and application not requiring electrical panel upgrade.

HP Sizing Option	Baseline Description	Baseline Equipment		Efficient Equipment	Baseline cost	Efficient cost	Incremental cost
		A/C unit	Furnace				
	Replace heating and it had cooling in place	Existing A/C	New Furnace	ccASHP + New Furnace	New Furnace + Control	ccASHP + New Furnace + Control + Panel Upgrade	ccASHP (+ Panel Upgrade)
	Replace heating and it didn't have cooling in place (add cooling)	No cooling					
	Customer is looking to replace heating and cooling	New A/C	New Furnace	ccASHP	New A/C + New Furnace + Control	ccASHP + New Furnace + Control + Panel Upgrade	ccASHP (+ Panel Upgrade) - New A/C
4D	Replace existing A/C unit with New one Add cooling (new A/C)	New A/C	Existing Furnace	ccASHP with Elec. Back-up + Air handler	New A/C + Control	ccASHP + Control + Air Handler + Panel Upgrade	ccASHP + Air Handler (+ Panel Upgrade) - New A/C –
	Replace heating and it had cooling in place	Existing A/C	New Furnace	ccASHP with Elec. Back-up + Air handler	New Furnace + Control	ccASHP + Control + Air Handler + Panel Upgrade*	ccASHP + Air Handler (+ Panel Upgrade) - New Furnace
	Replace heating and it didn't have cooling in place (add cooling)	No cooling					
	Customer is looking to replace heating and cooling	New A/C	New Furnace	ccASHP with Elec. Back-up + Air handler	New A/C + New Furnace + Control	ccASHP + Control + Air Handler + Panel Upgrade	ccASHP +Air Handler (+ Panel Upgrade) - New A/C - New Furnace

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

Version Date and Revision History	
Version	3.1 (minor update)
OEB Filing Date	March 19, 2026
OEB Approval Date	
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 1 Technology	Doorway without Air Curtain, nor Dock Door Seals								
Baseline 2 Technology	Replacing existing deteriorated dock door seals with Air Curtain								
Efficient Technology	Air curtain that meets the minimum standards of the Air Movement and Control Association International, Inc. (AMCA)								
Market Type	Commercial								
	Door size (W' x H')								
Annual Natural Gas Savings (m^3/yr per door) Baseline 1	**8' x 8'**	**8' x 9'**	**8' x 10'**	**9' x 8'**	**9' x 9'**	**9' x 10'**	**10' x 8'**	**10' x 9'**	**10' x 10'**
	3,480	3,588	3,675	3,710	3,810	3,888	3,940	4,032	4,101
Annual Natural Gas Savings (m^3/yr per door) Baseline 2	1,538	1,610	1,671	1,604	1,674	1,732	1,670	1,738	1,793
Annual Natural Gas Savings (m^3/yr per door) Baseline 1, 24/7[1]	14,729	15,155	15,475	15,703	16,092	16,374	16,677	17,029	17,272
Annual Natural Gas Savings (m^3/yr per door) Baseline 2, 24/7	6,510	6,801	7,036	6,789	7,070	7,294	7,069	7,339	7,552

[1] 24/7 refers to dock door operations (the truck is engaged at the dock door) of 20 hr/day or more. This identifier is applicable to Natural Gas Savings and Electricity impacts for both Baseline 1 and Baseline 2

Parameter	Definition								
Annual Electric Penalty (kWh/yr per door) Baseline 1	-1,394	-1,310	-1,225	-2,636	-2,552	-2,467	-2,553	-2,469	-2,384
Annual Electric Penalty (kWh/yr per door) Baseline 2	-2,094	-2,048	-2,001	-3,395	-3,348	-3,302	-3,371	-3,325	-3,278
Annual Electric Penalty (kWh/yr per door) Baseline 1, 24/7	-7,477	-7,284	-7,093	-12,505	-12,312	-12,122	-12,308	-12,117	-11,927
Annual Electric Penalty (kWh/yr per door) Baseline 2, 24/7	-9,135	-9,028	-8,922	-14,302	-14,196	-14,090	-14,246	-14,140	-14,035
Measure Life	15 years								
Incremental Cost ($ CAD)	**8 x 8**	**8 x 9**	**8 x 10**	**9 x 8**	**9 x 9**	**9 x 10**	**10 x 8**	**10 x 9**	**10 x 10**
	$6,962	$7,625	$7,625	$7,625	$7,625	$8,432	$8,855	$8,855	$8,855
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 for only 2 specific arrangements: (1) The Shipping/Receiving door had no Air curtain (baseline 1) or has Deteriorated seals in place (baseline 2). If Air Curtain (broken or not) is present at the shipping/receiving door, this measure is not eligible. In addition, the space must be 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 in 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 [2]

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 per year per door (kWh/yr per door) respectively.

APPLICATION

This measure is applicable to the installation of air curtains or replacing deteriorated seals with 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 door way. 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

BASELINE TECHNOLOGY

The current baselines are shown in Table 2.

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

Table 2. Baseline Technology

Scenario	Requirement
Baseline Technology 1	Exterior doorway without air curtain
Baseline Technology 2	Dock door with deteriorated seals

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 2025 ASHRAE Fundamentals Chapters 16 and 24 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 crack geometry, general building leakage and mechanical system. For uniform indoor air temperatures, the formulas for pressure across a building crack/penetration for a given time period are given below.

Wind pressure:

$$P_U = W_p \times \rho_o \times \frac{U^2}{2} \quad (1)\ [2]$$

Stack Pressure: $$P_T = -\rho_o \left[\frac{(T_i - T_o)}{T_i}\right] \times g \times (H_{NPL} - H) \quad (2)\ [3]$$

Pressure difference across each gap: $$\Delta p = P_U + P_T - \Delta p_I \quad (3)\ [4]$$

Where:

P_U	=	Wind surface pressure relative to outdoor static pressure in undisturbed flow (Pa)
W_p	=	Wind surface pressure coefficient (dimensionless)
ρ_o	=	Density of outdoor air (kg/m^3)
U	=	Wind speed (m/s)
P_T	=	Stack pressure (Pa)
T_o	=	Absolute outdoor temperature (K)
T_i	=	Absolute indoor temperature (K)
g	=	Gravitational acceleration (m/s^2)
H_{NPL}	=	Height of neutral pressure plan (m)
H	=	Height of point of interest above reference plane[3] (m)
Δp	=	Pressure difference across each gap (Pa)
Δp_I	=	Pressure that acts to balance inflows and outflows, including mechanical systems (Pa)

1a. Calculation of the Wind surface pressure coefficient [5] and Wind speed

$if\ cos\theta > 0, then$: $if\ cos\theta < 0, then$:

$$W_{\mathrm{p}}(\theta) = \frac{1}{2} \times \begin{Bmatrix} [C_p(1) + C_p(2)] \times (cos^2\theta)^{\frac{1}{4}} \\ +[C_p(1) - C_p(2)] \times (cos\theta)^{\frac{3}{4}} \\ +[C_p(3) + C_p(4)] \times (sin^2\theta)^2 \\ +[C_p(3) - C_p(4)] \times sin\theta \end{Bmatrix} \quad W_{\mathrm{p}}(\theta) = \frac{1}{2} \times \begin{Bmatrix} [C_p(1) + C_p(2)] \times (cos^2\theta)^{\frac{1}{4}} \\ -[C_p(1) - C_p(2)] \times (cos\theta)^{\frac{3}{4}} \\ +[C_p(3) + C_p(4)] \times (sin^2\theta)^2 \\ +[C_p(3) - C_p(4)] \times sin\theta \end{Bmatrix} \quad (1a)\ [5]$$

$$U = s \times U_H \quad (1b)\ [6]$$

$$U_H = U_{met} \times \left(\frac{\delta_{met}}{H_{met}}\right)^{a_{met}} \times \left(\frac{H^*}{\delta}\right)^{a} \quad (1c)\ [7]$$

$$H_{NPL} = \frac{H^*}{2} \quad (1d)$$

[3] Reference plane = ground level

Where:

θ	=	Wind direction (°)
$C_p(1)$	=	pressure coefficient when wind is at 0°
$C_p(2)$	=	pressure coefficient when wind is at 180°
$C_p(3)$	=	pressure coefficient when wind is at 90°
$C_p(4)$	=	pressure coefficient when wind is at 270°
U	=	Wind speed (m/s)
s	=	Shelter factor applicable to the given gap (dimensionless)
U_H	=	Effective wind speed (m/s)
U_{met}	=	Wind speed from the nearby meteorological station (m/s)
δ_{met}	=	Atmospheric boundary layer thickness from the nearby meteorological station (m)
H_{met}	=	Height at which the anemometer that records U_{met} is located, usually 10 m above ground level (33 ft)
a_{met}	=	Local building terrain from the nearby meteorological station (dimensionless)
H^*	=	Undisturbed wind height (m)
δ	=	Atmospheric boundary layer thickness (m)
a	=	Local building terrain (dimensionless)

1b. Calculation of the gap height of the point of interest above reference plane

$$H = d_p + \frac{h_d}{2} \tag{2a}$$

Where:

H	=	Height of point of interest above reference plane (m)
d_p	=	The typical dock position off the ground (m)
h_d	=	Door height (m)

2. Calculation of the airflow through openings

Airflow through openings: $$Q = C_{dh} \times A \times \sqrt{\left(\frac{2|\Delta p|}{\rho_o}\right)} \quad (4)\ [8]$$

Discharge coefficient for openings (SI): $$C_D = 0.40 + 0.0045|T_i - T_0| \quad (4a)\ [9]$$

Where:

Q = Total airflow rate through the doorway (m^3/s)

C_D = Discharge coefficient for openings (dimensionless)

A = Cross-sectional area of opening (m^2)

T_i = Absolute indoor temperature (K)

T_o = Absolute outdoor temperature (K)

2a. Calculation of the cross-sectional area of opening for Baseline 1 Doorway without Air Curtain, nor Dock Door Seals

Figure 3 Illustrates the schematics of the opening area

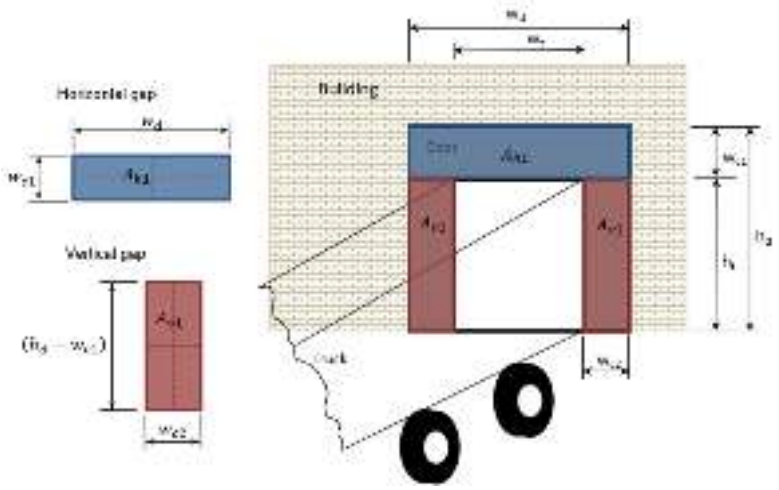

Figure 3 Dock Door opening area for Baseline 1

$$A_1 = A_{v1} + A_{h1} \quad (4b)$$

$$A_{v1} = 2 \times (h_d - w_{c1}) \times w_{c2} \quad (4c)$$

$$A_{h1} = w_d \times w_{c1} \quad (4d)$$

Where:

A_1 = Total gap area per door dock for Baseline 1 (m²)

A_{v1} = Vertical gap area for Baseline 1 (m²)

A_{h1} = Horizontal gap area for Baseline 1(m²)

h_d = Door height (m)

w_{c1} = Gap between the top of the truck and the top of the dock door (m) for Baseline 1

w_{c2} = Gap between the side of the truck and the side of the dock door (m) for Baseline 1

A_h = Horizontal gap area (m²)

w_d = Door width (m)

2b. Calculation of the cross-sectional area of opening for Baseline 2. Replacing existing deteriorated dock door seals with Air Curtain

Figure 4 illustrates the schematics of the opening area.

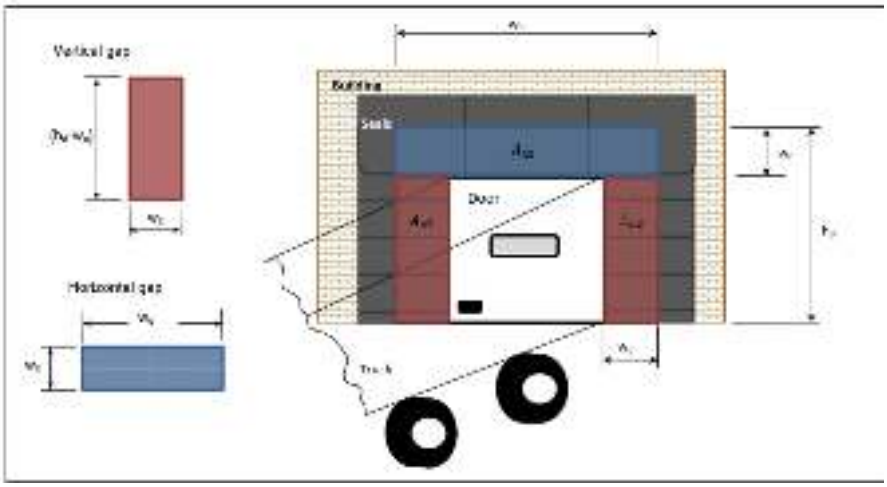

Figure 4 Dock Door opening area for Baseline 2

$$A_2 = A_{v2} + A_{h2} \quad (4e)$$

$$A_{v2} = 2 \times (h_d - w_c) \times w_c \quad (4f)$$

$$A_{h2} = w_d \times w_c \quad (4g)$$

Where:

A_2 = Total gap area per door dock for Baseline 2 (m²)

A_{v2} = Vertical gap area for Baseline 2 (m²)

A_{h2} = Horizontal gap area for Baseline 2 (m^2)

h_d = Door height (m)

w_c = Gap between the side of the truck and the side of the dock door (m)

w_d = Door width (m)

3. Calculation of the energy required (natural gas)

$$q_s = Q \times \rho_0 \times C_p \times (T_i - T_o) \quad (5)\ [10]$$

Where:

q_s = Sensible heat load (W)

Q = Total airflow rate through the doorway (m^3/s)

C_p = Specific heat of air (J/(kg.K)

ρ_o = Density of outdoor air (kg/m^3)

T_i = Absolute indoor temperature (K)

$T_{i-heating}$ = heating Temperature Setpoint Schedule

$T_{i-cooling}$ = cooling Temperature Setpoint Schedule

T_o = Absolute outdoor temperature (K)

4. Calculation of the natural gas savings

$$NG_{saving} = \sum_{h=1}^{8760} NG_{hourly} \quad (6)$$

$$NG_{hourly} = 3.412 \times \frac{q_s}{35{,}738 \times Eff} \times O_p \times H_{heating} \times E \quad (6a)$$

Where:

NG_{saving} = Annual Natural Gas Savings (m^3/yr per door)

NG_{hourly} = Hourly Natural Gas Savings (m3/hr)

O_p = Multiplier to account for hours of the day that the truck is engaged at the door. The multiplier is 1(or a fraction of the hour), at the specific hours of the day the truck in engaged at the door and 0 for all other hours (dimensionless)

$H_{heating}$	=	Multiplier to account for hours of the year when the heating system is enabled. The multiplier is 1 when the outside air temperature is below the heating system balance point temperature and 0 for all other hours (dimensionless)
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 total Electricity impact**

$$E_{total} = Elec_{fan-c} + Elec_{fan-h} + Elec_{cooling} \quad (7)$$

Where:

E_{total}	=	Total Electricity impact due to the operation of the air curtain (kWh/yr)
$Elec_{fan-c}$	=	Annual Electricity Penalty- due to the operation of the fan on the air curtain during the cooling season (kWh/yr)
$Elec_{fan-h}$	=	Annual Electricity Penalty- due to the operation of the fan on the air curtain during the heating season (kWh/yr)
$Elec_{cooling}$	=	Annual Electricity Savings= due to the reduction of cooling load (kWh/yr)

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

$$Elec_{fan-h} = \sum_{h=1}^{8760} E_{fan-h} \quad (8)$$

$$E_{fan-h} = -HP \times 0.7457 \times O_p \times H_{heating} \quad (8a)$$

Where:

$Elec_{fan-h}$ = Annual Electricity Penalty- due to the operation of the fan on the air curtain during the heating season (kWh/yr)

E_{fan-h} = Hourly Electricity Penalty- due to the operation of the fan on the air curtain during the heating season (kWh/yr)

HP = Air curtain fan electric input power (hp)

0.7457 = Conversion factor (1 horsepower = 0.7457 kilowatts)

O_p = Multiplier to account for hours of the day that the truck is engaged at the door. The multiplier is 1 (or a fraction of the hour), at the specific hours of the day the truck in engaged at the door and 0 for all other hours (dimensionless)

$H_{heating}$ = Multiplier to account for hours of the year when the heating system is enabled. The multiplier is 1 when the outside air temperature is below the heating system balance point temperature and 0 for all other hours (dimensionless)

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

$$Elec_{fan-c} = \sum_{h=1}^{8760} E_{fan-c} \quad (9)$$

$$E_{fan-c} = -HP \times 0.7457 \times O_p \times H_{cooling} \quad (9a)$$

Where:

$Elec_{fan-c}$ = Annual Electricity Penalty- due to the operation of the fan on the air curtain during the cooling season (kWh/yr)

E_{fan-c} = Hourly Electricity Penalty- due to the operation of the fan on the air curtain during the cooling season (kWh/hr)

HP = Air curtain fan electric input power (hp)

0.7457 = Conversion factor (1 horsepower = 0.7457 kilowatts)

O_p = Multiplier to account for hours of the day that the truck is engaged at the door. The multiplier is 1 (or a fraction of the hour), at the specific hours of the day the truck in engaged at the door and 0 for all other hours (dimensionless)

$H_{cooling}$ = Multiplier to account for hours of the year when the cooling system is enabled. The multiplier is 1 when the outside air

temperature is above the cooling system balance point temperature and 0 for all other hours (dimensionless)

4. Calculation of the Electricity saving-cooling season due to the reduction of cooling load (infiltration reduction)

$$Elec_{cooling} = \sum_{h=1}^{8760} Elec_{hourly} \quad (10)$$

$$E_{hourly} = \frac{q_c}{COP} \times O_p \times H_{cooling} \times E \quad (10a)$$

Where:

$Elec_{cooling}$	=	Annual Electricity savings due to the reduction of cooling load (kWh/yr)
$Elec_{hourly}$	=	Hourly Electricity Impacts- due to the reduction of cooling load (kWh)
q_c	=	Rate of heat transfer through doorway without vestibule (kW)
COP	=	Seasonal COP, cooling
E	=	Air Curtain effectiveness

5. Calculation of the energy required (electricity)

$$q_c = \rho_o \times Q \times (h_{oc} - h_{ic}) \quad (11)$$

Where:

Q	=	Airflow rate through the doorway (m^3/s)
h_{oc}	=	Outside enthalpy-cooling season (kJ/kg)
h_{ic}	=	Inside enthalpy-cooling season (kJ/kg)
ρ_o	=	Air density (kg/m^3)

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 (at or near sea level)		Hourly calculation based on CWEC 2020, London, ON [11]
$T_{i-heating}$	Absolute indoor temperature (K). Heating Temperature Setpoint Schedule	various	Hourly profile based on 2020 NECB Heating Temperature Setpoint Schedule [12] and fraction of the hour the truck is engaged at the door.
$T_{i-cooling}$	Absolute indoor temperature (K). Cooling Temperature Setpoint Schedule	various	
T_o	Absolute outdoor temperature (K)	various	Hourly profile based on CWEC 2020, London, ON [11]
HR	Hour per day door is open	7.23 hr/day	Average value from sample of EGI 94 projects
O_p	Fraction of the hour the day the truck in engaged at the door	various	Calculated based on value from sample of 94 EGI projects, HR and 2020 NECB hourly Occupancy Schedule [12]

		Weekdays only operation		Full-week operation	
	Hours of day	**Weekday**	**Weekend**	**Weekday**	**Weekend**
$T_{i-heating}$ (℃)	1-5	18	18	18	18
	6	20	18	20	20
	7-20	22	18	22	22
	21-24	18	18	18	18
$T_{i-cooling}$ (℃)	1-5	26	26	26	26
	6-20	24	26	24	24
	21-24	26	26	26	26
O_p	1	0	0	0	0
	2-8	0	0	1	1
	9-15	1	0	1	1
	16	0.23	0	1	1
	17-22	0	0	1	1
	23	0	0	0.19	0.19
	24	0	0	0	0

Δp_I	Pressure that acts to balance inflows and outflows, including mechanical systems (Pa)	0	Assumed that no system will balance inflows and outflows
$C_p(1)$	Pressure coefficient when wind is at 0°	0.6	[5]
$C_p(2)$	Pressure coefficient when wind is at 180°	-0.3	

Variable	Definition	Value and Unit	Source/Comments
$C_p(3)$	Pressure coefficient when wind is at 90°	-0.65	
$C_p(4)$	Pressure coefficient when wind is at 270°	-0.65	
U_{met}	Hourly wind speed		Hourly profile based on CWEC 2020, London, ON [11]
δ_{met}	Atmospheric boundary layer thickness from a nearby meteorological station	270 m	Based on Terrain Category 3 [13]
H_{met}	Height at which the anemometer that records U_{met} is located	9 m	
a_{met}	Local building terrain from the nearby meteorological station	0.14	
δ	Local atmospheric boundary layer thickness	370 m	Based on Terrain Category 2 [13]
a	Local building terrain	0.22	
	Specific gas constant for dry air	287.05 J/kg.K	[14]
	Specific gas constant for water vapor	461.52 J/kg.K	
s	Shelter factor	0.7	Based on Shelter Class 3 [15], [16]
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 [17] and standard door sizes
w_{c2}	Gap width between the side of the truck and the side of the dock door	16.71 in (0.42 m)	
w_c	Gap between the side of the truck and the side of the dock door with seal (m)	0.11 m (4.21 in)	Calculated based on value from sample of 94 EGI projects
C_p	Specific heat of air	1,000 J/(kg·K)	Common assumptions table
h_{ic}	Inside enthalpy for cooling season		Hourly calculation based on indoor properties of the air (cooling temperature setpoint schedule and indoor relative humidity)[4]

[4] Enthalpy is estimated using a polynomial approximation based on dry-bulb temperature and relative humidity, adapted from a simplified method found in an online source (https://www.mrexcel.com/board/threads/excel-formula-for-calculating-airs-enthalpy-from-dry-bulb-temperature-and-relative-humidity.871843/). While this approach is not fully rigorous, a due diligence comparison against standard online tools using approved psychrometric methods showed an average deviation of 0.1%, which is considered acceptable for this analysis.

Variable	Definition	Value and Unit	Source/Comments
h_{oc}	Outside enthalpy for cooling season		Hourly calculation based on outdoor properties of the air (dry bulb temperature and relative humidity) from CWEC 2020, London, ON [11][4]
d_p	The typical dock position off the ground	4.16 ft (1.27m)	Calculated based on value from sample of 94 EGI projects
H^*	Average building height	27ft (8.2m)	Calculated based on value from sample of 94 EGI projects
C_D	Discharge coefficient for opening		Hourly calculation using ASHRAE algorithm [9] and based on CWEC weather data for London, ON (2020)
E	Effectiveness of air curtain	75% (range between 60% - 90%)	[18]
Eff	Commercial heating system efficiency	80%	Common assumptions table
COP	Commercial cooling system seasonal COP	3.8	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	[19]
	Density conversion factor from metric to imperial, multiply by	0.062428 (lb/ft^3)/(kg/m^3)	[20]
	Conversion factor from Watt to Btu/hr	1 Watt = 3.412 Btu/hr	[21]
	Enthalpy rate conversion factor from imperial to metric, multiply by	2.326 kJ/kg/Btu/lb	[22]
	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

	8' x 8'	8' x 9'	8' x 10'	9' x 8'	9' x 9'	9' x 10'	10' x 8'	10' x 9'	10' x 10'
$h_d(ft)$	8	9	10	8	9	10	8	9	10
$w_d(ft)$	8	8	8	9	9	9	10	10	10
HP	2	2	2	3	3	3	3	3	3

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') = 3,480 m^3/yr + 3,675 m^3/yr = 7,155 m3/yr

Annual Electrical Impact:

1 (8'x8') + 1 (8'x10') = -1,394 – 1,225 = -2,619 kWh/yr

The total annual natural gas savings are 7,155 m3/yr and the total electrical impact is -2,619 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 space must be heated during heating season by natural gas fueled equipment.

MEASURE LIFE

The measure life is 15 years. [23]

INCREMENTAL COST

The purchase and installation cost for air curtains is summarized in the table below. [24]

Table 5. Incremental Cost

Definition	Door size (W' x H')								
	8' x 8'	8' x 9'	8' x 10'	9' x 8'	9' x 9'	9' x 10'	10' x 8'	10' x 9'	10' x 10'
Ave. Total cost	$6,962	$7,625	$7,625	$7,625	$7,625	$7,625	$7,625	$8,432	$8,855

REFERENCES

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

[2] ASHRAE, "Wind Pressure," in *ASHRAE Handbook Fundamentals (SI Edition), Chapter 16*, 2025, pp. 16.7, Equation (15).

[3] ASHRAE, "Stack Pressure," in *ASHRAE Handbook Fundamentals (SI Edition), Chapter 16*, 2025 , pp. 16.6, Equation (14).

[4] ASHRAE, "Combining Driving Forces," in *ASHRAE Handbook Fundamentals (SI Edition), Chapter 16* ,, 2025, pp. 16.8, Equation (17).

[5] ASHRAE , "Wind surface pressure coefficient," in *ASHRAE Handbook Fundamentals (SI Edition), Chapter 24*, 2025, pp. 24.6 , Equation (5).

[6] ASHRAE, "Wind Pressure," in *ASHRAE Handbook Fundamentals (SI Edition), Chapter 16*, 2025, pp. 16.7, equation (16).

[7] ASHRAE, "Approach Wind Speed," in *ASHRAE Handbook Fundamentals (SI Edition), Chapter 24*, 2025, pp. 24.4, Equation (4).

[8] ASHRAE, "Airflow through openings," in *ASHRAE Handbook Fundamentals (SI Edition) , Chapter 16*, 2025, pp. 16.33, Equation (48).

[9] ASHRAE, "Discharge coefficient for opening," in *ASHRAE Handbook Fundamentals (SI Edition) , Chapter 16*, 2025, pp. 16.33, Equation (51).

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

Version Date and Revision History	
Version	1.1 (minor update)
OEB Filing Date	March 19, 2026
OEB Approval Date	
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					
	Door size (W' x H')					
	10' x 10'	**12' x 12'**	**14' x 14'**	**16' x 16'**	**18' x 18'**	**20' x 20'**
Annual Natural Gas Savings (m^3/yr per door), weekdays	3,927	4,682	5,325	5,842	6,212	6,440
Annual Natural Gas Savings (m^3/yr per door), full week	5,599	6,678	7,595	8,331	8,857	9,175
Annual Electricity Impacts (kWh/yr per door), weekdays	290	587	574	873	551	856
Annual Electricity Impacts (kWh/yr per door), full week	380	784	767	1,173	735	1,150
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'**
	$8,855	$11,703	$13,599	$22,840	$26,621	$32,862
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					

Parameter	Definition
	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.

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

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

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.

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

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, 19 and 24 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.

Driving mechanisms:

Wind pressure:
$$P_U = W_p \times \rho_o \times \frac{U^2}{2} \quad (1)\ [2]$$

Stack pressure:
$$P_T = -\rho_o \times \left[\frac{(T_i - T_o)}{T_i}\right] \times g \times (H_{NPL} - H) \quad (2)\ [3]$$

Pressure difference across each gap:
$$\Delta p = P_U + P_T - \Delta p_I \quad (3)\ [4]$$

Where:

P_U = Wind surface pressure relative to outdoor static pressure in undisturbed flow (Pa)

ρ_o = Density of outdoor air (kg/m^3)

W_p = Wind surface pressure coefficient (dimensionless)

U = Wind speed (m/s)

P_T = Stack pressure (Pa)

T_o = Absolute outdoor temperature (K)

T_i = Absolute indoor temperature (K)

g = Gravitational acceleration (m/s^2)

H_{NPL} = Height of neutral pressure plan (m)

H = Height of point of interest above reference plane[3] (m)

Δp = Pressure difference across each gap (Pa)

Δp_I = Pressure that acts to balance inflows and outflows, including mechanical systems (Pa)

[3] Reference plane = ground level

1a. Calculation of the Wind surface pressure coefficient [5] **and Wind speed**

$if\ cos\theta > 0, then$: $if\ cos\theta < 0, then$:

$$W_{\mathrm{p}}(\theta) = \frac{1}{2} \times \begin{Bmatrix} \left[C_p(1) + C_p(2)\right] \times (cos^2\theta)^{\frac{1}{4}} \\ +\left[C_p(1) - C_p(2)\right] \times (cos\theta)^{\frac{3}{4}} \\ +\left[C_p(3) + C_p(4)\right] \times (sin^2\theta)^2 \\ +\left[C_p(3) - C_p(4)\right] \times sin\theta \end{Bmatrix} \qquad W_{\mathrm{p}}(\theta) = \frac{1}{2} \times \begin{Bmatrix} \left[C_p(1) + C_p(2)\right] \times (cos^2\theta)^{\frac{1}{4}} \\ -\left[C_p(1) - C_p(2)\right] \times (cos\theta)^{\frac{3}{4}} \\ +\left[C_p(3) + C_p(4)\right] \times (sin^2\theta)^2 \\ +\left[C_p(3) - C_p(4)\right] \times sin\theta \end{Bmatrix} \quad \text{(1a) [5]}$$

$$U = s \times U_H \quad \text{(1b) [6]}$$

$$U_H = U_{met} \times \left(\frac{\delta_{met}}{H_{met}}\right)^{a_{met}} \times \left(\frac{H^*}{\delta}\right)^{a} \quad \text{(1c) [7]}$$

$$H_{NPL} = \frac{H^*}{2} \quad \text{(1d)}$$

Where:

θ	=	Wind direction (°)
$C_p(1)$	=	Pressure coefficient when wind is at 0°
$C_p(2)$	=	Pressure coefficient when wind is at 180°
$C_p(3)$	=	Pressure coefficient when wind is at 90°
$C_p(4)$	=	Pressure coefficient when wind is at 270°
U	=	Wind speed (m/s)
s	=	Shelter factor applicable to the given gap (dimensionless)
U_H	=	Effective wind speed (m/s)
U_{met}	=	Wind speed from the nearby meteorological station (m/s)
δ_{met}	=	Atmospheric boundary layer thickness from the nearby meteorological station (m)
H_{met}	=	Height at which the anemometer that records U_{met} is located, usually 10 m above ground level (33 ft)
a_{met}	=	Local building terrain from the nearby meteorological station (dimensionless)
H^*	=	Undisturbed wind height (m)
δ	=	Atmospheric boundary layer thickness (m)
a	=	Local building terrain (dimensionless)

1b. Calculation of the height of the point of interest above reference plane

$$H = \frac{h_d}{2} \quad (2a)$$

Where:

h_d = Door height (m)

2. Calculation of the airflow through openings

Airflow through openings: $$\mathrm{Q} = \mathrm{C}_D \times \mathrm{A} \times \sqrt{\left(\frac{2|\Delta p|}{\rho_o}\right)} \quad (4)\ [8]$$

Discharge coefficient for openings (SI): $$C_D = 0.4 + 0.0045 + |T_i - T_o| \quad (4a)\ [9]$$

Where:

Q = Total airflow rate through the doorway (m^3/s)

C_D = Discharge coefficient for openings (dimensionless)

A = Cross-sectional area of opening (m^2)

T_i = Absolute indoor temperature (K)

T_o = Absolute outdoor temperature (K)

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

Figure 3 Illustrates the schematics of the opening area

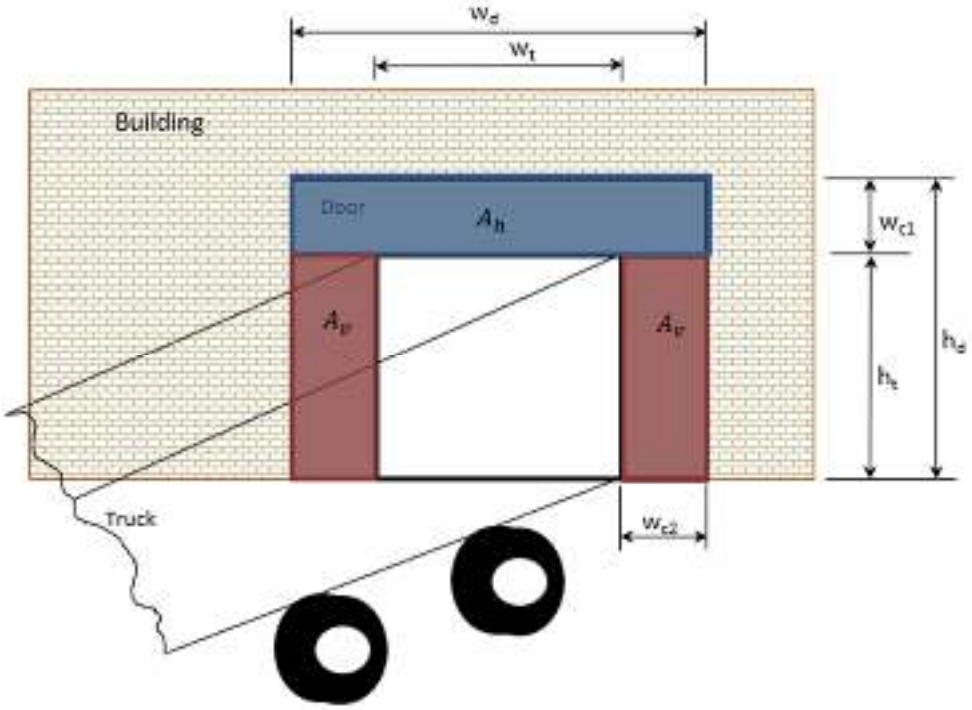

Figure 3 Dock Door opening area

$$A = A_V + A_h$$

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

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

Where:

A_V = Vertical gap area (m²)

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 (m²)

w_d = Door width (m)

A = Total gap area per door dock (m²)

3. Calculation of the energy required (natural gas)

$$q_s = Q \times \rho_o \times C_p \times (T_i - T_o) \quad (5)\ [10]$$

Where:

q_s = Sensible heat load (W)

C_p = Specific heat of air (J/(kg.K)

ρ_o = Density of outdoor air (kg/m^3)

T_i = Absolute indoor temperature (K):

$T_{i-heating}$ = heating Temperature Setpoint Schedule

$T_{i-cooling}$= cooling Temperature Setpoint Schedule

T_o = Absolute outdoor temperature (K)

4. Calculation of the natural gas savings

$$NG_{saving} = \sum_{h=1}^{8760} NG_{hourly} \quad (6)$$

$$NG_{hourly} = 3.412 \times \frac{q_s}{35{,}738 \times Eff} \times O_p \times H_{heating} \times E \quad (6a)$$

Where:

NG_{saving} = Annual Natural Gas Savings (m^3/yr per door)

NG_{hourly} = Hourly Natural Gas Savings (m3/hr)

O_p = Multiplier to account for hours of the day that the truck is engaged at the door. The multiplier is 1 (or a fraction of the hour), at the specific hours of the day the truck in engaged at the door and 0 for all other hours (dimensionless)

$H_{heating}$ = Multiplier to account for hours of the year when the heating system is enabled. The multiplier is 1 when the outside air temperature is below the heating system balance point temperature and 0 for all other hours (dimensionless)

Eff = Heating System efficiency

E = Air Curtain 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

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 total Electricity impact**

$$E_{total} = Elec_{fan-c} + Elec_{fan-h} + Elec_{cooling} \quad (7)$$

Where:

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

$Elec_{fan-c}$ = Annual Electricity Penalty- due to the operation of the fan on the air curtain during the cooling season (kWh/yr)

$Elec_{fan-h}$ = Annual Electricity Penalty- due to the operation of the fan on the air curtain during the heating season (kWh/yr)

$Elec_{cooling}$ = Annual Electricity Savings= due to the reduction of cooling load (kWh/yr)

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

$$Elec_{fan-h} = \sum_{h=1}^{8760} E_{fan-h} \quad \textbf{(8)}$$

$$E_{fan-h} = -HP \times 0.7457 \times O_p \times H_{heating} \quad \textbf{(8a)}$$

Where:

$Elec_{fan-h}$ = Annual Electricity Penalty- due to the operation of the fan on the air curtain during the heating season (kWh/yr)

E_{fan-h} = Hourly Electricity Penalty- due to the operation of the fan on the air curtain during the heating season (kWh/hr)

HP = Air curtain fan electric input power (hp)

0.7457 = Conversion factor (1 horsepower = 0.7457 kilowatts)

O_p = Multiplier to account for hours of the day that the truck is engaged at the door. The multiplier is 1 (or a fraction of the

hour), at the specific hours of the day the truck in engaged at the door and 0 for all other hours (dimensionless)

$H_{heating}$ = Multiplier to account for hours of the year when the heating system is enabled. The multiplier is 1 when the outside air temperature is below the heating system balance point temperature and 0 for all other hours (dimensionless)

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

$$Elec_{fan-c} = \sum_{h=1}^{8760} E_{fan-c} \quad \textbf{(9)}$$

$$E_{fan-c} = -HP \times 0.7457 \times O_p \times H_{cooling} \quad \textbf{(9a)}$$

Where:

$Elec_{fan-c}$ = Annual Electricity Penalty- due to the operation of the fan on the air curtain during the cooling season (kWh/yr)

E_{fan-c} = Hourly Electricity Penalty- due to the operation of the fan on the air curtain during the cooling season (kWh/hr)

HP = Air curtain fan electric input power (hp)

0.7457 = Conversion factor (1 horsepower = 0.7457 kilowatts)

O_p = Multiplier to account for hours of the day that the truck is engaged at the door. The multiplier is 1 (or a fraction of the hour), at the specific hours of the day the truck in engaged at the door and 0 for all other hours (dimensionless)

$H_{cooling}$ = Multiplier to account for hours of the year when the cooling system is enabled. The multiplier is 1 when the outside air temperature is above the cooling system balance point temperature and 0 for all other hours (dimensionless)

4. Calculation of the Electricity saving-cooling season due to the reduction of cooling load (infiltration reduction)

$$Elec_{cooling} = \sum_{h=1}^{8760} Elec_{hourly} \quad (10)$$

$$E_{hourly} = \frac{q_c}{COP} \times O_p \times H_{cooling} \times E \quad (10a)$$

Where:

$Elec_{cooling}$ = Annual Electricity impacts - due to the reduction of cooling load (kWh/yr)

$Elec_{hourly}$ = Hourly Electricity Impacts- due to the reduction of cooling load (kWh)

q_c = Rate of heat transfer through doorway without vestibule (kW)

COP = Seasonal COP, cooling

E = Air Curtain effectiveness

5. Calculation of the energy required (electricity)

$$q_c = \rho_o \times Q \times (h_{oc} - h_{ic}) \quad (11)$$

Where:

Q = Airflow rate through the doorway (m^3/s)

h_{oc} = Outside enthalpy-cooling season (kJ/kg)

h_{ic} = Inside enthalpy-cooling season (kJ/kg)

ρ_o = Density of air density (kg/m^3)

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
$T_{i-heating}$	Absolute indoor temperature (K). Heating Temperature Setpoint Schedule	various	Hourly profile based on 2020 NECB Heating Temperature Setpoint Schedule [11] and the fraction of the hour the truck is engaged at the door.
$T_{i-cooling}$	Absolute indoor temperature (K). Cooling Temperature Setpoint Schedule	various	
T_o	Absolute outdoor temperature (K)	various	Hourly profile based on CWEC 2020, London, ON [12]

HR	Hour per day door is open		1.70 hr/day		Calculated based on a sample of 128 survey
O_p	Fraction of the hour the truck is engaged at the door		various		Calculated based on average traffic characteristics of a sample of 128 survey, HR and 2020 NECB hourly Occupancy Schedule [11]
		Weekdays only operation		**Full week operation**	
	Hours of day	**Weekday**	**Weekend**	**Weekday**	**Weekend**
$T_{i-heating}$ (℃)	1-5	18	18	18	18
	6	20	18	20	20
	7-20	22	18	22	22
	21-24	18	18	18	18
$T_{i-cooling}$ (℃)	1-5	26	26	26	26
	6-20	24	26	24	24
	21-24	26	26	26	26
O_p	1-8	0	0	0	0
	9-16	0.21	0	0.21	0.21
	17-24	0	0	0	0
ρ_0	Density of outdoor air (at or near sea level)				Hourly calculation based on CWEC 2020, London, ON [12]
Δp_I	Pressure that acts to balance inflows and outflows, including mechanical systems (Pa)		0		Assumed that no system will balance inflows and outflows
$C_p(1)$	Pressure coefficient when wind is at 0°		0.6		[5]
$C_p(2)$	Pressure coefficient when wind is at 180°		-0.3		
$C_p(3)$	Pressure coefficient when wind is at 90°		-0.65		
$C_p(4)$	Pressure coefficient when wind is at 270°		-0.65		

U_{met}	Hourly wind speed	various	Hourly profile based on CWEC 2020, London, ON [12]
δ_{met}	Atmospheric boundary layer thickness from a nearby meteorological station	270 m	Based on Terrain Category 3 [13]
H_{met}	Height at which the anemometer that records U_{met} is located	9 m	
a_{met}	Local building terrain from the nearby meteorological station	0.14	
δ	Local atmospheric boundary layer thickness	370 m	Based on Terrain Category 2 [13]
a	Local building terrain	0.22	
	Specific gas constant for dry air	287.05 J/kg.K	[14]
	Specific gas constant for water vapor	461.52 J/kg.K	
s	Shelter factor	0.7	Based on Shelter Class 3 [15], [16]
w_{c1}	Gap width between the top of the truck and the top of the dock door	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	Various	Hourly calculation based on indoor properties of the air (cooling temperature setpoint schedule, and indoor relative humidity) [4]

[4] Enthalpy is estimated using a polynomial approximation based on dry-bulb temperature and relative humidity, adapted from a simplified method found in an online source (https://www.mrexcel.com/board/threads/excel-formula-for-calculating-airs-enthalpy-from-dry-bulb-temperature-and-relative-humidity.871843/). While this approach is not fully rigorous, a due diligence

h_{oc}	Outside enthalpy for cooling season	various	Hourly calculation based on outdoor properties of the air (dry bulb temperature and relative humidity) from CWEC 2020, London, ON [12] [4]
	Indoor relative humidity	30%	Common assumptions table
H^*	Average building height	27ft (8.2m)	Average value from sample of 94 projects
E	Effectiveness of air curtain	75% (Range between 60% - 90%)	[17]
Eff	Commercial heating system efficiency	80%	Common assumptions table
COP	Commercial cooling system seasonal COP	3.8	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	[18]
	Density conversion factor from metric to imperial, multiply by	0.062428 (lb/ft^3)/(kg/m^3)	[19]
	Conversion factor from Watt to Btu/hr	1 Watt = 3.412 Btu/hr	[20]
	Enthalpy rate conversion factor from imperial to metric, multiply by	2.326 kJ/kg/Btu/lb	[21]
	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

	Door size (W' x H')					
	10' x 10'	**12' x 12'**	**14' x 14'**	**16' x 16'**	**18' x 18'**	**20' x 20'**
$h_d(ft)$	10	12	14	16	18	20
$w_d(ft)$	10	12	14	16	18	20
$Totalh_p$	3	3	4	4	6	6

comparison against standard online tools using approved psychrometric methods showed an average deviation of 0.1%, which is considered acceptable for this analysis.

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 ("Drive-in" doors) in a retail store that operated weekdays only. The sizes of the door are: 10'x10' and 14'x14'

Annual Gas Savings:

1 (10'x10') + 1 (14'x14') = 3,927 m^3/yr + 5,325 m^3/yr = 9,252 m^3/yr

Annual Electrical Impact:

1 (10'x10') + 1 (14'x14') = 290 + 574 = 864 kWh/yr

The total annual gas savings is 9,252 m^3/yr and the total electrical savings is 864 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. [22]

INCREMENTAL COST

The purchase and installation cost for air curtains is summarized in the table below. [23]

Table 5. Incremental Cost

Description	Door size (W' x H')					
	10x10	12x12	14x14	16x16	18x18	20x20
Ave. Total cost	$8,855	$11,703	$13,599	$22,840	$26,621	$32,862

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

Version Date and Revision History	
Version	2.1 (minor update)
OEB Filing Date	March 19, 2026
OEB Approval Date	
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					
Annual Natural Gas Saving- without vestibule (m3/yr per door)- week day[1]	**Door size (W' x H')**					
	3'x7'	**6'x7'**	**6'x8'**	**2x (3'x7')**	**2x (6'x7')**	**2x (6'x8')**
	1,062	2,124	2,374	2,124	4,249	4,749
Annual Natural Gas Saving- with vestibule (m3/yr per door)- week day	680	1,360	1,520	1,360	2,719	3,039
Annual Natural Gas Saving- without vestibule (m3/yr per door)- all week[2]	489	978	1,094	978	1,957	2,187

[1] Weekday refers to buildings that operates less than 7 days in a week. For example: Small Office, Medium office, Primary School, Secondary School, Outpatient Health Care. This identifier is applicable to Natural Gas Savings and Electricity impacts for both with and without vestibule

[2] All week refers to buildings that operates 7 days in a week. For example: Standalone Retail, Strip Mall -large store, Strip Mall - small store, Quick Service Restaurant, Sit-down Restaurant, Small Hotel, Mid-rise Apartment. This identifier is applicable to Natural Gas Savings and Electricity impacts for both with and without vestibule

Parameter	Definition					
Annual Natural Gas Saving- with vestibule (m3/yr per door)- all week	313	626	700	626	1,252	1,400
Annual Electric Impact- without vestibule (kWh/yr per door)- week day	250	454	528	499	908	1,056
Annual Electric Impact- with vestibule (kWh/yr per door)- week day	150	256	303	301	512	606
Annual Electric Impact- without vestibule (kWh/yr per door)- all week	94	168	197	188	336	393
Annual Electric Impact- with vestibule (kWh/yr per door)- all week	56	92	110	112	183	220
Measure Life	15 years					
Incremental Cost ($ CAD	**3'x7'**	**6'x7'**	**6'x8'**	**2x (3'x7')**	**2x (6'x7')**	**2x (6'x8')**
Vestibule	$2,525	$3,433	$3,433	$4,005	$5,261	$5,261
Without Vestibule	$2,780	$4,800	$4,800	$4,515	$7,995	$7,995
Average Incremental Cost ($ CAD)	$2,653	$4,117	$4,117	$4,260	$6,628	$6,628
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 the winter months. • New Construction applications for which the Air Curtains have been installed instead 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.

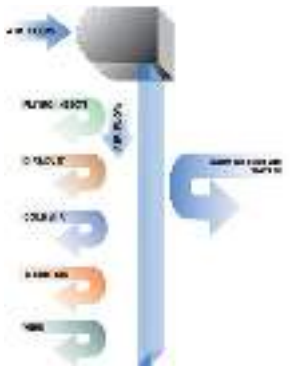

Figure 1. Air Curtain Installation [3]

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

EFFICIENT TECHNOLOGY

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

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

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 24 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.

Wind pressure:
$$P_U = W_p \times \rho_o \times \frac{U^2}{2} \quad (1)\ [2]$$

Stack pressure:
$$P_T = -\rho_o \times \left[\frac{(T_i - T_o)}{T_i}\right] \times g \times (H_{NPL} - H) \quad (2)\ [3]$$

Pressure difference across each gap:
$$\Delta p = P_U + P_T - \Delta p_I \quad (3)\ [4]$$

Where:

P_U = Wind surface pressure relative to outdoor static pressure in undisturbed flow (Pa)

W_p	=	Wind surface pressure coefficient (dimensionless)
ρ_o	=	Density of outdoor air (kg/m^3)
U	=	Wind speed (m/s)
P_T	=	Stack pressure (Pa)
T_o	=	Absolute outdoor temperature (K)
T_i	=	Absolute indoor temperature (K)
g	=	Gravitational acceleration (m/s^2)
H_{NPL}	=	Height of neutral pressure plan (m)
H	=	Height of point of interest above reference plane[4] (m)
Δp	=	Pressure difference across each gap (Pa)
Δp_I	=	Pressure that acts to balance inflows and outflows, including mechanical systems (Pa)

1a. Calculation of the Wind surface pressure coefficient [5] **and Wind speed**

$if\ cos\theta > 0, then$: $if\ cos\theta < 0, then$:

$$W_{\mathrm{p}}(\theta) = \frac{1}{2} \times \begin{Bmatrix} [C_p(1) + C_p(2)] \times (cos^2\theta)^{\frac{1}{4}} \\ +[C_p(1) - C_p(2)] \times (cos\theta)^{\frac{3}{4}} \\ +[C_p(3) + C_p(4)] \times (sin^2\theta)^2 \\ +[C_p(3) - C_p(4)] \times sin\theta \end{Bmatrix} \quad W_{\mathrm{p}}(\theta) = \frac{1}{2} \times \begin{Bmatrix} [C_p(1) + C_p(2)] \times (cos^2\theta)^{\frac{1}{4}} \\ -[C_p(1) - C_p(2)] \times (cos\theta)^{\frac{3}{4}} \\ +[C_p(3) + C_p(4)] \times (sin^2\theta)^2 \\ +[C_p(3) - C_p(4)] \times sin\theta \end{Bmatrix} \quad \begin{matrix} \text{(1a)} \\ \text{[5]} \end{matrix}$$

$$U = s \times U_H \quad \begin{matrix} \text{(1b)} \\ \text{[6]} \end{matrix}$$

$$U_H = U_{met} \times \left(\frac{\delta_{met}}{H_{met}}\right)^{a_{met}} \times \left(\frac{H^*}{\delta}\right)^{a} \quad \begin{matrix} \text{(1c)} \\ \text{[7]} \end{matrix}$$

$$H_{NPL} = \frac{H^*}{2} \quad \text{(1d)}$$

1a. Where:

θ	=	Wind direction (°)
$C_p(1)$	=	Pressure coefficient when wind is at 0°
$C_p(2)$	=	Pressure coefficient when wind is at 180°
$C_p(3)$	=	Pressure coefficient when wind is at 90°

[4] Reference plane = ground level

$C_p(4)$	=	Pressure coefficient when wind is at 270°
U	=	Wind speed (m/s)
s	=	Shelter factor applicable to the given gap (dimensionless)
U_H	=	Effective wind speed (m/s)
U_{met}	=	Wind speed from the nearby meteorological station (m/s)
δ_{met}	=	Atmospheric boundary layer thickness from the nearby meteorological station (m)
H_{met}	=	Height at which the anemometer that records U_{met} is located, usually 10 m above ground level (33 ft)
a_{met}	=	Local building terrain from the nearby meteorological station (dimensionless)
H^*	=	Undisturbed wind height (m)
δ	=	Atmospheric boundary layer thickness (m)
a	=	Local building terrain (dimensionless)

1b. Calculation of the height of the point of interest above reference plane

$$\boldsymbol{H = \frac{h_d}{2}} \qquad \textbf{(1e)}$$

Where:

h_d	=	Door height (m)

2. Calculation of the airflow through openings

$$Q = C_D \times A \times \sqrt{\left(\frac{2|\Delta p|}{\rho_o}\right)} \qquad (4)\ [8]$$

$$C_D = 0.40 + 0.0045|T_i - T_0| \qquad (4a)\ [9]$$

Where:

Q	=	Airflow rate (m^3/s)
C_D	=	Discharge coefficient for openings (dimensionless)
A	=	Cross-sectional area of opening (m^2)
T_i	=	Absolute indoor temperature (K)
T_o	=	Absolute outdoor temperature (K)

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

$$A = h_d \times w_d \times \%opening \quad (4b)$$

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)

$$q_s = Q \times \rho_0 \times C_p \times (T_i - T_o) \quad (5)\ [10]$$

Where:

q_s = Sensible heat load (W)

C_p = Specific heat of air (J/(kg.K)

ρ_o = Density of outdoor air (kg/m^3)

T_i = Absolute indoor temperature (K):
$T_{i-heating}$ = heating Temperature Setpoint Schedule
$T_{i-cooling}$= cooling Temperature Setpoint Schedule

T_o = Absolute outdoor temperature (K)

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

$$NG_{saving} = \sum_{h=1}^{8760} NG_{hourly} \quad (6)$$

$$NG_{hourly} = 3.412 \times \frac{q_s}{35{,}738 \times Eff} \times O_p \times H_{heating} \times E \quad (6a)$$

Where:

NG_{saving} = Annual Natural Gas Savings (m^3/yr per door)

NG_{hourly} = Hourly Natural Gas Savings (m3/hr)

O_p	=	Multiplier to account for hours of the day that the pedestrian traffic is engaged at the door. The multiplier is 1 (or a fraction of the hour), at the specific hours of the day the truck in engaged at the door and 0 for all other hours (dimensionless)
$H_{heating}$	=	Multiplier to account for hours of the year when the heating system is enabled. The multiplier is 1 when the outside air temperature is below the heating system balance point temperature and 0 for all other hours (dimensionless)
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.

$$NG_{saving} = \sum_{h=1}^{8760} NG_{hourly-vastibule} \tag{7}$$

$$NG_{hourly-vastibule} = 3.412 \times \frac{(q_b - q_a)}{35{,}738 \times Eff} \times O_p \times H_{heating} \tag{7a}$$

$$q_b = q_s \times (1 - VE) \tag{7b}$$

$$q_a = q_b \times (1 - E) \tag{7c}$$

Where:

NG_{saving}	=	Annual Natural Gas Savings (m^3/yr per door)
NG_{hourly}	=	Hourly Natural Gas Savings (m3/hr)
q_b	=	Sensible heat load- accounting for vestibule effectiveness (W)
q_a	=	Sensible heat load- accounting for air curtain effectiveness (W)
O_p	=	Multiplier to account for hours of the day that the pedestrian traffic is engaged at the door. The multiplier is 1 (or a fraction of the hour), at the specific hours of the day the truck in engaged at the door and 0 for all other hours (dimensionless)

$H_{heating}$	=	Multiplier to account for hours of the year when the heating system is enabled. The multiplier is 1 when the outside air temperature is below the heating system balance point temperature and 0 for all other hours (dimensionless)
Eff	=	Heating System efficiency (dimensionless)
E	=	Air Curtain effectiveness (dimensionless)
VE	=	Vestibule 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 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 total Electricity impact**

$$E_{total} = Elec_{fan-c} + Elec_{fan-h} + Elec_{cooling} \quad (8)$$

Where:

E_{total}	=	Total Electricity impact due to the operation of the air curtain (kWh/yr)
$Elec_{fan-c}$	=	Annual Electricity Penalty- due to the operation of the fan on the air curtain during the cooling season (kWh/yr)
$Elec_{fan-h}$	=	Annual Electricity Penalty- due to the operation of the fan on the air curtain during the heating season (kWh/yr)
$Elec_{cooling}$	=	Annual Electricity Savings= due to the reduction of cooling load (kWh/yr)

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

$$Elec_{fan-h} = \sum_{h=1}^{8760} E_{fan-h} \quad (9)$$

$$E_{fan-h} = -HP \times 0.7457 \times O_p \times H_{heating} \quad (9a)$$

Where:

$Elec_{fan-h}$ = Annual Electricity Penalty- due to the operation of the fan on the air curtain during the heating season (kWh/yr)

E_{fan-h} = Hourly Electricity Penalty- due to the operation of the fan on the air curtain during the heating season (kWh)

HP = Air curtain fan electric input power (hp)

0.7457 = Conversion factor (1 horsepower = 0.7457 kilowatt)

O_p = Multiplier to account for hours of the day that the pedestrian traffic is engaged at the door. The multiplier is 1 (or a fraction of the hour), at the specific hours of the day pedestrians are engaged at the door and 0 for all other hours (dimensionless)

$H_{heating}$ = Multiplier to account for hours of the year when the heating system is enabled. The multiplier is 1 when the outside air temperature is below the heating system balance point temperature and 0 for all other hours (dimensionless)

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

$$Elec_{fan-c} = \sum_{h=1}^{8760} E_{fan-c} \quad (10)$$

$$E_{fan-c} = -HP \times 0.7457 \times O_p \times H_{cooling} \quad (10a)$$

Where:

$Elec_{fan-c}$ = Annual Electricity Penalty- due to the operation of the fan on the air curtain during the cooling season (kWh/yr)

E_{fan-c} = Hourly Electricity Penalty- due to the operation of the fan on the air curtain during cooling season (kWh)

HP = Air curtain fan electric input power (hp)

0.7457 = Conversion factor (1 horsepower = 0.7457 kilowatt)

O_p = Multiplier to account for hours of the day that the pedestrian traffic is engaged at the door. The multiplier is 1 (or a fraction of the hour), at the specific hours of the day pedestrian are engaged at the door and 0 for all other hours (dimensionless)

$H_{cooling}$ = Multiplier to account for hours of the year when the cooling system is enabled. The multiplier is 1 when the outside air temperature is above the cooling system balance point temperature and 0 for all other hours (dimensionless)

4. **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**

$$\boldsymbol{Elec_{cooling} = \sum_{h=1}^{8760} E_{savings-1}} \quad (11)$$

$$\boldsymbol{E_{savings-1} = \frac{q_c}{COP} \times O_p \times H_{cooling} \times E} \quad (11a)$$

Where:

$E_{savings-1}$ = Hourly Electricity Savings- Cooling Season due to the reduction of cooling load for Baseline 1 (kWh)

q_c = Rate of heat transfer through doorway without vestibule - cooling season (kW)

COP = Seasonal COP, cooling

E = Air Curtain effectiveness (dimensionless)

5. **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**

$$Elec_{cooling} = \sum_{h=1}^{8760} E_{savings-2} \quad (12)$$

$$E_{savings-2} = \frac{(q_d - q_e)}{COP} \times O_p \times H_{cooling} \quad (12a)$$

$$q_d = q_c \times (1 - VE) \quad (12b)$$

$$q_e = q_d \times (1 - E) \quad (12c)$$

Where:

$E_{savings-2}$ = Hurly Electricity Savings- due to the reduction of cooling load during cooling season for Baseline 2 (kWh)

q_c = Rate of heat transfer through doorway without vestibule (kW)

q_d = Sensible heat load cooling season - accounting for vestibule effectiveness (kW)

q_e = Sensible heat load cooling season - accounting for air curtain effectiveness (kW)

E = Air Curtain effectiveness (dimensionless)

VE = Vestibule effectiveness (dimensionless)

6. Calculation of the energy required (electricity)

$$q_c = \rho_o \times Q \times (h_{oc} - h_{ic}) \quad (13)$$

Where:

Q = Airflow rate through the doorway (m^3/s)

h_{oc} = Outside enthalpy-cooling season (kJ/kg)

h_{ic} = Inside enthalpy-cooling season (kJ/kg)

ρ_o = Density of air density (kg/m^3)

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		Hourly calculation based on CWEC 2020, London, ON [11]

Variable	Definition	Value and Unit	Source/Comments
Δp_I	Pressure that acts to balance inflows and outflows, including mechanical systems (Pa)	0	Assumed that no system will balance inflows and outflows
$T_{i-heating}$	Absolute indoor temperature (K). Heating Temperature Setpoint Schedule	various	Hourly profile based on 2020 NECB Heating Temperature Setpoint Schedule [12]
$T_{i-cooling}$	Absolute indoor temperature (K). Cooling Temperature Setpoint Schedule	various	
O_p	Fraction of the hour the pedestrian is engaged at the door	various	Door-opening frequency estimation by building type from PNNL [13]

		Weekdays only operation		Full week operation	
	Hours of day	**Weekday**	**Weekend**	**Weekday**	**Weekend**
$T_{i-heating}$ ($\mathcal{C}$)	1-5	18	18	18	18
	6	20	18	20	20
	7-20	22	18	22	22
	21-24	18	18	18	18
$T_{i-cooling}$ ($\mathcal{C}$)	1-5	26	26	26	26
	6-20	24	26	24	24
	21-24	26	26	26	26
O_p	1-6	0	0	0	0
	7	0.01	0	0.01	0.01
	8	0.52	0	0.05	0.05
	9	0.08	0	0.01	0.01
	10	0.08	0	0.01	0.01
	11	0.08	0	0.05	0.05
	12	0.08	0	0.05	0.05
	13	0.11	0	0.07	0.07
	14	0.08	0	0.07	0.07
	15	0.08	0	0.05	0.05
	16	0.49	0	0.05	0.05
	17	0.34	0	0.05	0.05
	18	0.11	0	0.07	0.07
	19	0.04	0	0.04	0.04
	20	0	0	0.04	0.04
	21	0	0	0.06	0.06

Variable	Definition	Value and Unit	Source/Comments
	22-24	0 0 0.01 0.01	
T_o	Absolute outdoor temperature (K)		Hourly profile based on CWEC 2020, London, ON [11]
$C_p(1)$	Pressure coefficient when wind is at 0°	0.6	[5]
$C_p(2)$	Pressure coefficient when wind is at 180°	-0.3	
$C_p(3)$	Pressure coefficient when wind is at 90°	-0.65	
$C_p(4)$	Pressure coefficient when wind is at 270°	-0.65	
U_{met}	Hourly wind speed		Hourly profile based on CWEC 2020, London, ON [11]
δ_{met}	Atmospheric boundary layer thickness from a nearby meteorological station	270 m	Based on Terrain Category 3 [14]
H_{met}	Height at which the anemometer that records U_{met} is located	9 m	
a_{met}	Local building terrain from the nearby meteorological station	0.14	
δ	Local atmospheric boundary layer thickness	370 m	Based on Terrain Category 2 [14]
a	Local building terrain	0.22	
s	Shelter factor	0.7	Based on Shelter Class 3 [15], [16]
C_p	Specific heat of air	1,000 J/(kg·K)	Common assumptions table
h_{ic}	Inside enthalpy for cooling season		Hourly calculation based on indoor properties of the air (cooling temperature setpoint schedule, and indoor relative humidity) [5]

[5] Enthalpy is estimated using a polynomial approximation based on dry-bulb temperature and relative humidity, adapted from a simplified method found in an online source (https://www.mrexcel.com/board/threads/excel-formula-for-calculating-airs-enthalpy-from-dry-bulb-temperature-and-relative-humidity.871843/). While this approach is not fully rigorous, a due diligence

Variable	Definition	Value and Unit			Source/Comments
h_{oc}	Outside enthalpy for cooling season				Hourly calculation based on outdoor properties of the air (dry bulb temperature and relative humidity) from CWEC 2020, London, ON [11] [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)	3	6	6	
HP	Air curtain horsepower	1/15	1/8	1/8	[17]
H^*	Average building height	27ft (8.2m)			Average value from sample of 94 EGI projects
E	Effectiveness of air curtain	75% (Range between 60% - 90%)			[18]
VE	Effectiveness of vestibule	36%			[19]
Eff	Commercial heating system efficiency	80%			Common assumptions table
COP	Commercial cooling system seasonal COP	3.8			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			[20]
	Density conversion factor from metric to imperial, multiply by	0.062428 (lb/ft^3)/(kg/m^3)			[21]
	Conversion factor from Watt to Btu/hr	1 Watt = 3.412 Btu/hr			[22]
	Enthalpy rate conversion factor from imperial to metric, multiply by	2.326 kJ/kg/Btu/lb			[23]
	Energy density of natural gas	35,738 Btu/m^3			Common assumptions table

comparison against standard online tools using approved psychrometric methods showed an average deviation of 0.1%, which is considered acceptable for this analysis.

Variable	Definition	Value and Unit	Source/Comments
	Conversion from HP to kWh	0.7457 kW/HP	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′) = 1,400 m^3/yr = 1,400 m3/yr

Annual Electrical Impact:

2 (6′x8′) = 220 kWh/yr = 220 kWh/yr

The total natural gas savings is 1,400 m3/yr and the total electrical savings is 220 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 [24].

INCREMENTAL COST

The purchase and installation cost for air curtains is summarized in the table below. Table 5. Incremental Cost

Table 2 Incremental cost

Definition	Door size (W' x H')					
	3'x7'	6'x7'	6'x8'	2x (3'x7')	2x (6'x7')	2x (6'x8')
Vestibule	$2,525	$3,433	$3,433	$4,005	$5,261	$5,261

Without Vestibule	$2,780	$4,800	$4,800	$4,515	$7,995	$7,995
Average Incremental cost ($ CAD)	$2,653	$4,117	$4,117	$4,260	$6,628	$6,628

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

Version Date and Revision History	
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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	0.35	0.79
	2 Speed	1.05	2.11
	VFD	1.75	2.59
Annual Electric Savings Rate (kWh/CFM)	Constant Speed	0	0
	2 Speed	1.33	1.70
	VFD	2.22	2.42
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:

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

And,

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

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	68°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$_{72}$	188,974 hr °F	83,612 hr °F
Cooling Degree Hours$_{72}$	11,144 hr °F	9,802 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.

$$Heat\ Load\ Rate = 1.08 \frac{Btu}{hr\ °F\ CFM} \times 83{,}612\ hr\ °F = 90{,}301 \frac{Btu}{CFM}$$

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

$$NG\ Savings\ Factor = \frac{90{,}301\ Btu/CFM}{35{,}738 \frac{Btu}{m^3}} \times \left(\frac{100\%}{80\%} - \frac{50\%}{90\%}\right) = 1.75 \frac{m^3}{CFM}$$

Therefore, annual natural gas savings are:

$$Annual\ NG\ Savings = 1{,}700\ CFM \times 1.75 \frac{m^3}{CFM} = 2{,}983\ m^3$$

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

$$Motor\ kWh\ Rate = \sum_{h=1}^{24\ hrs} \left(V_h - {V_h}^{2.5}\right) \times 365 \frac{days}{yr} \times \frac{1\ hp}{90\% - 5\%} \times 0.746 \frac{kW}{hp} \div 1{,}700\ CFM$$
$$= 1.86 \frac{kWh}{CFM}$$

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.

$$Cooling\ Load\ Rate = \left(1.08 \frac{Btu}{hr\ °F\ CFM} \times 9{,}802\ hr\ °F\right) = 10{,}586 \frac{Btu}{CFM}$$

And,

$$Cool\ kWh\ Rate = 10{,}586 \frac{Btu}{CFM} \times (100\% - 50\%) \div 12{,}000 \frac{Btu}{ton} \times\ 0.924 \frac{kW}{ton} = 0.41 \frac{kWh}{CFM}$$

The total electrical savings rate is then:

$$kWh\ Savings\ Rate^{6} = 1.86 \frac{kWh}{CFM} + 0.41 \frac{kWh}{CFM} = 2.27 \frac{kWh}{CFM}$$

There for the annual electric savings are:

$$Annual\ kWh\ Savings = 1{,}700\ CFM \times 2.27 \frac{kWh}{CFM} = 3{,}857\ kWh$$

[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

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

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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

<table>
<tr><th>Parameter</th><th colspan="3">Definition</th></tr>
<tr><td>Measure Category</td><td>Name identifier</td><td>New Construction (NC)</td><td>Time of Natural Replacement (TNR)</td></tr>
<tr><td rowspan="4">Baseline Technology</td><td rowspan="2">Storage DHW_UEF</td><td colspan="2">Non-condensing natural gas-fired storage water heater have an input rate of ≥ 75 kBtu/hr but ≤ 105 kBtu/hr, have rated nominal volume of ≤ 120 US gallon, use single-phase power, and limit water temperatures to < 180°F</td></tr>
<tr><td>UEF = 0.8107-0.00021Vs</td><td>UEF = 0.6597-0.00024Vs</td></tr>
<tr><td rowspan="2">Storage DHW_TE</td><td colspan="2">Natural gas-fired commercial storage water heater with input rate ≥ 75 kBtu/hr. Other than described in baseline Storage DHW_UEF</td></tr>
<tr><td>TE =90%</td><td>TE = 80%</td></tr>
<tr><td rowspan="4">Efficient Technology</td><td rowspan="2">Storage DHW_UEF</td><td colspan="2">Condensing natural gas-fired storage water heater have an input rate of ≥ 75 kBtu/hr but ≤ 105 kBtu/hr, have rated nominal volume of ≤ 120 US gallon, use single-phase power, and limit water temperatures to < 180°F, with minimum efficiency:</td></tr>
<tr><td colspan="2">UEF = 0.86</td></tr>
<tr><td rowspan="2">Storage DHW_TE</td><td colspan="2">Condensing natural gas-fired commercial storage water heater have an input rate of ≥ 75 kBtu/hr other than described in efficient Storage DHW_UEF, with minimum efficiency:</td></tr>
<tr><td>TE = 95%</td><td>TE = 92%</td></tr>
</table>

<table>
<tr><th>Parameter</th><th colspan="6">Definition</th></tr>
<tr><td>Market Type</td><td colspan="6">Commercial</td></tr>
<tr><td rowspan="11">Annual Natural Gas Savings Rate (m³ per kBtu/hr of rated input)</td><td rowspan="2">Name Identifier</td><td rowspan="2">Measure Category</td><td rowspan="2">Efficiency level</td><td colspan="3">Utilization Category*</td></tr>
<tr><td>Low</td><td>Medium</td><td>High</td></tr>
<tr><td rowspan="4">Storage DHW_UEF</td><td rowspan="2">TNR</td><td>UEF = 0.86</td><td>2.515</td><td>4.103</td><td>5.699</td></tr>
<tr><td>UEF = 0.89</td><td>2.868</td><td>4.677</td><td>6.497</td></tr>
<tr><td rowspan="2">NC</td><td>UEF = 0.86</td><td>0.584</td><td>0.952</td><td>1.323</td></tr>
<tr><td>UEF = 0.89</td><td>0.869</td><td>1.417</td><td>1.968</td></tr>
<tr><td rowspan="5">Storage DHW_TE</td><td rowspan="3">TNR</td><td>TE = 92%</td><td>1.137</td><td>1.855</td><td>2.577</td></tr>
<tr><td>TE = 95%</td><td>1.422</td><td>2.319</td><td>3.221</td></tr>
<tr><td>TE = 97%</td><td>1.611</td><td>2.628</td><td>3.651</td></tr>
<tr><td rowspan="2">NC</td><td>TE = 95%</td><td>0.421</td><td>0.687</td><td>0.954</td></tr>
<tr><td>TE = 97%</td><td>0.590</td><td>0.962</td><td>1.336</td></tr>
<tr><td colspan="6">*See Table 2 for utilization categories by facility type</td></tr>
<tr><td>Measure Life</td><td colspan="6">15 years</td></tr>
<tr><td rowspan="2">Incremental Cost ($ CAD)</td><td colspan="3">250 KBtu/hr input rating and below</td><td colspan="3">$2,591</td></tr>
<tr><td colspan="3">Above 250 KBtu/hr input rating</td><td colspan="3">$4,464</td></tr>
<tr><td>Restrictions</td><td colspan="6">This measure applies to the installation of condensing natural gas storage water heaters in commercial facilities.</td></tr>
</table>

OVERVIEW

The measure involves installing 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 minimum efficiency required by regulation and the average efficiency values derived by the AHRI and ENERGY star data base of equipment sold in Canada.

There is continuous heat loss from the storage water heater tanks 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 applies to the installation of natural gas condensing storage water heaters in commercial facilities for either new construction or time of natural replacement measure category. The units provide hot water for entire commercial facilities, or in some cases for selected loads within the facility.

Water heaters are a regulated product in Ontario, Canada. Commercial natural gas-fired storage water heater means a stationary gas-heated water container that uses propane or natural gas for fuel, has an input rate of greater than 21.97 kW (75,000 Btu/h) and has a Vr of at least 76 L (20 US gallons) as described by the government of Canada in the Energy Efficiency Regulation. [1]

This measure applies to the following type of commercial natural gas-fired storage water heaters:

1. Commercial gas-fired storage water heaters that have an input rate of > 21.97 kW (75,000 Btu/h) but ≤ 30.5 kW (105,000 Btu/h), have a Vr of ≤ 454 L (120 US gallons), use single-phase power and limit water temperatures to < 82°C (180°F). "Storage DHW_UEF" is the name identifier used throughout this document.
2. Commercial gas-fired storage water heaters, other than those described in item 1. "Storage DHW_TE" is the name identifier used throughout this document.

BASELINE TECHNOLOGY

The baseline technology for NC measure category is a natural gas fueled storage water heater, with input rate 75 kBtu/hr. and greater, providing the hot water needs for all or portions of commercial facilities.

The baseline technology for TNR measure category is a non-condensing natural gas fueled storage water heater, rated 75 kBtu/hr. and greater, providing the hot water needs for all or portions of commercial facilities.

The performance parameter (thermal efficiency or uniform energy factor) is defined by the federal and provincial regulations given the input rate of the water heater [1]:

1. For commercial gas-fired storage water heater with an input rate of > 75,000 Btu/hr but ≤ 105,000 Btu/hr and nominal volume of 20 US gallons or more up to 120 US gallons, the performance parameter used to define the efficiency is the Uniform Energy Factor (UEF). The minimum requirement for replacement units is UEF = 0.6597-0.00024 Vs, whereas for other than replacement units the minimum requirement is UEF = 0.8107-0.00021 Vs. This defines the baseline for time of natural replacement and new construction measure categories-respectively for natural gas-fired storage water heaters with name identifier "Storage DHW_UEF".
2. For commercial gas-fired storage water heater, other than those described in item 1 above, the performance parameter used to define the efficiency is Thermal Efficiency (TE). The minimum requirement for replacement units is TE = 80%, whereas for other than replacement units the minimum requirement is TE = 90%. This defines the baseline for time of natural replacement and new construction measure categories-respectively-for natural gas-fired storage water heaters with name identifier "Storage DHW_TE".

EFFICIENT TECHNOLOGY

The high efficiency technology is a natural gas fueled condensing storage water heater. The performance parameter (thermal efficiency or uniform energy factor) is defined by the federal and provincial regulations given the input rate of the commercial gas-fired water heater:

1. For commercial natural gas-fired storage water heater with name identifier "Storage DHW_UEF" as described in the Baseline Technology section, the efficient technology is a condensing gas-fired storage water heater with minimum UEF = 0.86 for new construction and for natural replacement measure categories.
2. For commercial natural gas-fired instantaneous water heater, with name identifier "Storage DHW_TE" as described in the Baseline Technology section, the efficient technology is a condensing gas-fired storage water heater with minimum TE = 95% for new construction and TE=92% for natural replacement measure categories, respectively [2] [3].

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.

ENERGY IMPACTS

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

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

Neither electric, nor water consumption impacts associated with this measure were assessed.

NATURAL GAS SAVINGS ALGORITHMS

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 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,

$Natural\ Gas\ Savings$	=Annual natural gas savings factor expressed as m^3 per kBtu/hr. input rating of the new condensing storage water heater
$EFLH$	=Annual Equivalent Full Load Hours for the utilization category (hours)
$\eta_{proposed}$	=The average efficiency for condensing storage water heater efficient technology.
$\eta_{baseline}$	=The average efficiency for the baseline storage water heater
NG_{ec}	= Natural gas energy content (kBtu/hr/m^3)

ASSUMPTIONS

The 2023 ASHRAE HVAC Applications 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 service hot water demand for a specific building type (US gallon/occupant-hour) [4] [5]

OS_{factor} = Typical storages water heater oversizing factor relative to 15-minute peak demand (130%) [5]

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

Table 2 provides the EFLH values derived from this data and a description of typical building types and end uses for each utilization category.

Table 2. 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

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

Table 3. Assumptions

Variable	Definition	Inputs		Source/Comments
EFLH	Annual equivalent full load hours of operation	Table 2		Based on data from the ASHRAE HVAC Application Handbook [4] as shown in EFLH formula in the Natural Gas Savings Algorithm section.
$\eta_{baseline}$	Baseline efficiency for name identifier "Storage DHW_UEF"	NC	UEF = 0.80[1]	Energy Efficiency Regulation for Commercial gas-fired storage water heaters [1].
		TNR	UEF = 0.65[1]	
	Baseline efficiency for name identifier "Storage DHW_TE"	NC	TE = 90%	
		TNR	TE = 80%	

[1] Baseline technology, UEF=0.80 and 0.65 was obtained by substitution of Vs = 58 US gallons (average storage volume of units available in the market) into UEF = 0.8107-0.00021Vs and UEF = 0.6597-0.00024Vs as per regulation for NC and TNR measure categories respectively.

Variable	Definition	Inputs		Source/Comments
$\eta_{proposed}$	Efficient technology Efficiency for name identifier "Storage DHW_UEF"	NC/ TNR	UEF = 0.86 UEF = 0.89	Two levels of efficiency identified from the qualifying equipment available in the market [6], [7]
	Efficient technology Efficiency for name identifier "Storage DHW_TE"	NC	TE= 95% TE= 97%	Different levels of efficiency identified from the qualifying equipment available in the market [8], [9]
		TNR	TE= 92% TE= 95% TE= 97%	
NG_{ec}	Energy density of natural gas	35.738 kBtu/m^3		Common assumptions table
	Water heater storage Volume	58 Us gallons		Average storage volume of units available in the market [6], [7]

SAVINGS CALCULATION EXAMPLE

The example below illustrates the savings calculation for the installation of a condensing storage water heater with rated input capacity of 400 kBtu/hr and TE = 95%. at time of natural replacement in a full-service restaurant.

Table 2 above indicates that installation in a full-service restaurant is in the high utilization category, with a savings value from Table 1= 3.221 m^3 per kBtu/hr. rated input capacity.

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

$$3.221\, m^3 \Big/ \frac{kBtu}{hr} \times 400 \frac{kBtu}{hr} = 1{,}289\, m^3$$

USES AND EXCLUSIONS

This measure applies to natural gas-fueled condensing storage water heaters installed in commercial facilities and serving all or part of the service water heating load. This is applicable to measure categories new construction and time of natural replacement installation. The replacement of a preexisting tankless water heater is not eligible.

MEASURE LIFE

The measure life is 15 years. [10]

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 [11], and is consistent with data from other studies.

Table 6. Incremental Cost[2]

Input Rating	Incremental Cost of Equipment	Incremental Cost of Installation[3]	Total Incremental
250 KBtu/hr and below	CAD $2,432 [12] [13] [14]	$159 [11]	$2,591
Above 250 kBtu/hr	CAD $4,306 [12] [13] [14]	$159 [11]	$4,464

REFERENCES

[1] Government of Canada, "Energy Efficiency Regulation for Gas-fire storage water heaters-commercial," [Online]. Available: https://natural-resources.canada.ca/energy-efficiency/energy-efficiency-regulations/guide-canadas-energy-efficiency-regulations/gas-fired-storage-water-heaters-commercial/25218. [Accessed 13 December 2023].

[2] Ontario, "Building Code 332/12," 1992. [Online]. Available: https://www.ontario.ca/laws/regulation/120332.

[3] Ontario, "ENERGY AND WATER EFFICIENCY - APPLIANCES AND PRODUCTS 509/18," 1998. [Online]. Available: https://www.ontario.ca/laws/regulation/180509#BK12.

[4] ASHRAE, 2023 HVAC Applications Handbook - Section 51, Table 6, Atlanta, GA: ASHRAE, 2023.

[2]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/).

[3] The incremental cost for installation of a condensing storage water heater is similar to a condensing tankless water heater.

[5] M. Armstrong, "Enbridge Prescriptive Commerecial Bolier Program - Prescriptive Savings Analysis, pages 14-15," AMEC, Cambridge, Ontario, 2012.

[6] E. S. C. c. equipment, "Commercial Water Heaters sold in Canada- ENERGY Star database_UEF," [Online]. Available: https://www.energystar.gov/productfinder/product/certified-water-heaters/results?SetLanguage=English&NRCAN=on. [Accessed 13 December 2023].

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[8] E. S. C. e. TE, "Commercial Water Heaters sold in Canada- ENERGY Star database_TE," [Online]. Available: https://www.energystar.gov/productfinder/product/certified-commercial-water-heaters/results?SetLanguage=English&NRCAN=on. [Accessed 13 December 2023].

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

Version Date and Revision History	
Version	3.1
OEB Filing Date	April 30, 2024
OEB Approval Date	
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

Parameter		Definitions		
Measure Category		New Construction (NC) Time of Natural Replacement (TNR)		
Baseline Technology		80% Thermal Efficiency, 78% Annual Efficiency		
Efficient Technology		90% Thermal Efficiency, 89% Annual Efficiency		
Market Type		Commercial, Multi-residential		
Annual Natural Gas Savings Rate (m^3 /kBtu/hr)		New Construction	4.62 m^3 per kBtu/hr input rating	
		Time of Natural Replacement	6.52 m^3 per kBtu/hr input rating	
Annual Electric Impacts (kWh/year)		**30 – <125 kBtu/hr**	**125 – <225 kBtu/hr**	**225 – <325 kBtu/hr**
	NC	-173 kWh	-310 kWh	-320 kWh
	TNR	-244 kWh	-438 kWh	-451 kWh
Measure Life		18 years		
Incremental Cost ($ CAD)		$16.07 per kBtu/hr input rating		
Restrictions		Must be a new commercial installation of a condensing unit heater		

OVERVIEW

The measure is for the installation of a condensing unit heater in commercial facilities. A condensing unit heater is a power-vented unit with a primary, non-condensing heat exchanger, followed by a secondary heat exchanger in which waste heat from the flue gases is recovered. As heat is extracted from the flue gases, some water vapor

condensation occurs in the flue gases. 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 unit's operating efficiency. 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)

$Elect_{base}$ = Electrical power of the baseline unit (kW)

$Elect_{EE}$ = Electrical power 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	1,172 hrs	Common assumptions table
$EFLH_{TNR}$	Equivalent full load hours for a unit heater – time of natural replacement	1,651 hrs	Common assumptions table

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

Table 5. Average Electrical Power [1]

Size Range*	Baseline (kW)	Efficient (kW)
30 – <125 kBtu/hr	0.155	0.301**
125 – <225 kBtu/hr	0.392	0.657

Size Range*	Baseline (kW)	Efficient (kW)
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 power 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.

$$NG\ savings\ factor = \frac{1{,}172\frac{hr}{yr}}{35.738\frac{kBtu}{m^3}} \times \left(\frac{89\%}{78\%} - 1\right) = 4.62\ m^3/year \text{ per kBtu/hr input}$$

$$Annual\ NG\ savings = 4.62\frac{\frac{m^3}{yr}}{\frac{kBtu}{hr}} \times 162.5\frac{kBtu}{hr} = 751\frac{m^3}{yr}$$

The annual electric penalty is:

$$Annual\ kWh\ Penalty = 1{,}172\ hrs \times (0.392 - 0.657)\ kW = -310\ kWh$$

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]

REFERENCES

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

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[4] Econoler, "Evaluation Du Programme PE225 - Aerotherme a Condensation," Gaz Metro, 2016.

[1] The incremental costs for a condensing unit heater were derived from the NGTC report, reference [1]; however, the size ranges used in this substantiation document deviate from the reference. 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 and adjusted for inflation at the rate of 1.85%. Inflation rates retrieved from https://www.bankofcanada.ca/rates/related/inflation-calculator/.

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

Version Date and Revision History	
Version history	3.1
OEB Filing Date	March 19, 2026
OEB Approval Date	
End date	
Commercial → Space Heating → Demand Controlled Ventilation → Retrofit/Time of Natural Replacement/New Construction	

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	Retrofit (R), Time of Natural Replacement (TNR), and New Construction (NC)			
Baseline Technology	Unscheduled ventilation system with natural gas fueled heating	Provides constant volume ventilation that meets the minimum outdoor air requirement for full occupancy as specified in Table 6-1 of ASHRAE Standard 62.1-2022. [1]		
	Scheduled ventilation system with natural gas fueled heating	Designed and operating in a manner that provides the minimum outdoor air requirement as specified in Table 6-1 of ASHRAE Standard 62.1-2022 [1], but is scheduled to turn off ventilation during unoccupied periods.		
Efficient technology	Demand Control 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.		
Market type	Commercial			
Annual Natural Gas Savings[1] (m^3/ft^2)	**Space Type category**	**Space type subcategory (all spaces included)**	**Unscheduled baseline**	**Scheduled baseline**
	Libraries	Public libraries, Educational facilities libraries, Office Buildings main entry lobbies	0.548	0.082
	Office	Office space, Office computer room (not printing), Bank vaults/ safe deposit	0.307	0.034
	Office Buildings Reception areas	Office Buildings reception areas, Other Buildings reception areas	0.907	0.218
	Conference/meeting space_Office	Office Buildings conference/meeting space, Office Buildings breakrooms, Office Buildings telephone/data entry, Legislative chambers,	1.525	0.387

[1] Please note that the annual natural gas savings and electricity impact are specific to the conditioned space floor area and is does not refers to the entire building conditioned floor area. Therefore, for implementation purposes of the savings/impacts in table 1, the floor area of the specific conditioned qualifying space must be collected.

	Conference/meeting space_Other	Other Buildings conference/meeting space, Hotels/Motels/Resorts/Dormitories/Multi-Residential main lobbies/prefunction	1.314	0.391
	Senior/Nursing/Long-Term Care Facility (Common Areas)	Senior/Nursing/Long-Term Care Facility (Common Areas)	1.257	0.632
	Restaurants dining rooms[2]	Restaurant dining rooms, Fast Food and Quick Service, Bars and Nightlife Venues	3.430	1.705
	Bowling alley (seating)	Bowling alley (seating)[3]	2.059	1.010
	Warehouse	Warehouse	0.200	0.001
	Exercise Center/Sports Arena	Gymnasium, Sports arena (play arena), Game arcades, Sport court, Health club/weight rooms	1.024	0.413
	Health club aerobics room	Health club aerobics room, Yoga/Pilates studio, Dance studio	3.755	2.021
	Sports and Entertainment	Sports and Entertainment Spectator areas, Gambling casinos	4.842	2.558
	Disco/dance floors	Disco/dance floors	9.207	5.052
	Public Assembly Spaces	Museums/galleries, Museums (children's), Mall common areas	1.673	0.494
	Public Assembly Spaces_Courtrooms	Courtrooms	1.853	0.508
	Multipurpose assembly	Hotels/Motels/Resorts/Dormitories/Multi-Residential multipurpose assembly space, Beauty and nail salons	2.892	0.906
	Multipurpose assembly_ Arts & Sport	Sports and Entertainment stages/studios, Educational facilities multi-use assembly[4], Public Assembly Spaces auditorium seating area, Public assembly lobbies[5]	3.690	1.215
	Places of religious worship	Places of religious worship	3.228	0.967
	Retail	Retail/Sales space, Pharmacy (prep. area), Barbershop, Manufacturing where hazardous materials are not used, Pet shops (animal areas)	0.917	0.163
	Retail_Supermarket/ Grocery store	Supermarket, Grocery store, Convenience store	0.471	0.099
	Retail_Coin-operated laundries	Coin-operated laundries	1.085	0.247
	Educational Facilities	Primary Education Classrooms (ages 5-8), Educational Facilities Computer lab, Educational Facilities Media center, Educational Facilities Art classroom, Educational Facilities Wood/ metal shop	1.633	0.338

[2] It does not include kitchen area/space

[3] It refers to the seating that is usually in the open space

[4] It does not include Educational facilities Gymnasium

[5] It does not include Office Buildings main entry lobbies, Banks lobbies, Public assembly lobbies, Hotels/Motels/Resorts/Dormitories/Multi-Residential main/prefunction lobbies

	Secondary Education Classroom	Secondary Education Classroom	2.142	0.515
	Primary/Secondary Education Gymnasium	Primary/Secondary Education Gymnasium	1.314	0.206
	Post-Secondary Education Classroom	Post-Secondary Education Classroom	2.613	0.717
	Post-Secondary Education Lecture Hall	Post-Secondary Education Lecture Hall	5.758	1.654
	Other Educational Facilities	Music/theater/dance classroom, Daycare (through age 4), Daycare sickroom, Science laboratories, University/College laboratories	1.872	0.397
	Hotels, Motels, Resorts, Dormitories[6]	Hotels/ Motels/Resorts/Dormitories bedroom/living room/barracks sleeping areas, University/College bedroom/living room and barracks sleeping areas	0.300	0.300
	Multi-Residential[7]	Multi-Residential bedroom/living room/barracks sleeping areas	0.158	0.158
	Laundry room	Laundry rooms (central) or within dwelling units for: Hotels, Motels, Resorts, Dormitories, University/College, Multi-Residential	0.610	0.082
	Other Commercial spaces[8]	Coffee stations[9], Photo studios, Banks, Bank lobbies, Sorting/ Packing/Light assembly, Break rooms	0.692	0.128
Annual Electricity Impacts[10] (kWh/ft^2)	**Space Type**	**Similar Space Types**	**Unscheduled baseline**	**Scheduled baseline**
	Libraries	Public libraries, Educational facilities libraries, Office Buildings main entry lobbies	0.085	0.053
	Office	Office space, Office computer room (not printing), Bank vaults/ safe deposit	0.062	0.016
	Office Buildings Reception areas	Office Buildings reception areas, Other Buildings reception areas	0.219	0.105
	Conference/meeting space_Office	Office Buildings conference/meeting space, Office Buildings breakrooms, Office Buildings telephone/data entry, Legislative chambers,	0.376	0.187
	Conference/meeting space_Other	Other Buildings conference/meeting space, Hotels/Motels/Resorts/Dormitories/Multi-Residential main lobbies/prefunction	0.376	0.187
	Senior/Nursing/Long-Term Care Facility (Common Areas)	Senior/Nursing/Long-Term Care Facility (Common Areas)	0.316	0.254

[6] Please note that this refers only to floor area from living room and bedroom.

[7] It does not include Hotels/Motels/Resorts/Dormitories/College/University bedroom/living room and barracks sleeping areas. In addition, please note that this refers only to floor area from living room and bedroom within an in-suite/apartment in a multi-family building.

[8] It does not include warehouse.

[9] This refers to an enclosed space dedicated for coffee stations, like a business area etc. Coffee station as part of a very open and/or multi-function space does not qualify

[10] Annual Electricity impacts are not applicable to system with free cooling economizer as electricity savings will be less than presented in table 1.

	Restaurants dining rooms[11]	Restaurant dining rooms, Fast Food and Quick Service, Bars and Nightlife Venues	0.396	0.313
	Bowling alley (seating)	Bowling alley (seating)	1.073	0.846
	Warehouse	Warehouse	0.639	0.501
	Exercise Center/Sports Arena	Gymnasium, Sports arena (play arena), Game arcades, Sport court, Health club/weight rooms	0.034	0.000
	Health club aerobics room	Health club aerobics room, Yoga/Pilates studio, Dance studio	0.285	0.205
	Sports and Entertainment	Sports and Entertainment Spectator areas, Gambling casinos	1.231	1.003
	Disco/dance floors	Disco/dance floors	1.570	1.269
	Public Assembly Spaces	Museums/galleries, Museums (children's), Mall common areas	3.054	2.507
	Public Assembly Spaces_Courtrooms	Courtrooms	0.400	0.321
	Multipurpose assembly	Hotels/Motels/Resorts/Dormitories/Multi-Residential multipurpose assembly space, Beauty and nail salons	0.468	0.245
	Multipurpose assembly_ Arts & Sport	Sports and Entertainment stages/studios, Educational facilities multi-use assembly, Public Assembly Spaces auditorium seating area, Public assembly lobbies	0.722	0.588
	Places of religious worship	Places of religious worship	0.955	0.789
	Retail	Retail/Sales space, Pharmacy (prep. area), Barbershop, Manufacturing where hazardous materials are not used, Pet shops (animal areas)	1.170	0.499
	Retail_Supermarket/ Grocery store	Supermarket, Grocery store, Convenience store	0.157	0.106
	Retail_Coin-operated laundries	Coin-operated laundries	0.089	0.064
	Educational Facilities	Primary Education Classrooms (ages 5-8), Educational Facilities Computer lab, Educational Facilities Media center, Educational Facilities Art classroom, Educational Facilities Wood/ metal shop	0.217	0.160
	Secondary Education Classroom	Secondary Education Classroom	0.401	0.180
	Primary/Secondary Education Gymnasium	Primary/Secondary Education Gymnasium	0.552	0.274
	Post-Secondary Education Classroom	Post-Secondary Education Classroom	0.705	0.381
	Post-Secondary Education Lecture Hall	Post-Secondary Education Lecture Hall	1.581	0.880

[11] It does not include kitchen area/space

	Other Educational Facilities	Music/theater/dance classroom, Daycare (through age 4), Daycare sickroom, Science laboratories, University/College laboratories	0.463	0.211
	Hotels, Motels, Resorts, Dormitories	Hotels/ Motels/Resorts/Dormitories bedroom/living room/barracks sleeping areas, University/College bedroom/living room and barracks sleeping areas	0.157	0.157
	Multi-Residential[12]	Multi-Residential bedroom/living room/barracks sleeping areas	0.103	0.103
	Laundry room	Laundry rooms (central) or within dwelling units for: Hotels, Motels, Resorts, Dormitories, University/College, Multi-Residential	0.089	0.053
	Other Commercial spaces[13]	Coffee stations[14], Photo studios, Banks, Bank lobbies, Sorting/ Packing/Light assembly, Break rooms	0.155	0.062

Measure life	15 years	
Incremental Cost ($)	**Retrofit**	**Time of Natural Replacement/New Construction**
	$\$900 \times n + \$1{,}690$	$\$900 \times n + \$590$
	Where " n " is the number of sensors	
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. Systems equipped with heat recovery capabilities are not eligible for this prescriptive measure. Applications with free cooling economizers are eligible for this prescriptive measure[15]. For new construction applications, this measure is not eligible to buildings/spaces where Demand Control Ventilation (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

[12] It does not include Hotels/Motels/Resorts/Dormitories/College/University bedroom/living room and barracks sleeping areas
[13] It does not include warehouse
[14] This refers to an enclosed space dedicated for coffee stations, like a business area etc. Coffee station as part of a very open and/or multi-function space does not qualify
[15] The electricity impacts presented in table 1 are not applicable to system with free cooling economizer.

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 an individual space of a commercial building. 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.

Typical DCV implementation includes:

- Sensors: 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.
- Dampers: motorized outside air dampers that can modulate to align with ventilation required.
- Fans: variable speed fan with variable frequency drive (VFD) or electronically commutated motor (ECM).
- Controls: the sensor outputs are provided to an automated control system with a programmed 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 the HVAC equipment.
- HVAC equipment: typically, DCV control is implemented with a packaged roof top unit (RTU), air handling unit (AHU), or make-up air unit (MUA).

Demand Control Ventilation (DCV) can be applied to complex systems - such as multi-zone and variable air volume (VAV) configurations. The energy savings and impacts outlined here are based on a typical DCV setup, as described above. However, this measure isn't limited to that specific design: any DCV installation that's properly commissioned and calibrated to adjust outdoor-air intake in each commercial space according to actual occupancy will achieve comparable performance.

BASELINE TECHNOLOGY

The baseline technology is represented by a, 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 6-1 of ASHRAE Standard 62.1-2022. [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 6-1 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.

Two baseline scenarios are identified:

- Unscheduled baseline: the system provides the minimum outdoor air requirement on a continuous basis throughout the occupied and unoccupied periods of the building schedule.
- Scheduled baseline: the system provides the 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[16].

  Table 2 presents the baseline requirements.

Table 2 Baseline Technology

Type	Requirement
Unscheduled ventilation system with natural gas-fueled heating	Provides constant volume ventilation that meets the minimum outdoor air requirement for full occupancy as specified in Table 6-1 of ASHRAE Standard 62.1-2022. [1]
Scheduled ventilation system with natural gas fueled heating	Designed and operating in a manner that provides the minimum outdoor air requirement as specified in Table 6-1 of ASHRAE Standard 62.1-2022 [1], during the occupied periods, but is scheduled to turn off ventilation during unoccupied periods.

[16] 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 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 6-1 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
Demand Control ventilation (DCV) system with natural gas-fueled heating	Ventilation rate to the space 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. Ventilation is turned off during unoccupied periods.

ENERGY IMPACTS

The primary energy impact associated with the implementation of DCV is lower heating fuel consumption resulting from a reduction in the quantity of outside air introduced into the space during the heating season. Table 1 provides annual natural gas savings values (m^3/ft^2 area served) differentiated by space type. The savings are based on climate data for London, Ontario, using the Canadian Weather Year for Energy Calculation (CWEC). [2].

DCV also impacts electricity consumption for space cooling by reducing the quantity of outside air introduced into the space during the cooling season. Annual Electric impact values (kWh/ft^2) differentiated by space type are provided in Table 1.

There is no water consumption impact associated with this measure.

NATURAL GAS SAVINGS ALGORITHM

The annual natural gas savings calculations for each space type is 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. Resource Innovations has updated this tool to include updated weather information [2], and additional space types.

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.

$$Imperial: Flow_{Desing} = \frac{Occ_{Desing}}{1{,}000} \times R_p + R_a \quad (1)$$

$$Metric: Flow_{Desing} = \frac{Occ_{Desing}}{100} \times R_p + R_a \quad (1a)$$

where,

$Flow_{Desing}$	=	The design ventilation airflow rate (cfm/ft²) or (L/s/m²)
Occ_{Desing}	=	The design occupants per 1000 ft² or per 100 m² (from 2022 ASHRAE 62.1, Table 6-1)
R_p	=	The occupant ventilation rate, cfm or L/s per person (from 2022 ASHRAE 62.1, Table 6-1)
R_a	=	The area ventilation rate, cfm per ft² or L/s/m² (from 2022 ASHRAE 62.1, Table 6-1)

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.

$$Flow_{DCV} = \frac{Occ_{Desing}}{1{,}000} \times R_p \times \%Occ + R_a \quad (2)$$

Where,

$Flow_{DCV}$	=	The hourly efficient case ventilation airflow rate (cfm/ft²)
$\%Occ$	=	Percent of peak design occupancy, typical occupancy schedule for the specified space type [4]

3. **Input Energy Requirement**

$$NG_{Hourly-base} = \frac{60 \times Flow_{Desing} \times \rho_{Air} \times Cp_{Air} \times \left(T_{i-heating} - T_{db}\right) \times Hr_{heating}}{35{,}738 \times Eff} \quad (3)$$

$$NG_{Hourly-EE} \frac{60 \times Flow_{DCV} \times \rho_{Air} \times Cp_{Air} \times (T_i - T_{db}) \times Hr_{heating}}{35{,}738 \times Eff} \quad (4)$$

where,

$NG_{Hourly-base}$	=	The input heating energy requirement per hour for the baseline ($m^3/hr/ft^2$)
$NG_{Hourly-EE}$	=	The input hating energy requirement per hour for the DCV case ($m^3/hr/ft^2$)
60	=	Conversion factor (min/hr)
ρ_{Air}	=	The density calculated from typical weather data representing each hour in the specific climate zone (lb/ft^3)
Cp_{Air}	=	The specific heat of air (Btu/lb-°F)
$T_{i-heating}$	=	Indoor heating setpoint temperature (°F) – schedule-based temperature setback
T_{db}	=	Outdoor dry bulb temperature (°F)
$Hr_{heating}$	=	Multiplier to account for hours of the year when the heating system is enabled. The multiplier is 1 when the outside air temperature is below the heating system balance point temperature and 0 for all other hours
35,738	=	Energy density of natural gas (Btu/m^3)
Eff	=	The average heating system efficiency (%)

4. **Annual Natural Gas Savings:** Sum the hourly results to determine the annual natural gas input of the baseline and efficient case conditions and deduct the annual efficient case natural gas input from the baseline value to determine the predicted annual natural gas savings in m^3/ft^2.

$$NG_{Savings} = \sum_{0}^{8760} NG_{Hourly-EE} - \sum_{0}^{8760} NG_{Hourly-base} \quad (5)$$

where,

$NG_{Savings}$	=	The annual natural gas savings ($m^3/year/ft^2$)
$\sum_{0}^{8760} NG_{Hourly-EE}$	=	The sum of the efficient case (DCV) hourly natural gas consumption ($m^3/year/ft^2$)

$\sum_{0}^{8760} NG_{Hourly-base}$ = The sum of the baseline hourly natural gas consumption (m^3/year/ft^2)

5. **Calibration Factors:** Original DCV measure savings employed a calibration factor to modify the annual savings calculated by the methodology described above. 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. These calibration factors were used to determine a single calibration factor that is applied to all space types covered in Table 1.

$$NG_{Savings-calibrated} = NG_{Savings} \times Calibration\ factor \quad (6)$$

ELECTRIC IMPACTS ALGORITHMS

The annual electric impact calculations use a similar approach to the natural gas savings algorithm. The spreadsheet tool's multi-step algorithm is used to predict annual electric impacts for individual spaces.

The specific steps in the spreadsheet algorithm are as follows:

6. **Cooling Input Energy Requirement**.

$$Elec_{Hourly-base} = \frac{60 \times Flow_{Desing} \times \rho_{Air} \times Cp_{Air} \times (h_{oc} - h_{ic}) \times Hr_{cooling}}{ERR \times 1{,}000} \quad (7)$$

$$Elec_{Hourly-EE} \frac{60 \times Flow_{DCV} \times \rho_{Air} \times Cp_{Air} \times (h_{oc} - h_{ic}) \times Hr_{cooling}}{ERR \times 1{,}000} \quad (8)$$

$Elec_{Hourly-base}$ = The cooling energy requirement per hour for the baseline (kWh/ft^2)

$Elec_{Hourly-EE}$ = The cooling energy requirement per hour for the DCV case (kWh/ft^2)

h_{oc} = Enthalpy of outdoor air[17], calculated from typical weather data representing each hour in the specific climate zone (Btu/lb)

[17] To calculate Enthalpy of moist air (total heat content) based on dry bulb temperature (Tdb) and relative humidity (RH) using a fourth-degree polynomial approximation was used, to avoid complex iterative or lookup tables. Source: https://www.mrexcel.com/forum/excel-questions/871843-excel-formula-calculating-airs-enthalpy-dry-bulb-temperature-relative-

h_{ic}	=	Enthalpy of indoor air, calculated at setpoint temperature and indoor relative humidity (Btu/lb)
$Hr_{cooling}$	=	Multiplier to account for hours of the year when the cooling system is enabled. The multiplier is 1 when the outside air temperature is above the cooling system balance point temperature and 0 for all other hours.
EER	=	The average cooling system Energy Efficiency Ratio (Btu/hr/Watt)

7. **Annual Electricity Impacts:** Sum the hourly results to determine the annual electricity input of the baseline and efficient case conditions and deduct the annual efficient case natural gas input from the baseline value to determine the predicted annual electricity impact in kWh/ft².

$$Elec_{Impacts} = \sum_{0}^{8760} Elec_{Hourly-EE} - \sum_{0}^{8760} Elec_{Hourly-base} \quad (9)$$

where,

$Elec_{Impacts}$	=	The annual electricity impacts (kWh/year/ft²)
$\sum_{0}^{8760} Elec_{Hourly-EE}$	=	The sum of the efficient case (DCV) hourly electricity consumption (kWh/year/ft²)
$\sum_{0}^{8760} Elec_{Hourly-base}$	=	The sum of the baseline hourly electricity consumption (kWh/year/ft²)

humidity.html While this approach is not fully rigorous, a due diligence comparison against standard online tools using approved psychrometric methods showed an average deviation of 0.1%, which is considered acceptable for this analysis.

ASSUMPTIONS

Table 4 provides a list of assumptions used in the calculations of the natural gas savings and electricity impacts.

Table 4: Assumptions

Parameter	Value	Units	Reference
Heating Temperature Setpoint Schedule ($T_{i-heating}$)	various	°C	Hourly profile based on 2020 NECB Heating Temperature Setpoint Schedule [5]
Cooling Temperature Setpoint Schedule ($T_{i-cooling}$)	various	°C	
Percent of peak design occupancy, taken from building typical occupancy schedule for the specified space type ($\%Occ$)	various	%	
Outdoor temperature (T_{db})	various	°C	Hourly profile based on CWEC 2020, London, ON [6]

Variable	Schedule	Hours	Weekday	Saturday	Sunday
$\%Occ$	A	1-6	0%	0%	0%
		7	10%	0%	0%
		8	70%	0%	0%
		9-11	90%	0%	0%
		12-13	50%	0%	0%
		14-16	90%	0%	0%
		17	70%	0%	0%
		18	30%	0%	0%
		19-22	10%	0%	0%
		23-24	0%	0%	0%
	B	1	10%	30%	30%
		2-8	0%	0%	0%
		9	10%	10%	0%
		10	20%	20%	10%
		11	50%	50%	40%
		12	90%	90%	50%
		13	80%	80%	50%
		14	50%	50%	40%
		15-16	20%	20%	20%
		17	30%	30%	20%
		18	60%	60%	50%

		19-20	90%	90%	70%
		21	90%	90%	50%
		22	60%	60%	30%
		23	40%	60%	10%
		24	30%	50%	10%
	C	1-7	0%	0%	0%
		8	10%	10%	10%
		9	20%	20%	20%
		10	50%	50%	50%
		11	50%	60%	60%
		12	70%	80%	80%
		13-15	70%	90%	90%
		16	80%	80%	80%
		17	70%	70%	70%
		18	50%	50%	50%
		19-20	30%	20%	0%
		21-24	0%	0%	0%
	D	1-7	0%	0%	0%
		8	10%	0%	0%
		9-11	90%	0%	0%
		12-15	80%	0%	0%
		16	50%	0%	0%
		17	20%	0%	0%
		18	10%	0%	0%
		19-21	30%	0%	0%
		22	10%	0%	0%
		23-24	0%	0%	0%
	F	1-6	63%	63%	63%
		7	49%	49%	49%
		8-9	28%	28%	28%
		10-15	14%	14%	14%
		16	21%	21%	21%
		17-19	35%	35%	35%
		20-21	49%	49%	49%
		22	56%	56%	56%

		23-24	63%	63%	63%
	G	1-6	90%	90%	90%
		7	70%	70%	70%
		8	40%	50%	50%
		9	30%	50%	50%
		10-16	30%	50%	50%
		17	50%	70%	70%
		18-24	90%	90%	90%
	I	1-7	0%	0%	0%
		8	0%	0%	20%
		9	0%	0%	40%
		10-11	0%	10%	80%
		12	0%	10%	40%
		13	0%	40%	20%
		14	0%	60%	0%
		15	10%	80%	0%
		16	10%	60%	0%
		17	10%	40%	0%
		18	40%	20%	0%
		19	80%	40%	0%
		20-21	80%	80%	0%
		22	60%	60%	0%
		23	40%	40%	0%
		24	10%	10%	0%
$T_{i-heating}$	A	1-5	18	18	18
		6	20	18	18
		7-20	22	18	18
		21-24	18	18	18
	B	1	22	22	22
		2-7	18	18	18
		8	20	20	18
		9	22	22	20
		10-22	22	22	22
		23-24	22	22	18

	C	1-6	18	18	18
		7	20	20	18
		8	22	22	18
		9	22	22	20
		10-18	22	22	22
		19-20	22	22	18
		21-24	18	18	18
	D	1-6	18	18	18
		7	20	18	18
		8-22	22	18	18
		23-24	18	18	18
	F	1-6	18	18	18
		7	20	20	20
		8-24	22	22	22
	G	1-6	18	18	18
		7	20	20	20
		8-24	22	22	22
	I	1-6	18	18	18
		7	18	18	20
		8-9	18	18	22
		10	18	20	22
		11-13	18	22	22
		14	20	22	18
		15-23	22	22	18
		24	18	18	18
$T_{i-cooling}$	A	1-5	24	26	26
		6-20	24	26	26
		21-24	28	26	26
	B	1-7	26	26	26
		8	24	24	26
		9-22	24	24	24
		23-24	24	24	26
	C	1-6	26	26	26
		7-18	24	24	24

		19-20	24	24	26
		21	26	26	26
	D	1-6	26	26	26
		7-22	24	26	24
		23-24	28	26	28
	F	1-24	24	24	24
	G	1-24	24	24	24
	I	1-6	26	26	26
		7-13	26	26	24
		14-23	24	24	26
		24	26	26	26

Commercial heating system efficiency	80	%	Common assumptions table
Specific gas constant for dry air	287.05	J/kg.K	[7]
Specific gas constant for water vapor	461.52	J/kg.K	
Energy Density of Natural Gas	35,738	Btu/m^3	Common assumptions table
Indoor relative humidity	30	%	Common assumptions table
Cooling seasonal COP	3.81		Common assumptions table
Density conversion factor from metric to imperial, multiply by	0.062428	(lb/ft^3)/(kg/m^3)	[8]
Specific heat of air	0.24	Btu/lb·°F	setumptions table
Conversion factor for the specific heat of air	1 Btu/lb·°F = 4186.8 J/kg·K		[9] Converting between commonly used Units
Calibration factor	0.9285		Average values from analysis and comparison between engineering calculations and 21 building energy models developed in EnergyPlus

Space type	**Occupancy schedule**	
Office	Schedule A	[4]
Office Buildings Reception areas		
Conference/meeting space_Office		
Warehouse		
Public Assembly Spaces_Courtrooms		
Other Commercial spaces		
Long-Term Care Facility (Common Areas)	Schedule B	
Restaurants dining rooms		
Bowling alley (seating)		
Exercise Center/Sports Arena		
Health club aerobics room		

Sports and Entertainment		
Disco/dance floors		
Libraries	Schedule C	
Conference/meeting space_Other		
Public Assembly Spaces		
Multipurpose assembly		
Multipurpose assembly_ Arts & Sport		
Retail		
Retail_Supermarket/Grocery store		
Retail_Coin-operated laundries		
Laundry room		
Educational Facilities	Schedule D	
Secondary Education Classroom		
Primary/Secondary Education Gymnasium		
Post-Secondary Education Classroom		
Post-Secondary Education Lecture hall		
Other Educational Facilities		
Hotels, Motels, Resorts, Dormitories	Schedule F	
Multi-Residential	Schedule G	
Places of religious worship	Schedule I	

SAVINGS CALCULATION EXAMPLE

DCV with CO_2 sensors was installed in 3 Secondary Education classrooms and a secondary Education gym that were operating under constant volume ventilation (unscheduled baseline). The floor area of the spaces where the DCV with CO_2 sensors was installed is as follows:

- floor area classrooms 1 & 2 = 500 ft^2 each
- floor area classroom 3 = 600 ft^2
- floor area gymnasium = 3,600 ft^2

Assessing the floor area, annual natural gas savings and electricity impact for the applicable spaces: The 3 classrooms can be assessed under the DCV space type "Secondary Education Classroom:

- The annual natural gas savings from Table 1 = 2.142 m^3/ft^2
- The annual electricity impacts from Table 1 = 0.552 kWh/ft^2
- The total floor area = (2 x 500) + (1 x 600) = 1,600 ft^2

$$NG_{Savings-classrooms} = 1{,}600\ ft^2 \times 2.142\ \frac{m^3}{ft^2} = 3{,}427\ m^3/yr$$

$$Elec_{Impacts-clasrooms} = 1{,}600\ ft^2 \times 0.552\ \frac{kWh}{ft^2} = 883\ kWh/yr$$

The gymnasium can be assessed under DCV space type "Primary/Secondary Education Gymnasium"

- The annual natural gas savings from Table 1 = 1.314 m^3/ft^2
- The annual electricity impacts from Table 1 = 0.299 kWh/ft^2
- The total floor area = 3,600 ft^2

$$NG_{Savings-gym} = 3{,}600\ ft^2 \times 1.314\ \frac{m^3}{ft^2} = 4{,}730\ m^3/yr$$

$$Elec_{Impacts-gym} = 3{,}600\ ft^2 \times 0.299\ \frac{kWh}{ft^2} = 1{,}076\ kWh/yr$$

Total annual natural gas savings and electricity impacts

$$NG_{Savings-gym} = 3{,}427\frac{m^3}{yr} + 4{,}730\frac{m^3}{yr} = 8{,}158\frac{m^3}{yr}$$

$$Elec_{Impacts-gym} = 883\frac{kWh}{yr} + 1{,}076\frac{kWh}{yr} = 1{,}960\frac{kWh}{yr}$$

USES AND EXCLUSIONS

To qualify for this measure, DCV must be implemented for an individual space within a commercial building, ventilation system with natural gas fueled heating that previously operated to provide constant ventilation meeting at least the minimum outdoor air requirements specified by 2022 ASHRAE 62.1 Table 6-1.

Systems equipped with energy or heat recovery capabilities are not eligible for this 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. [10] 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 is 15 years or more, depending upon the manufacturer.

INCREMENTAL COST

Table 5 presents the measure incremental cost. This table summarizes DCV incremental cost information gathered from interviews with different vendors. [11]

Table 5: Measure Incremental Cost

Measure Category	Equipment cost	Installation cost	Total Incremental cost
Retrofit	$\$900 \times n + 1{,}100$[18]	$\$590$	$\$900 \times n + \$1{,}690$
NC/TNR	$\$900 \times n$	$\$590$	$\$900 \times n + \$590$
Where " n " is the number of sensors			

REFERENCES

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

Version Date and Revision History	
Version	3.1 (minor update)
OEB Filing Date	March 19, 2026
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							
	Fan Diameter (ft)							
		12	**14**	**16**	**18**	**20**	**22**	**24**
Annual Natural Gas Savings (m^3/ fan)	**NC**	661	900	1,175	1,487	1,836	2,222	2,644
	R	893	1,215	1,587	2,009	2,480	3,001	3,571
Measure Life	15 years							
	Fan Diameter (ft)			**Incremental Cost ($ CAD)**				
	12 to 18			$12,090				
Incremental Cost ($ CAD)	20 to 24			$13,312				

Parameter	Definition
Restrictions	This measure is restricted to HVLS fans with minimum diameter of 12 feet for use in warehousing-type[1] buildings with a minimum of 22-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 stratification such as radiant heaters and/or high velocity vertical throw unit heaters are present in the influence area where destratification fan will be installed, this measure is not eligible. It is assumed that the building is operating without night setbacks. Installation must follow manufacturer recommendations sufficient to effectively destratify the entire space. Only for the purpose of the savings captured in table 1 of this document, the number of fans installed in the space should not exceed: $$\frac{Building\ length(ft) \times Building\ width(ft) \times S_{destratified}}{A_{roof_fan}}$$ Please see table 2 for $S_{destratified}$ and A_{roof_fan} values.

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 space heater is located at ceiling level. As there is a call for heat by the floor level thermostat, heat is introduced into the space by the space heating equipment such as 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.

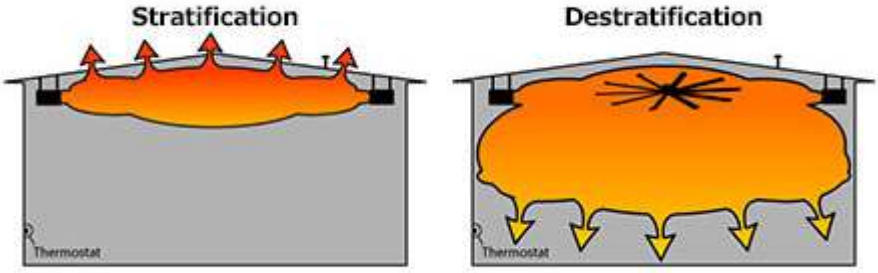
The installation of HVLS destratification fans helps to decrease thermal stratification of the air by pushing the warmer air at the ceiling to the ground creating comfort for the people working while bringing the colder air at ground level to the ceiling to be heated. This convection effect mixes the

[1] Warehousing-type of buildings refers to the space temperature setting, on average 69^0F.

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 (m^3/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 fans 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 stratification, 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 of a minimum diameter of 12 feet.

[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 natural gas impact in cubic meters per fan. The total natural gas savings, NG Savings, is calculated based on the heat loss reduction through the roof, walls, and infiltrations/ventilation due to the installation of 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 2
ED_{NG}	=	Energy density of natural gas, see table 2
η	=	Commercial heating system efficiency, see table 2

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:

$$\begin{aligned}\Delta Q_{roof} &= q_{roof_bd} - q_{roof_ad} \\ &= U_{roof} \times A_{roof_fan} \times (t_{roof_ibd} - t_o) - U_{roof} \times A_{roof,fan} \times (t_{roof_iad} - t_o) \\ &= U_{roof} \times A_{roof_fan} \times (t_{roof_ibd} - t_{roof_iad})\end{aligned}$$

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 /ft²·°F·h), see table 2

A_{roof_fan} = Area of roof influenced by destratification fans (ft²), see table 2

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

t_{roof_ibd} = Average temperature of the roof, indoor, before destratification (°F), see table 2

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 2

t_{tstat} = Thermostat temperature setting (°F), see table 2

H_{ah} = Height above heaters to roof (ft), see table 2

H_{bh} = Height below heaters to floor (ft), see table 2

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 2
$Ratio_{wr}$	=	Roof to wall influence ratio, see table 2
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:

$$t_{wall_ibd} = t_{roof_ibd} - \frac{Building_{H_avg} \times (t_{roof_ibd} - t_{tstat})}{2 \times (H_{tstat-roof})}$$

$$t_{wall_iad} = t_{roof_iad} - \frac{Building_{H_avg} \times (t_{roof_iad} - t_{tstat})}{2 \times (H_{tstat-roof})}$$

where,

t_{tstat}	=	Thermostat temperature setting (°F), see table 2
$Building_{H_avg}$	=	Average Building height (ft), see table 2
$H_{tstat-roof}$	=	Height above thermostat to roof (ft), see table 2

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". [1]

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.

$$\Delta Q_{vent} = q_{vent_bd} - q_{vent_ad}$$

$$\Delta Q_{vent} = 0.018 \times ACH_n \times A_{roof_fan} \times Building_{H_{avg}} \times \frac{Ratio_{wr} \times \left(t_{wall_ibd} - t_{wall_iad}\right) + \left(t_{roof_ibd} - t_{roof_iad}\right)}{(1 + Ratio_{wr})}$$

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.ft³/h)
ACH_n	=	Air changes per hour (1/h), see table 2
$Building_{H_avg}$	=	Average Building height (ft), see table 2

ASSUMPTIONS

Table 2 provides a list of assumptions utilized in the measure savings algorithm to derive the stipulated savings values listed in Table 1 above.

Table 2. Assumptions

Variable	Definition	Value		Source/Comments
hrs_{hs}	Heating hours per year	Balance Point 55°F (12.8˚C)		Based on CWEC data for London, ON (2020). Annual hours on heating hours below 56°F [2]
		6,019		
ED_{NG}	Energy density of natural gas	35,738 Btu/m^3		Common assumption
η	Commercial heating system efficiency	80%		Common assumption
U_{roof}	Average heat transfer coefficient for the roof	Retrofit	New Construction	New Construction based on NECB (weighted average based on number of buildings per climate zone) [3] Retrofit based on Enbridge destratification Custom projects[3]
		0.050 Btu/°F·h·ft^2 (R-20)	0.026 Btu/°F·h·ft^2 (R-38)	
U_{wall}	Average heat transfer coefficient for the wall	0.064 Btu/°F-h-ft^2 (R-16)	0.045 Btu/°F-h-ft^2 (R-22)	
A_{roof_fan}	Area of roof influenced by destratification fans	Fan Diameter (ft)	A_{roof_fan} (ft^2)	Extrapolated based on the following equation: $1.0257 \times \pi \times \left(5 \times \frac{D_{fan}}{2}\right)^2$
		12	2,900	
		14	3,947	
		16	5,156	
		18	6,525	
		20	8,056	
		22	9,748	
		24	11,600	Based on a field study [1]
$S_{destratified}$	On average, 75% of the entire space had been destratified	0.75		Based on average data from Enbridge destratification Custom projects
$Ratio_{wr}$	Ratio of wall to roof area for subject buildings	0.37		Based on average data from Enbridge destratification Custom projects[4]

[3] Data from the Enbridge custom projects (between 2011 and 2020) was used to develop the average insulation level for retrofit building which have utilized the destratification energy savings measure.

[4] The ratio of wall area divided by roof area used the following average dimensions: Building height = 31 ft, Building width = 294 ft, Building length = 366 ft. The roof area = 107,787 ft^2, and the Wall area = 40,310ft^2

Variable	Definition	Value		Source/Comments
t_{roof_ibd}	Average temperature of the roof before destratification	84.82 °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[5] [4]
H_{ah}	Height above heaters to roof	8 ft		Minimum requirements are 8 feet from floor or ceiling [5]
H_{bh}	Height below heaters to floor	23 ft		Minimum requirements are 8 feet from floor or ceiling [5]. Assuming a ceiling height of 31ft.
$Building_{H_avg}$	Average Building height	31 ft		Based on average of data from Enbridge custom projects
ACH_n	Air Changes per hour	Retrofit	New Construction	Retrofit: Based on average of data from Enbridge custom projects NC: based on ASHRAE 62.1, 2022
		0.13	0.12	

SAVINGS CALCULATION EXAMPLE

The example below illustrates the savings value for the installation of 12, 20ft diameter HVLS destratification fans in a new commercial warehouse. The room has a 31-foot ceiling, the building length = 376 ft, and the building width =299 ft.

From Table 1, verify the maximum number of fans restriction:

$$\#Fans = \frac{Building\ length(ft) \times Building\ width(ft) \times S_{destratified}}{A_{roof_{fan}}}$$

[5] 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.

$$\#Fans = \frac{376ft \times 299ft \times 0.75}{8{,}056ft^2} = 11^6$$

While the facility installed 12 fans as recommended by manufacturer, the maximum number of fans allowed to be claimed using table 1 savings is 11.

$$Natural\ Gas\ savings = 11 \times 1{,}836\ m^3/fan/yr = 20{,}199\ m^3/yr$$

USES AND EXCLUSIONS

This measure is restricted to fans with a minimum diameter of 12 feet for use in warehousing-type[7] commercial buildings with a minimum of 22-foot ceiling. These spaces affected by destratification fans must be heated by ceiling mounted natural gas forced air space heating systems including unit heaters and an unobstructed thermostat with no other mechanisms that combat stratification, such as radiant heaters and high velocity vertical throw 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 stratification such as radiant heaters and/or high velocity vertical throw unit heaters are present in the influence area where destratification fan will be installed, this measure is not eligible.

It is assumed that the building is operating without night setbacks.

Installation must follow manufacturer recommendations sufficient to effectively destratify the entire space. Only for the purpose of the savings captured in table 1 of this document, the number of fans installed in the space should not exceed:

$$\frac{Building\ length(ft) \times Building\ width(ft) \times S_{destratified}}{A_{roof_fan}}$$

Please see assumptions table for $S_{destratified}$ and A_{roof_fan} values.

[6] The calculated value is 10.5 rounded up to 11 as # of fans installed are only whole numbers

[7] Warehousing-type of buildings refers to the space temperature setting, on average 69ºF.

MEASURE LIFE

The measure life is 15 years [6].

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 for 20 to 24 feet diameters fans were derived using historical program participant invoices from Enbridge's program and for fans 12 to 18 ft diameter estimates from distributor data collection was used. Table 3 presents a summary of the incremental cost.

Table 3. Incremental cost ($ CAD)

Fan size (ft)	Equipment cost ($ CAD)	Installations cost ($ CAD)	Incremental cost ($ CAD)
12 to 18	$6,850	$5,240	$12,090
20 to 24	$9,568	$3,744	$13,312

REFERENCES

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COMMERCIAL – DOCK DOOR SEALS–RETROFIT

Version Date and Revision History	
Version	1.0
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]

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

$$C_{dh} = 0.40 + 0.0045 \times |T_i - T_0|$$

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 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/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
		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

REFERENCES

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

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

[3] "Government of Canada, Canadian Weather Year for Energy Calculation (CWEC)," 2016. [Online]. Available: http://climate.weather.gc.ca/prods_servs/engineering_e.html. [Accessed 01 11 2018].

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

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

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

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

COMMERCIAL – INCREMENTAL ENERGY RECOVERY VENTILATION (ERV) (55% EFFECTIVENESS BASELINE) – NEW CONSTRUCTION/TIME OF NATURAL REPLACEMENT

Version Date and Revision History	
Version	2.3 (minor update)
OEB Filing Date	March 19, 2026
OEB Approval Date	
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 (m^3/working CFM), ε_{EE} 1**	**Group**	**Average Group Gas Savings (m^3/working CFM)**

Parameter	Definition			
Annual Gas Savings Rate with a Minimum ERV Sensible Heat Recovery Effectiveness of 65%, ε_{EE} 1 (m^3/ working CFM)[2]	Multi-Family, Health Care and Nursing Homes	0.97	High Use	0.97
	Hotels	0.69	Medium Use	0.54
	Restaurant	0.50		
	Retail	0.42		
	Office	0.37	Low Use	0.34
	Warehouse	0.35		
	School	0.31		
Measure Efficiency	**Building Type**	**Gas Savings Rate (m^3/working CFM), ε_{EE} 2**	**Group**	**Average Group Gas Savings (m^3/working CFM)**
Annual Natural Gas Savings with a Minimum ERV Sensible Heat Recovery Effectiveness of 75%, ε_{EE} 2 (m^3/ working CFM)[1]	Multi-Family, Health Care and Nursing Homes	1.94	High Use	1.94
	Hotels	1.38	Medium Use	1.08
	Restaurant	1.00		
	Retail	0.84		
	Office	0.74	Low Use	0.69
	Warehouse	0.70		
	School	0.62		
Measure Efficiency	**Building Type**	**Gas Savings Rate (m^3/working CFM), ε_{EE} 3**	**Group**	**Average Group Gas Savings (m^3/working CFM)**
Annual Natural Gas Savings with a Minimum ERV Sensible Heat Recovery Effectiveness of	Multi-Family, Health Care and Nursing Homes	2.91	High Use	2.91
	Hotels	2.08	Medium Use	1.62
	Restaurant	1.51		
	Retail	1.26		

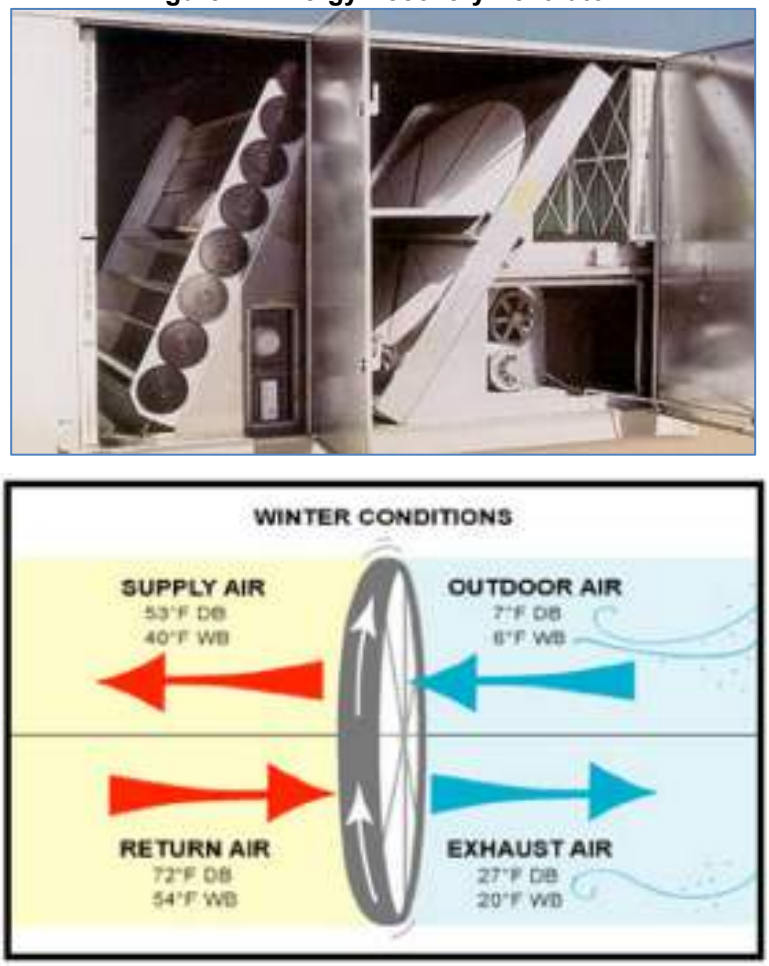
<table>
<tr><th>Parameter</th><th colspan="4">Definition</th></tr>
<tr><td rowspan="3">85%, ε_{EE} 3 (m³/ working CFM)[1]</td><td>Office</td><td>1.11</td><td rowspan="3">Low Use</td><td rowspan="3">1.03</td></tr>
<tr><td>Warehouse</td><td>1.06</td></tr>
<tr><td>School</td><td>0.93</td></tr>
<tr><td>Measure Life</td><td colspan="4">14 Years</td></tr>
<tr><td rowspan="3">Incremental Costs ($ CAD)</td><td colspan="4">$1.00 per CFM at ε_{EE} 1</td></tr>
<tr><td colspan="4">$2.00 per CFM at ε_{EE} 2</td></tr>
<tr><td colspan="4">$3.00 per CFM at ε_{EE}3</td></tr>
<tr><td>Restrictions</td><td colspan="4">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]</td></tr>
</table>

OVERVIEW

An energy recovery ventilator (ERV) refers to heat exchanger equipment that is designed to transfer heat and moisture between the building exhaust air and the outside supply air. During the heating season, this raises the temperature of the outside supply air through heat transfer within the heat exchanger and typically adjusts the humidity of the supply air through moisture transfer. By doing so, the amount of energy wasted in heat through the exhaust air stream is reduced and energy is saved through decreased load on the building heating system. ERVs are available as desiccant rotary wheels or membrane plate exchangers [1].

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.

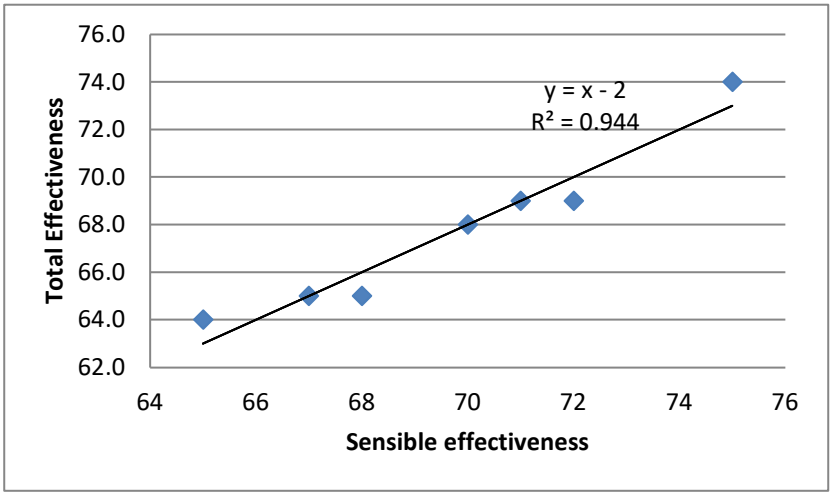
NATURAL GAS SAVINGS ALGORITHMS

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]	6,019 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)	68°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.

$$hrs = 6{,}253\ hrs \times \frac{168\ \frac{hrs}{week}}{168\frac{hrs}{week}} = 6{,}253\frac{hrs}{year}$$

and,

$$NG\ Savings = 6{,}253\frac{hrs}{year} \times \frac{60\ min}{hr} \times 0.0741\frac{lb_m}{ft^3} \times \frac{(73\% - 53\%)}{80\%} \times \frac{1}{35{,}738\frac{Btu}{m^3}} \times \left(22.72\frac{Btu}{lb_m} - 11.82\frac{Btu}{lb_m}\right) \times \left(1 - \frac{5\%}{100\%}\right) = 2.01\frac{m^3}{CFM \cdot year}$$

Therefore,

$$NG\ Savings = 500\ CFM \times\ 2.01\frac{m^3}{CFM \cdot year} = 1{,}007\ \frac{m^3}{year}$$

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].

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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	2.3 (minor update)
OEB Filing Date	March 19, 2026
OEB Approval Date	
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

Parameter	Definitions			
Measure Category	New construction (NC), ERV not required by Ontario Building Code Retrofit (R)			
Baseline Technology	No ERV			
Efficient Technology	ERV with Minimum 55% Sensible Heat Recovery Effectiveness[1] and 53% Total Energy Recovery Effectiveness at 32°F			
	ERV with Minimum 65% Sensible Heat Recovery Effectiveness and 63% Total Energy Recovery Effectiveness at 32°F			
	ERV with Minimum 75% with Sensible Heat Recovery Effectiveness and 73% Total Energy Recovery Effectiveness at 32°F			
	ERV with Minimum 85% Sensible Heat Recovery Effectiveness and 83% Total Energy Recovery Effectiveness at 32°F			
Market Type	Commercial			
	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	Definitions			
Annual Gas Savings Rate with a Minimum ERV Sensible Heat Recovery Effectiveness of 55%, ε_{EE} 1 (m³/ working CFM)[1]	Multi-Family, Health Care and Nursing Homes	5.14	High Use	5.14
	Hotels	3.67	Medium Use	2.85
	Restaurant	2.66		
	Retail	2.23		
	Office	1.96	Low Use	1.82
	Warehouse	1.87		
	School	1.65		
Annual Gas Savings Rate with a Minimum ERV Sensible Heat Recovery Effectiveness of 65%, ε_{EE} 2 (m³/ working CFM)[1]	**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	6.11	High Use	6.11
	Hotels	4.36	Medium Use	3.39
	Restaurant	3.16		
	Retail	2.65		
	Office	2.33	Low Use	2.17
	Warehouse	2.22		
	School	1.96		
Annual Gas Savings Rate With a Minimum ERV Sensible Heat Recovery Effectiveness of 75%, ε_{EE} 3 (m³/ working CFM)[1]	**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	7.08	High Use	7.08
	Hotels	5.05	Medium Use	3.93
	Restaurant	3.66		
	Retail	3.07		
	Office	2.70	Low Use	2.51
	Warehouse	2.57		
	School	2.27		

<table>
<tr><th>Parameter</th><th colspan="4">Definitions</th></tr>
<tr><td rowspan="9">Annual Gas Savings Rate with a Minimum ERV Sensible Heat Recovery Effectiveness of 85%,
ε_{EE} 4 (m³/ working CFM)[1]</td><td>Building Type</td><td>Gas Savings Rate (m³/working CFM),
ε_{EE} 4</td><td>Group</td><td>Average Group Gas Savings (m³/working CFM),
ε_{EE} 4</td></tr>
<tr><td>Multi-Family, Health Care and Nursing Homes</td><td>8.04</td><td>High Use</td><td>8.04</td></tr>
<tr><td>Hotels</td><td>5.75</td><td rowspan="3">Medium Use</td><td rowspan="3">4.47</td></tr>
<tr><td>Restaurant</td><td>4.17</td></tr>
<tr><td>Retail</td><td>3.50</td></tr>
<tr><td>Office</td><td>3.06</td><td rowspan="3">Low Use</td><td rowspan="3">2.86</td></tr>
<tr><td>Warehouse</td><td>2.92</td></tr>
<tr><td>School</td><td>2.59</td></tr>
<tr><td rowspan="9">Annual Electric Impact[2] (kWh/ working CFM)</td><td>Building Type</td><td>Electric Impact Rate (kWh/working CFM)</td><td>Group</td><td>Average Group Electric Impact (kWh/working CFM)</td></tr>
<tr><td>Multi-Family, Health Care and Nursing Homes</td><td>-5.00</td><td>High Use</td><td>-5.00</td></tr>
<tr><td>Hotels</td><td>-3.57</td><td rowspan="3">Medium Use</td><td rowspan="3">-2.78</td></tr>
<tr><td>Restaurant</td><td>-2.59</td></tr>
<tr><td>Retail</td><td>-2.17</td></tr>
<tr><td>Office</td><td>-1.90</td><td rowspan="3">Low Use</td><td rowspan="3">-1.77</td></tr>
<tr><td>Warehouse</td><td>-1.81</td></tr>
<tr><td>School</td><td>-1.61</td></tr>
<tr><td>Measure Life</td><td colspan="4">14 Years</td></tr>
<tr><td rowspan="2">Incremental First Cost ($ CAD)
ε_{EE} 1</td><td colspan="2">Integrated ERV</td><td colspan="2">Standalone or Bolt-On ERV</td></tr>
<tr><td colspan="2">$4.86/CFM</td><td colspan="2">$7.80/CFM</td></tr>
<tr><td rowspan="2">Incremental Cost ($ CAD)</td><td colspan="2">$4.86 + $1.00 per CFM at $\boldsymbol{\varepsilon_{EE}}$ 2</td><td colspan="2">$7.80 + $1.00 per CFM at $\boldsymbol{\varepsilon_{EE}}$ 2</td></tr>
<tr><td colspan="2">$4.86 + $2.00 per CFM at ε_{EE} 3</td><td colspan="2">$7.80 + $2.00 per CFM at ε_{EE} 3</td></tr>
</table>

[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]	

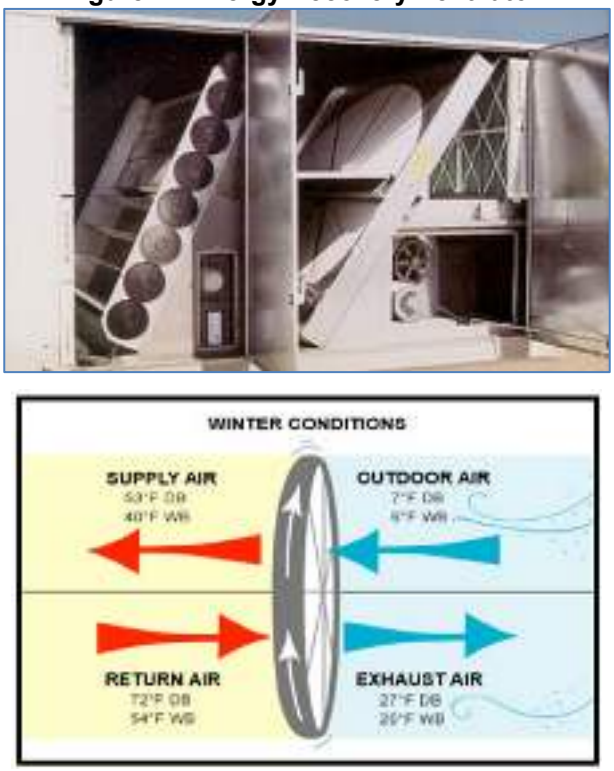
OVERVIEW

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.

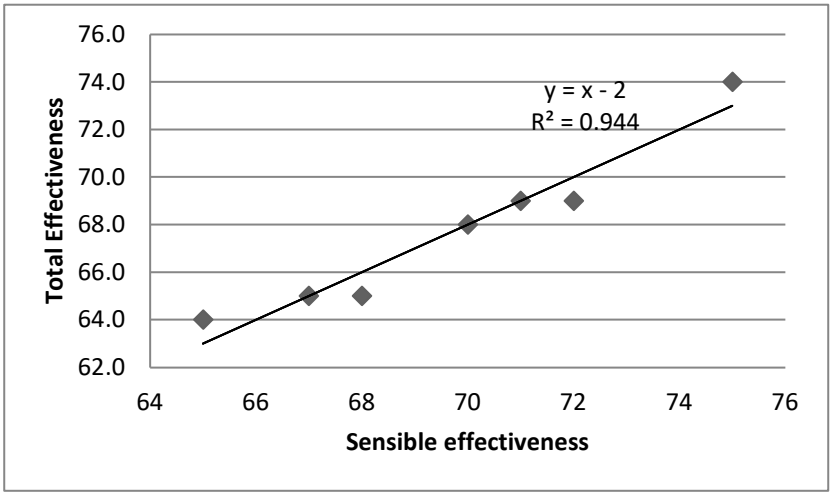
NATURAL GAS SAVINGS ALGORITHMS

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,

$$NG\ Savings = hrs \times \frac{60min}{hr} \times \frac{\varepsilon_{EE}}{\eta} \times \frac{\rho}{35{,}738\frac{Btu}{m^3}} \times (h_3 - h_1) \times (1 - \frac{DF}{100\%})$$

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]	6,019 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)	68°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.

$$hrs = 6{,}019\ hrs \times \frac{168\frac{hrs}{week}}{168\frac{hrs}{week}} = 6{,}019\frac{hrs}{year}$$

and,

$$NG\ Savings = 6{,}019\frac{hrs}{year} \times \frac{60min}{hr} \times 0.0741\frac{lb_m}{ft^3} \times \frac{1}{35{,}738\frac{Btu}{m^3}} \times \left(22.72\frac{Btu}{lb_m} - 11.82\frac{Btu}{lb_m}\right) \times \left(1 - \frac{5\%}{100\%}\right) = 6.11\frac{m^3}{CFM \cdot year}$$

Therefore,

$$NG\ Savings = 500\ CFM \times 6.11\frac{m^3}{CFM \cdot year} = 3{,}053\ \frac{m^3}{year}$$

The electrical penalty can be calculated as the following.

$$kWh\ penalty = 500\ CFM \times -0.83\frac{W}{CFM} \times 6{,}019\ \frac{hrs}{year} \times \frac{1kW}{1000W} = -2{,}498\ \frac{kWh}{year}$$

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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[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].

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[3] 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].

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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 15, 2021
OEB Approval Date	December 15, 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/m^3		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:

$$Daily\ Preheat = 19{,}000\frac{Btu}{day}$$

$$Daily\ Cooking\ Time = \frac{100\frac{lbs}{day}}{70\frac{lbs}{hr}} = 1.43\frac{hrs}{day}$$

$$Idle\ Time = 12\frac{hrs}{day} - 0.2\frac{hrs}{day} - 1.43\frac{hrs}{day} = 10.4\frac{hrs}{day}$$

$$Daily\ Idle = 10.4\ \frac{hrs}{day}\ \times\ 18{,}000\frac{Btu}{hr} = 186{,}686\frac{Btu}{day}$$

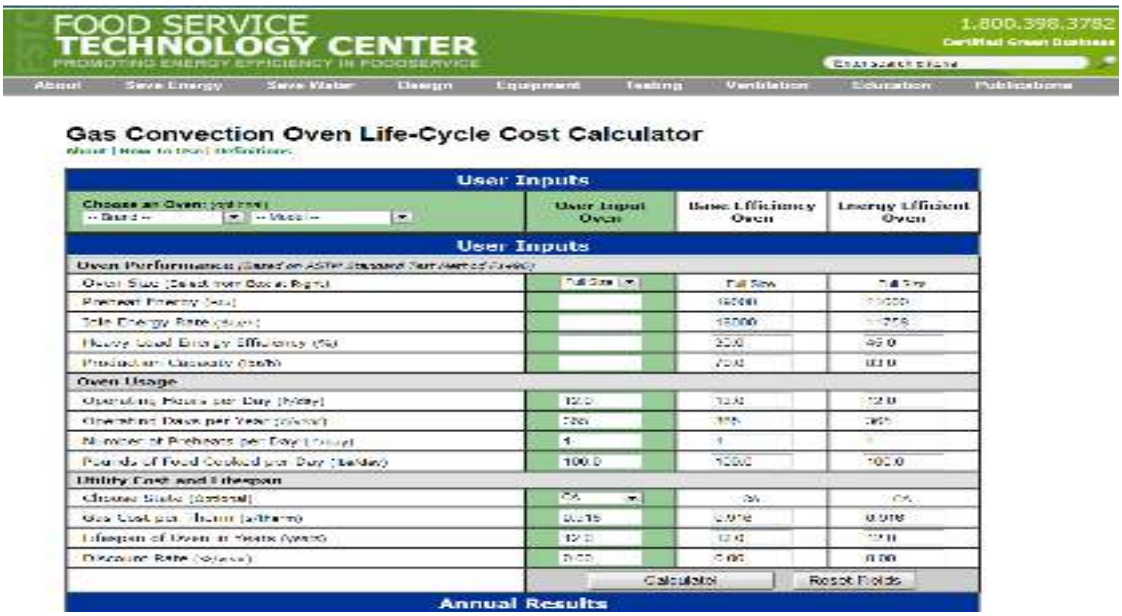
$$Daily\ Cooking = \frac{100\frac{lbs}{day}\ \times\ 250\frac{Btu}{lb}}{30\%} = 83{,}333\frac{Btu}{day}$$

$$NG\ Usage = \left(19{,}000\frac{Btu}{day} + 186{,}686\frac{Btu}{day} + 83{,}333\frac{Btu}{day}\right) \times 344\frac{days}{year} = 99{,}422{,}536\frac{Btu}{year}$$

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	2.0
OEB Filing Date	November 14, 2022
OEB Approval Date	
Commercial → Water Heating → ENERGY STAR Dishwasher→ New Construction/ Time of Natural Replacement	

Table 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	A non-ENERGY STAR® rated dishwasher			
Efficient Technology	An ENERGY STAR® rated[1] dishwasher			
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	285	2,767	41,995
	Stationary Single Tank Door	1,262	6,032	185,951
	Single Tank Conveyor	1,167	7,599	171,888
	Multi Tank Conveyor	2,970	14,386	437,533
	Low Temperature Dishwashers			
	Under Counter	438	1,405	64,458
	Stationary Single Tank Door	2,846	946	419,302
	Single Tank Conveyor	2,546	3,474	375,028
	Multi Tank Conveyor	3,447	3,375	507,851
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		

[1] Based on qualifying products under ENERGY STAR Commercial Dishwasher Product Criteria V 3.0

Parameter	Definitions		
Incremental cost ($ CAD)	**Dishwasher Type**	**High Temperature**	**Low Temperature**
	Under Counter	$2,538	$293
	Stationary Single-Tank Door	$1,247	$830
	Single-Tank Conveyor	$2,570	$0
	Multi-Tank Conveyor	$1,216	$1,216
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 Ontario's Health Protection and Promotion Act, O. Reg 493/17 [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.

APPLICATION

This applies to the installation of ENERGY STAR-rated[2] dishwashers in a commercial setting.

BASELINE TECHNOLOGY

The baseline technology is a standard dishwasher that does not meet the ENERGY STAR criteria due to their low efficiency and high idle energy rate.

EFFICIENT TECHNOLOGY

ENERGY STAR-rated dishwashers must have idle energy and water consumption rates as defined in Table 2.

Table 2. ENERGY STAR Energy Efficiency Requirements for Commercial Dishwashers [4]

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	≤ 0.30 kW	≤ 0.86 GPR	≤ 0.25 kW	≤ 1.19 GPR
Stationary Single Tank Door	≤ 0.55 kW	≤ 0.89 GPR	≤ 0.30 kW	≤ 1.18 GPR
Single Tank Conveyor	≤ 1.20 kW	≤ 0.70 GPR	≤ 0.85 kW	≤ 0.79 GPR
Multiple Tank Conveyor	≤ 1.85 kW	≤ 0.54 GPR	≤ 1.00 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 [4].

[2] GPR = gallons per rack

ENERGY IMPACTS

Natural gas and electrical savings are achieved because the higher efficiency equipment requires less heated water and typically less electricity for each load than its baseline non-ENERGY STAR counterpart.

[2] Based on qualifying products under ENERGY STAR Dishwashers Product Criteria V 3.0 [4]

NATURAL GAS, WATER, 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.

First, 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). Next, the heat input required to raise the water to the desired temperature (Q_{in}) is calculated on a per gallon basis. Finally, the fuel savings (natural gas) are calculated using results from the previous calculations.

Water Savings Algorithms

1. **Calculation of the water consumed by the dishwasher**

   $$Water = GPR \times RPD \times days$$

   where:

$Water$	=	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)

2. **Calculation of the Annual water savings**

   $$Water_{savings} = Water_b - Water_E$$

   where:

$Water_{savings}$	=	Annual water savings (gallons/year)
$Water_b$	=	Annual water consumption of the baseline dishwasher (gallons/year)
$Water_E$	=	Annual water consumption of the ENERGY STAR dishwasher (gallons/year)

Natural Gas Savings Algorithms

1. **Calculation of the water temperature increase that is satisfied by the building's water heating system**

   $$\Delta T = T_{in} - T_{out}$$

   where:

ΔT	=	Temperature increase required by building heating

system to heat city supply water to feed hot water tank (°F)

T_{In} = City supply water temperature (°F)

T_{out} = Commercial hot water tank temperature (°F)

2. Calculation of the water heater natural gas consumption

$$Q_{In} = \Delta T \times C_P \times \frac{\rho}{Eff_{Gas}}$$

where:

Q_{In} = Water heater specific energy consumption (Btu/gal)

ΔT = Temperature increase required by building heating system to heat city supply water to feed hot water tank (°F)

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

ρ = Density of water (lb/gal)

Eff_{Gas} = Building water heating system efficiency (%)

3. Calculation of the natural gas savings

$$NG_{savings} = \frac{Q_{In} \times Water_{savings}}{35{,}738}$$

where:

$NG_{savings}$ = Natural Gas savings (m^3/yr)

$Water_{savings}$ = Annual water savings (gallons/year)

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

Electricity impact Algorithms

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.

1. Calculation of electricity consumption of a dishwasher

$$Elec = IER \times \left(hrs \times days - days \times RPD \times \frac{TWT}{60} \right)$$

where:

$Elec$ = Annual electricity consumption (kWh)

IER = Idle energy rate (kW)

hrs = Average daily operation (hours/day)

$days$ = Annual days of operation (days/year)

RPD = Racks washed per day (racks/day)
TWT = Typical wash time (minutes)
60 = Conversion factor (min/hr)

2. Calculation of electricity impact

$$Elec_{savings-Idle} = Elec_b - Elec_E$$

where:

$Elec_{savings-Idle}$ = Annual electricity impact (kWh/yr)
$Elec_b$ = Annual electricity consumption for the baseline dishwasher(kWh/yr)
$Elec_E$ = Annual electricity consumption for the ENERGY STAR dishwasher(kWh/yr)

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.

3. Calculation of the water temperature increase that is satisfied by the electrical booster heater

$$\Delta T_{Boost} = T_{set} - T_{out}$$

where:

ΔT_{Boost} = Temperature difference between the primary water heater setpoint and the booster heater high temperature setpoint (°F)
T_{set} = Booster heater high temperature setpoint (°F)
T_{out} = Commercial hot water tank temperature (°F)

4. Calculation of the booster heater electricity consumption

$$Q_{Boost} = \Delta T_{Boost} \times C_P \times \frac{\rho}{Eff_{Elec} \times 3{,}412}$$

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)
ΔT_{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 = Conversion factor (Btu/kWh)

5. Calculation of the booster heater electricity impacts

$$Elec_{Boost} = Q_{Boost} \times Water_{savings}$$

where:

$Elec_{Boost}$ = Annual electricity impacts from the booster heater (kWh/yr)
$Water_{savings}$ = Annual water savings (gallons/year)

6. Calculation of the booster heater total electricity impacts- High Temp dishwasher

$$Elec_{savings} = Elec_{savings-Idle} + Elec_{Boost}$$

where:

$Elec_{savings}$ = Total annual electricity impacts for high temp. dishwasher (kWh/yr)
$Elec_{Boost}$ = Annual electricity impacts from the booster heater (kWh/yr)
$Elec_{savings-Idle}$ = Annual electricity impact (kWh/yr)

ASSUMPTIONS

Table 3 shows the list of common assumptions used in the savings algorithm.

Table 3. 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
T_{In}	City supply water temperature	47.4°F	Common assumptions table
T_{out}	Commercial hot water tank temperature	140°F	Common assumptions table
T_{set}	Commercial hot water booster heater high temperature setpoint	180°F	[2]

Variable	Definition	Inputs for Baseline and Energy Efficient Options	Source/Comments
Eff_{Gas}	Commercial water heating efficiency	83.6%	Common assumptions table
Eff_{Elec}	Electric booster heater efficiency	98%	[5]
hrs	Average daily operation	12 hrs	[6]
days	Food service days per year	344 days	Common assumptions table
	Conversion factor	60 min/hr	
	Energy density of natural gas	35,738 Btu/m^3	Common assumptions table
	Conversion factor (kWh to Btu)	3,412 Btu/kWh	Common assumptions table
	Conversion factor (gallons to liter)	3.78541 liter/gallon	Common assumptions table

Table 4 shows the assumptions used for racks washed per day.

Table 4. Assumptions for Racks Washed Per Day [5]

Dishwasher Type- High and Low Temperature	Racks Washed Per (rack/day)
Under counter	75
Stationary single-tank door	280
Single-tank conveyor	400
Multi-tank conveyor	600

Table 5 shows the assumptions used for typical wash times.

Table 5. Assumptions for Typical Wash Time Minutes [5]

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

Non-ENERGY STAR-rated dishwashers are assumed to have the parameters shown in Table 6. The baseline value is derived from the ENERGY STAR commercial kitchen

equipment calculator [7], which cites EPA/Food Service Technology Center's equipment specification research, 2013, as their source.

Table 6. Baseline Technology Assumptions [5]

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	1.60	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 [4].

[2] GPR = gallons per rack

ENERGY STAR-rated dishwashers parameters shown in Table 7 have been derived from the ENERGY STAR-rated data. [8]

Table 7. ENERGY STAR Average Performance Parameters [5]

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	0.25	0.66	0.07	1.07
Stationary Single Tank Door	0.41	0.78	0.05	0.95
Single Tank Conveyor	1.03	0.54	0.59	0.59
Multiple Tank Conveyor	1.74	0.41	0.91	0.39

[1] Idle result 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 [4].

[2] GPR = gallons per rack

There are two important assumptions 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 calculations are shown below, it assumes that an ENERGY STAR-rated high temperature single-tank conveyor dishwasher will be installed.

Water Savings

1. **Calculation of the water consumed by the dishwasher**

$$Water_b = 0.87\frac{gallons}{rak} \times 400\frac{racks}{day} \times 344\frac{days}{yr} = 119{,}712\frac{gallons}{yr}$$

$$Water_E = 0.54\frac{gallons}{rak} \times 400\frac{racks}{day} \times 344\frac{days}{yr} = 74{,}304\frac{gallons}{yr}$$

2. **Calculation of the Annual water savings**

$$Water_{savings} = 119{,}712\frac{gallons}{yr} - 74{,}304\frac{gallons}{yr} = 45{,}408\frac{gallons}{yr}$$

$$Water_{savings} = 45{,}048\frac{gallons}{yr} \times 3.78541\frac{liter}{gallon} = 171{,}888\frac{liter}{yr}$$

Natural Gas Savings

1. **Calculation of the water temperature increase that is satisfied by the building's water heating system**

$$\Delta T = 140°\text{F} - 47.4\ °\text{F} = 92.6°\text{F}$$

2. **Calculation of the water heater natural gas consumption**

$$Q_{In} = 92.6°\text{F} \times 1\frac{Btu}{lb \cdot °\text{F}} \times \frac{8.29\frac{lb}{gallon}}{0.836} = 918.2\frac{Btu}{gallon}$$

3. **Calculation of the natural gas savings**

$$NG_{savings} = \frac{918.2\frac{Btu}{gallon} \times 45{,}408\frac{gallons}{yr}}{35{,}738\frac{Btu}{m^3}} = 1{,}167\frac{m^3}{yr}$$

Electricity impact

1. **Calculation of electricity consumption of a dishwasher**

$$Elec_b = 1.93kW \times \left(12\frac{hrs}{day} \times 344\frac{days}{yr} - 344\frac{days}{yr} \times 400\frac{rack}{day} \times \frac{0.3\ min}{60\frac{min}{hr}}\right)$$

$$= 6{,}639\frac{kWh}{yr}$$

$$Elec_E = 1.03kW \times \left(12\frac{hrs}{day} \times 344\frac{days}{yr} - 344\frac{days}{yr} \times 400\frac{rack}{day} \times \frac{0.3\,min}{60\frac{min}{hr}} \right)$$

$$= 3{,}543\frac{kWh}{yr}$$

2. **Calculation of electricity impact**

$$Elec_{savings-Idle} = 3{,}096\frac{kWh}{yr}$$

Since this is a high temperature model there is also an electric component that is attributable to the booster heater.

3. **Calculation of the water temperature increase that is satisfied by the electrical booster heater**

$$\Delta T_{Boost} = 180°\text{F} - 140°\text{F} = 40°\text{F}$$

4. **Calculation of the booster heater electricity consumption**

$$Q_{Boost} = 40°\text{F} \times 1\frac{Btu}{lb \cdot °\text{F}} \times \frac{8.29\frac{lb}{gallon}}{0.98 \times 3{,}412\frac{Btu}{kWh}} = 0.0992\frac{kWh}{gallon}$$

5. **Calculation of the booster heater electricity impacts**

$$Elec_{Boost} = 0.0992\frac{kWh}{gallon} \times 45{,}408\frac{gallons}{yr} = 4{,}503\frac{kWh}{yr}$$

6. **Calculation of the booster heater total electricity impacts- High Temp dishwasher**

$$Elec_{savings} = 3{,}096\frac{kWh}{yr} + 4{,}503\frac{kWh}{yr} = 7{,}599\frac{kWh}{yr}$$

USES AND EXCLUSIONS

The installed dishwasher must be ENERGY STAR-qualified and installed in a commercial setting.

MEASURE LIFE

Table 8 shows the measure life for each type of dishwasher.

Table 8 Equipment Lifetime (Years) [4] [9]

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 9 shows the equipment incremental costs for each type of dishwasher.

Table 9. Incremental Costs[3] [9]

Dishwasher Type	High Temperature	Low Temperature
Under counter	$2,538	$293
Stationary single-tank door	$1,247	$830
Single-tank conveyor	$2,570	$0
Multi-tank conveyor	$1,216	$1,216

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 History	2.0
OED Filing Date	November 14, 2022
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	Definition	
Measure Category	New Construction (NC), Time of Natural Replacement (TNR)	
Baseline Technology	A non-ENERGY STAR® rated Fryer	
Efficient Technology	An ENERGY STAR® rated[1] Fryer	
Market Type	Commercial	
	Standard Vat	**Large Vat**
Annual Natural Gas Savings (m^3/yr per vat)	1,466	1,709
Incremental Cost (CAD $ per vat)	$2,657	$3,113
Measure Life	12 years	
Restrictions	Restricted to commercial facilities with standard or large open-vat natural gas fryers for food service.	

OVERVIEW

Fryers are used in commercial and institutional food service preparation for frying food in heated oil. Despite being available in a range of configurations, most fryers share a common design. The food is immersed in a vat that holds the oil, which is typically heated by atmospheric or infrared gas burners underneath the vat, or via "fire tubes" running through the kettle wall. The heating elements are controlled by a thermostat. The vat holds enough oil so that the food is supported by displacement of

[1] Based on qualifying products under ENERGY STAR Commercial Fryer Key Product Criteria V3.0 [1]

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.

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.

APPLICATION

This measure applies to ENERGY STAR[2] 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. Fryer vat insulation reduces standby losses resulting in a lower idle energy rate.

BASELINE TECHNOLOGY

The baseline technology is an open-vat commercial fryer that does not meet the ENERGY STAR Commercial Fryer Key Product Criteria, Version 3.0 [1]. Key energy consumption metrics include cooking-energy efficiency and idle rate when tested according to American Society for Testing and Materials (ASTM) Standard F1361, *Standard Test Method for the Performance of Open-Vat Fryers* [2] and ASTM F2144, *Standard Test Method for Performance of Large Open-Vat Fryers* [3]

EFFICIENT TECHNOLOGY

The Efficient technology is an open-vat fryer that meets ENERGY STAR Commercial Fryer Key Product Criteria V 3.0 (Rev. December 2020). This includes vat sizes: standard, large, and split.
ENERGY STAR Commercial Fryer Key Product Criteria V 3.0 distinguishes fryer sizes as follows:

- **Standard Fryer:** A fryer with a vat that measures ≥ 12 inches and < 18 inches wide and has a shortening capacity ≥ 25 pounds and ≤ 65 pounds.
- **Large Vat Fryer:** A fryer with a vat that measures ≥ 18 inches and ≤ 24 inches wide and has a shortening capacity > 50 pounds.
- **Split Vat Fryer:** A standard or large vat fryer with an internal wall that separates the vat into two equal sides.

[2] Based on qualifying products under ENERGY STAR Commercial Fryer Key Product Criteria V3.0 [1]

Error! Reference source not found.2 summarizes the minimum criteria for ENERGY STAR qualifying gas fryers. [1]

Table 2 Efficient Technology[3]

Fryer Type	Heavy-Load Cooking Energy Efficiency	Idle Energy Rate
Standard Vat	≥ 50%	≤ 9,000 Btu/hr
Large Vat	≥ 50%	≤ 12,000 Btu/hr

ENERGY IMPACTS

ENERGY STAR fryers require less natural gas during preheating, idling, and cooking. Natural gas savings are achieved through reduced cooking input rate and lower idle energy rate. There are no electric impacts for this measure.

NATURAL GAS SAVINGS ALGORITHM

The industry standards for evaluating fryers are ASTM F1361, *Standard Test Method for the Performance of Open-Vat Fryers* [2] and ASTM F2144, *Standard Test Method for Performance of Large Open-Vat Fryers* [3]. The results of these testing procedures form the basis for the energy savings calculation of open-vat fryers. Annual energy consumption is also greatly affected by the hours of operation per day, days operating per year, and number of preheats 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 open-vat fryers is as follows:

1. **Calculation of the daily natural gas consumed by the fryer**

   $E_{day} = E_{cooking} + E_{Idle} + E_{pre-heat}$

   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)

[3] Includes split vat fryers

1a. Calculation of the daily natural gas consumed by the fryer- cooking mode

$$E_{cooking} = \frac{Lb_{food} \times E_{food}}{Eff}$$

where:

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 (%)

1b. Calculation of the daily natural gas consumed by the fryer- idle mode

$$E_{Idle} = Idle \times \left(T_{on} - \frac{Lb_{food}}{PC} - nP \times \frac{TP}{60}\right)$$

where:

$Idle$ = Natural Gas Idle Energy Rate (Btu/hr)

T_{on} = Operating Hours per Day- fryer (hr/day)

Lb_{food} = Pounds of Food Cooked per Day (lb/day)

PC = Production Capacity (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 fryer- preheat mode

$$E_{pre-heat} = nP \times EP$$

where:

nP = Number of Preheats per Day (preheats/day)

EP = Preheat Energy (Btu/preheat)

2. Calculation of the annual natural gas consumption for baseline and ENERGY STAR fryers

$$NG_{usage} = E_{day} \times days$$

where:

NG_{usage} = Annual natural gas consumption by the fryer (Btu/year)

E_{day} = Daily energy consumption- Natural Gas (Btu/day)

$days$ = The number of days per year the fryer 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:

$NG_{savings-tier1}$ = Annual natural gas savings (m^3/year)

NG_{usage_b} = Annual natural gas consumption of the baseline fryer (Btu/year)

NG_{usage_E} = Annual natural gas consumption of the ENERGY STAR fryer (Btu/year)

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

ASSUMPTIONS

The Food Service Technology Center has tested multiple baseline and efficient gas fryers per the ASTM standard test methods. [2] [3] The baseline fryers are units that do not meet the ENERGY STAR Commercial Fryers Criteria, V3.0. Key energy consumption metrics include cooking energy efficiency and idle energy rate when tested in accordance with ASTM F1361 [2] or F2144 [3]. Baseline energy consumption for fryers has been taken from the average of the FSTC dataset (which is unpublished due to proprietary manufacturer data) that does not meet the ENERGY STAR product criteria.
The assumptions used to calculate energy savings are shown in Tables 3 and 4.

Table 3 Standard Vat Fryer Assumptions

Performance Parameters	Baseline Model	ENERGY STAR	Unit	Source
Preheat Time	11.7	10.5	min/preheat	[4]
Preheat Energy	16,186	10,072	Btu/preheat	[4]
Idle Energy Rate	12,952	5,765	Btu/h	[4]
Heavy Load Cooking Energy Efficiency	36	55	%	[4]
Production Capacity	56	66	lb/hr	[4]
Pounds of Food Cooked per Day	150		lb/day	[5]
ASTM Energy to Food- Fryers	577		Btu/lb	[2]
Number of Preheats per Day	1			
Operating Hours/Day	12		hr/day	[6]
Food Service Days/Year	344		day/yr	common assumption
Conversion factor (min to hr)	60		min/hr	
Conversion factor (Btu to m^3)	35,738		Btu/m^3	common assumption

Table 4 Large Vat Fryer Assumptions

Performance Parameters	Baseline Model	ENERGY STAR	Unit	Source
Preheat Time	11.1	12.7	min/preheat	[4]
Preheat Energy	21,997	16,613	Btu/preheat	[4]
Idle Energy Rate	20,425	7,860	Btu/h	[4]
Heavy Load Cooking Energy Efficiency	46	59	%	[4]
Production Capacity	100	93	lb/hr	[4]
Pounds of Food Cooked per Day	150		lb/day	[5]
ASTM Energy to Food- Fryers	577		Btu/lb	[3]
Number of Preheats per day	1			
Operating Hours/Day	12		hr/day	[6]
Food Service Days/Year	344		day/yr	common assumption
Conversion factor (min to hr)	60		min/hr	
Conversion factor (Btu to m^3)	35,738		Btu/m^3	common assumption

SAVINGS CALCULATION EXAMPLE

The example below illustrates the annual natural gas savings calculations for the replacement of a conventional fryer with an ENERGY STAR standard, single vat fryer.

Calculation of the daily natural gas consumption for baseline equipment

$$E_{cooking-base} = \frac{150\frac{lb}{day} \times 577\frac{Btu}{lb}}{0.36} = 240{,}417\frac{Btu}{day}$$

$$E_{Idle-base} = 12{,}952\frac{Btu}{hr} \times \left(12\frac{hr}{day} - \frac{150\frac{lb}{day}}{56\frac{lb}{hr}} - 1\frac{preheat}{day} \times \frac{11.7\frac{min}{preheat}}{60\frac{min}{hr}}\right) = 118{,}206\frac{Btu}{day}$$

$$E_{pre-heat-base} = 16{,}186\frac{Btu}{day}$$

$$E_{day-base} = 240{,}417\frac{Btu}{day} + 118{,}206\frac{Btu}{day} + 16{,}186\frac{Btu}{day} = 374{,}808\frac{Btu}{day}$$

Calculation of the daily natural gas consumption for ENERGY STAR equipment

$$E_{cooking-ES} = \frac{150\frac{lb}{day} \times 577\frac{Btu}{lb}}{0.55} = 157{,}364\frac{Btu}{day}$$

$$E_{Idle-ES} = 5{,}765\frac{Btu}{hr} \times \left(12\frac{hr}{day} - \frac{150\frac{lb}{day}}{66\frac{lb}{hr}} - 1\frac{preheat}{day} \times \frac{10.5\frac{min}{preheat}}{60\frac{min}{hr}}\right) = 55{,}069\frac{Btu}{day}$$

$$E_{pre-ES} = 10{,}072\frac{Btu}{day}$$

$$E_{day-ES} = 157{,}364\frac{Btu}{day} + 55{,}069\frac{Btu}{day} + 10{,}072\frac{Btu}{day} = 222{,}504\frac{Btu}{day}$$

Annual Natural Gas Savings Standard, Single Vat Fryer:

$$NG_{savigns} = \frac{\left(374{,}808\frac{Btu}{day} - 222{,}504\frac{Btu}{day}\right) \times 344\frac{day}{yr}}{35{,}738\frac{Btu}{m^3}} = 1{,}466\frac{m^3/yr}{vat}$$

USES AND EXCLUSIONS

To qualify for this measure, the fryer must be utilized 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 Fryer Key Product Criteria V3.0. [1]

MEASURE LIFE

The measure life attributed to this measure is 12 years. [5]

INCREMENTAL COST

The incremental cost is shown in the table below.

Table 5 Fryer Incremental Cost *[7]*

Description	Standard Vat	Large Vat
Incremental cost CAD ($) per vat	$2,657	$3,113

REFERENCES

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COMMERCIAL – ENERGY STAR STEAM COOKER– NEW CONSTRUCTION/TIME OF NATURAL REPLACEMENT

Version Date and Revision History	
Version History	2.0
OED Filing Date	November 14, 2022
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Commercial → Food Service → ENERGY STAR Steam Cooker→ 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 non-ENERGY STAR® rated Steam cooker
Efficient Technology	An ENERGY STAR® rated[1] Steam cooker
Market Type	Commercial
Annual Natural Gas Savings (m^3/yr per steamer)	8,461
Annual Water Savings (liters/yr per steamer)	1,109,458
Incremental Cost (CAD $ per steamer)	$3,045
Measure Life	12 years
Restrictions	Restricted to natural gas steam cookers (5-pans or larger in size) 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.

The steam can be delivered to the cavity in several different ways. These can be categorized into two main groups: pressure-less steamers and pressure steamers. In a pressure-less steamer, steam is injected through

[1] Based on qualifying products under ENERGY STAR Commercial Steam cooker Product Criteria V 1.2 [1]

openings in the sides of the cooking compartment, which allows the cooking compartment door to be opened at any time during the cooking procedure. Pressure steamers use steam that has been pressurized to 5 to 15 psi, which requires the cooking compartment to be depressurized before it can be opened.

The steam being supplied to the compartment may be produced in several ways:

- Boiler steamer: The steamer has an external boiler (relative to the cooking compartment) that generates potable steam.
    - Pressure-less steamer: The compartment is openly connected to a condensate drain and the pressure in the compartment is at or slightly above atmospheric pressure.
    - Pressurized steamers: The pressurized steam is delivered as demanded by control settings. Compartment must be depressurized before it is opened.
- 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.

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 in terms of number of pans and compartments, but steamers holding six or more pans are the most common.

APPLICATION

This measure applies to the installation of natural gas fueled ENERGY STAR rated[2] steam cookers (5-pan or larger in size) 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.

ENERGY STAR rated steam cookers offer shorter cook times, higher production rates, and reduced heat loss due to better insulation and more efficient steam delivery system.

BASELINE TECHNOLOGY

The baseline technology is a standard boiler-based steam cooker that does not meet the ENERGY STAR criteria due to their low efficiency and high idle energy rate.

[2] Based on qualifying products under ENERGY STAR Commercial Steam cooker Product Criteria V 1.2 [1]

EFFICIENT TECHNOLOGY

The efficient technology is an ENERGY STAR rated steam cooker that meets ENERGY STAR Commercial Steam Cooker Key Product Criteria V 1.2 [1]. Table 2 summarizes the minimum criteria for ENERGY STAR qualifying steam cookers.

Table 2 Efficient Technology

Pan Capacity	Heavy-Load Cooking Energy Efficiency	Idle Energy Rate
5-pan	≥ 38%	≤ 10,450 Btu/hr
6-pan and larger	≥ 38%	≤ 12,500 Btu/hr

ENERGY IMPACTS

The 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.

ENERGY STAR qualified steam cookers idle rate requirement varies with the size of the steamer. The savings are achieved through shorter cook times, higher production rates, 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. There are no electric impacts for this measure.

NATURAL GAS SAVINGS ALGORITHM

The industry standard for evaluating steam cookers is the American Society for Testing and Materials (ASTM) F1484, *Standard Test Method for Performance of Steam Cookers* [2]. The performance of steamers is determined by preheat time, preheat energy consumption, idle energy consumption, cooking energy consumption, cooking energy efficiency, and production capacity. The results of this testing procedure form the basis for the energy savings calculation of steam cookers.

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 ("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 steamer is as follows:

1. **Calculation of the daily natural gas consumed by the steamer**

$$E_{day} = E_{cooking} + E_{Idle} + E_{pre-heat}$$

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 steamer- cooking mode

$$E_{cooking} = \frac{Lb_{food} \times E_{food}}{Eff}$$

where:

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 (%)

1b. **Calculation of the daily natural gas consumed by the steamer- idle mode**

$$E_{Idle} = Idle_{actual} + Idle_{residual}$$

where:

$Idle_{actual}$ = Natural gas consumed when the unit is idling-actually (Btu/day)

$Idle_{residual}$ = Natural gas consumed in manual mode during idling-residual (Btu/day)

<u>Actual idling</u>

$$Idle_{actual} = (1 - \%_{Manual\ mode}) \times Idle \times \left(T_{on} - \frac{Lb_{food}}{PC} - nP \times \frac{TP}{60}\right)$$

where:

$\%_{Manual\ mode}$ = Percentage of time the unit is injecting steam in the cavity but is not cooking

$Idle$ = Natural Gas Idle Energy Rate (Btu/hr)

T_{on} = Operating Hours per Day- steam cooker (hr/day)

Lb_{food} = Pounds of Food Cooked per Day (lb/day)

PC = Production Capacity (lb/hr)

nP = Number of Preheats per Day (preheats/day)

TP = Preheat Time (min/preheat)

Residual idling

$$Idle_{residual} = \%_{Manual\ mode} \times \frac{PC \times E_{food}}{Eff} \times \left(T_{on} - \frac{Lb_{food}}{PC} - nP \times \frac{TP}{60}\right)$$

where:

$\%_{Manual\ mode}$ = Percentage of time the unit is injecting steam in the cavity but is not cooking

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 (%)

T_{on} = Operating Hours per Day- steam cooker (hr/day)

Lb_{food} = Pounds of Food Cooked per Day (lb/day)

PC = Production Capacity (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 steamer- preheat mode

$$E_{pre-heat} = nP \times EP$$

where:

nP = Number of Preheats per Day (preheats/day)

EP = Preheat Energy (Btu/preheat)

2. Calculation of the annual natural gas consumption for baseline and ENERGY STAR steamers

$$NG_{usage} = E_{day} \times days$$

where:

NG_{usage} = Annual natural gas consumption by the steam cooker (Btu/year)

E_{day} = Daily energy consumption- Natural Gas (Btu/day)

$days$ = The number of days per year the steam cooker is in use (day/yr)

3. Calculation of the natural gas savings

$$NG_{savings} = \frac{(NG_{usage_b} - NG_{usage_E})}{35{,}738}$$

where:

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

NG_{usage_b} = Annual natural gas consumption of the baseline steam cooker (Btu/year)

NG_{usage_E} = Annual natural gas consumption of the ENERGY STAR steam cooker (Btu/year)

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

WATER SAVINGS ALGORITHM

The amount of water saved annually is the difference between the baseline and efficient case water consumption. Steamer annual water consumption is a function of the water consumed while in preheat, cooking and idle modes.

$$Water_{impac} = 3.78541 \times (Water\ Usage_{baseline} - Water\ Usage_{ENERGYSTAR}) \times T_{on} \times days$$

where,

$Water_{impac}$ = Annual water impact (L/year)

$W_{baseline}$ = Annual water consumption for the baseline steamer (gal/hr)

$W_{ENERGYSTAR}$ = Annual water consumption ENERGY STAR steamer (gal/hr)

3.78541 = Conversion factor (L/gal)

T_{on} = Operating Hours per Day (hr/day)

$days$ = The number of days per year the steamer is in use

ASSUMPTIONS

The Food Service Technology Center has tested multiple baseline and efficient gas steamers per the ASTM standard test methods. [2] Key energy consumption metrics include cooking energy efficiency and idle energy rate when tested according to ASTM F1484. Baseline energy consumption for steamers has been taken from the average of the FSTC dataset (which is unpublished due to proprietary manufacturer data) that does not meet the ENERGY STAR product criteria.

The assumptions used to calculate natural gas savings are shown in Table 3.

Table 3 Steam Cooker Assumptions

Performance	Baseline Model	ENERGY STAR	Unit	Source
Preheat Time	12.8	13.7	min/preheat	[3]
Preheat Energy	19,476	11,021	Btu/preheat	[3]
Idle Energy Rate	8,195	4,384	Btu/h	[3]
Heavy Load Cooking Energy Efficiency	21%	44%	%	[3]
Production Capacity	175	122	lb/hr	[3]
Average Water Consumption Rate	76	5	gal/hr	[3]
Percentage of Time in Constant Steam Mode	90%	0%	%	[4]
Pounds of Food Cooked per Day	100		lb/day	[4]
ASTM Energy to Food- Steam cooker	105		Btu/lb	[2]
Number of Preheats per day	1			
Operating Hours/Day	12		hr/day	[5]
Food Service Days/Year	344		day/yr	common assumption
Conversion factor (min to hr)	60		min/hr	
Conversion factor (Btu to m^3)	35,738		Btu/m^3	common assumption

SAVINGS CALCULATION EXAMPLE

The example below illustrates the annual natural gas savings and water impact for the replacement of a conventional steam cooker with an ENERGY STAR steam cooker.

Calculation of the daily natural gas consumption for baseline equipment

$$E_{cooking-base} = \frac{100\,\frac{lb}{day} \times 105\,\frac{Btu}{lb}}{0.21} = 50{,}000\,\frac{Btu}{day}$$

$$Idle_{base} = \left(12\frac{hr}{day} - \frac{100\frac{lb}{day}}{175\frac{lb}{hr}} - 1\frac{preheat}{day} \times \frac{12.8\frac{min}{preheat}}{60\frac{min}{hr}}\right) \times \left[(1 - 0.9) \times 8{,}195 + 0.9 \times \frac{175\frac{lb}{hr} \times 105\frac{Btu}{lb}}{0.21}\right]$$

$$Idle_{base} = 892{,}391\frac{Btu}{day}$$

$$E_{pre-heat} = 19{,}476\frac{Btu}{day}$$

$$E_{day-base} = 50{,}000\ Btuday + 892{,}391\frac{Btu}{day} + 19{,}476\frac{Btu}{day} = 961{,}867\frac{Btu}{day}$$

Calculation of the daily natural gas consumption for ENERGY STAR equipment

$$E_{cooking-ES} = \frac{100\frac{lb}{day} \times 105\frac{Btu}{lb}}{0.44} = 23{,}864\frac{Btu}{day}$$

$$Idle_{ES} = \left(12\frac{hr}{day} - \frac{100\frac{lb}{day}}{122\frac{lb}{hr}} - 1\frac{preheat}{day} \times \frac{13.7\frac{min}{preheat}}{60\frac{min}{hr}}\right) \times \left[(1 - 0.9) \times 4{,}384 + 0.9 \times \frac{175\frac{lb}{hr} \times 105\frac{Btu}{lb}}{0.44}\right]$$

$$Idle_{ES} = 48{,}014\frac{Btu}{day}$$

$$E_{pre-heat} = 11{,}021\frac{Btu}{day}$$

$$E_{day-ES} = 23{,}864\ Btuday + 48{,}014\frac{Btu}{day} + 11{,}021\frac{Btu}{day} = 82{,}898\frac{Btu}{day}$$

Annual Natural Gas Savings:

$$NG_{savigns} = \frac{\left(961{,}867\frac{Btu}{day} - 82{,}898\frac{Btu}{day}\right) \times 344\frac{day}{yr}}{35{,}738\frac{Btu}{m^3}} = 8{,}461\frac{m^3/yr}{steam\ cooker}$$

Annual Water Savings:

$$Water_{impac} = \frac{3.78541 liter}{gall} \times \frac{(76-5) gal}{hr} \times 12 \frac{hr}{day} \times 344 \frac{day}{yr} = 1{,}109{,}458\ L/yr$$

USES AND EXCLUSIONS

To qualify for this measure, the steam cooker must be utilized 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 Steam Cooker Key Product Criteria V1.2. [1] The measure is limited to steam cookers that have either a connectionless or steam-generator design.

MEASURE LIFE

The measure life attributed to this measure is 12 years. [4]

INCREMENTAL COST

The incremental cost is shown in the table below.

Table 4 Steam Cooker Incremental cost *[6]*

Description	Incremental cost
Incremental cost CAD ($) per steamer	$3,045

REFERENCES

[1] ENERGY STAR, "Commercial Steam Cooker Program Requirements, Version 1.2," [Online]. Available: https://www.energystar.gov/sites/default/files/asset/document/comm-steamers-prog_req_draft_v1.2.pdf. [Accessed March 2022].

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COMMERCIAL – INCREMENTAL HEAT RECOVERY VENTILATION (HRV) (55% EFFECTIVENESS BASELINE) – NEW CONSTRUCTION/TIME OF NATURAL REPLACEMENT

Version Date and Revision History	
Version	2.3 (minor update)
OEB Filing Date	March 19, 2026
OEB Approval Date	
Commercial → Space Heating → Incremental Heat 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) where HRV is required by Ontario Building Code Time of Natural Replacement (TNR)			
Baseline Technology	HRV with Minimum 55% Sensible Heat Recovery Effectiveness as per Ontario Building Code 2017, Supplement SB-10 January 1, 2017			
Efficient Technology	HRV with Minimum 65% Sensible Heat Recovery Effectiveness[1] 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			
Measure Efficiency	**Building Type**	**Gas Savings Rate (m^3/working CFM), ε_{EE} 1**	**Group**	**Average Group Gas Savings (m^3/working CFM)**
Annual Natural Gas Savings Rate with a HRV with Minimum 65% Sensible Heat Recovery	Multi-Family, Health Care and Nursing Homes	0.71	High Use	0.71
	Hotels	0.51		

[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	0.37	Medium Use	0.39
	Retail	0.31		
	Office	0.27	Low Use	0.25
	Warehouse	0.26		
	School	0.23		
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	1.42	High Use	1.42
	Hotels	1.01	Medium Use	0.79
	Restaurant	0.73		
	Retail	0.62		
	Office	0.54	Low Use	0.50
	Warehouse	0.51		
	School	0.46		
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	2.13	High Use	2.13
	Hotels	1.52	Medium Use	1.18
	Restaurant	1.10		
	Retail	0.92		
	Office	0.81	Low Use	0.75
	Warehouse	0.77		
	School	0.68		
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]

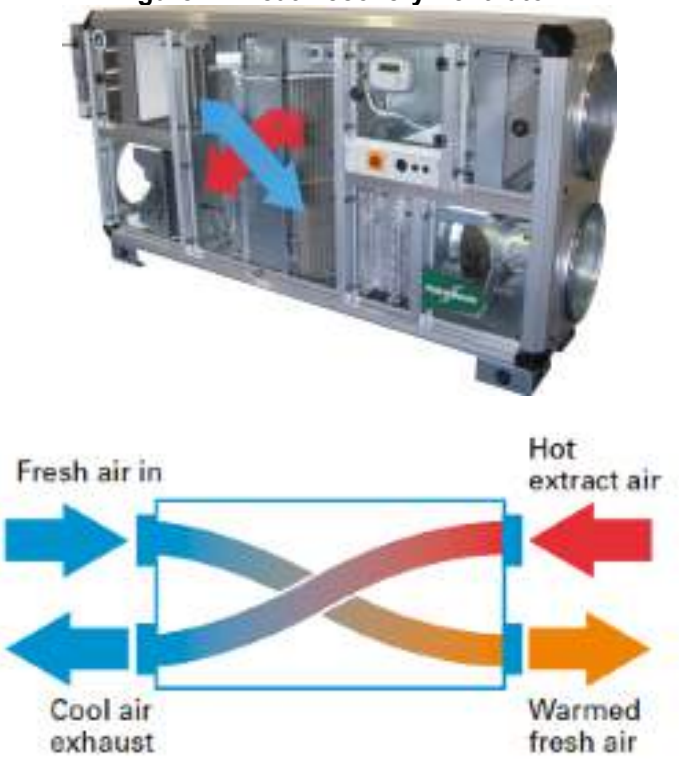
OVERVIEW

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]	6,019 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)	68°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.

$$hrs = 6{,}019\frac{hrs}{year} \times \frac{168\ \frac{hrs}{week}}{168\frac{hrs}{week}} = 6{,}019\frac{hrs}{year}$$

and,

$$NG\ Savings = 6{,}019\frac{hrs}{year} \times \frac{60min}{hr} \times 0.0741\frac{lb_m}{ft^3} \times \frac{75\% - 55\%}{80\%} \times \frac{0.240\frac{Btu}{lb_m - °F}}{35{,}738\frac{Btu}{m^3}}$$

$$\times (68°F - 34.8°F) \times \left(1 - \frac{5\%}{100\%}\right) = 1.42\frac{m^3}{CFM \cdot year}$$

Therefore,

$$NG\ Savings = 500\ CFM \times 1.42\frac{m^3}{CFM \cdot year} = 709\ \frac{m^3}{year}$$

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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[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].

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COMMERCIAL – HEAT RECOVERY VENTILATION (HRV) (NO HRV BASELINE) – NEW CONSTRUCTION/RETROFIT

Version Date and Revision History	
Version	2.3 (minor update)
OEB Filing Date	March 19, 2026
OEB Approval Date	
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	3.90	High Use	3.90
	Hotels	2.78	Medium Use	2.16
	Restaurant	2.02		
	Retail	1.69		
	Office	1.48	Low Use	1.38
	Warehouse	1.41		
	School	1.25		
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	4.61	High Use	4.61
	Hotels	3.29	Medium Use	2.56
	Restaurant	2.38		
	Retail	2.00		
	Office	1.75	Low Use	1.64
	Warehouse	1.67		
	School	1.48		
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	5.31	High Use	5.31
	Hotels	3.80	Medium Use	2.95
	Restaurant	2.75		
	Retail	2.31		
	Office	2.02	Low Use	1.89

<table>
<tr><th>Parameter</th><th colspan="4">Definition</th></tr>
<tr><td></td><td>Warehouse</td><td>1.93</td><td></td><td></td></tr>
<tr><td></td><td>School</td><td>1.71</td><td></td><td></td></tr>
<tr><td rowspan="9">Annual Gas Savings Rate with a Minimum HRV Sensible Heat Recovery Effectiveness of 85%, ε_{EE} 4 (m³/ working CFM)</td><td>Building Type</td><td>Gas Savings Rate (m³/working CFM), ε_{EE} 4</td><td>Group</td><td>Average Group Gas Savings (m³/working CFM) ε_{EE} 4</td></tr>
<tr><td>Multi-Family, Health Care and Nursing Homes</td><td>6.02</td><td>High Use</td><td>6.02</td></tr>
<tr><td>Hotels</td><td>4.30</td><td rowspan="3">Medium Use</td><td rowspan="3">3.35</td></tr>
<tr><td>Restaurant</td><td>3.12</td></tr>
<tr><td>Retail</td><td>2.62</td></tr>
<tr><td>Office</td><td>2.29</td><td rowspan="3">Low Use</td><td rowspan="3">2.14</td></tr>
<tr><td>Warehouse</td><td>2.19</td></tr>
<tr><td>School</td><td>1.94</td></tr>
<tr><td rowspan="9">Annual Electric Impact[2] (kWh/ working CFM)</td><td>Building Type</td><td>Electric Impact Rate (kWh/working CFM)</td><td>Group</td><td>Average Group Electric Impact (kWh/working CFM)</td></tr>
<tr><td>Multi-Family, Health Care and Nursing Homes</td><td>-5.00</td><td>High Use</td><td>-5.00</td></tr>
<tr><td>Hotels</td><td>-3.57</td><td rowspan="3">Medium Use</td><td rowspan="3">-2.78</td></tr>
<tr><td>Restaurant</td><td>-2.59</td></tr>
<tr><td>Retail</td><td>-2.17</td></tr>
<tr><td>Office</td><td>-1.90</td><td rowspan="3">Low Use</td><td rowspan="3">-1.77</td></tr>
<tr><td>Warehouse</td><td>-1.81</td></tr>
<tr><td>School</td><td>-1.61</td></tr>
<tr><td>Measure Life</td><td colspan="4">14 Years</td></tr>
<tr><td rowspan="2">First Incremental Cost ($ CAD) ε_{EE} 1</td><td colspan="2">Integrated HRV</td><td colspan="2">Standalone or Bolt-On HRV</td></tr>
<tr><td colspan="2">$5.35/CFM</td><td colspan="2">$8.28/CFM</td></tr>
</table>

[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 $\varepsilon_{EE}4$	$8.28 +$3.00 per CFM at$\varepsilon_{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

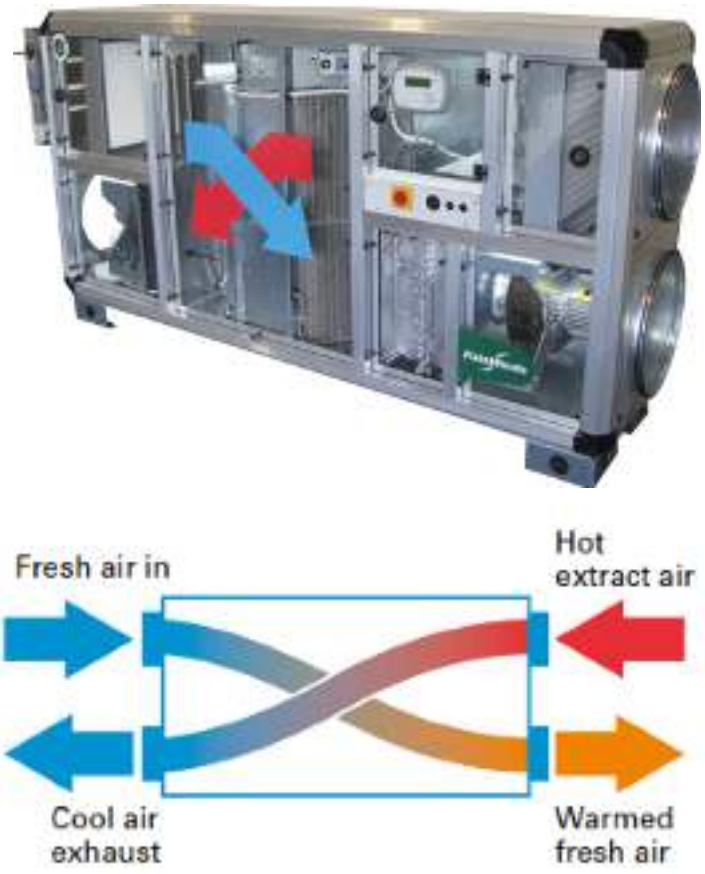
A heat recovery ventilator (HRV) refers to heat exchanger equipment that is designed to transfer sensible heat from the building exhaust air to the outside supply air. The temperature of the outside supply air is raised by the heat transferred from the exhaust air stream within the heat exchanger. By 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]	6,019 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)	68°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.

$$hrs = 6{,}019\ hrs \times \frac{168\frac{hrs}{week}}{168\frac{hrs}{week}} = 6{,}019\frac{hrs}{year}$$

and,

$$NG\ Savings = 6{,}019\frac{hrs}{year} \times \frac{60min}{hr} \times 0.0741\frac{lb_m}{ft^3} \times \frac{65\%}{80\%} \times \frac{0.240\frac{Btu}{lb_m - °R}}{35{,}738\frac{Btu}{m^3}}$$
$$\times (68°F - 34.8°F) \times \left(1 - \frac{5\%}{100\%}\right) = 4.61\frac{m^3}{CFM \cdot year}$$

Therefore,

$$NG\ Savings = 500\ CFM \times 4.61\frac{m^3}{CFM \cdot year} = 2{,}303\frac{m^3}{year}$$

The electrical penalty can be calculated as the following.

$$kWh\ penalty = 500\ CFM \times -0.83\frac{W}{CFM} \times 6{,}019\ \frac{hrs}{year} \times \frac{1kW}{1000W} = -2{,}498\ \frac{kWh}{year}$$

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.

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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	2.1
OEB Filing Date	August 7, 2024
OEB Approval Date	
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	0.690 m^3 per kBtu/hr input capacity
	Time of Natural Replacement	0.973 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 (m^3/yr)/(kBtu/hr)
$EFLH$	= Equivalent full load hours (hrs), see Table 4
$35.738\frac{kBtu}{m^3}$	= Conversion of rated heating capacity from input kBtu/hr to m^3/hr, common assumptions table
$AFUE_{base}$	= Baseline equipment thermal efficiency (%), see Table 2

[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	1,172 hours	Common assumptions table
		TNR	1,651 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.

$$NG\ Savings\ Factor = \frac{1{,}172\ hrs}{35.738\frac{kBtu}{m^3}} \times \left(\frac{97\%}{95\%} - 1\right) = \frac{0.690\ (m^3/yr)}{\frac{kBtu}{hr}}$$

And,

$$Annual\ NG\ savings = \frac{0.690\left(\frac{m^3}{yr}\right)}{\frac{kBtu}{hr}} \times 110\frac{kBtu}{hr} = 76\ m^3$$

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

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[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 – ENERGY-EFFICIENT UNDERFIRED BROILER– NEW CONSTRUCTION/TIME OF NATURAL REPLACEMENT

Version Date and Revision History	
Version	2.0
OEB Filing Date	November 14, 2022
OEB Approval Date	
Commercial → Food Service → Underfired Broiler→ 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 underfired broiler				
Efficient Technology	A high-efficiency underfired broiler: low idle energy rate (≤ 22,000 Btu/hr per linear foot) while maintaining 600°F when tested according to ASTM F1695 [1]				
Market Type	Commercial				
	Broiler Width				
	2-foot	**3-foot**	**4-foot**	**5-foot**	**6-foot**
Annual Natural Gas Savings (m3/yr per broiler)	1,757	2,636	3,515	4,393	5,272
Measure Life	12 years				
Incremental Cost ($ CAD/ broiler)	$1,264	$1,868	$2,948	$3,820	$4,134
Restrictions	Restricted to commercial/institutional food service broilers using natural gas, 2-feet wide or larger				

OVERVIEW

Underfired broilers (often referred to as "char-broilers") are among the most energy-intensive pieces of equipment in commercial kitchens. A workhorse on the production line, underfired broilers are used for a range of tasks from marking or searing food to cooking large volumes to finishing/expediting items to order. Underfired broilers consist of a cooking grate suspended above a radiant heat source that contains burners spaced every four to twelve inches. Utilizing high temperature radiant heat, broilers produce a characteristic taste and aroma that cannot be achieved through other cooking processes.

Underfired broilers are operated by user-adjustable manual controls that adjust the volume of gas flowing to the burners. The Food Service Technology Center (FSTC) monitored baseline and efficient equipment with various underfired broiler designs at nine different sites representing different types of operations. [2] The study found that most broilers are operated at high input rates over long operating periods.

The new generation of underfired broilers are all infrared (IR) designs and achieve higher effective broiling temperatures with lower energy input ratings. These energy-efficient underfired broilers can make a significant impact on an operation by utilizing radiant heat more effectively, resulting in higher productivity with lower energy use.

The industry standard for evaluating underfired broiler energy consumption and performance is the American Society for Testing and Materials (ASTM) Standard F1695, *Standard Test Method for Performance of Underfired Broilers*. [1] This standard defines the specific ways that underfired broilers must be tested to document temperature uniformity, preheat energy consumption, idle energy use, and cooking energy efficiency and production capacity.

APPLICATION

Commercial broilers are one of the most energy intensive kitchen appliances due to their high-energy usage and long operating hours.

There are multiple types and sizes of underfired broilers to fit different applications. This measure is applicable to 2-foot wide or larger broilers that meet the efficiency criteria. The key energy consumption metric for efficient underfired broilers is a low idle energy rate (≤22,000 Btu/hr per linear foot) while maintaining 600°F when tested according to ASTM F1695. [1]

BASELINE TECHNOLOGY

The baseline technology is a conventional underfired broiler with atmosphere burners. Broiler energy usage can be characterized based on the normalized energy use per hour per linear foot

length. Key energy consumption metrics include high idle energy rate (>22,000 Btu/hr per linear foot) while maintaining 600°F when tested according to ASTM F1695. [1]

EFFICIENT TECHNOLOGY

The efficient technology is defined as an energy-efficient underfired broiler. The key energy consumption metric for efficient underfired broilers is a low idle energy rate (≤ 22,000 Btu/hr per linear foot) while maintaining 600°F when tested according to ASTM F1695.

ENERGY IMPACTS

Efficient broilers require less natural gas during the preheat and cook/idle modes. Natural gas savings are achieved through advanced burner designs that provide more heat to the broiling area with lower operating energy consumption rates. There are no electric impacts for this measure.

NATURAL GAS SAVINGS ALGORITHM

The industry standard for evaluating underfired broilers is ASTM F1695, *Standard Test Method for Performance of Underfired Broilers*. [1] The performance of underfired broilers is determined by preheat time, preheat energy consumption, and idle energy consumption (full burn load). Broiler idle energy rate is the same as cooking energy rate because they are manually controlled and always left on due to high throughput. The algorithm is based upon methodology used by the FSTC. The calculation to determine the daily energy usage of baseline and energy-efficient underfired broilers is as follows:

1. **Calculation of the daily natural gas consumed by the underfired broiler**

$$E_{day} = E_{cooking} + E_{pilot} + E_{pre-heat}$$

where,

E_{day} = Daily energy consumption- Natural Gas (Btu/day)

$E_{cooking}$ = Daily energy consumption cooking mode- Natural Gas (Btu/day)

E_{pilot} = Daily energy consumption by the underfired broiler's pilot- 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 underfired broiler-cooking mode

$$E_{cooking} = F_{load} \times \left(T_{on} - nP \times \frac{TP}{60}\right)$$

where,

F_{load} = Full Burn Load (Btu/hr)

T_{on} = Operating Hours per Day (hr/day)

nP = Number of Preheats per Day (preheats/day)

TP = Preheat Time (min/preheat)

60 = Conversion factor minutes to hours (min/hr)

1b. Calculation of the daily natural gas consumed by the underfired broiler's pilot

$$E_{pilot} = Pilot \times T_{on}$$

where,

E_{pilot} = Daily natural gas consumption by the underfired broiler's pilot (Btu/day)

$Pilot$ = Rate of natural gas consumption by the underfired broiler's pilot (Btu/hr)

T_{on} = Operating Hours per Day (hr/day)

1c. Calculation of the daily natural gas consumed by the underfired broiler-preheat mode

$$E_{pre-heat} = nP \times EP$$

where,

nP = Number of Preheats per Day (preheats/day)

EP = Preheat Energy (Btu/preheat)

2. Calculation of the annual natural gas consumption for baseline and energy-efficient underfired broilers

$$NG_{usage} = E_{day} \times days$$

where,

NG_{usage} = Annual natural gas consumption by the underfired broiler (Btu/yr)

E_{day} = Daily energy consumption- Natural Gas (Btu/day)

$days$ = The number of days per year the underfired broiler 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/yr)

NG_{usage_b} = Annual natural gas consumption by the baseline underfired broiler (Btu/yr)

NG_{usage_E} = Annual natural gas consumption by the energy-efficient underfired broiler (Btu/yr)

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

ASSUMPTIONS

The Food Service Technology Center has tested multiple baseline and efficient gas underfired broilers per the ASTM standard test method. [1] Key energy consumption metrics include cooking energy efficiency and full load burn rate when tested according to ASTM F1695. Field data was accompanied by controlled laboratory testing of thirteen different models of underfired broilers using the industry standard test method. [3] Baseline energy consumption for underfired broilers has been taken from the average of the FSTC dataset (which is unpublished due to proprietary manufacturer data) that does not meet the efficient technology criteria.

The assumptions used to calculate natural gas savings are shown in Table 2.

Table 2 Underfired Broiler Assumptions: 3-foot

Performance	Baseline Model	Energy-Efficient Model	Unit	Source
Preheat Time	20.7	19.4	min/preheat	[3]
Preheat Energy	35,183	32,700	Btu/preheat	[3]
Idle Energy Rate (full burn load)	82,259	58,721	Btu/hr	[3]
Pilot Energy Rate	759	900	Btu/hr	[3]
Number of Preheats per Day	1			
Operating Hours/Day	12		hr/day	[4]
Food Service Days/Year	344		day/yr	common assumption
Conversion factor (min to hr)	60		min/hr	
Conversion factor (Btu to m^3)	35,738		Btu/m^3	common assumption

SAVINGS CALCULATION EXAMPLE

The example below illustrates the annual natural gas savings calculation from the replacement of a 3-foot conventional underfired broiler with an energy-efficient underfired broiler.

Calculation of the daily natural gas consumption for baseline equipment

$$E_{cooking-base} = 82{,}259\frac{Btu}{hr} \times \left(12\frac{hr}{day} - 1\frac{preheat}{day} \times \frac{20.7\frac{min}{preheat}}{60\frac{min}{hr}}\right) = 958{,}729\frac{Btu}{day}$$

$$E_{pilot-base} = 759\frac{Btu}{hr} \times 12\frac{hr}{day} = 9{,}108\frac{Btu}{day}$$

$$E_{pre-heat-base} = 35{,}183\frac{Btu}{day}$$

$$E_{day-base} = 958{,}729\frac{Btu}{day} + 9{,}108\frac{Btu}{day} + 35{,}183\frac{Btu}{day} = 1{,}003{,}020\frac{Btu}{day}$$

Calculation of the daily natural gas consumption for efficient equipment

$$E_{cooking-EE} = 58{,}721\frac{Btu}{hr} \times \left(12\frac{hr}{day} - 1\frac{preheat}{day} \times \frac{19.4\frac{min}{preheat}}{60\frac{min}{hr}}\right) = 685{,}666\frac{Btu}{day}$$

$$E_{pilot-EE} = 900\frac{Btu}{hr} \times 12\frac{hr}{day} = 10{,}800\frac{Btu}{day}$$

$$E_{pre-EE} = 32{,}700\frac{Btu}{day}$$

$$E_{day-EE} = 685{,}666\frac{Btu}{day} + 10{,}800\frac{Btu}{day} + 32{,}700\frac{Btu}{day} = 729{,}166\frac{Btu}{day}$$

Annual Natural Gas Savings 3-foot Underfired Broiler:

$$NG_{savigns} = \frac{\left(1{,}003{,}020\frac{Btu}{day} - 729{,}166\frac{Btu}{day}\right) \times 344\frac{day}{yr}}{35{,}738\frac{Btu}{m^3}} = 2{,}636\ m^3/yr$$

Using the average annual natural gas savings for a 3ft underfired broiler calculated above, the natural gas savings were normalized per linear ft of broiler width. This results in a normalized savings of 879 m3/yr per linear foot of broiler width. The normalized savings per linear foot is then used to extrapolate the annual savings to all common underfired broiler sizes: 2ft, 3ft, 4ft, 5ft and 6ft. An example of this calculation for a 2ft underfired broiler is shown below and the extrapolated, normalized savings per common broiler size are summarized in Table 3.

$$2ft \times 879\ \frac{m^3}{yr\ \cdot ft} = 1{,}757\ m^3/yr$$

Table 3 Normalized Annual Natural Gas Savings - Underfired Broiler

Description	2-ft	3ft	4ft	5ft	6ft
Normalized annual nat. gas savings (m3/yr per underfired broiler)	1,757	2,636	3,515	4,393	5,272

USES AND EXCLUSIONS

To qualify for this measure, the broiler must be utilized for food preparation or processing with natural gas as its fuel source and must meet the energy efficiency criteria for commercial underfired broilers by having an idle energy rate ≤ 22,000 Btu/hr per linear foot while maintaining 600°F when tested in accordance with ASTM F1695. [1]

MEASURE LIFE

The measure life attributed to this measure is 12 years. [2]

INCREMENTAL COST

The incremental cost is shown in the table below.

Table 4 Underfired Broiler Incremental Cost [5]

Broiler Width	Incremental Cost ($ CAD per broiler)
2-foot	$1,264
3-foot	$1,868
4-foot	$2,948
5-foot	$3,820

REFERENCES

[1] American Society for Testing and Materials (ASTM), "Standard Test Method for the Performance of Underfired Broilers," American Society for Testing and Materials (ASTM) F1695, West Conshohocken, PA, 2020.

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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 15, 2021
OEB Approval Date	December 15, 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:

$$Multifamily\ Savings = 21.4\ \frac{\frac{m^3}{yr}}{gpm \cdot showerhead} \times\ (baseline\ rated\ gpm - high\ efficiency\ gpm) \times SF\ People \times \frac{}{MF\ People}$$

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:

$$Multifamily\ Savings\left(\frac{m^3}{yr}per\ showerhead\right) = \frac{31.0\frac{m^3}{yr}}{gpm} \times\ (baseline\ rated\ gpm - high\ efficiency\ gpm)$$

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:

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

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[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 15, 2021
OEB Approval Date	December 15, 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:

$$As - Used\ Flow\ Rate^{4} = 0.542 \times Nominal\ Flow\ Rate + 0.691 \text{ [5]}$$

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 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

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COMMERCIAL — OZONE LAUNDRY TREATMENT — NEW CONSTRUCTION/ RETROFIT

Version Date and Revision History	
Version	2.1 (minor changes)
OEB Filing Date	November 14, 2022
OEB Approval Date	November 14, 2022
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

<table>
<tr><th>Parameter</th><th colspan="4">Definitions</th></tr>
<tr><td>Measure Category</td><td colspan="4">New Construction (NC)
Retrofit (R)</td></tr>
<tr><td>Baseline Technology</td><td colspan="4">Commercial laundry with no ozone treatment system</td></tr>
<tr><td>Efficient Technology</td><td colspan="4">Ozone treatment system for commercial laundry</td></tr>
<tr><td>Market Type</td><td colspan="4">Commercial, Multi-residential[1]</td></tr>
<tr><td>Annual Natural Gas Savings[2]
Annual Electric Savings
Annual Water Savings</td><td colspan="4"><table>
<tr><th>Washer Type</th><th>Natural Gas Savings Factor - NGSF (m^3/lb)</th><th>Electric Savings Factor - ESF (kWh/lb)</th><th>Water Savings Factor - WSF (L/lb)</th></tr>
<tr><td>Extractor Washers</td><td>0.0376</td><td>0.00211</td><td>2.10</td></tr>
<tr><td>Tunnel Washers</td><td>0.0295</td><td>0.00150</td><td>1.29</td></tr>
</table></td></tr>
<tr><td>Measure Life</td><td colspan="4">15 years</td></tr>
<tr><td>Incremental Cost
($ CAD)</td><td colspan="4"><table>
<tr><th>Washer Type</th><th>Incremental Cost</th></tr>
<tr><td>Washer extractor – ≤ 60 lbs</td><td>$15,714</td></tr>
<tr><td>Washer extractor – > 60 lbs and < 500 lbs</td><td>$35,714</td></tr>
<tr><td>Washer extractor – ≥ 500 lbs</td><td>$44,286</td></tr>
<tr><td>Tunnel washer – ≤ 120 lbs</td><td>$71,429</td></tr>
<tr><td>Tunnel washer – > 120 lbs and < 500 lbs</td><td>$150,000</td></tr>
<tr><td>Tunnel washer – ≥500 lbs</td><td>$228,571</td></tr>
</table></td></tr>
</table>

[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.

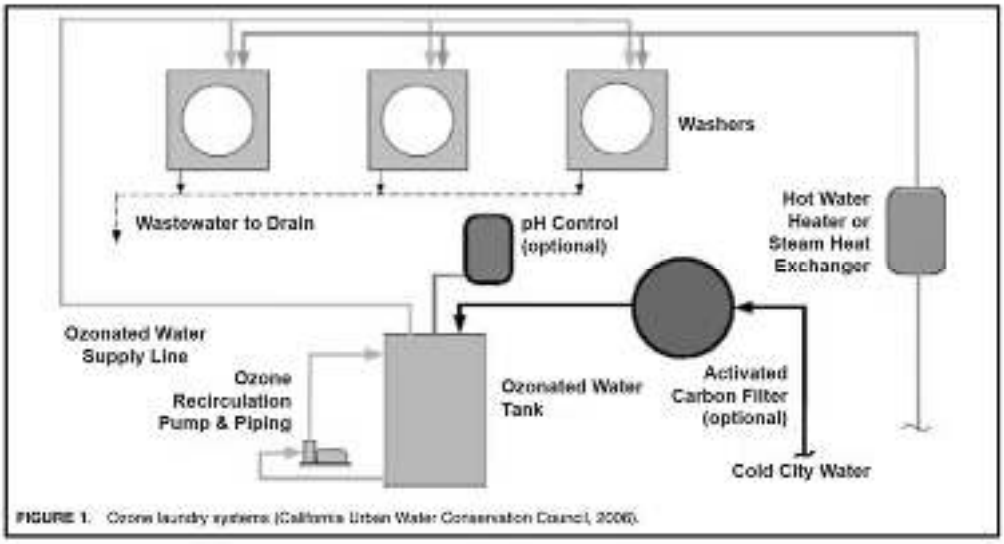
Parameter	Definitions
Restrictions	This measure is restricted to commercial clothes washers using water heated by natural gas. Washers dedicated to cleaning heavily soiled laundry are not eligible.

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



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) [2]. 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 [3]. 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 [4] . 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	8.53 C (47.35 F)	Common assumptions table
Commercial water heating efficiency	83.6%	Common assumptions table
Ratio of water recycled	30.0%	[5]
Water temperature for medium soil (ozone)	20.0°C	[4] [3]

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:

$$\Delta(m^3) = 0.0295\frac{(m^3)}{lb} \times 120\frac{lb}{load} \times 84{,}000\frac{loads}{yr} = 297{,}360\ \frac{m^3}{yr}$$

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 [4].

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 [4] [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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[2] J. R. G. Riopelle, *Redacted - Final Report DSM Ozone Laundry Calculator,* 2009, updated 2014.

[3] Laundry Consulting, "Ozone Laundry Systems," [Online]. Available: http://laundryconsulting.com/solution/green-laundry-technology/ozone-laundry-systems/. [Accessed April 2014].

[4] Natural Gas Technologies Centre, "DSM OPPORTUNITIES ASSOCIATED WITH OZONE LAUNDRY TREATMENT (FOR HOSPITALITY AND HEALTH CARE FACILITIES), p.5," Union Gas, Boucherville, November 25, 2009.

[5] Alliance for Water Efficiency, "Laundries and Dry Cleaning Operations," [Online]. Available: http://www.allianceforwaterefficiency.org/uploadedFiles/Resource_Center/Library/non_residential/EBMUD/EBMUD_WaterSmart_Guide_Laundries_Dry-Cleaning_Operations.pdf. [Accessed April 2014].

[6] EcoTex, Interviewee, *Manufacturer.* [Interview]. May 1, 2014, conducted by ERS.

[7] O. Del, Interviewee, *Manufacturer.* [Interview]. May 12, 2014, conducted by ERS.

[8] Articlean, Interviewee, *Manufacturer.* [Interview]. May 14, 2014, conducted by ERS.

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

Version Date and Revision History	
Version	2
OEB Filing Date	April 30, 2024
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

Parameter	Definition	
Measure Category	New Construction (NC), Time of Natural Replacement (TNR)	
	Name identifier	**Definition**
Baseline Technology	Tankless DHW < 200 kBtu/hr	Storage Water Heater, that has an input rate ≥75 kBtu/hr up to 105 kBtu. Rated nominal volume ≥ 20 up to 120 US gallons. NC Uniform Energy Factor (UEF) = 0.8107-0.00021Vs TNR Uniform Energy Factor (UEF) = 0.6597-0.00024Vs
	Tankless DHW ≥ 200 kBtu/hr	Storage Water Heater, that has an input rate ≥75 kBtu/hr or greater, NC Thermal efficiency (TE) = 90%, Stand-by Loss (Btuh/hr) $0.84(Q/800+110\sqrt{V_0})$ TNR Thermal efficiency (TE) = 80%, Stand-by Loss (Btuh/hr) $Q/800 +110\sqrt{V_0}$
Efficient Technology	Tankless DHW < 200 kBtu/hr	Condensing Tankless Water Heater, has an input rate ≥75kBtu/hr up to <200kBtu/hr. NC UEF ≥ 0.95, negligible stand-by losses. TNR UEF ≥ 0.90, negligible stand-by losses.
	Tankless DHW ≥ 200 kBtu/hr	Condensing tankless water heater, has an input rate 200kBtu/hr. and greater. NC TE ≥ 96%, negligible stand-by losses. TNR TE ≥ 94%, negligible stand-by losses.
Market Type	Commercial	

<table>
<tr><th>Parameter</th><th colspan="9">Definition</th></tr>
<tr><td></td><td>Name identifier</td><td>Measure Category</td><td>Efficient Technology</td><td colspan="3">Efficiency Savings (m^3/ kBtu/hr. input)</td><td>New tankless water heater Input rate (kBtu/hr)</td><td>Storage Savings (m^3)</td></tr>
<tr><td></td><td></td><td></td><td></td><td>Low</td><td>Medium</td><td>High</td><td></td><td></td></tr>
<tr><td rowspan="10">Annual Natural Gas Savings Rate (m^3/ kBtu/hr + m^3)</td><td rowspan="2">Tankless DHW < 200 kBtu/hr</td><td>TNR</td><td>UEF = 0.90</td><td>1.918</td><td>3.128</td><td>4.349</td><td>< 200</td><td>212</td></tr>
<tr><td></td><td>UEF = 0.95</td><td>2.299</td><td>3.748</td><td>5.211</td><td></td><td></td></tr>
<tr><td></td><td>NC</td><td>UEF = 0.95</td><td>0.922</td><td>1.503</td><td>2.090</td><td>< 200</td><td>178</td></tr>
<tr><td rowspan="6">Tankless DHW ≥ 200 kBtu/hr</td><td rowspan="3">TNR</td><td>TE = 94%</td><td>0.862</td><td>1.405</td><td>1.954</td><td>≥ 200 to < 1,000</td><td>351</td></tr>
<tr><td>TE = 96%</td><td>0.985</td><td>1.606</td><td>2.233</td><td>≥ 1,000 to < 2,500</td><td>521</td></tr>
<tr><td>TE = 98%</td><td>1.108</td><td>1.807</td><td>2.512</td><td>≥ 2,500</td><td>867</td></tr>
<tr><td rowspan="3">NC</td><td>TE = 96%</td><td>0.328</td><td>0.535</td><td>0.744</td><td>≥ 200 to < 1,000</td><td>295</td></tr>
<tr><td rowspan="2">TE = 98%</td><td rowspan="2">0.438</td><td rowspan="2">0.714</td><td rowspan="2">0.992</td><td>≥ 1,000 to < 2,500</td><td>438</td></tr>
<tr><td>≥ 2,500</td><td>728</td></tr>
<tr><td>Measure Life</td><td colspan="9">20 years</td></tr>
<tr><td rowspan="2">Incremental Cost ($ CAD)</td><td colspan="2">New construction</td><td colspan="7">$1,030</td></tr>
<tr><td colspan="2">Time of Natural Replacement</td><td colspan="7">$3,030</td></tr>
<tr><td>Restrictions</td><td colspan="9">This measure applies to the installation of natural gas condensing tankless water heaters in commercial facilities.</td></tr>
</table>

OVERVIEW

The measure involves installing 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 efficiency (uniform energy factor or thermal efficiency-depending on the input rate of the water heater) 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 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.

Uniform energy Factor

The Uniform Energy Factor (UEF) describes how much energy a similar water heater uses and how much energy is used to power the water heater itself. The EUF is used for water heater units with less than 200 kBtu/hr whereas thermal efficiency is retained to quantify the efficiency of larger water heater units.

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.

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

Water heaters are a regulated product in Ontario, Canada by both the Federal and provincial governments. For the purpose of these Regulations, a gas-fired instantaneous water heater is one of the following types [1]:

> (a) household, if it has an input rate of less than 58.56 kW (200,000 Btu/h), has a Vr of no greater than 7.6 L (2 US gallons) and is designed to provide hot water at a temperature no greater than 82°C (180°F); or
>
> (b) commercial, if it is not described in paragraph (a).

This measure applies to the following type of water heaters installed in commercial facilities:

1. Commercial gas-fired instantaneous water heater means a flow-activated water heater that uses natural gas for fuel, has an input rate greater than 58.56 kW (200,000 Btu/h), has a Vr greater than 7.6 L (2 US gallons) and is designed to provide hot water at a temperature greater than 82°C (180°F). [1]. "Tankless DHW ≥ 200 kBtu/hr" is the name identifier used throughout this document.
2. Household gas-fired instantaneous water heater means a flow-activated water heater that uses natural gas, has an input of 21.97 kW (75,000 Btu/h) and greater but less than 58.56 kW (200,000 Btu/h), has a Vr of no greater than 7.6 L (2 US gallons) and is designed to provide hot water at a temperature no greater than 82°C (180°F). "Tankless DHW < 200 kBtu/hr" is the name identifier used throughout this document.

   Where, L = Litres

   Vr = the rated nominal volume, typically used in marketing material

   Vs = the measured storage volume as defined in the testing standard

   Q = the nameplate input rate in Btu/hr

BASELINE TECHNOLOGY

The baseline technology for NC measure category is a natural gas fueled storage water heater, rated 75 kBtu/hr. and greater, providing the hot water needs for all or portions of commercial facilities.

The baseline technology for TNR measure category is a non-condensing natural gas fueled storage water heater, rated 75 kBtu/hr. and greater, providing the hot water needs for all or portions of commercial facilities.

The performance parameter (thermal efficiency or uniform energy factor) is defined by the federal and provincial regulations given the input rate of the water heater [2]:

1. For commercial gas-fired storage water heater with an input rate of > 75,000 Btu/hr but ≤ 105,000 Btu/hr and nominal volume of 20 US gallons or more up to 120 US gallons, the performance parameter used to define the efficiency is the Uniform Energy Factor (UEF). The minimum requirement for replacement units is UEF = 0.6597-0.00024 Vs, whereas for other than replacement units the minimum requirement is UEF = 0.8107-0.00021 Vs. This defines the baseline for time of natural replacement and new construction measure categories-respectively- for Instantaneous water heaters with input rate less than 200,000 Btu/hr
2. For commercial gas-fired storage water heater, other than those described in item 1 above, the performance parameter used to define the efficiency is Thermal Efficiency (TE). The minimum requirement for replacement units is TE = 80%, whereas for other than replacement units the minimum requirement is TE = 90%. This defines the baseline

for time of natural replacement and new construction measure categories-respectively-for Instantaneous water heaters with input rate ≥ 200,000 Btu/hr.

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 the service water needs, or selected end uses. Units with input capacity of 75 kBtu/hr. [3] [4] 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.

The performance parameter (thermal efficiency or uniform energy factor) is defined by the federal and provincial regulations given the input rate of the instantaneous (tankless) water heater:

1. For gas-fired instantaneous water heater with an input rate of < 200,000 Btu/hr, the performance parameter used to define the efficiency is the Uniform Energy Factor (UEF). [5]
2. For commercial gas-fired instantaneous water heater, with an input rate of ≥ 200,000 Btu/hr, the performance parameter used to define the efficiency is Thermal Efficiency (TE). [1]

Table 2 summarizes the efficient technology minimum requirement for time of natural replacement and new construction measure categories for Instantaneous water heaters.

Table 2. Efficient technology minimum requirement

Input rate	Measure Category	Performance parameter
< 200 kBtu/hr	Time of natural replacement (TNR)	UEF ≥ 0.90
	New Construction (NC)	UEF ≥ 0.95
≥200 kBtu/hr	Time of natural replacement (TNR)	TE ≥ 94%
	New Construction (NC)	TE ≥ 96%

ENERGY IMPACTS

Natural gas savings are achieved because of the higher overall average efficiency of the condensing tankless units and elimination of storage or standby losses when compared to the baseline technology.

Neither electric, nor water consumption impacts associated with this measure were assessed.

NATURAL GAS SAVINGS ALGORITHMS

The 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 efficiency values for each utilization category based on the following algorithm.

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

Where,

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/yr) (see Table 3)
$\boldsymbol{\eta}_{\text{proposed}}$	=Efficiency for tankless water heater efficient technology
$\boldsymbol{\eta}_{\text{baseline}}$	=The average Efficiency for baseline storage water heater
NG_{ec}	= Natural Gas Energy content (kBtu/m^3)

The stand-by loss equation from the Energy Efficiency Regulations [2] was used to determine annual stand-by losses for the new construction and time of natural replacement baseline storage water heaters.

$$SL_{baseline\ (TNR)} = \left(\frac{Q_{baseline}}{800} + 110\ X\ \sqrt{V_{0\ baseline}}\right) \times HR$$

$$SL_{baseline\ (NC)} = 0.84 \times \left(\frac{Q_{baseline}}{800} + 110\ X\ \sqrt{V_{0\ baseline}}\right) \times HR$$

Where,

$SL_{baseline}$	= The calculated stand-by losses from the storage water heater (Btu/yr.)
$Q_{baseline}$	= The input energy rating for the storage water heater (Btu/hr.)[1]
$V_{0\ baseline}$	= The storage capacity of the storage water heater (gallons)[2]
HR	= The stand-by-losses hours per year (hr/yr)

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

[2] 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.

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

$$Total\ Savings = Efficiency\ Savings \times Input\ rate\ of\ new\ water\ heater + Eliminated\ Standby\ Losses$$

ASSUMPTIONS

The 2023 ASHRAE Application Handbook provides typical peak hourly demand and average daily hot water consumption data for several building types. [6] A 2012 Enbridge Gas funded study [7] 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) [6]
$Demand_{peak\ 15\ minute}$	= The peak 15-minute hot water demand for a specific building type (US gallon/occupant-hour) [6] [7]
OS_{factor}	= Typical tankless water heater oversizing factor relative to 15-minute peak demand (200%)[3] [7]
$Days\ per\ year$	= 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.

[3] 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. 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

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	Value		Source/Comments
EFLH	Annual equivalent full load hours of operation	Table 3		Based on data from the ASHRAE HVAC Application Handbook [6] as shown in EFLH formula in the Natural Gas Savings Algorithm section.
$\eta_{baseline}$	Baseline efficiency for name identifier "Tankless <200 kBtu/hr"	NC	UEF = 0.80[4]	Energy Efficiency Regulation for Commercial gas-fired storage water heaters [2]
		TNR	UEF = 0.65[4]	
	Baseline efficiency for name identifier "Tankless ≥ 200 kBtu/hr"	NC	TE = 90%	
		TNR	TE = 80%	
$\eta_{proposed}$	Efficient technology Efficiency for name identifier "Tankless <200 kBtu/hr"	NC	UEF = 0.95	Program admin level of efficiency target
		TNR	UEF = 0.90	
			UEF = 0.95	
	Efficient technology Efficiency for name identifier "Tankless ≥200 kBtu/hr	NC	TE = 96%	
			TE = 98%	
		TNR	TE = 94%	
			TE = 96%	
			TE = 98%	

[4] Baseline technology, UEF=0.80 and 0.65 was obtained by substitution of Vs = 50 US gallons (average storage volume of units available in the market) into UEF = 0.8107-0.00021Vs and UEF = 0.6597-0.00024Vs as per regulation for NC and TNR measure categories respectively.

Variable	Definition	Value		Source/Comments
$Q_{baseline}$	Input rating for equivalent storage water heater	Assumed to be 65% of tankless input rating		Water heater sizing guidelines from AMEC 2012 report [7]
NG_{ec}	Natural Gas Energy content	35.738 kBtu/m^3 or 35,738 Btu/m^3		Common assumption table
$V_{0\ baseline}$	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
		Input rate range (kBtu/hr)	**Value (Btu/hr)**	
	Average input rating tankless water heater	<200	182,641	Average Input rate of Energy Star rated tankless water heater sold in Canada < 200 kBtu [8]
		≥200 to < 1,000	533,150	Average Input rate of Energy Star rated tankless water heater sold in Canada ≥ 200 kBtu [9]
		≥1,000 to < 2,500	1,449,960	
		≥2,500	3,307,769	

SAVINGS CALCULATION EXAMPLE

The example below illustrates how savings would be calculated for a time of natural replacement tankless water heater with rated input capacity of 400 kBtu/hr. and TE = 94% 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 1.945 m^3 per kBtu/hr. rated input capacity, and standby loss value of 351 m^3.

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

$$1.945\ m^3 \Big/ \frac{kBtu}{hr} \times 400 \frac{kBtu}{hr} + 351\ m^3\ = 1{,}132 m^3$$

USES AND EXCLUSIONS

This measure applies to natural gas-fueled condensing tankless water heaters installed in commercial facilities and serving all or part of the service water heating load. This is applicable to measure category new construction and time of natural replacement installation. TNR measure category where the preexisting unit was a natural gas-fired non-condensing storage water heater. The replacement of a preexisting non-condensing tankless water heaters is not eligible.

MEASURE LIFE

The measure life is 20 years. [10]

INCREMENTAL COST

The incremental cost data is taken from California's 2023 eTRM documentation. [11]Incremental costs were derived based on the efficiency values outlined in Table 2.

Incremental costs vary based on the efficiency of the baseline technology and replacement technology for smaller commercial units (75-200 kBtu). In addition to varying incremental costs based on efficiency, larger unit (>200 kBtu) incremental costs were also shown to vary based on sizing between the two technologies.

Table 7. Incremental Cost[5]

Type	Material	Installation	Total
New Construction	$580	$450	$1,030
Natural Replacement	$2,580	$450	$3,030

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

Version Date and Revision History	
Version	2.1 (minor change)
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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	4,307 m^3 per year
	5,001 – 10,000 CFM	10,768 m^3 per year
	10,001 – 15,000 CFM	17,947 m^3 per year
Annual Electric Impacts (kWh)	**Hood Capacity**	**Savings**
	Up to 5,000 CFM	15,865 kWh per year
	5,001 – 10,000 CFM	22,364 kWh per year
	10,001 – 15,000 CFM	29,586 kWh per year
Measure Life	15 years	
Incremental Cost ($ CAD)	**Hood Capacity**	**Incremental Cost**
	Up to 5,000 CFM	$5,490
	5,001 – 10,000 CFM	$13,725
	10,001 – 15,000 CFM	$22,875
Restrictions	Limited to spaces with natural gas fueled space heating and commercial kitchen hoods with capacity of 15,000 CFM or less.	

OVERVIEW

Commercial Kitchen Ventilation (CKV) systems exhaust smoke, flue gases, heat and cooking odors. Traditional systems use simple on/off fan 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 seventeen 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 seventeen installations as follows.

$\%\ Flow\ Reduction$ = *((Flow Baseline – Flow EE)/Flow Baseline) x 100%*

% Flow Reduction = (1 – (Flow EE/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)

[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.

This resulted in a percent reduction in flow for each of the nineteen case studies ranging from 14.9% to 42.5% with an overall average percent reduction of 25.7%.

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	4,307
7,500	10,768
12,500	17,947

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 seventy-one case-studies revealed a relatively consistent increase in fan power relative to system capacity.[2] The values were plotted against system capacity and revealed a roughly linear relationship described by the following equation.

$$Fan\ Input\ Power_{baseline} = 0.3955 \times System\ Capacity + 3.286$$

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	4.47
7,500	6.25
12,500	8.23

The values from table two, the average 25.7% 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)

[2] Combining case studies from five references results in seventy-one case studies, excluding outliers. The five references are [2], [3], [4], [5], and [8].

$\%\ Flow\ Reduction$ = 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 (5,950 Hours/Year)[3]

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

Table 4. Fan Power Savings

Hood Capacity (CFM)	Savings (kWh/year)
3,000	15,695
7,500	21,941
12,500	28,881

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)

[3] Seventeen hours per day, 350 days per year based on seventy-two field data. [8]

$OACL$	= The weighted average annual outdoor air cooling load (Btu/Year per CFM)
$Capacity$	= The midpoint of the kitchen hood size range (CFM)
$\%\ Flow\ Reduction$	= The average % reduction in the exhaust flow rate resulting from the DCV installation (% of baseline flow)
$Eff_{cooling}$	= Efficiency of the space cooling equipment (COP = 3.8)
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. Cooling Savings

Hood Capacity (CFM)	Savings (kWh/year)
3,000	169
7,500	423
12,500	706

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	25.7%	Derived from empirical fan input power data from seventeen case studies.	[2] [3] [4] [5]
Unitary Fan Input Power $_{baseline}$	Baseline fan input power per CFM of exhaust hood capacity	0.3955 × 1000 CFM + 3.286	Derived from empirical fan input power data from eleven 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	80%		Common

Variable	Definition	Value	Inputs	Source
	system efficiency			assumptions table
$Eff_{Cooling}$	Commercial cooling system efficiency	13 SEER 3.8 COP		Common assumptions table
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	5,950	17 hours per day, 350 days per year, consistent with seventy-two field data	[8]

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 × 25.7%)/ (80.0% × 35,738 Btu/m^3)

= 10,768 m^3 per year

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

= (6.25 kW – 6.25 kW × (1 – 25.7%)^3 × 5,950 hours per year

= 21,941 kWh per year

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

= (2,856 Btu/CFM × 7,500 CFM × 25.7%) / (3.8 × 3,412 Btu/kWh)

= 423 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. [9][4]

INCREMENTAL COST

Cost data provided for seventy-two field data reflected an average installed measure cost of $3.66 per CFM of hood capacity for retrofit installations [8]. 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 seventy-two field data to the midpoint of the three size categories leads to the incremental cost values reported here.

Table 7: Incremental Cost [5]

Category	Incremental Cost
Up to 5,000 CFM	$5,490
5,001 – 10,000 CFM	$13,725
10,001 – 15,000 CFM	$22,875

[4] 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.

[5] Adjusted for CPI inflation based on U.S. Bureau of Labor Statistics (https://www.bls.gov/data/inflation_calculator.htm) and converted to CAD based on Annual Currency Converted for Bank of Canada, as of 11/20/2023. (https://www.bankofcanada.ca/rates/exchange/currency-converter/)

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COMMERCIAL – KITCHEN – DEMAND CONTROLLED VENTILATION – RETROFIT

Version Date and Revision History	
Version	2.1 (minor update)
OEB Filing Date	March 19, 2026
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	4,307 m^3 per year
	5,001 – 10,000 CFM	10,768 m^3 per year
	10,001 – 15,000 CFM	17,947 m^3 per year
Annual Electric Impacts (kWh)	**Hood Capacity**	**Savings**
	Up to 5,000 CFM	15,865 kWh per year
	5,001 – 10,000 CFM	22,364 kWh per year
	10,001 – 15,000 CFM	29,586 kWh per year
Measure Life	15 years	
Incremental Cost ($CAD)	**Hood Capacity**	**Incremental Cost**
	Up to 5,000 CFM	$10,980
	5,001 – 10,000 CFM	$27,450
	10,001 – 15,000 CFM	$45,750
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 flowrate, 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 are 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 seventeen 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 seventeen installations as follows.

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

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

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

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

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)

[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.

This resulted in a percent reduction in flow for each of the seventeen case studies ranging from 14.9% to 42.5% with an overall average percent reduction of 25.7%.

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	4,307
7,500	10,768
12,500	17,947

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 from seventy-one case-studies revealed a relatively consistent increase in fan power relative to system capacity.[2] The values were plotted against system capacity and revealed a roughly linear relationship described by the following equation.

$$Fan\ Input\ Power_{baseline} = 0.3955 \times System\ Capacity + 3.286$$

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	4.47
7,500	6.25
12,500	8.23

The values from table two, the average 25.7% 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)

[2] Combining case studies from five references results in seventy-one case studies, excluding outliers. The five references are [2], [3], [4], [5], and [8].

$\%\ Flow\ Reduction$ = 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 (5,950 Hours/Year)[3]

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

Table 4. Fan Power Savings

Hood Capacity (CFM)	Savings (kWh/year)
3,000	15,695
7,500	21,941
12,500	28,881

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)

[3] Seventeen hours per day, 350 days per year based on seventy-two field data. [8]

$OACL$	= The weighted average annual outdoor air cooling load (Btu/Year per CFM)
$Capacity$	= The midpoint of the kitchen hood size range (CFM)
$\%\ Flow\ Reduction$	= The average % reduction in the exhaust flow rate resulting from the DCV installation (% of baseline flow)
$Eff_{cooling}$	= Efficiency of the space cooling equipment (COP = 3.8)
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. Cooling Savings

Hood Capacity (CFM)	Savings (kWh/year)
3,000	169
7,500	423
12,500	706

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	25.7%	Derived from empirical fan input power data from seventeen case studies.	[2] [3] [4] [5]
Unitary Fan Input Power $_{baseline}$	Baseline fan input power per CFM of exhaust hood capacity	0.3955 × 1000 CFM + 3.286	Derived from empirical fan input power data from eleven 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]

Variable	Definition	Value	Inputs	Source
$Eff_{Heating}$	Commercial heating system efficiency	80%		Common assumptions table
$Eff_{Cooling}$	Commercial cooling system efficiency	13 SEER 3.8 COP		Common assumptions table
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	5,950	17 hours per day, 350 days per year, consistent with seventy-two field data	[8]

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 × 25.7%) / (80.0% × 35,738 Btu/m³)

= 10,768 m³ per year

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

= (6.25 kW – 6.25 kW × (1 – 25.7%)³) × 5,950 hours per year

= 21,941 kWh per year

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

= (2,856 Btu/CFM × 7,500 CFM × 25.7%) / (3.8 × 3,412 Btu/kWh)

= 423 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. [9][4]

INCREMENTAL COST

Cost data provided for seventy-two field data reflected an average installed measure cost of $3.66 per CFM of hood capacity [8]. Applying this value to the midpoint of the three size categories leads to the incremental cost values reported here.

Table 7: Incremental Cost [5]

Category	Incremental Cost
Up to 5,000 CFM	$10,980
5,001 – 10,000 CFM	$27,450
10,001 – 15,000 CFM	$45,750

[4] 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.

[5] Adjusted for CPI inflation based on U.S. Bureau of Labor Statistics (https://www.bls.gov/data/inflation_calculator.htm) and converted to CAD based on Annual Currency Converted for Bank of Canada, as of 11/20/2023. (https://www.bankofcanada.ca/rates/exchange/currency-converter/)

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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 15, 2021
OEB Approval Date	December 15, 2021
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**

$$E_{day} = \frac{(Lb_{food} \times E_{food})}{Eff} + Idle \times \left(T_{on} - \frac{Lb_{food}}{PC} - nP \times \frac{TP}{60}\right) + nP \times EP$$

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

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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 15, 2021
OEB Approval Date	December 15, 2021
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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COMMERCIAL – ENERGY STAR GRIDDLE– NEW CONSTRUCTION/TIME OF NATURAL REPLACEMENT

Version Date and Revision History	
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OED Filing Date	November 14, 2022
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Commercial → Food Service → ENERGY STAR Griddle → 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 non-ENERGY STAR® Griddle
Efficient Technology	An ENERGY STAR® certified[1] Griddle
Market Type	Commercial
Annual Natural Gas Savings (m3/yr per ft of griddle width)	439
Annual Natural Gas Savings (m3/yr per griddle)	1,974
Incremental Cost ($ CAD/yr per ft of griddle width)	$1,096
Incremental Cost ($ CAD /yr per griddle)	$4,581
Measure Life	12 years
Restrictions	Restricted to single-side griddles using natural gas.

[1] Based on qualifying products under ENERGY STAR Commercial Griddles Key Product Criteria V1.2 (REV DEC 2020) [3]

OVERVIEW

Griddles are used throughout the commercial foodservice and hospitality industry as workhorse appliances that cook food by direct contact with a heated surface. Griddles are used to crisp and brown foods such as potatoes and breads, sear vegetables, and proteins, and for warming and toasting sandwiches and buns. The relatively simple design of a griddle can have very different performance characteristics.

Griddles vary in size, input rate, heating method, griddle-plate construction, and control strategy. All designs cook via contact with a heated metal plate that has splashguards attached to the sides and rear and a shallow trough to guide grease and scraps into a holding tray. The griddle plate is heated from underneath by gas burners or electric elements, and controls are generally located on the front of the appliance.

The industry standard for evaluating griddle energy consumption and performance is the American Society for Testing and Materials (ASTM) F1275 *Standard Test Method for Performance of Griddles* [1] and the ASTM F1605 *Standard Test Method for Performance of Double-Sided Griddles* [2]. These standard test methods define the specific ways that griddles must be tested to document temperature uniformity, preheat energy consumption, idle energy use, cooking energy efficiency and production capacity.

APPLICATION

This measure applies to the installation of ENERGY STAR rated griddles (natural gas, single-side griddles) based on qualifying products under ENERGY STAR Commercial Griddles Key Product Criteria V1.2 [3] in commercial food settings.

BASELINE TECHNOLOGY

The baseline technology is a griddle that does not meet the ENERGY STAR Program Requirements for Commercial Griddles, Version 1.2. Key energy consumption metrics includes cooking-energy efficiency and idle rate when tested according to ASTM test methods.

EFFICIENT TECHNOLOGY

ENERGY STAR Griddles feature a lower idle energy rate than traditional griddles. Several other innovations, such as thermostatic controls, different plate materials, double-sided cooking, advanced burner technology and entirely new heating designs, also give newer griddle models a

higher energy-to-food ratio than traditional griddles. This means that more of the energy being supplied to heat the surface is used for cooking the food and less energy is wasted.

Energy-efficient models must be ENERGY STAR rated Griddles based on ENERGY STAR Commercial Griddle Key Product Criteria V2.1 [3]. Table 2 summarizes the efficient technology threshold.

Table 2 Efficient Technology Threshold

Idle Energy Rate *	Cooking Energy-Efficiency
<2,650 Btu/h per ft²	Reported

*Idle rate only includes gas energy

ENERGY IMPACTS

ENERGY STAR Griddles require less natural gas during preheating, idling, and cooking. Natural gas savings are achieved through reduced cooking input rate and lower idle energy rate.

NATURAL GAS SAVINGS ALGORITHM

The industry standard for evaluating griddle energy consumption and performance is the American Society for Testing and Materials (ASTM) F1275 *Standard Test Method for Performance of Griddles* [1]. The results of this testing procedure form the basis for the energy savings calculation of griddles. 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 FSTC. The calculation to determine the daily energy usage of baseline and ENERGY STAR griddles is as follows:

1. **Calculation of the daily natural gas consumed by the griddle**

   $E_{day} = E_{cooking} + E_{Idle} + E_{pre-heat}$

   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 griddle- cooking mode

$$E_{cooking} = \frac{Lb_{food} \times E_{food}}{Eff}$$

where:

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 (%)

1b. Calculation of the daily natural gas consumed by the griddle- idle mode

$$E_{Idle} = A_s \times Idle \times \left(T_{on} - \frac{Lb_{food}}{PC} - nP \times \frac{TP}{60}\right)$$

where:

A_s = Surface cooking area of the griddle (ft2)

$Idle$ = Normalized Natural Gas Idle Energy Rate (Btu/(hr·ft2))

T_{on} = Operating hours per day (hr./day)

Lb_{food} = Pounds of Food Cooked per Day (lb./day)

PC = Production Capacity (lb./hr)

nP = Number of preheats per day (preheats/day)

TP = Preheat Time (min/preheat)

60 = Conversion factor minutes to hours (min/hr.)

1c. Calculation of the daily natural gas consumed by the griddle- preheat mode

$$E_{pre-heat} = nP \times EP$$

where:

nP = Number of preheats per day (preheats/day)

EP = Preheat Energy (Btu/preheat)

2. Calculation of the annual natural gas consumption for baseline and ENERGY STAR griddles

$$NG_{usage} = E_{day} \times days$$

where:

NG_{usage} = Annual natural gas consumption by the griddle (Btu/year)

E_{day} = Daily natural gas consumption by the griddle (Btu/day)

$days$ = The number of days per year the griddle 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 griddle (Btu/year)

NG_{usage_E} = Annual natural gas consumption of the ENERGY STAR griddle (Btu/year)

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

ASSUMPTIONS

The Food Service Technology Center has tested multiple baseline and efficient gas griddles per the ASTM standard test methods for 3-foot and 4-foot-wide griddles [4]. The baseline griddles are units that do not meet the ENERGY STAR Commercial Griddle Criteria for Griddles, V1.2. Key energy consumption metrics include cooking-energy efficiency and idle energy rate when tested according to ASTM F1275 [1] or F1605 [2]. Baseline energy consumption for griddles has been taken from the average of the FSTC dataset (which is unpublished due to proprietary manufacturer data) that does not meet the ENERGY STAR product criteria. For this analysis, a depth of two feet is used in the calculations as a standard depth for a representative griddle.

Double-sided griddles were not included in these natural gas savings calculations, as there was not sufficient lab testing data to substantiate input assumptions required in the calculations.

Operational input assumptions were determined based on the results of the end-user online market survey that was administered in November 2018 to Enbridge Gas commercial customers in Ontario [4]. The survey concluded that normalized average operating hours across different market segments were 12 hours per day.

The assumptions used to calculate energy savings are shown in Tables 3 and 4.

Table 3 Griddle Assumptions: 3 foot

Performance	Baseline Model	Energy-Efficient Model	Unit	Source
Preheat Time	18	15	min/preheat	[4]
Preheat Energy	20,044	17,410	Btu/preheat	[4]
Normalized Idle Energy Rate	3,145	2,330	Btu/(h.ft^2)	[4]
Heavy Load Cooking Energy Efficiency	33	44	%	[4]
Production Capacity	35	47	lb/hr	[4]
Griddle Width or Length (ft)	3		ft	[4]
Griddle Depth	2		ft	Standard size
Operating Hours/Day	12		hr/day	[4]
Food Service Days/Year	344		day/yr	common assumption table
Number of Preheats per Day	1		preheat/day	[4]
Pounds of Food Cooked per Day	100		lb/day	[4]
ASTM Energy to Food - griddles	475		Btu/lb	[1]
Conversion factor (min to hr)	60		min/hr	
Conversion factor (Btu to m^3)	35,738		Btu/m^3	common assumption table

Table 4 Griddle Assumptions: 4 foot

Performance	Baseline Model	Energy-Efficient Model	Unit	Source
Preheat Time	19.4	13.8	min/preheat	[4]
Preheat Energy	33,300	21,737	Btu/preheat	[4]
Normalized Idle Energy Rate	4,673	2,281	Btu/(h.ft^2)	[4]
Heavy Load Cooking Energy Efficiency	24	41	%	[4]
Production Capacity	35	51	lb/hr	[4]
Griddle Width (length-ft)	4		ft	[4]
Griddle Depth	2		ft	Standard size
Operating Hours/Day	12		hr/day	[4]
Food Service Days/Year	344		day/yr	common assumption table
Number of Preheats per Day	1		preheat/day	[4]
Pounds of Food Cooked per Day	133		lb/day	[4]
ASTM Energy to Food - griddles	475		Btu/lb	[1]
Conversion factor (min to hr)	60		min/hr	
Conversion factor (Btu to m^3)	35,738		Btu/m^3	common assumption table

SAVINGS CALCULATION EXAMPLE

The example below illustrates the average annual natural gas savings calculations for the replacement of a conventional griddle with an ENERGY STAR griddle.

Annual NG usage for a 3-ft wide conventional griddle:

$$E_{cooking} = \frac{100\frac{lbs}{day} \times 475\frac{Btu}{lb}}{33\%} = 143{,}939\frac{Btu}{day}$$

$$E_{Idle} = 6\,ft^2 \times 3{,}145\frac{Btu}{hrs \cdot ft^2} \times \left(12\,hrs - \frac{100\frac{lbs}{day}}{35\frac{lbs}{hrs}} - 1\frac{preheat}{day} \times \frac{18\frac{mins}{preheat}}{60\,\frac{mins}{hrs}}\right)$$

$$E_{Idle} = 166{,}865\frac{Btu}{day}$$

$$E_{pre-heat} = 1\frac{preheat}{day} \times 20{,}044\frac{Btu}{preheat} = 20{,}044\frac{Btu}{day}$$

$$E_{day} = 143{,}939\frac{Btu}{day} + 166{,}865\frac{Btu}{day} + 20{,}044\frac{Btu}{day} = 330{,}848\frac{Btu}{day}$$

$$NG_{usage} = 330{,}848\frac{Btu}{day} \times 344\ days = 113{,}811{,}749\ Btu/yr$$

Annual NG usage for a 3-ft ENERGY Star griddle, 4-ft conventional griddle and 4-ft ENERGY Star griddle are calculated in the same way as shown above, yielding the following savings.

Annual NG savings for an average 3-ft wide griddle:

$$NG_{savings} = \frac{\left(113{,}811{,}749\frac{Btu}{yr} - 89{,}400{,}393\frac{Btu}{yr}\right)}{35{,}738} = 683\frac{m^3}{yr}$$

Annual NG savings for an average 4-ft wide griddle:

$$NG_{savings} = \frac{\left(203{,}300{,}723\frac{Btu}{yr} - 117{,}996{,}611\frac{Btu}{yr}\right)}{35{,}738} = 2{,}387\frac{m^3}{yr}$$

Using the average annual natural gas savings for 3ft and 4ft calculated above, the natural gas savings were normalized per linear ft of griddle width. This results in a normalized savings of 439 m^3/yr per linear ft of griddle width. The normalized savings per linear ft is then used to extrapolate the annual savings to all common griddle sizes: 2ft, 3ft, 4ft, 5ft and 6ft. An example of this calculation for 2ft griddle is shown below and the extrapolated, normalized savings per common griddle size are summarized in table 5.

$$2ft \times 439\ \frac{m^3}{yr\ \cdot ft} = 877\ m^3/yr$$

Table 5 Normalized annual natural gas savings

Description	2-ft	3ft	4ft	5ft	6ft
Normalized annual nat. gas savings (m3/yr per griddle)	877	1,316	1,754	2,193	2,631

Lastly, a weighted average across all common griddle sizes is calculated resulting in annual average savings of $1{,}974\frac{m^3}{yr}$.

USES AND EXCLUSIONS

To qualify for this measure, the griddle must be utilized for food preparation or processing with natural gas as its fuel source and must be ENERGY STAR rated based on ENERGY STAR Commercial Griddle Key Product Criteria V1.2. [3]. This is not applicable to double-sided griddles.

MEASURE LIFE

The measure life attributed to this measure is 12 years. [5]

INCREMENTAL COST

The incremental cost is summarized in the table below. [4]

Table 5 Griddle Incremental cost

Description	$ CAD/yr per Griddle	$ CAD/yr per ft of Griddle Width
Incremental Cost	$4,581	$1,096

REFERENCES

[1] American Society for Testing and Materials (ASTM), Standard Test Method for Performance of Griddles, West Conshohocken, PA: ASTM Designation F1275-14. In Annual Book of ASTM Standards, 2020.

[2] American Society for Testing and Materials (ASTM), Standard Test Method for Performance of Double Sided Griddles, West Conshohocken, PA: ASTM Designation F1605-14. In Annual Book of ASTM Standards, 2019.

[3] ENERGY Star, "Commercial Griddles Key Product Criteria v 2.1, (Rev. Dec. 2020)," 2021. [Online]. Available: www.energystar.gov/products/commercial_food_service_equipment/commercial_griddles/key_products_criteria.. [Accessed 05 2021].

[4] Frontier Energy, "Technology Assessment Report. Commercial Gas Energy Star Griddles," Frontier Energy Inc, San Ramon, 2021.

[5] ENERGY Star, Food Service Technology Center (FSTC), "Commercial Kitchen Equipment Calculator," ENERGY Star, 2021.

COMMERCIAL – EFFICIENT CONVEYOR OVEN – NEW CONSTRUCTION/TIME OF NATURAL REPLACEMENT

Version Date and Revision History	
Version History	1.0
OED Filing Date	November 14, 2022
OEB Approval Date	
Commercial → Food Service → Efficient Conveyor 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	Ovens that don't meet the efficiency criteria or have no efficiency rating	
Efficient Technology	**Cooking Chamber Area (in^2)**	**Cooking Efficiency Requirement[1]**
	<1520	37%
	≥1520	45%
Market Type	Commercial	
	Small Conveyor Oven Chamber Area <1520 in^2	**Large Conveyor Oven Chamber Area ≥ 1520 in^2**
Annual Natural Gas Savings (m^3/yr per conveyor oven)	562	1,519
Annual Electricity Impact (kWh/yr per conveyor oven)	619	2,601
Incremental cost ($ CAD/yr per conveyor oven)	$859	$1,994
Measure Life	12 years	
Restrictions	Restricted to conveyor ovens using natural gas and tested in accordance with ASTM F1817.	

[1] Performance of conveyor oven determined when tested in accordance with ASTM F1817, *Standard Test Method for Performance of Conveyor Ovens* [1]

OVERVIEW

A conveyor oven consists of a baking chamber inside which food is cooked from top and bottom while being moved through the chamber on a belt. They are highly flexible and can be used to bake or roast a wide variety of products including pizza, casseroles, meats, breads, and pastries. The result is a fast, simple process that achieves consistent results, while minimizing the impact of the operator.

Conveyor ovens are available in many different sizes and configurations, with the main differences being overall belt width and cooking chamber length. They are available in small enough sizes to satisfy low-volume and in large enough sizes to meet the demands of high-volume delivery operations. Most conveyor ovens can be stacked up to three units high, significantly increasing production capacity without requiring increased floor space.

The industry standard for evaluating conveyor oven energy consumption and performance is the American Society for Testing and Materials (ASTM) F1817 Standard Test Method for Performance of Conveyor Ovens. The standard test method defines the specific operations, preheat time, energy consumption, idle energy use, cooking-energy efficiency, and production capacity. [1]

Gas conveyor ovens are heated by one or more of the following methods: infrared (IR) radiation, conduction, forced convection, and high velocity air impingement. IR conveyor ovens employ a high temperature heat source that radiates heat towards the food product as it passes through the oven cavity. Conduction-based designs use a conveyor with ceramic or stone sections that are heated to approximately 500°F to cook the product from the bottom up. Forced convection designs use a blower to circulate the air within the oven cavity. The most common conveyor design uses hot air impingement. Air impingement ovens employ a series of baffles and plenums to intensify and focus the air movement within the oven cavity towards the food load. These high-velocity jets of hot air hit the food and force heat into the product much more quickly than is possible using more traditional convection designs.

In recent years, more manufacturers are producing conveyor oven models with energy saving measures, such as advanced controls, internal air baffles, improved insulation, and air barriers between the end of the baking chamber and the oven entrance and exit. Each of these design improvements help to reduce energy use both during cooking and when the unit is idling. Energy efficient conveyor ovens feature a lower idle energy rate than traditional conveyor ovens and utilize more of the energy being supplied to the cooking chamber for cooking the food product.

APPLICATION

This measure applies to the installation of natural gas Efficient Conveyor Ovens in commercial food settings as per qualifying criteria derived in the Efficient Technology section.

BASELINE TECHNOLOGY

The baseline technology is a conveyor oven that does not meet the criteria specified in the Efficient Technology section or does not have a cooking efficiency performance rating. Key energy consumption metrics include cooking-energy efficiency and idle rate when tested according to ASTM F1817. [1]

EFFICIENT TECHNOLOGY

Table 2 presents the key cooking energy efficiency criteria for energy-efficient gas conveyor ovens. Performance of conveyor oven determined when tested in accordance with ASTM F1817, *Standard Test Method for Performance of Conveyor Ovens* [1].

Table 2 Efficient Technology Threshold

Cooking Chamber	Cooking Chamber Area (in^2)	Cooking Efficiency Requirement
Small Conveyor Oven	<1520	37%
Large Conveyor Oven	≥1520	45%

ENERGY IMPACTS

Energy Efficient Conveyor Ovens require less natural gas during preheating, idling, and cooking. Natural gas savings are achieved through reduced cooking input rate, lower preheat and idle energy rates.

Electricity savings are achieved through reduced motor power usage. The efficient conveyor ovens have controls for the conveyor speed and therefore the conveyor can be turned off when the equipment is not in use.

NATURAL GAS SAVINGS ALGORITHM

The industry standard for energy use and cooking performance of conveyor ovens is ASTM F1817, *Standard Test Method for Performance of Conveyor Ovens* [1]. The results of this testing procedure form the basis for the energy savings calculation for conveyor 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 amount of food cooked per day will be different for each size category of conveyor ovens.

The natural gas savings algorithm is based upon methodology used by the Food Service Technology Center (FSTC).

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

$$E_{cooking} = \frac{Lb_{food} \times E_{food}}{Eff}$$

where:

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 (%)

1b. Calculation of the daily natural gas consumed by the oven- idle mode

$$E_{Idle} = Idle \times \left(T_{on} - \frac{Lb_{food}}{PC} - nP \times \frac{TP}{60}\right)$$

where:

$Idle$ = Natural Gas Idle Energy Rate (Btu/hr)

T_{on} = Operating hours per day- oven (hr/day)

Lb_{food} = Pounds of Food Cooked per Day (lb/day)

PC = Production Capacity (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

$$E_{pre-heat} = nP \times EP$$

where:

nP = Number of Preheats per day (preheats/day)

EP = Preheat Energy (Btu/preheat)

2. Calculation of the annual natural gas consumption for baseline and efficient conveyor ovens

$$NG_{usage} = E_{day} \times days$$

where:

NG_{usage} = Annual natural gas consumption by the conveyor oven (Btu/year)

E_{day} = Daily energy Consumption- Natural Gas (Btu/day)

$days$ = The number of days per year the conveyor 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 efficient conveyor 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

$$E_{day-elec} = T_{on} \times Idle_{elec}$$

where:

$E_{day-elec}$ = Daily Electricity consumption by the oven (kWh/day)

T_{on} = Operating hours per day- oven (hr/day)

$Idle_{elec}$ = Idle Energy Rate- electricity (kW)

2. Calculation of the annual electricity consumption for baseline and efficient conveyor ovens

$$Elec_{usage} = E_{day-elec} \times days$$

where:

$Elec_{usage}$ = Electricity consumed by the conveyor oven annually (kWh/year)

$days$ = The number of days per year the conveyor 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 efficient conveyor oven (kWh/year)

ASSUMPTIONS

The assumptions used to calculate energy savings are shown in Tables 3 and 4.

Table 3 Small Single-Deck Conveyor Oven Assumptions (chamber area <1520 in^2)

Performance	Baseline Model	Energy-Efficient Model	Unit	Source
Preheat Time	18	11	min/preheat	[2]
Preheat Energy	25,769	17,506	Btu/preheat	[2]
Idle Energy Rate - natural gas	44,571	40,735	Btu/h	[2]
Idle Energy Rate - electricity	0.50	0.35	kW	[2]
Cooking Energy Efficiency	25	40	%	[2]
Production Capacity	108	228	lb/hr	[2]
Operating Hours/Day	12		hr/day	[2]
Food Service Days/Year	344		day/yr	common assumption table
Number of Preheats per Day	1		preheat/day	[2]
Pounds of Food Cooked per Day	196		lb/day	[2]
ASTM Energy to Food – conveyor ovens	190		Btu/lb	[1]
Conversion factor (min to hr)	60		min/hr	
Conversion factor (Btu to m^3)	35,738		Btu/m3	common assumption table

Table 4 Large Single-Deck Conveyor Oven Assumptions (chamber area ≥1520 in²)

Performance	Baseline Model	Energy-Efficient Model	Unit	Source
Preheat Time	9	10	min/preheat	[2]
Preheat Energy	19,457	23,519	Btu/preheat	[2]
Idle Energy Rate - natural gas	53,647	40,434	Btu/h	[2]
Idle Energy Rate - electricity	1.15	0.52	kW	[2]
Cooking Energy Efficiency	38	47	%	[2]
Production Capacity	258	312	lb/hr	[2]
Operating Hours/Day	12		hr/day	[2]
Food Service Days/Year	344		day/yr	common assumption table
Number of Preheats per Day	1		preheat/day	[2]
Pounds of Food Cooked per Day	268		lb/day	[2]
ASTM Energy to Food – conveyor ovens	190		Btu/lb	[1]
Conversion factor (min to hr)	60		min/hr	
Conversion factor (Btu to m³)	35,738		Btu/m3	common assumption table

SAVINGS CALCULATION EXAMPLE

The example below illustrates the annual natural gas savings and electrical impact due to the replacement of a conventional conveyor oven with an efficient conveyor oven with a large chamber area.

Annual NG savings for a large, single-deck conveyor oven:

$$E_{cooking} = \frac{268\frac{lb}{day} \times 190\frac{Btu}{lb}}{38\%} = 133{,}928\frac{Btu}{day}$$

$$E_{Idle} = 53{,}647\frac{Btu}{hr} \times \left(12\ hr - \frac{268\frac{lb}{day}}{258\frac{lb}{hr}} - 1\frac{preheat}{day} \times \frac{9\frac{min}{preheat}}{60}\right) = 580{,}020\frac{Btu}{day}$$

$$E_{pre-heat} = 1\frac{preheat}{day} \times 19{,}457\frac{Btu}{preheat} = 19{,}457\frac{Btu}{day}$$

$$E_{day} = 133{,}928\frac{Btu}{day} + 580{,}020\frac{Btu}{day} + 19{,}457\frac{Btu}{day} = 733{,}406\frac{Btu}{day}$$

$$NG_{usage} = 733{,}406\frac{Btu}{day} \times 344\ days = \ 252{,}291{,}624\frac{m^3}{yr}$$

Annual NG usage for a large, single-deck ENERGY Star conveyor oven is calculated in the same way as shown above, yielding the following savings.

$$NG_{savings} = \frac{\left(252{,}291{,}624\frac{m^3}{yr} - 197{,}991{,}752\frac{m^3}{yr}\right)}{35{,}738} = \ 1{,}519\frac{m^3}{yr}$$

The average annual NG savings for a large, single-deck conveyor oven is:

$$1\ oven \times 1{,}519\ \frac{m^3/yr}{oven} = 1{,}519\ m^3/yr$$

Annual Electrical Impact for a large, single-deck conveyor oven:

$$E_{day-elec} = 12.0\frac{hr}{day} \times 1.15\ kW = 13.8\ \frac{kWh}{day}$$

$$Elec_{usage} = 13.8\frac{kWh}{day} \times 344\ days = 4{,}747\frac{kWh}{yr}$$

Annual electricity usage for a large, single-deck ENERGY Star conveyor oven is calculated in the same way as shown above, yielding the following savings.

$$Elec_{savings} = 4{,}747\frac{kWh}{yr} - 2{,}147\frac{kWh}{yr} = 2{,}601\frac{kWh}{yr}$$

The average annual electrical impact for a large, single-deck conveyor oven is:

$$1\ oven \times 2{,}601\ \frac{kWh/yr}{oven} = 2{,}601\ kWh/yr$$

USES AND EXCLUSIONS

To qualify for this measure, the conveyor oven must be utilized for food preparation or processing with natural gas as its fuel source and must be tested according to ASTM F1817 [1] to determine its performance parameters.

MEASURE LIFE

The measure life attributed to this measure is 12 years. [3]

INCREMENTAL COST

The incremental cost is summarized in the table below. [2]

Table 5 Conveyor Oven Incremental cost

Description	Small Conveyor Oven Chamber Area <1520 in^2 $ CAD/yr	Large Conveyor Oven Chamber Area ≥1520 in^2 $ CAD/yr
Incremental Cost	$859	$1,994

REFERENCES

[1] American Society for Testing and Materials (ASTM), Standard Test Method for Performance of Conveyor Ovens, West Conshohocken: ASTM Designation F1817-17. In Annual Book of ASTM Standards, 2020.

[2] Frontier Energy, "Technology Assessment Report. Commercial Gas Energy Efficient Conveyor Ovens," Frontier Energy Inc, San Ramon, 2021.

[3] Food Service Technology Center, "Food Service Technology Center. Life-Cycle & Energy Cost Calculator: Conveyor Ovens," [Online]. Available: http://www.fishnick.com/saveenergy/tools/calculators/. [Accessed June 2020].

COMMERCIAL – ENERGY-EFFICIENT CONVEYOR BROILER– NEW CONSTRUCTION/TIME OF NATURAL REPLACEMENT

Version Date and Revision History	
Version	1.0
OEB Filing Date	November 14, 2022
OEB Approval Date	
Commercial → Food Service → Conveyor Broiler→ 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 conveyor broiler		
Efficient Technology	A high-efficiency conveyor broiler with a catalyst and an idle input rate less than the rates listed below or a dual stage or modulating gas valve with a capability of throttling the input rate below the idle rates[1] listed below, while maintaining 600°F when tested in accordance with ASTM F2239 [1]		
	Conveyor Broiler Width (in.)	**Idle Energy Rate (Btu/h)**	
	< 22”	≤ 40, 000	
	22” - 26”	≤ 60, 000	
	> 26”	≤ 70, 000	
Market Type	Commercial		
	Conveyor Broiler Width		
	< 22”	**22” - 26”**	**> 26”**
Annual Natural Gas Savings (m3/yr per conveyor broiler)	1,954	3,070	3,768
Annual Electricity Impact (kWh/yr per conveyor broiler)	2,443	3,839	4,712

[1] Or any other method of achieving input rates below the idle rates specified in Table 3

Parameter	Definition		
Measure Life	12 years		
Incremental Cost ($ CAD/ conveyor broiler)	$3,154	$3,933	$4,586
Restrictions	Restricted to commercial/institutional food service conveyor broilers using natural gas.		

OVERVIEW

Broilers are a workhorse in commercial kitchens. Utilizing high temperature radiant heat, broilers produce a characteristic taste and aroma that cannot be achieved through other cooking processes. Conveyor broilers represent a modern innovation on the traditional broiler design by incorporating automation, reducing dedicated labour, and increasing cooking consistency. These appliances can be used for a variety of concepts and menu types but are ideally suited to broiling uniform meat products (such as hamburgers and chicken breasts) in large quantities.

Conveyor broilers operate by transporting food on a steel belt (or chain) through a high-temperature cooking chamber with radiant heat sources located above and below the belt. The belt carries the food product through the cooking cavity and deposits the cooked product into a collection tray. Conveyor broilers can be configured as a pass-through design where food is placed on the belt at one end and exits on the opposite end; or return design where food is placed on the belt, flows through the cooking chamber and it is returned to the loading side by a return belt or chute.

A standard feature on many conveyor broilers is a secondary conveyor belt that is used to toast hamburger buns. The conveyor carries the buns beneath an electric resistance heated bun platen, located below the main broiler chamber, and is commonly heated by electric elements.

Commercial conveyor broilers vary in size, input, number of cooking lanes, and capacity. Conveyor broilers can be configured with single or multiple belts, depending on the flexibility desired. A recent innovation incorporates a catalyst above the broiler to reduce the grease particulate emissions from the broiling process.

The industry standard for evaluating conveyor broiler energy consumption and performance is the American Society for Testing and Materials (ASTM) Standard F2239, *Standard Test Method for the Performance of Conveyor Broilers* [1]. This standard defines the specific parameters that conveyor broilers must be tested at to document temperature uniformity, preheat energy consumption, idle energy use, cooking energy efficiency and production capacity.

APPLICATION

There are multiple types and sizes of conveyor broilers to fit different applications. They may be designed for continuous or batch cooking. Conveyor broilers are sized based on the number of cooking lanes. Some conveyor broilers are equipped with a single conveyor belt for the entire cooking chamber, while others offer multiple cooking belts to accommodate different cook times in the same chamber. Most conveyor broilers maintain an average cavity temperature between 600°F and 700°F (315 – 371°C) and operate at a constant input rate.

In recent years, manufacturers are producing conveyor broiler models with energy saving measures, such as emissions catalysts, more efficient burner designs and waste energy recuperation. This measure is restricted to conveyor broilers using natural gas that meets the energy-efficient criteria shown in the Efficient Technology section.

BASELINE TECHNOLOGY

The baseline technology is a conventional conveyor broiler that does not meet the criteria specified in the Efficient Technology section.

EFFICIENT TECHNOLOGY

The key energy consumption metric for efficient conveyor broilers is a low idle energy rate as per Table 3, while maintaining 600°F when tested according to ASTM F2239. The efficient technology must have a catalyst and an idle input rate less than the rates listed in Table 3 or a dual stage or modulating gas valve with a capability of throttling the input rate below the idle rates listed in Table 3, while maintaining 600°F when tested in accordance with ASTM.

Table 2 Efficient Technology

Conveyor Broiler Width (in.)	Idle Energy Rate (Btu/h)
2-Lane Width (< 22”)	≤ 40, 000
3-Lane Width (22” - 26”)	≤ 60, 000
4-Lane Width (> 26”)	≤ 70, 000

ENERGY IMPACTS

Efficient conveyor broiler models utilize energy recovery strategies to capture waste heat as it exists the broiler chamber and refocus the waste heat back down onto the food product. The convective heat transfer maximizes the heat to the food product and allows the burner size to be

reduced substantially over traditional radiant-only designs. The recycled heat also warms a toasting platen and reduces the supplemental electricity required to heat the secondary bun toasting platen.

NATURAL GAS SAVINGS ALGORITHM

The industry standard for evaluating conveyor broilers is ASTM F2239, *Standard Test Method for Performance of Conveyor Broilers*. [1] The performance of conveyor broilers is determined by preheat time, preheat energy consumption, and idle energy consumption (full burn load). Most conveyor broilers maintain an average cavity temperature between 600°F and 700°F (315 – 371°C) and operate at a constant input rate. These types of conveyor broilers do not differentiate between cooking and idle operation. [2] . The algorithm is based upon methodology used by the Food Service Technology Center ("FSTC"). The calculation to determine the daily energy usage of baseline and energy-efficient conveyor broilers is as follows:

1. Calculation of the daily natural gas consumed by the conveyor broiler

$$E_{day} = E_{cooking} + E_{pre-heat}$$

where,

E_{day}	=	Daily energy consumption- Natural Gas (Btu/day)
$E_{cooking}$	=	Daily energy consumption cooking mode- Natural Gas (Btu/day)
$E_{pre-heat}$	=	Daily energy consumption pre-heat mode- Natural Gas (Btu/day)

1a. Calculation of the daily natural gas consumed by the conveyor broiler- cooking mode

$$E_{cooking} = F_{load} \times \left(T_{on} - nP \times \frac{TP}{60}\right)$$

where,

F_{load}	=	Full Burn Load (Btu/hr)
T_{on}	=	Operating Hours per Day (hr/day)
nP	=	Number of Preheats per Day (preheats/day)
TP	=	Preheat Time (min/preheat)
60	=	Conversion factor minutes to hours (min/hr)

1b. Calculation of the daily natural gas consumed by the conveyor broiler- preheat mode

$$E_{pre-heat} = nP \times EP$$

where,

nP = Number of Preheats per Day (preheats/day)

EP = Preheat Energy (Btu/preheat)

2. Calculation of the annual natural gas consumption for baseline and energy-efficient conveyor broilers

$$NG_{usage} = E_{day} \times days$$

where,

NG_{usage} = Annual natural gas consumption by the conveyor broiler (Btu/yr)

E_{day} = Daily energy consumption- Natural Gas

$days$ = The number of days per year the conveyor broiler 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/yr)

NG_{usage_b} = Annual natural gas consumption by the baseline conveyor broiler (Btu/yr)

NG_{usage_E} = Annual natural gas consumption by the energy-efficient conveyor broiler (Btu/yr)

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

ELECTRICITY SAVINGS ALGORITHM

Standard conveyor broilers operate continuously during the day with the heat source constantly energized. The most typical designs utilize infrared gas burners to heat the broiling chamber and electric motors to drive the conveyor through the chamber. A secondary chain runs beneath the main cooking chamber with electrically heated platens for toasting buns.

The annual electric energy impact is the difference between the baseline and efficient equipment energy consumption conveyor broiler

1. **Calculation of the daily electricity consumed by the conveyor broiler**

$$E_{day-elec} = T_{on} \times Idle_{elec}$$

where:

$E_{day-elec}$	=	Daily energy consumption- Electricity (kWh/day)
T_{on}	=	Operating Hours per Day (hr/day)
$Idle_{elec}$	=	Idle Energy Rate- Electricity (kW)

2. **Calculation of the annual electricity consumption for baseline and energy-efficient conveyor broilers**

$$Elec_{usage} = E_{day-elec} \times days$$

where:

$Elec_{usage}$	=	Electricity consumed by the conveyor broiler annually (kWh/year)
$days$	=	The number of days per year the conveyor broiler 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 conveyor broiler (kWh/year)
$Elec_{usage_E}$	=	Annual electricity consumption of the energy-efficient conveyor broiler (kWh/year)

ASSUMPTIONS

The Food Service Technology Center has tested multiple baseline and efficient gas conveyor broilers per the ASTM standard test method. [1] Key energy consumption metrics include idle energy rate while maintaining 600°F when tested according to ASTM F2239. Baseline energy consumption for conveyor broilers has been taken from the average of the FSTC dataset (which is unpublished due to proprietary manufacturer data) that does not meet the efficient technology criteria.

The assumptions used to calculate natural gas savings are shown in Table 4.

Table 4 Conveyor Broiler Assumptions: 3-Lane Width (22" – 26")

Performance	Baseline Model	Energy-Efficient Model	Unit	Source
Preheat Time	18.4	18.6	min/preheat	[3]
Preheat Energy	26,214	17,212	Btu/preheat	[3]
Full Burn load	79,491	53,001	Btu/hr	[3]
Electricity Cooking Rate	1.34	0.41	kW	[3]
Number of Preheats per Day	1			[3]
Operating Hours/Day	12		hr/day	[4]
Food Service Days/Year	344		day/yr	Common assumption table
Conversion factor (min to hr)	60		min/hr	
Conversion factor (Btu to m^3)	35,738		Btu/m^3	Common assumption table

SAVINGS CALCULATION EXAMPLE

The example below illustrates the annual natural gas savings calculation from the replacement of a 22″ width conventional conveyor broiler with an energy-efficient conveyor broiler.

Calculation of the daily natural gas consumption for baseline equipment

$$E_{cooking_b} = 79{,}491\frac{Btu}{hr} \times \left(12\frac{hr}{day} - 1\frac{preheat}{day} \times \frac{18.4\frac{min}{preheat}}{60\frac{min}{hr}}\right) = 929{,}515\frac{Btu}{day}$$

$$E_{pre-heat_b} = 1\frac{preheat}{day} \times 26{,}214\frac{Btu}{preheat} = 26{,}214\frac{Btu}{day}$$

$$E_{day_b} = 929{,}515\frac{Btu}{day} + 26{,}214\frac{Btu}{day} = 955{,}729\frac{Btu}{day}$$

Calculation of the daily natural gas consumption for efficient equipment

$$E_{cooking_E} = 53{,}001\frac{Btu}{hr} \times \left(12\frac{hr}{day} - 1\frac{preheat}{day} \times \frac{18.6\frac{min}{preheat}}{60\frac{min}{hr}}\right) = 619{,}582\frac{Btu}{day}$$

$$E_{pre-heat_E} = 1\frac{preheat}{day} \times 17{,}212\frac{Btu}{preheat} = 17{,}212\frac{Btu}{day}$$

$$E_{day_E} = 619{,}582\frac{Btu}{day} + 17{,}212\frac{Btu}{day} = 636{,}794\frac{Btu}{day}$$

Annual Natural Gas Savings for an Average 22″ Wide Conveyor Broiler:

$$NG_{savings} = \frac{\left(955{,}729\frac{Btu}{day} - 636{,}794\frac{Btu}{day}\right) \times 344\frac{day}{yr}}{35{,}738\frac{Btu}{m^3}} = 3{,}070\frac{m^3}{yr}$$

Using the average annual natural gas savings for a 22″ wide conveyor broiler calculated above, the natural gas savings were normalized per linear inch of conveyor broiler width. This results in a normalized savings of 140 m^3/yr per linear inch of conveyor broiler width. The normalized savings per linear inch is then used to extrapolate the annual savings to all common conveyor broiler size ranges: < 22″, 22″- 26″ and > 27″. An example of this calculation for < 22″ (average width = 14″) conveyor is shown below and the extrapolated, normalized savings per common conveyor oven size ranges are summarized in Table 5.

$$14\ in \times 140\ \frac{m^3}{yr\ \cdot in} = 1{,}954\ m^3/yr$$

Table 5 Normalized Annual Natural Gas Savings – Conveyor Broiler

Description	<22”	22”-26”	>27”
Normalized annual nat. gas savings (m3/yr per conveyor broiler)	1,954	3,070	3,768

Electricity Impact:

Calculation of the daily electricity consumption for baseline equipment

$$E_{day-elec_b} = 12\frac{hr}{day} \times 1.34\ kW = 16.1\frac{kWh}{day}$$

Calculation of the daily electricity consumption for efficient equipment

$$E_{day-elec_E} = 12\frac{hr}{day} \times 0.41\ kW = 4.9\frac{kWh}{day}$$

Annual Electricity Savings for an Average 22″ Wide Conveyor Broiler:

$$Elec_{savings} = \left(16.1\frac{kWh}{day} - 4.9\frac{kWh}{day}\right) \times 344\frac{day}{yr} = 3{,}838\frac{kWh}{yr}$$

Using the average annual electricity savings for a 22″ wide conveyor broiler calculated above, the electricity savings was normalized per linear inch of conveyor broiler width. This results in a normalized savings of 175 kWh/yr per linear inch of conveyor broiler width. The normalized savings per linear inch is then used to extrapolate the annual savings to all common conveyor broiler size ranges: < 22″, 22″- 26″ and > 27″. An example of this calculation for < 22″ (average width = 14″) conveyor is shown below and the extrapolated, normalized savings per common conveyor oven size ranges are summarized in Table 6.

$$14\ in \times 175\ \frac{kWh}{yr\ \cdot in} = 2{,}443\ kWh/yr$$

Table 6 Normalized Annual Electricity Savings – Conveyor Broiler

Description	<22"	22"-26"	>27"
Normalized annual electricity savings (kWh/yr per conveyor broiler)	2,443	3,839	4,712

USES AND EXCLUSIONS

To qualify for this measure, the conveyor broiler must be utilized for food preparation or processing with natural gas as its fuel source and must meet the energy efficiency criteria for commercial conveyor broilers by having a low idle energy rate as shown in Table 3 while maintaining 600°F when tested according to ASTM F2239. [1]

MEASURE LIFE

The measure life attributed to this measure is 12 years. [5]

INCREMENTAL COST

The incremental cost is shown in the table below.

Table 7 Conveyor Broiler Incremental Cost [2]

Conveyor Broiler Width (in.)	Incremental Cost ($ CAD per broiler)
< 22”	$3,154
22” - 26”	$3,933
> 26”	$4,586

REFERENCES

[1] American Society for Testing and Materials (ASTM), "Standard Test Method for the Performance of Conveyor Broilers," American Society for Testing and Materials (ASTM) F2239, West Conshohocken, PA, 2020.

[2] Frontier Energy, "Technology Assessment Report: Commercial Conveyor Broilers," San Ramon, 2022.

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COMMERCIAL – SMALL AND MEDIUM BUSINESS ADAPTIVE THERMOSTAT – RETROFIT

Version Date and Revision History	
Version	1
OEB Filing Date	March 17, 2025
OEB Approval Date	
Sector → End Use → Technology → Measure Category	

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	Non-Programmable (NPT) or Programmable Thermostat (PT)
Efficient Technology	Adaptive Thermostat
Market Type	Commercial
Annual Natural Gas Savings (m^3)	380 m^3 per device
Annual Electric impact for buildings equipped with air conditioning system	995 kWh per device
Measure Life	10 years
Incremental Cost ($ CAD)	$235
Restrictions	This measure requires that an adaptive thermostat would replace a conventional programmable or non-programmable thermostat serving a natural gas-fired space heating system in a commercial building. This sub-doc does not apply to buildings that have or are in the process of installing a hybrid (dual-fuel) space heating system (e.g., an electric air-source heat pump with natural gas furnace backup, a ground-source heat pump with a natural gas furnace backup, etc.).

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 monitoring weather,

occupancy, and remote access for additional flexibility and control, an important feature when the business plans for the day have changed.

APPLICATION

Applicable to commercial buildings, including industrial facilities, that use a natural gas heating system. In addition, applicable to commercial buildings that have either a programmable or non-programmable/manual thermostat.

BASELINE TECHNOLOGY

Baseline technology is defined as a non-programmable/manual thermostat or programmable thermostat. Canada's and Ontario's Energy Efficiency Regulations do not currently require thermostats of a particular type or thermostats with specific features. [1]

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 and lifestyle related questions.
- Pro-active or forced automatic energy savings adjustment features.
- Greater control with remote web or app-based control over building's settings if schedule changes
- Maintenance alerts.
- Ongoing "learning" of 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 occupancy related questions. [2]

Occupancy-Based Setbacks

For businesses that do not maintain a regular schedule, this feature has an automated way of determining when a space is unoccupied. Adaptive thermostats use geofencing and occupancy sensors to detect occupancy in the building and automatically implement temperature setback during unoccupied periods.

System Performance Optimization

System performance optimization capabilities use analytics to run a building's HVAC equipment more efficiently. 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, occupancy and temperature. Most adaptive thermostats build schedules by asking users simple questions during setup to understand typical schedules and comfort preferences. Algorithm-based software establishes heating and cooling schedules accordingly resulting in natural gas savings and electric cooling savings, in some cases even modifying the schedules for additional moderate savings.

NATURAL GAS SAVINGS ALGORITHM

Resource Innovations conducted a gas savings analysis on the Small and Medium Business Energy Management System Innovation Pilot in May 2023. [3] The Wi-fi thermostat used in the pilot was an adaptive thermostat. The study reflected the climate conditions for the Ontario Gas utilities.

A total of 481 accounts participated in the program accounting for 574 thermostats. 7 of the participating accounts did not have sufficient billing data to establish annual gas consumption patterns before participating in the pilot. These were removed from the analysis, resulting in a final analysis dataset consisting of 474 accounts. Participating accounts were primarily located

in the Kitchener/Waterloo region. The analysis was based on pre and post-installation business gas usage.

A regression model was developed to predict natural gas use based on heating degree days (HDD) and the installation of an adaptive thermostat.

$$m^3 = \beta_0 + \beta_1 \times HDD + \beta_2 \times Quantity + \varepsilon$$

The β_2 coefficient is the key parameter of interest, as it determines the impact of adaptive thermostat installation where the Quantity term is assigned a value equal to the number of thermostats installed in the post-installation period, and a value of zero in the pre-installation period. The annual gas savings were then normalized to typical weather conditions based on weather data CWEC (2020) for London, ON. [4] The normalization process involves predicting customer-level consumption for both the pre-treatment and post-treatment periods under identical, "typical" weather conditions. Because the weather data does not vary across periods, it is necessary to introduce a model term that interacts the pre and post period variable (the quantity term) and the normalized weather (the HDD term). The model specification for weather normalized gas consumption is shown below.

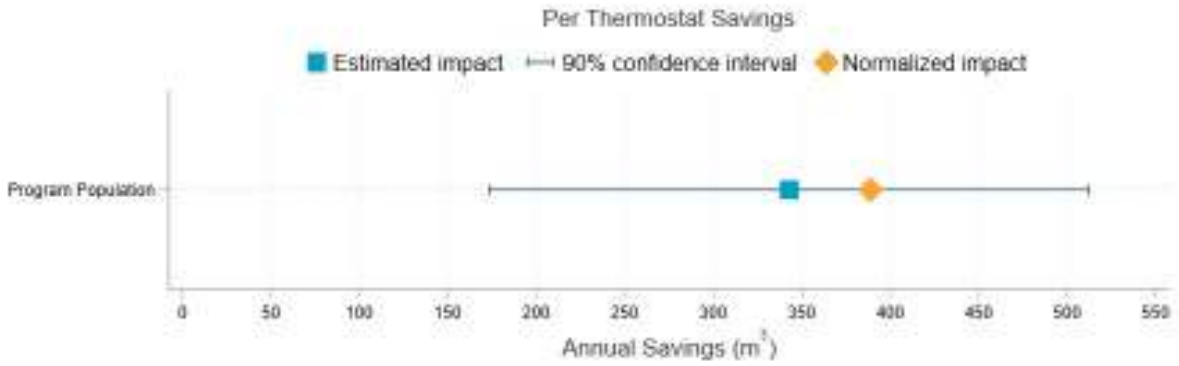
$$m^3 = \beta_0 + \beta_1 \times HDD + \beta_2 \times Quantity + \beta_3(\text{Quantity} \times \text{HDD}) + \varepsilon$$

The estimated weather-normalized natural gas savings per thermostat installed are shown below.

Table 2. Weather-Normalized Natural Gas Savings [3]

Normalized natural gas savings per thermostat installed (m^3/year)
380 m^3/year

Figure 1: Achieved and Weather-Normalized Natural Gas Savings [3]



ELECTRIC IMPACTS ALGORITHM

The Independent Electricity System Operator (IESO) retained Nexant, Inc., (now Resource Innovations) to conduct an evaluation of its Business Programs for the 2017 evaluation cycle. This included an impact evaluation of the same Small and Medium Business Energy Management System Innovation Pilot. Nexant's analysis approach utilized hourly interval and monthly billed consumption data provided by the LDCs for all accounts known to be participating in the pilot at the time of the data request, and for a large pool of non-participants, to perform a difference-in-differences regression analysis using a matched control group.

The annual electricity savings attributed to the adaptive thermostat was 995 kWh per thermostat installed. [5]

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
HDD_{Ref}	Heating System Enabled	55°F(12.78°C)	Common assumptions table [6]

SAVINGS CALCULATION EXAMPLE

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

USES AND EXCLUSIONS

Not applicable to buildings that have or are in the process of installing a hybrid (dual-fuel) space heating systems (e.g., an electric air-source heat pump with natural gas furnace backup, a ground-source heat pump with a natural gas furnace backup, etc.).

MEASURE LIFE

Enbridge independently completed a jurisdictional scan of demand side management (DSM) technical reference manuals (TRMs) to estimate the effective useful life of an adaptive thermostat. It is recommended that a measure life of 10 years be used as per the results of the Enbridge jurisdictional scan.

INCREMENTAL COST

Enbridge independently completed a jurisdictional scan of demand side management (DSM) technical reference manuals (TRMs) to estimate the incremental cost of installing an adaptive thermostat. It is recommended that an incremental cost of $235 CAD be applied per the results of the Enbridge jurisdictional scan.

REFERENCES

[1] Natural Resouces Canada, "Energy Efficiency Regulations by Province," [Online]. Available: https://natural-resources.canada.ca/energy-efficiency/energy-efficiency-regulations/energy-efficiency-regulations-province/20986. [Accessed June 2023].

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COMMERCIAL – HYBRID HEAT PUMP ROOF TOP UNIT– TIME OF NATURAL REPLACEMENT/ NEW CONSTRUCTION

Version Date and Revision History	
Version	for OEB staff use
OEB Filing Date	for OEB staff use
OEB Approval Date	for OEB staff use
Commercial → Space Heating → Hybrid Heat Pump Roof Top Unit → 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), or Time of Natural Replacement (TNR)								
Baseline Technology	Standard natural gas Roof Top Unit (RTU)								
Efficient Technology	Hybrid heat pump RTU: electric heat pump with gas furnace auxiliary heat that meets the criteria specified on the Efficient technology section								
Market Type	Commercial								
Annual Natural Gas Savings (m^3/ kBtu/hr Heating capacity[1])	**Tier 1**		**Tier 2**		**Tier 3**		**Tier 4**		**Tier 5**
	Switchover temp 41°F (5°C)		**Switchover temp 32°F (0°C)**		**Switchover temp 30°F (-1.1°C)**		**Switchover temp 20°F (-6.7°C)**		**Simultaneous control type**
	3		13		16		27		36
Annual Electric Impact (kWh/ kBtu/hr Heating capacity)	**Tier 1**		**Tier 2**		**Tier 3**		**Tier 4**		**Tier 5**
	Switchover temp 41°F (5°C)		**Switchover temp 32°F (0°C)**		**Switchover temp 30°F (-1.1°C)**		**Switchover temp 20°F (-6.7°C)**		**Simultaneous control type**
	Staged[2]	**VSF[3]**	**Staged[2]**	**VSF[3]**	**Staged[2]**	**VSF[3]**	**Staged[2]**	**VSF[3]**	**VSF[3]**
	-5	60	-32	34	-42	24	-82	-14	-45
Winter Peak Electric Impact (kW/ kBtu/hr Heating capacity)	-0.0067	0.0059	-0.0293	-0.0194	-0.0318	-0.0224	-0.0464	-0.0398	-0.0485

[1] Heating capacity refers to the RTU heat pump rated heating capacity at 47ºF (8.3ºC) in kBtu/hr. This definition is applicable to all parameters: Annual natural gas savings, annual electricity impacts, winter & summer peak electricity impacts and incremental cost.
[2] Staged refers to standard fans (can be single speed, basic staged), and no requirements for compressor type (could be single stage, though 2-stage).
[3] VSF refers to, high efficiency-variable speed fans, and variable speed compressors.

<table>
<tr><th>Parameter</th><th colspan="8">Definition</th></tr>
<tr><td>Summer Peak Electric Impact (kW/ kBtu/hr Heating capacity)</td><td>0</td><td>0.0360</td><td>0</td><td>0.0360</td><td>0</td><td>0.0360</td><td>0</td><td>0.0360</td></tr>
<tr><td>Measure Life</td><td colspan="8">16 years</td></tr>
<tr><td rowspan="5">Incremental Cost ($ CAD)</td><td colspan="4">Heating Capacity (kBtu/hr)</td><td colspan="4">Incremental Cost ($CAD/heating kBtu/hr)</td></tr>
<tr><td colspan="4"><33</td><td colspan="4">$130</td></tr>
<tr><td colspan="4">≥33 and <78</td><td colspan="4">$120</td></tr>
<tr><td colspan="4">≥78 up to and including110</td><td colspan="4">$110</td></tr>
<tr><td colspan="4">>110</td><td colspan="4">$90</td></tr>
<tr><td>Restrictions</td><td colspan="8">This measure is restricted to packaged single-zone hybrid[4] heat pump RTUs installed outdoors for a commercial building. Multi-zone RTU or RTU paired with in-zone Variable Air Volume (VAV) systems are not eligible for this prescriptive measure. This measure does not apply to split systems, standalone furnaces, make-up air units, dedicated outdoor air systems (DOAS), buildings for which the cooling requirement is satisfied by natural gas chillers, space types that directly serve kitchens, nor spaces that are unconditioned.</td></tr>
</table>

OVERVIEW

Rooftop units (RTU) are packaged HVAC equipment that can provide heating and cooling to a space and can be found in any type of commercial building. Natural gas RTUs are one of the most common forms of heating and cooling in commercial buildings and present large opportunities for natural gas savings since furnace efficiency has not seen large improvements over the last decade. Heat pump (HP) technology has been used in residential applications for decades, but RTU manufacturers have not sold HP RTUs until recently. As the demand for carbon reduction technology increases, manufacturers have responded with new products utilizing heat pump technologies, including hybrid HP RTUs. Hybrid HP RTUs utilize an electric heat pump as the main heat source but also include a gas furnace for back-up and auxiliary heating. Natural gas savings from this measure are achieved because a large portion of the space heating load can be shifted to a more efficient electric heat pump.

[4] The Comstock energy models simulate rooftop units (RTUs) that serve individual zones within a commercial building; hence, the savings/impact values in table 1 are most representative of single-zone RTU applications. Multi-zone RTU or RTU paired with in-zone Variable Air Volume (VAV) systems are not eligible for this prescriptive measure. Multi-zone RTU (one RTU serving multiple spaces within a building) would have a different energy use profile (and therefore different savings/impacts) because they are commonly designed with in-zone reheat (e.g., a VAV box). To clarify, this is not intended to restrict the measure to single zone buildings but is intended for single zone RTU's. If multiple RTU's serve the same zone (e.g. in a big box retail application) this would still qualify for the measure because the RTUs are each serving a single zone. A single RTU serving multiple spaces within a building will not qualify.

APPLICATION

RTUs serve as the primary space heating system for an entire building or -portion of a building- and are typically installed on a roof. Though less common, they can also be installed on the ground outside a commercial building. This measure applies to the replacement of an existing natural gas RTU used for space heating with a packaged single-zone hybrid heat pump RTU installed outdoors for a commercial building or the addition of a packaged single-zone hybrid heat pump RTU to a new construction building. The application for this measure is based on the use case and occupancy patterns of the space the RTU serves (i.e., the space type) rather than the entire building. For example, an RTU serving and office space within a hotel would be defined as "Office" space type and hence assess accordingly for the applicability of this measure.

Hybrid heat pump RTUs are required to meet more than one performance rating, as their cooling efficiency, heat pump efficiency, and gas efficiency are all rated and regulated separately. These requirements have been captured in the efficient technology section.

BASELINE TECHNOLOGY

RTUs in Ontario are designed and installed to provide heating and cooling in a commercial building. The heating and cooling components of RTUs are regulated by the Federal and Provincial government.

Table 2 describes the Baseline for the heating components and Table 3 describes the Baseline for the cooling components of RTUs in Ontario.

Table 2. Baseline Natural Gas RTU- heating component [1]

Input Rate	Product Category	Requirement	Reference
< 225,000 Btu/hr (65.92 kW)	Single phase, outdoor furnaces with an integrated cooling component	AFUE[5] = 81%	[2] Schedule 3. Furnaces and other space heating equipment. Section 4.2.
	Three-phase, outdoor furnaces with an integrated cooling component	AFUE = 78% or TE[6] = 80%	
≥ 225,000 Btu/hr (65.92 kW)	Outdoor furnaces with an integrated cooling component	TE = 81%	[2] Schedule 3. Furnaces and other space heating equipment. Section 9. [3]

[5] AFUE = Annual Fuel Utilization Efficiency
[6] TE = Thermal Efficiency

A variety of efficiency metrics are used for heat pump RTUs, which can make understanding system performance somewhat confusing. Below is a breakdown of efficiency terms used in Table 3. [4]

SEER = Seasonal energy efficiency ratio. SEER measures the cooling efficiency of the heat pump over the entire cooling season. It is determined by dividing the total cooling provided over the cooling season (in Btu) by the total energy used by the heat pump during that time (in Watt-hours). The SEER is based on a climate with an average summer temperature of 28°C.

- SEER 2 = Seasonal energy efficiency ratio (2) – the total cooling of heat pump in Btu during its normal annual usage period for cooling, divided by the electric power usage in watt-hours during the same period in accordance with 10 C.F.R. Appendix M1. [5]
- SEER = Seasonal energy efficiency ratio– the total cooling of a heat pump in Btu during its normal annual usage period for cooling, divided by the electric power usage in watt-hours during the same period in accordance with CAN/CSA-C656-14. [5]

EER = Energy Efficiency Ratio. The EER is similar to the COP (Table 4) and describes the steady-state cooling efficiency of a heat pump. It is determined by dividing the cooling capacity of the heat pump in Btu/h by the electrical energy input in Watts (W) at a specific temperature (under designated operating conditions). EER is strictly associated with describing the steady-state cooling efficiency, unlike COP which can be used to express the efficiency of a heat pump in heating as well as cooling. [4]

IEER = Integrated Energy Efficiency Ratio. IEER means a single-number figure of merit expressing cooling part-load energy efficiency for heat pump equipment that is based on weighted operation at various load capacities of the equipment, as described in the applicable standards referenced. [6]

Table 3. Baseline Natural Gas RTU- cooling component

Cooling capacity	Product Category	Heating type	Requirement	Reference
< 19 kW (65,000 Btu/h)	Air-cooled, single phase AC[7]	Natural Gas	SEER 2 ≥ 13.4	[2]Schedule 4. Air conditioning and related Equipment. Section 6. Table 1. [5]
	Air-cooled, three-phase AC	Natural Gas	SEER ≥ 14.0	
≥ 19 kW and < 40 kW, ≥65,000 Btu/h and < 135,000 Btu/h	Air-cooled AC	Natural Gas	EER ≥ 11.0 IEER ≥ 12.7	[2] Schedule 4. Section 8., Table 1 Large Unitary Air Conditioners. Column items 4, 5 and 6 [7]
≥ 40 kW and < 70 kW (≥135,000 Btu/h and < 240,000 Btu/h)	Air-cooled AC	Natural Gas	EER ≥ 10.8 IEER ≥ 12.2	
≥ 70 kW and < 223 kW (≥240,000 Btu/h and < 760,000 Btu/h)	Air-cooled AC	Natural Gas	EER ≥ 9.8 IEER ≥ 11.4	

[7] Additionally, it requires a Max. Average Off Mode Electrical Power Consumption ≤ 30 W.

EFFICIENT TECHNOLOGY

The efficient technology is a hybrid heat pump RTU with:

- heat pump portion that meets the heating and cooling requirement presented in table 4, and
- the back-up natural gas furnace that meets the requirements presented in table 2.

In addition to the efficiency terms identified in the baseline section, below is a breakdown of efficiency terms used in Table 4.

HSPF = Heating Seasonal Performance Factor. HSPF is a ratio of how much energy the heat pump delivers to the building over the full heating season (in Btu), to the total energy (in Watthours) it uses over the same period. Weather data characteristics of long-term climate conditions are used to represent the heating season in calculating the HSPF. However, this calculation is typically limited to a single region and may not fully represent performance across Canada. Some manufacturers can provide an HSPF for another climate region upon request; however typically HSPFs are reported for Region 4, representing climates similar to the Midwestern US. Region 5 would cover most of the southern half of the provinces in Canada, from the B.C interior through New Brunswick. [4]

- HSPF 2 (Region V) = Heating seasonal performance factor (2) (Region V) – the total heating output of a heat pump during its normal annual usage period for heating, divided by the total electric power input in watt-hours during the same time period in accordance with 10 C.F.R. Appendix M1. [5]

COP = Coefficient of Performance means, for a heat pump in the heating mode, the ratio of the rate of net heat output to the total energy input expressed in consistent units and under designated rating conditions, as described in the standards referenced in Table 4; for refrigerating equipment or a heat pump in the cooling mode, COP means the ratio of the rate of heat removal to the rate of energy input in consistent units and under designated rating conditions, as described in the standards referenced in Table 4. [6]

Table 4. Efficient Technology for hybrid heat pump RTU

Cooling capacity	Product Category	Heating requirement[8]	Cooling requirement	Reference
< 19 kW (65,000 Btu/h)	Air-cooled, single phase HP[9]	HSPF 2 (Region V) ≥ 5.4	SEER 2 ≥ 13.4	[2]Schedule 4. Air conditioning and related Equipment. Section 6. Tables 1 and 2. [5]
	Air-cooled, three-phase HP	HSPF 2 (Region V) ≥ 7.0	SEER ≥ 14.0	

[8] For units tested using the relevant AHRI Standards, all COP values must be rated at 47 °F outdoor dry-bulb temperature for air-cooled equipment.

[9] Additionally, it requires a Max. Average Off Mode Electrical Power Consumption ≤ 33 W.

Cooling capacity	Product Category	Heating requirement[8]	Cooling requirement	Reference
≥19 kW and <40 kW, (≥65,000 Btu/h and < 135,000 Btu/h)	Air-cooled HP	COP at inlet air at 47ºF (8.3ºC) ≥ 3.3 COP at inlet air at 17ºF (-8.3ºC) ≥ 2.25	EER = 10.8 IEER = 12.0	[2] Schedule 4. Section 8., Table 2 Large Unitary heat pumps. Heating type B, Columns 4, 5, 6, and 7. [7]
≥40 kW and <70 kW (≥135,000 Btu/h and < 240,000 Btu/h)	Air-cooled HP	COP at inlet air at 47ºF (8.3ºC) = 3.2 COP at inlet air at 17ºF (-8.3ºC) = 2.05	EER = 10.4 IEER = 11.4	
≥70 kW and <223 kW (≥240,000 Btu/h and < 760,000 Btu/h)	Air-cooled HP	COP at inlet air at 47ºF (8.3ºC) = 3.2 COP at inlet air at 17ºF (-8.3ºC) = 2.05	EER = 9.3 IEER = 10.4	

Other components or features of an RTU besides the efficiency metrics in Tables 3 and 4 can impact energy consumption, such as control methodology or lower outside air switchover temperatures, increased levels of enclosure insulation, low leakage outside air dampers, and improved cabinet construction to reduce cabinet leakage.
This measure includes three levels or tiers of operational efficiency to drive different levels of natural gas savings:

- Tier 1: Hybrid heat pump RTU with controls enabling a 41ºF (5°C) switchover temperature.
- Tier 2: Hybrid heat pump RTU with controls enabling a 32ºF (0°C) switchover temperature.
- Tier 3: Hybrid heat pump RTU with controls enabling a 30ºF (-1.1°C) switchover temperature.
- Tier 4: Hybrid heat pump RTU with controls enabling a 20ºF (-6.7°C) switchover temperature.
- Tier 5: Hybrid heat pump RTU with controls enabling simultaneous heat pump and gas furnace operation.

Below is an explanation for each efficiency tier.

- **Tier 1.** This tier assumes a switchover temperature of 41ºF (5°C). This means the heat pump will operate in heating mode when outside air temperatures are at or below the balance point temperature and will switch to the backup natural gas furnace when outside air temperatures are at or below 41ºF (5°C).
- **Tier 2.** This tier assumes a switchover temperature of 32ºF (0°C). This means the heat pump will operate in heating mode when outside air temperatures are at or below the balance point temperature and will switch to the backup natural gas furnace when outside air temperatures are at or below 32ºF (0°C).
- **Tier 3.** This tier assumes a 30ºF (-1.1°C) switchover temperature, which manufacturers reported as a default setting for hybrid heat pump RTUs. This means the heat pump will operate in heating mode when outside air temperatures are at or below the balance

point temperature, and it will switch to the backup natural gas furnace when outside air temperatures are at or below 30ºF (-1.1°C).

- **Tier 4.** This tier assumes a switchover temperature of 20ºF (-6.7°C). This means the heat pump will operate in heating mode when outside air temperatures are at or below the balance point temperature and will switch to the backup natural gas furnace when outside air temperatures are at or below 20ºF (-6.7°C).
  Tier 5. This tier assumes the same hybrid heat pump RTU as Tier 1 but requires controls that enable simultaneous operation of the heat pump and the backup natural gas to optimize efficiency and heating capacity of the heat pump.

This measure also characterizes the electric impact of a unit that meets additional requirements for fans and variable compressors.

- **Staged:** refers to a heat pump with standard fans (single speed or basic staged) and standard compressors (could be single speed or 2-stage).
- **VSF:** refers to a heat pump with high efficiency-variable speed fans, and variable speed compressors.

ENERGY IMPACTS

The primary energy impact associated with the installation of a hybrid heat pump RTU is the reduction in natural gas consumption due to the use of an electric heat pump for a portion of the heating load. However, this measure also leads to a proportional increase in electric energy use during the heating season.

Hybrid heat pump RTUs include both an electric heat pump and a natural gas furnace, and they can operate using either system or both simultaneously. These units can be controlled to maximize the use of the heat pump down to specific outside air conditions, only relying on the natural gas furnace for auxiliary heat below specific outside air temperatures when the heat pump cannot meet the entire heating demand.

This measure includes five levels or tiers of operational efficiency, each driving different levels of natural gas savings- ranging from the least savings at Tier 1 to the most at Tier 5. The highest savings at Tier 5 are achieved through advanced controls that enables the operation of the heat pump and natural gas furnace simultaneously, ensuring maximum efficiency and utilization of the heat pump's capacity during the entire heating season.

NATURAL GAS SAVINGS ALGORITHM

The natural gas savings for this measure are calculated using a database of commercial building energy models. These models are used to estimate savings between a baseline gas RTU and a hybrid HP RTU. The ComStock database is a set of thousands of detailed building energy models developed by the U.S. Department of Energy. [8] ComStock consists of a large set of baseline energy models designed to represent the existing commercial building stock, and a variety of efficient measure upgrade models, including a hybrid HP RTU measure, that can be

compared against the baseline models to estimate savings. The models use multiple data sources to calibrate results to the building stock based on hundreds of combinations of building characteristics, occupant behaviors, building geometry, vintage, and location.

The natural gas savings calculation includes the following steps, the first three involving accessing the ComStock database and the last steps performing post-processing analysis of the data to ensure the data set is representative of the Ontario building stock and the measure definitions. Additional details on these steps can be found in the supporting report. [9]

Accessing the ComStock Database

1. **Select measure from the ComStock Database and filter database for relevant buildings.** By selecting the measure "Heat Pump RTU with Original Fuel Backup" the ComStock database was filtered for commercial building models with packaged single-zone RTUs with natural gas space heating source as the baseline. This building set was further filtered for buildings within Ontario climate zones, or geographically adjacent to Ontario. This filtering process results in a final set of 16,000 unique models used to estimate savings.
2. **Map each of the ComStock models in the final set to Ontario Locations.** After downloading the relevant models, map each of the ComStock models to an Ontario city using HDD from each model's weather input data as reference for the mapping exercise. For example, ComStock buildings with US weather stations 726060 and 726425 (Portland/Inttnl. Jet and Sheboygan Co Mem respectively) have been mapped to Canada weather station 712630 (Hamilton A) due to the similar HDD.
3. **Calculate building-level natural gas savings.** Each of the 16,000 models includes the annual difference in gas and electric heating energy consumption (i.e., measure savings) between the buildings' energy use with the baseline natural gas RTU and the efficient hybrid heat pump. The result is a data output from the 16,000 individual building model runs, each with unique consumption and savings values, by building type and climate zone.

After creating the relevant data set of energy models, additional analysis and adjustments were performed to the data to ensure the savings are representative of the Ontario building stock and the baseline and efficient measure definitions.

4. **Normalize the savings for program implementation.** The ComStock models produce an average cubic meter of gas saved per building, by building type. The savings were normalized by a factor that can be used to scale the savings up and down with the size of the Hybrid heat pump RTU. Cadeo provided two normalization options for implementation, m^3/ton of cooling and m^3/ kBtu/hr heating capacity. It was determined that m^3/ kBtu/hr heating capacity has a higher correlation with natural gas savings, and therefore it will be a better scaling factor than m^3/ton of cooling. [10]
5. **Align the results with the hybrid HP RTU efficient tiers definition.** To ensure the ComStock models' estimated savings are in alignment with the hybrid HP efficiency tiers, adjustments are made to the savings to account for the different hybrid HP control

strategies between ComStock and the measure's tiers as described in the Efficient measure section. The following step explains how was this accomplished:

- A sample of each building type was selected from the ComStock data, and the 8,760-natural gas savings profile was extracted (10 ComStock buildings).
- To reflect the effect of switchover temperature at the different tier levels, an identifier was used to "turn off" the HP below 30ºF and 20ºF (tier 1 and tier 2 respectively). A natural gas savings adjustment factor was developed and applied to the ComStock natural gas savings (Tier 3) to obtain the savings for Tier 1 and Tier 2.

6. **Natural gas saving rate (m^3/kBtu/hr heating capacity).** A single natural gas savings factor (m^3/kBtu/hr heating capacity) was determined by combining the individual building savings in the form of weighted average. The distribution of building type in Ontario was used as the weight and are presented in Table 5 Assumptions.

ELECTRICITY IMPACTS ALGORITHM

The approach for quantifying the electricity impact from the installation of a hybrid heat pump RTU in Ontario used the same ComStock analysis approach described in the natural gas savings section (Steps 1-5). Unique analysis or adjustments made for the measure electric impacts are noted below. Additional detail on these steps can be found in the supporting report. [9]

1. **For Staged: Remove fan and cooling savings.** The ComStock measure definition includes above-code cooling and fan performance requirements which aligns with VSF units but is not applicable for Staged units. To adjust the electric impacts for Staged units, the ComStock model's fan and cooling impacts are removed from the calculated electric impacts before normalizing based on the installed measure heating capacity in kBtu/hr.
2. **Reflecting the effect of switch over temperature at the different tier levels.** Using the same approach described in the Natural Gas Savings Algorithm Step 5, the electricity impact adjustment factors by efficiency tiers (tier 1 to tier 4) were estimated, accounting for the switchover temperature approach for each building type and if the unit is Staged or VSF. The output of this step is hourly kW electricity impacts per building ($Elec_h$), by building type for the 10 building prototypes selected accounting for the tiers' switchover temperature for each building type and if the unit is Staged or VSF

WINTER AND SUMMER PEAK ELECTRICITY IMPACT ALGORITHM

The approach for quantifying the electricity summer and winter peak impact from the installation of a hybrid heat pump RTU in Ontario uses the analysis approach described in the IESO-CDM-CE-Tool-V9-2-Feb-17-2023 tool, modified to account for negative impacts in the summer and/or winter. [11]

1. **Calculate hourly summer and winter peak electricity impact.** The following equations were applied to the hourly profile for 10 building type prototypes (the same buildings identified in step 5 of the natural gas savings algorithms).

Eq.1) $$S_{Peak} = IF\ (S_{APeak-Min} < 0)$$
$$if\ True\ S_{Peak} = S_{APeak-Min}$$
$$if\ False\ S_{Peak} = S_{APeak-Max}$$

Eq.2) $$S_{APeak-Min} = [Min(AP_{Summer}), If\ (S_{Peak-h} = 0.04)\ ] + [Min(AP_{Summer}), If\ (S_{Peak-h} = 0.05)\ ] + [Min(AP_{Summer}), If\ (S_{Peak-h} = 0.42)\ ] + [Min(AP_{Summer}), If\ (S_{Peak-h} = 0.49)\ ]$$

Eq.3) $$S_{APeak-Max} = [Max(AP_{Summer}), If\ (S_{Peak-h} = 0.04)\ ] + [Max(AP_{Summer}), If\ (S_{Peak-h} = 0.05)\ ] + [Max(AP_{Summer}), If\ (S_{Peak-h} = 0.42)\ ] + [Max(AP_{Summer}), If\ (S_{Peak-h} = 0.49)\ ]$$

Eq.4) $$AP_{Summer} = S_{Peak-h} \times Elec_h \times Hr_{cooling}$$

Eq.5) $$W_{Peak} = IF\ (W_{APeak-Min} < 0)$$
$$if\ True\ W_{Peak} = W_{APeak-Min}$$
$$if\ False\ W_{Peak} = W_{APeak-Max}$$

Eq.6) $$W_{APeak-Min} = [Min(AP_{Winter}), If(W_{Peak-h} = 0.13)\ ] + [Min(AP_{Winter}), If(W_{Peak-h} = 0.24)\ ] + [Min(AP_{Winter}), If(W_{Peak-h} = 0.30)\ ] + [Min(AP_{Winter}), If(W_{Peak-h} = 0.33)]$$

Eq.7) $$W_{APeak-Max} = [Max(AP_{Winter}) If(W_{Peak-h} = 0.13)\ ] + [Max(AP_{Winter}), If(W_{Peak-h} = 0.24)\ ] + [Max(AP_{Winter}), If(W_{Peak-h} = 0.30)\ ] + [Max(AP_{Winter}), If(W_{Peak-h} = 0.33)\ ]$$

Eq.8) $$AP_{Winter} = W_{Peak-h} \times Elec_h$$

where,

S_{Peak} = Summer peak electricity impact (kW)

W_{Peak} = Winter peak electricity impact (kW)

$S_{APeak-Min}$ = Minimum alternative summer peak demand (kW)

$S_{APeak-Max}$ = Maximum alternative summer peak demand (kW)

$W_{APeak-Min}$ = Minimum alternative winter peak demand (kW)

$W_{APeak-Max}$ = Maximum alternative winter peak demand (kW)

AP_{Summer} = Hourly alternative summer peak demand in a typical year[10] (kW)

[10] Assumed 8,760 hours in a typical year.

$Hr_{cooling}$ = Cooling hour

$$Hr_{cooling} = IF\left(T_{dry-bulb} > T_{balance-cooling}\right)$$
$$If\ TRUE \rightarrow\ Hr_{cooling} = 1, \text{ cooling required.}$$

$$IF\ FALSE \rightarrow\ Hr_{cooling} = 0, \text{ no cooling required.}$$

S_{Peak-h} = Alternative summer peak hour fraction

AP_{Winter} = Hourly alternative winter peak demand in a typical year (kW)

W_{Peak-h} = Alternative winter peak hour fraction

$Elec_h$ = Hourly electricity impact in a typical year (kW)

2. **Align the results with the hybrid HP RTU measure efficient tiers definition**. Using the same approach described in the Natural Gas Savings Algorithm Step 5, the electric summer and winter peak impact adjustment factor by efficiency tiers is estimated, accounting for the tiers' switchover temperature for each building type and if the unit is Staged or VSF.
3. **Normalize the summer and winter peak electricity impact for program implementation**. Step 2 produced an average kW peak of electricity impact (summer and winter) by building type. The peak electricity impacts (summer and winter) were normalized by the Heating Capacity of the Hybrid heat pump RTU presented in Table 5 Assumptions.
4. **Summer electricity impact rate (kW/kBtu/hr heating capacity)**. A single electricity impact factor (kW/kBtu/hr heating capacity) was determined by combining the individual building electricity impacts in the form of weighted average from step 3, and the distribution of building type in Ontario presented in Table 5 Assumptions.
5. **Winter electricity impact rate (kW/kBtu/hr heating capacity)**. A single electricity impact factor (kW/kBtu/hr heating capacity) was determined by combining the individual building electricity impacts in the form of weighted average from step 3, and the distribution of building type in Ontario presented in Table 5 Assumptions.

ASSUMPTIONS

The measure impact analysis approach outlined in this document includes the assumptions listed in Table 5.

Table 5. Assumptions

Variable	Definition	Value	Source/Comments
Building type weight		Various	EGI distribution of commercial building, 2023
	Restaurant	4.6%	
	Office - Small, Other Commercial - Small	39.8%	
	Office - Large	0.7%	
	Schools - Small, Schools - Large, Other Commercial - Large	3.8%	
	Retail - Small, Hotel - Large, Hotel - Small, Multi-residential	41.1%	
	Retail - Large	1.1%	
	Long Term Care, Hospital	1.0%	
	Warehousing	7.9%	
Summer and winter Peak normalizing factor: Rated Heat Pump Heating Capacity at 47°F (kBtu/hr)		Various	ComStock databased, sample buildings with hourly profile.
	FullServiceRestaurant	211	
	RetailStripmall	1,026	
	SmallOffice	386	
	QuickServiceRestaurant	167	
	Warehouse	266	
	RetailStandalone	2,710	
	MediumOffice	1,431	
	PrimarySchool	2,406	
	Outpatient	306	
	LargeOffice	6,301	

SAVINGS CALCULATION EXAMPLE

The example below shows how to calculate the natural gas savings, and electricity impact, achieved from installing a hybrid heat pump RTU with a rated heating capacity @47°F (8.3°C) of 84,000 Btu/hr in a commercial building. This calculation is for a Tier 3 Staged unit which

assumes a standard hybrid heat pump with regulated minimum efficiencies and default switchover temperature controls.

$$Annual\ Natural\ Gas\ Savings = 16 \frac{m^3}{\frac{kBtu}{hr}} \times \frac{84\ kBtu}{hr} = 1{,}344\ m^3$$

$$Annual\ Electricity\ Impacts = -42 \frac{kWh}{\frac{kBtu}{hr}} \times 84 \frac{kBtu}{hr} = -3{,}528\ kWh$$

$$Winter\ Peak\ Electricity\ Impacts = -0.0318 \frac{kW}{kBtu/hr} \times 84\ kBtu/hr = -3 \text{kW}$$

$$Summer\ Peak\ Electricity\ Impacts = 0 \frac{kW}{kBtu/hr} \times 84\ kBtu/hr = 0\ \text{kW}$$

USES AND EXCLUSIONS

The new RTU must be a packaged single-zone hybrid heat pump (electric heat pump with natural gas furnace auxiliary/backup) installed outdoors on a commercial facility. This measure does not apply to split systems, standalone furnaces, make-up air units, DOAS units, buildings for which the cooling requirement is satisfied by natural gas chillers, space types that directly serve kitchens, nor spaces that are unconditioned.

The Comstock energy models simulate rooftop units (RTUs) that serve individual zones within a commercial building; hence, the savings/impact values in table 1 are most representative of single-zone RTU applications. Multi-zone RTU or RTU paired with in-zone Variable Air Volume (VAV) systems are not eligible for this prescriptive measure. Multi-zone RTU (one RTU serving multiple spaces within a building) would have a different energy use profile (and therefore different savings/impacts) because they are commonly designed with in-zone reheat (e.g., a VAV box). To clarify, this is not intended to restrict the measure to single zone buildings but is intended for single zone RTU's. If multiple RTU's serve the same zone (e.g. in a big box retail application) this would still qualify for the measure because the RTUs are each serving a single zone. A single RTU serving multiple spaces within a building will not qualify.

MEASURE LIFE

The measure life attributed to this measure is 16 years, based on the U.S. DOE 2016 Central Air Conditioners and Heat Pumps (CAC/HP) Final Rule Technical Support Document (TSD) [12].

INCREMENTAL COST

The incremental equipment cost varies with unit capacity and is higher for smaller capacity units, as summarized in Table 6 below. Additional detail on the sources of this cost data can be found in the supporting report [9].

Table 6. Incremental Equipment Cost for Hybrid HP RTU

Nominal rated heating capacity (kBtu/hr)	Incremental Cost ($CAD/heating kBtu/hr)
<33	$130
≥33 and <78	$120
≥78 up to and including110	$110
>110	$90

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